FOREST ECOSYSTEM POTENTIALS IN NIGERIA: OPPORTUNITIES FOR GREEN ECONOMY IN THE 21ST CENTURY

EDITORS

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Preface

The 3rd Commonwealth Forestry Association (CFA) Conference, 2020, Nigeria Chapter is a follow-up to the fifth CFA Workshop held in July, 2019 at Federal University of Technology Akure (FUTA), Akure, Ondo State, Nigeria. CFA, Nigeria Chapter is a non-profit association under the supervision of the CFA Headquarters, United Kingdom. Though, some Nigerians have been members since 1970s, the Nigerian Chapter of the Association was formally inaugurated on the 08 September, 2011 at the Federal University of Technology Akure, Ondo State, Nigeria. This is a research oriented conference that seeks to bring together forestry and allied natural resource scientists, graduates, development experts and policy makers from higher institutions and research institutes to proffer future solutions to the dwindling Nigerian Forest Estate. By standard, Nigeria is expected to have 25% of forest estate with gazette notice. However, Nigeria has less than 10% forest estate.

CFA CHARTER AND BYE-LAWS

The Royal charter of 1 November 1921, as amended by Supplemental Charter of 28 November, 1962, provides that the name of the Association shall be the Commonwealth Forestry Association. The Charter and Bye-Laws which follow incorporate amendments agreed at the Annual General Meeting on 5 May, 1981 and which submitted to the Privy Council for the granting of a further Supplemental Charter.

CHARTER

The objects and powers of the Association were prescribed as follows:

i. To promote for the public benefit the practice of Forestry both in the United Kingdom and throughout the world ;

ii. To advance education in the value of trees and forests for the conservation of wildlife, soil and water resources, amenity and recreation;

iii. To promote research for efficient and sustained production of timber resources and into the inter-relationship between trees and site fertility both for Forestry and Agriculture, publishing the useful results of such research;

iv. To encourage the establishment and management of trees and forests as part of the overall wise and sensible use of land; and

v. To be a centre for the exchange and dissemination of information on all aspects of forestry and forest products or provide or promote or assist in the provision or promotion of other centres similarly engaged.

The theme of 3rd Commonwealth Forestry Association Conference 2020 is **'Forest Ecosystem Potentials in Nigeria: Opportunities for Green Economy in the 21st Century'.**

Papers presented in the proceedings, which were peer reviewed, included lead papers and voluntary papers. They were classified under the following sub-themes:

1. Status and Extent of Nigeria's Forest Ecosystem in Different Ecological Zones
2. New Technologies and Approaches to Sustainable Forest Management in Nigeria
3. Forest Ecosystem and Climate Change Adaptation and Mitigation
4. Impact of Insurgency and Human/Wildlife Conflicts on Forest Ecosystem in Nigeria
5. Gender Perspectives on Forest Ecosystem in Nigeria
6. Forest Ecosystem Services for Mankind in Nigeria
7. Sustainable Development of Value-Addition of Wood Products in Nigeria
8. Sustainable Production, Harvest and Replenishment of NonTimber Forest Products (NTFPs) in Nigeria
9. Indigenous knowledge of Plants for Repertoire of Medicine
10. Forest Governance and Institutions in Nigeria.

The Commonwealth Forestry Association Nigeria Chapter appreciates the moral support of Professor Joseph Adeola Fuwape,the Vice-Chancellor, Federal University of Technology Akure, Nigeria for hosting the 3rd CFA Conference Nigeria Chapter. The efforts of members of Local Organizing Committee (LOC) namely: Dr. (Mrs). O. V. Oyerinde (Chairman), Dr. Johnson A. Olusola, Dr. Samuel Oluyinka Olaniran, Dr. Oluwatobi Emmanuel Olaniyi, Dr. (Mrs) Oluwayinka S. Oke, Dr. (Mrs) Olaide O. Oyeleke, Mrs. Oluwayemi Johnson, Dr. Opeyemi Boboye, Mr. O. I. Adetula, Mr. A.O. Agbo-Adediran are highly appreciated. I appreciate the immense contributions of all Executive Officers of CFA Nigeria Chapter for the success of this conference. They are Professor A. C. Adetogun (Vice-President), Dr. O. R. Adejoba (Secretary), Mr. A. O. Agbo-Adediran (Assistant Secretary), Professor A. O. Omole (Public Relations Officer), Dr. O. V. Oyerinde (Finance Secretary), Dr. I. O. Osunsina (Social Secretary), Professor S. A. Oluwalana (Ex-officio) and Professor S. O. Akindele (Ex-officio).

Professor B. O. Agbeja

President, Commonwealth Forestry Association Nigeria Chapter

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University of British Colombia, Vacouver, Canada
President, Commonwealth Forestry Association(CFA) Worldwide
Link to listen to Video mp4:
https://drive.google.com/file/d/1rHubhCdS0EugSyslA0H7YaHpi-K5HPRg/view

3RD Commonwealth Forestry Association (CFA) Conference, Nigeria Chapter

FEDERAL UNIVERSITY OF TECHNOLOGY AKURE (FUTA), ONDO STATE, NIGERIA

2-3 DECEMBER, 2020

THEME:

FOREST ECOSYSTEM POTENTIALS IN NIGERIA: OPPORTUNITIES FOR GREEN ECONOMY IN THE 21ST CENTURY

SPEECH

BY

Professor B. O. Agbeja
University of Ibada, Ibadan, Nigeria
President, Commonwealth Forestry Association(CFA) Nigeria Chapter

3RD Commonwealth Forestry Association (CFA) Conference, Nigeria Chapter

FEDERAL UNIVERSITY OF TECHNOLOGY AKURE (FUTA), ONDO STATE, NIGERIA
2-3 DECEMBER, 2020

Speech

The Vice-Chancellor, Federal University of Technology Akure (FUTA)
The Deputy Vice-Chancellor (Academic)
The Deputy Vice-Chancellor (Development)
Registrar
Bursar
Librarian
Deans of Faculties
Directors of Centres
Heads of Academic Departments
Heads of Units
Distinguished Keynote Presenters
Lecturers
Students
Men of the Press
Ladies and Gentlemen

I am delighted today, 2 December, 2020 that we are all witnessing the '**Virtual 3rd Commonwealth Forestry Association (CFA) Conference**', Nigeria Chapter at the Federal University of Technology Akure (FUTA), Ondo State, Nigeria. Today constitutes an epoch in the history of Commonwealth Forestry Association (CFA), Nigeria Chapter.

You recall that the 3rd CFA Conference could have been held on 9th to 11th June, 2020. However, we were constrained as a result of pandemic Corona virus (COVID-19) all over the world and also as a result of the strike embarked upon by Association of Academic Staff Union of Universities (ASUU) in Nigeria.

Some Nigerians have since 1970s been members of CFA International. A lot of them had benefitted and they are still benefitting from CFA. On **September, 2011** at this Federal University of Technology, Akure, the **First CFA Workshop** was held at the Faculty of Agriculture. The theme of the ***First CFA Nigeria Chapter Workshop*** was '**Hands across the Forest: Strengthening the Contributions of Stakeholders to Forestry Development across West Africa'**. Though, a few people thought it was an infraction to inaugurate CFA Nigeria Chapter and this would be a rivalry to other Forestry Associations in Nigeria. The objectives of CFA when highlighted are far from rivalry but significantly complimentary to other subsisting Forestry Organisations in Nigeria. One of the objectives of CFA International and Nigeria Chapter is what we are doing today. We therefore, still need more Associations for Environment and Renewable Natural Resources in Nigeria to expand the frontier of forestry knowledge and to favourably compete with our peers in Africa in particular and the world in general.

Ladies and gentlemen, permit me to reflect a bit on infraction mentioned above and to dissociate ourselves from myopic thinking that could forever cage Forestry Sector in Nigeria. It is disheartening to mention that Federal Department of Agriculture in Nigeria was instituted in **1968** while Federal Department of Forestry was instituted in **1970**. Imagine, only two years difference! The Agricultural sector in Nigeria is proudly thriving and expanding the frontier of knowledge. I went through the internet to seek information on a number of institutes in Nigeria. Nigeria has more than **60 institutes** and **Agricultural sector alone** has **more than twenty (20)**. Examples from Agricultural sector are *Cocoa Research Institute of Nigeria, National Horticultural Research Institute, Institute of Agricultural Research, National Agricultural Extension Research and Liaison Services, National Cereals Research Institute, National Animal Production Research Institute, National Centre for Genetic Resources and Biotechnology, National Root Crops Research Institute, National Institute for Oil Palm Research, Nigerian Institute for Trypanosomiasis Research*, to mention but a few. Forestry Sector has since been only **one umpire** i.e. only One Institute-**Forestry Research Institute of Nigeria (FRIN).** This one umpire has limited the frontier of knowledge as compared with Agricultural sector in Nigeria.

Therefore, inauguration of CFA Nigeria Chapter in 2011 was and is still a blessing for all foresters as well as added value to widen the Forestry Sector horizon; to be significantly relevant among various sectors in Nigeria, Africa and the world. I must express my gratitude to the initiators of CFA Nigeria Chapter in persons of ***Professor S. O. Akindele***, ***Messrs Tolulope Daramola*** and ***Julius Adewopo***. These three Forestry scientists really deserve our gratitude! It is high time we collectively as foresters, wildlife experts, environmental scientists and other renewable natural resource scientists identified our challenges and sensitized the Federal Government for creating **more Forestry Research Institutes** in Nigeria in order to scientifically solve our intractable problems in Forestry. The governance of Forest Reserves/Forest Estate under State Governments over the years has been anachronistic with negative consequences on Sustainable Forest Management and Development in Nigeria. The Federal Government must enact National Forestry Act in order to minimize deforestation and degradation of our remaining forest cover and to be fully accommodated in the international treaty of the United Nations Environment Programme.

CFA CHARTER AND BYE-LAWS

The royal charter of **1 November 1921**, as amended by supplemental charter of 28 November, 1962 provides that the name of the Association shall be the CFA. The charter and bye-laws which follow incorporate amendments agreed at the Annual General Meeting on 5 May 1981 and which submitted to the Privy Council for the granting of a further supplemental charter. One of the objects and powers of the CFA was prescribed as 'to promote for the public benefit the practice of Forestry both in the United Kingdom and throughout the world'.

WHAT CFA DOES

Sustainable forest management plays a central role in our future, which in turn requires the training and development of forestry professionals. That is where the CFA comes in. CFA works in all corners of the **Commonwealth** and beyond to promote the wise management of trees and forests, and CFA does this in five main ways, namely:

.
First, CFA ***publishes*** *world-class science in peer-reviewed forestry journal, the International Forestry Review, and the latest global forestry news and views in the CFA Newsletter*;

Second, CFA ***facilitates networking*** *of professional members and organisations and exchange of knowledge via CFA quarterly newsletter, website, Facebook page and Twitter feed;*

Third, CFA ***encourages professional excellence*** *and* ***promotes career development*** *using a range of awards, such as the Queen's Award for Forestry, the Young Forester Award and the Young Scientist Research Award;*

Fourth, CFA ***carries out a range of specific projects*** *in the field that have been identified by our membership; and*

Fifth, CFA ***promotes capacity building*** by helping to organise training courses, workshops, and conferences.

CFA NIGERIA CHAPTER

Commonwealth Forestry Association Nigeria Chapter is a Non-Profit Organisation under the tutelage of CFA, United Kingdom.

ACHIEVEMENTS REALIZEDSO FAR UNDER CFA NIGERIA CHAPTER

CFA Nigeria Chapter has been able to implement the following in Nigeria:

1. 1st CFA Workshop at the Federal University of Technology Akure (FUTA) from 6 to 8 September, 2011. The Theme of the workshop was '**Hands across the Forest: Strengthening the Contributions of Stakeholders to Forestry Development across West Africa'.**

2. On 08 September, 2011, CFA Nigeria Chapter Steering Committee was inaugurated and **Dr. B. O. Agbeja (now Professor B. O. Agbeja**) was appointed Chairman/Coordinator.

3. Commonwealth Forestry Association Nigeria Chapter participated in Northern Africa Regional Meeting (NARM) 2012 organised by International Forestry Students Association (IFSA) at Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana from 15-20 May, 2012. The Theme of the Meeting was ***'Green Environment and Economy for Africa: The Roles of Students'.*** The CFA Nigeria Chapter presented a paper at the meeting titled **'Sustainable Forest Estate Management in Africa: The Role of Commonwealth Forestry Association as a Non-Governmental Organisation'.** The CFA International sponsored the Chairman and Secretary, CFA Steering Committee Nigeria Chapter. The Secretary in person of Mr. Ibraheem Lawal now Dr. Ibraheem Lawal ably represented the Chairman at the meeting.

4. The 2nd CFA Workshop at University of Ibadan, Nigeria from 19 to 20 November, 2012. The Theme of the Workshop was ***'Methodology of Basic and Applied Research in Forestry and other Related Disciplines'.***

5. The CFA Nigeria Chapter on January, 2015 was able to open **three accounts at First Bank PLC**., University of Ibadan, Nigeria. The three accounts are in Naira, Pound Sterling and Dollars Currencies. Three Executive Officers are signatories to the accounts. They are Professor B. O. Agbeja (President, CFA Nigeria Chapter); Dr. O. R. Adejoba (Secretary, CFA Nigeria Chapter); and Dr. O.V. Oyerinde (Financial Secretary, CFA Nigeria Chapter). As a result of institutionalization of Treasury Single Account (TSA) in Nigeria, CFA Nigeria Chapter has not been availed to collecting membership fees in Naira, convert the Naira to either pound sterling or Dollars equivalent for onward payment into CFA International, United Kingdom. Every member has since been informed to pay his or her annual membership fee directly to CFA International using ATM Card.

6. The 3rd CFA Workshop at Forestry Research Institute of Nigeria (FRIN) from 6 to 8 October, 2015. The Theme of the Workshop was '***Research Proposal Writing and Use of Appropriate Statistical Tools for Analysis'***

7. On 8 October, 2015 at FRIN, the Executive Officers to pilot the corporate affairs of CFA Nigeria Chapter were democratically elected. Those elected include:

Professor B. O. Agbeja (the First President, CFA Nigeria Chapter).
Other executive officers include:
Professor A. C. Adetogun (Vice-President, CFA Nigeria Chapter);
Dr. O. R. Adejoba (Secretary, CFA Nigeria Chapter);
Professor A. O. Omole (Public Relations Officer, CFA Nigeria Chapter);
Dr. O. V. Oyerinde (Financial Secretary, CFA Nigeria Chapter);
Dr. O. I. Osunsina (Social Secretary, CFA Nigeria Chapter);
Mr. A. O. Agbo-Adediran (Assistant Secretary, CFA Nigeria Chapter);
Professor S. A. Oluwalana (Ex-officio/Adviser, CFA Nigeria Chapter); and
Professor S. O. Akindele (Ex-officio/Adviser, CFA Nigeria Chapter).

8. The 1st CFA Conference at Forestry Research Institute of Nigeria (FRIN) from 10 to 12 October, 2016. The Theme of the Conference was ***'Forestry and Allied Natural Resources Disciplines in Nigerian Institutions: Inputs for Future Solutions to Dwindling Forest Estate in Nigeria'.***

9. On 13 October, 2016, CFA was invited by Head of Forest Unit, IITA in person of **Deni Bown** as the first Forestry Association in Nigeria to plant *Nauclea diderichii* (Igi Opepe) at HERITAGE PARK as a mark of honour to commemorate and remember 1st CFA Nigeria Chapter Conference in Nigeria.

10. On 16 December, 2016, registration of CFA Nigeria Chapter with National Bibliographical Control Department , National Library of Nigeria, Garki, Abuja. CFA Nigeria Chapter was officially issued with **ISSN 2550-7532** for hardcopy of Conferences, Workshops and Journals and **E-ISSN 2550-7524** for electronic Conferences, Workshops and Journals.

11. **Professor B. O. Agbeja** and **Dr. O.V. Oyerinde** as the President and Financial Secretary, CFA Nigeria Chapter, respectively, were sponsored by CFA International and the Patron Queen Elizabeth II to attend and participate in **XIX COMMONWEALTH FORESTRY CONFERENCE** from 3 to 7 April, 2017 at Dehradun, India. Professor Agbeja was also appointed as a MODERATOR for Technical Session 13 A on 'Urban Forestry and Landscape Management' at the conference.

12. In our common effort, CFA Nigeria Chapter in 2016 initiated a process under Queen's Commonwealth Canopy Project (CCP) Accreditation and Check-list under her royal majesty for helping to raise fund for two nominated Forest Reserves in Nigeria. The two gazetted Forest Reserves nominated were Omo Forest Reserve in Ogun State and Queens Forest Reserve Akure in Ondo State. The Federal Ministry of Environment Abuja was later contacted by CFA International after the XIX CFC in India and CCP Processes were on-going. Anyway, to our surprise, the President, CFA International in person of Professor John Innes from UBC, Canada reported that two forest reserves nominated by Federal Government were Kiwara Forest Reserve in the North and IITA Forest in the South. What a surprise on gazetted Forest Reserves that were jettisoned!

13. The 4th CFA Workshop at Federal University of Agriculture Abeokuta (FUNAAB) from 7 to 9 November, 2017. The Theme of the Workshop was *'Forestry and Health Care Delivery in the Tropics complemented with Training Workshop on Data Analysis and Quantum Geographic Information System'.*

14. The 2nd CFA Conference at Federal University of Agriculture Abeokuta (FUNAAB) from 5 to 7 June, 2018. The Theme of the Conference was ***'Collaboration of Stakeholders for Dynamic Restoration of Forest Estate in Nigeria'.***

15. Provision of two Recommendation Letters written by CFA International and CFA Nigeria Chapter for a young Nigerian woman seeking for a related job in Forestry in USA. She paid her annual membership fee into CFA International Account and she collected her Membership number a few years ago. CFA International as a Chartered Organisation was highly recognized and the candidate was given the job.

15. The 5th CFA Workshop at Federal University of Technology Akure (FUTA) from 2 to 4 July, 2019. The Theme of the workshop was ***'Improving Skills in Natural Resources Management'***. This was complemented with a Lead Paper titled *'**Status of Natural Resources Management (Forestry and Wildlife) in Nigeria'*** by an erudite scholar in person of **Professor S. A. Oluwalana**.

16. We are all witnessing as from today 2nd December to 3rd December, 2020, a virtual 3rd CFA Conference. The Theme is ***'Forest Ecosystem Potentials in Nigeria: Opportunities for Green Economy in the 21st Century'.***
The Chief Host for the Virtual 3rd CFA Conference is **Professor J. A. Fuwape**, the Vice-Chancellor, Federal University of Technology Akure (FUTA), Ondo State, Nigeria.
Our keynote speakers are:

(i) **Professor Philip G. Oguntunde**, Deputy Vice-Chancellor (Development), Federal University of Technology Akure (FUTA), Ondo State, Nigeria;
(ii) **Professor Sidat Yaffa**, Dean, School of Agriculture and Environmental Sciences, University of The Gambia, Gambia;
(iii) **Professor S. A. Oluwalana**, an erudite Scholar, Federal University of Agriculture Abeokuta (FUNAAB), Nigeria; and
(iv) **Professor John A. Akande**, a former Deputy Vice-Chancellor, Bowen University, Iwo, Osun State, Nigeria.

Mr. Vice-Chancellor, I would like on behalf of Executive Officers, CFA Nigeria Chapter as well as all participants to appreciate you sir, your good office and other principal officers for hosting the virtual 3rd CFA Conference, Nigeria Chapter. We do also appreciate your unalloyed support for all the logistics to make the virtual conference a success.

Mr. Vice-Chancellor, I would like to crave your indulgence to express the CFA Executive officers' appreciation to all members of Local Organising Committee (LOC) at FUTA under our dynamic and amiable Chair lady -**Dr. (Mrs) O. V. Oyerinde** The following LOC members are also greatly appreciated: **Dr. J. A. Olusola, Dr. (Mrs) O. O. Oyeleke, Dr. (Mrs) O. S. Oke, Dr. O. S. Olaniran, Dr. O. E. Olaniyi, Dr. M. Boboye, Mr. A. O. Agbo-Adeniran Mr. O. I. Adetula and Mrs. O. J. Johnson**. In the same vein, I appreciate all academic members of staff of the Department of Forestry and Wood Technology, FUTA for their support and encouragement. I do appreciate all executive officers of CFA, Nigeria Chapter for their supports, encouragement, dedication and resilience.

Commonwealth Forestry Association, Nigeria Chapter is 9 years old in 2020. If one catches a glimpse of the highlighted achievements of CFA, Nigeria Chapter as shown above even with its 'Non-Profit Organisational Creed', it behooves on us to keep the flag flying. '*Therefore, when people throw you stones, it is because you are a good tree full of fruits. They see a lot of harvests in you. Do not go down to their level by throwing them back the stones, but throw them your FRUITS so that the seeds of yourself may inspire them to change their ways'.*

In conclusion ladies and gentlemen, we must as CFA members cherish our yesterday; we must dream our tomorrow; and we must live our today.

I wish all of us productive virtual 3rd CFA Conference!

Thank you and God Bless.

KEYNOTE ADDRESS I

FOREST ECOSYSTEM POTENTIALS IN NIGERIA: OPPORTUNITIES FOR GREEN ECONOMY IN THE 21ST CENTURY

DELIVERED

BY

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Abstract

The Nigerian economy needs restructuring to create desirable jobs and combat poverty. Albeit, the economy is markedly dependent on natural resources among which the renewable forest is significant. That means, the ability to generate needed growth in the future and meet wider development priorities is subject to what happens to the forests and this makes the green economy (GE) concept very relevant. As threats to the forest area and concomitant tree cover mounts, so also is the prospect for green economy. Available statistics and records from monitoring reports, IUCN global forest watch, FAO and other desk studies showed consistent and progressive loss of tree cover vis-à-vis Forest Ecosystem Potential (FEP) in Nigeria over the last decades. Loss of tree cover diminishes the FEP. Estimated tree cover area in Nigeria by 2018 was reported to be 10,326,662ha (which is 11.3% of the total land area) but the figure fell grossly below the 25% recommended by FAO and therefore calls for concern and care. Twenty years between 1990 and 2010, Nigeria lost almost 48% of her forest cover at a rate of 2.38% per year. Average loss/year rose from 25,500ha in the decade span (year 2001 – 2010) to 75,800ha (year 2011 – 2019) respectively. To mitigate the loss pattern, forest production, protection and certification as well as corporate-driven oil palm production are advocated. The history of palm plantation and development in Nigeria should be revisited and the potential for oil palm expansion explored with degraded soils and vegetation that may offer the best prospects. Forest certification system, on its own, regulate harvest and encourage sustainable forest practices. A forest contingent green economy is bolstered to ultimately increase human well-being and social equity while significantly reducing environmental risks and ecological scarcities. Green economy approach to forests in Nigeria will result in better, more secure lives for the people and a more productive natural capital base. Nigerian people's welfare derived from forest ecosystem services such as decent jobs, secure livelihoods and income, health, freedoms, and culture will improve. The ecological limits of forest removal or use will be identified, defined and respected to regulate climate, biodiversity and other planetary boundaries while enabling a safe operating space for best performance and efficiency.

Keywords: Green economy, forest ecosystem, sustainable management, oil palm, environmental services.

INTRODUCTION

Forest area normally refers to land under natural or planted stands of trees at least 5 meters in situ, whether productive or not, and excludes tree stands in agricultural production systems like fruit plantations and agro-forestry systems and trees in urban parks and gardens. In the context of this paper, forest ecosystem, shall include any area under forest cover or influence. Over the years, forest area has consistently diminished in Nigeria (see Figure 1) reducing the prospect for green economy. Forests have many positive roles to play in a green economy through the protection and delivery of water resources; protection and enhancement of biodiversity and prominent role in climate control and management. A green economy is expected to generate more green and decent jobs. Renewable forest resource provides goods and services that must be sustained for their economic values. Forests help to combat soil erosion; provide industrial timber and non-timber forest products including fuelwood, food, fruits, medicinal ingredients etc.; harbor biodiversity including wildlife in addition to mitigating the negative effects of climate change.There is inadequate statistics to make strong predictions of the Nigeria forest ecosystem. Available data are based on conservative projections and guesswork because the forest monitoring and evaluation activity network in the country had been comatose for more than a decade. Nigeria forest information and data according to U.N. FAO (2010) showed that 9.9% of about 9,041,000ha of Nigeria was forested. By 2018, tree cover in Nigeria was 10,326,662ha which represented marginal increase over eight years' period from 2010 to 2018. Tree cover of 11.3% of the total land area is still far below the recommended 25% by FAO and demands attention.

NIGERIA FOREST ECOSYSTEM POTENTIAL

Forests provide a wide range of goods and services that create opportunities for (1). Industrial development and Revenue generation (2). Human well-being and Citizen Empowerment. Forest resources directly support the livelihoods of Nigerians living in extreme poverty and are home to many tropical terrestrial biodiversity. The overall value of these goods and services is immense and if the value of carbon sequestration is added, the importance of the forest ecosystem for supporting local livelihoods and their security is clear.

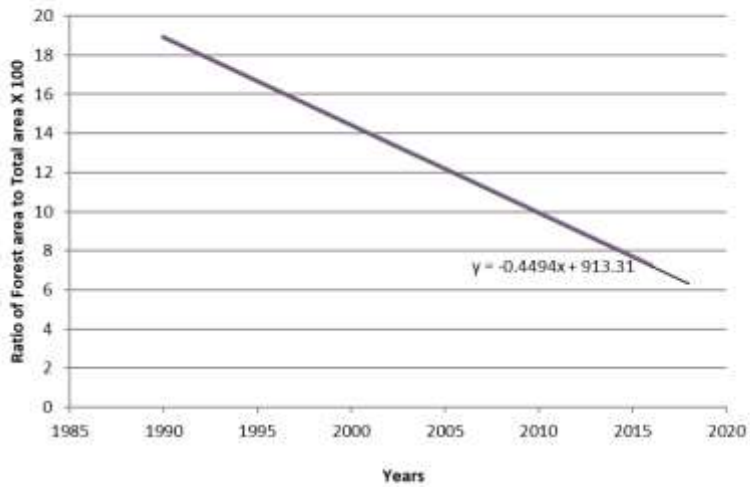

Figure 1: Declining forest area in Nigeria over years

Forest wealth include provision of construction lumber, fresh water, shade (microclimate and shelter), non-timber forest products (NTFPs), habitat functions, grazing, cultural (sacred groves, peace trees and plants, meeting places, boundaries and training areas), food, income or medical needs also aesthetic values. When we lose the forests, the entire ecosystem falls apart. Ironically, forest disappearance is the root cause of a vicious circle of draught and environmental decline. It is a significant contributor to global warming; thus, protection and conservation forest are inevitable. Today, approximately 2,500 full time employees are engaged in the management of protected conservation forests in Nigeria.

The term 'Reducing Emissions from Deforestation and Forest Degradation' (REDD) describes diverse sorts of programs, which use direct monetary or other incentives to encourage developing countries to limit and/or roll back deforestation. In both rain forests and dry forests, the agents of deforestation are similar but with the industry more prominent in the southern rain forest states, while support to human, livestock and wildlife survival is more prominent in the northern dry forests and woodlands.Nigeria's forest is estimated to contain 1,085 million metric tons of carbon in living forest biomass. The ecosystem also assists in biodiversity conservation. By 2010, the growing stock in Nigeria's forest was about 128m^3/ha totaling 1,161 million m^3. They are generally hardwoods of which less than 20% of them are classified as commercially known species. Nigeria also has some 1,417 known species of amphibians, birds, mammals and reptiles according to figures from the World Conservation Monitoring Centre. Of these, 1.2% is endemic, meaning they exist in no other country, and 3.5% are threatened. Nigeria is home to at least 4,715 species of vascular plants (Table 1) and 4.3% of these is endemic.

Table 1: Biodiversity and Conservation data in Nigeria (2018)

Taxa	*Species count*	*Threatened species count*
Mammals	285	31
Birds	864	21
Fishes	775	74
Vascular plants	4,715	205

Adapted from IUCN Red List- globalforestwatch.org/Nigeria

However up until now, the recognized functions of Nigeria forests, have not been adequately accounted for. Conservative estimates, according to Omofomwa and Osa-Edoh. (2008) are Production forests (29%), Conservation of Biodiversity (28%), other unknown or unclassified uses (43%). With this distribution, the contribution of the forest for soil and water protection, social services and landscaping and nature protection are either not clearly defined or virtually devalued. Nevertheless, people and economies depend on nature for everything; but, our economies have not reflected that dependency. Re-valuing our natural systems in terms of the societal, economic, cultural benefits that they bring will help to drive investment towards them and create new opportunities for local communities.

Appraising the Forest Ecosystem

Less appreciated are Nigerian forests and trees that support key sectors of the national economy, viz. energy, crop and livestock agriculture, wildlife and ecotourism, water, employment and incomes for livelihood support to many. Therefore, deforestation and forest degradation are linked to overall national socio-economic development. The forest ecosystem contents are therefore characterized to cover a broad spectrum from natural forests undisturbed by human intervention, natural forests with varying degrees of human modification, and various types of planted forests from semi-natural to intensive high yield plantations that provide forest ecosystem services and are important for livelihoods.

Anyhow, it is on record that in 20 years from 1990 to 2010, Nigeria lost 47.5% of its forest area (FAO, 2011) and such losses have continued unabated. For example, by 2010, Nigeria had 10.9 million ha of natural forest extending over 12% of its land area but by 2018, it had lost 118 thousand ha of the forest equivalent to 26.4Mt of CO_2 of emissions (Mongabay.com, 2019). At an average tree cover threshold of 50%, the calculus was that the country must have lost 98.7Mt of CO_2 of emissions between 2001 and 2018 (Table 2).

Forest cover in Nigeria

Going back to the year 2000, 11% of Nigeria was under natural forest cover. The nation had 10 million ha of Natural Forest, 28.6 thousand ha of Plantations and 80.8 million ha of non-forested areas. By 2010, Ekiti, Bayelsa, Osun, Ondo, Ogun and Cross River states represent 54% of all tree cover. Ekiti had the most relative tree cover at 78% compared to an average of 21% computed for the whole country.

Table 2: Biomass and land use carbon emission data for Nigeria

Tree cover threshold (TCT) %	Biomass loss 2001 – 2018 (Mt)	Average biomass loss/yr. (Mt)	Carbon emissions 2001 – 2018 (Mt)	Average Carbon emission/yr. (Mt)
10	220,383,607	12,243,534	404,036,627	22,446,479
15	203,401,224	11,300,068	372,902,256	20,716,792
20	144,936,896	8,052,050	265,717,650	14,762,092
25	137,165,111	7,620,284	251,469,428	13,970,524
30	109,738,753	6,096,597	201,187,712	11,177,095
50	53,871,793	2,992,877	98,764,986	5,486,944
75	3,916,887	217,605	7,180,957	398,942

TCT is the tree cover area threshold. 75% = area with > 75% tree cover (dense canopy); 10% = area with > 10% tree cover (open canopy). Adapted from IUCN Red list

Tree cover loss

Nigeria lost 818 thousand ha of tree cover from 2001 to 2018 (Table 3) equivalent to 8.5% decrease in tree cover since 2000 and 201Mt of CO_2 emissions. From 2001 to 2015, 15% of tree cover loss occurred in major municipalities like Sokoto, Katsina, Kebbi, Yobe and Gombe, all in northern Nigeria where the dominant drivers of loss resulted in deforestation. Sokoto and Katsina had the most relative tree cover loss at 100% compared to other areas in the region. It was the period between 2003 and 2009 that Nigeria experienced the lowest annual tree cover loss of less than 30 thousand ha/yr. Indeed, the average loss/year (2001-2010) was 25,531ha while the average loss/year (2011-2018) was 75,815ha. Some governments around the world are already acting to tackle similar problems and the projection was that by 2020, the global annual payments for ecosystem services would reach $300 billion. If correctly managed, these large sums could mean new jobs and livelihoods particularly for poorer countries. The forest sector has a key role to play in the transition towards a greener economy and a more sustainable society. This was the overriding consensus of the Policy Forum on "The Forest sector in the green economy" organized by the United Nations Economic Commission for Europe (UNECE) and the Food and Agriculture Organization of the United Nations (FAO) held on 15 October 2009 in Geneva involving participants from Governments, Industry, Trade associations, and academics from Europe, North America, Central Asia and China. Unfortunately, Nigeria and even the whole Africa was missing in that discuss.

Table 3: Tree cover loss in Nigeria in hectares (2001-2018)

Year	Primary forest	Tree cover loss (ha)
2001		43,540
2002	6,132	32,411
2003	1,830	13,406
2004	3,055	14,672
2005	1,922	14,672
2006	3,458	26,220
2007	2,753	24,630
2008	4,090	27,541
2009	3,924	25,350
2010	6,781	32,867
2011	7,403	54,011
2012	6,062	35,068
2013	6,385	43,546
2014	9,928	68,819
2015	5,318	41,020
2016	12,336	72,372
2017	17,389	171,538
2018	15,183	120,143

Tree Cover loss (2001-2018) = 818,286ha; Average loss/year (2001-2010) = 25,531ha; Average loss/year (2011-2018) = 75,815ha

Source: Adapted from IUCN Red List- globalforestwatch.org/Nigeria

Nevertheless, as evidence of ecological damage and economic costs mounted worldwide, interest in identifying alternatives to 'business-as-usual' has also increased. It is now agreed that sustainable forest management would bring (1). Sustainable landscape management (2). Positive ecological impacts (3). Positive ecosystem services impacts including tourism and (4). Positive socio-economic impacts. Harvesting patterns that continually sustain primary and secondary forests; sustain timber and non-timber forest production; encourage recycling, less wastes, renewable energies and labor efficiency; also minimizes pest and fire hazards while promoting increased carbon sequestration are on the green cards.

THE GREEN ECONOMY CONCEPT

Greening of the economy is a process of reconfiguring businesses and infrastructure to deliver better returns on natural, human and economic capital investments, while at the same time reducing greenhouse gas emissions, extracting and using fewer natural resources, creating less waste and reducing social disparities (Cato, 2009; Kennet and Kamarudin, 2012; Kennet *et al.*, 2012). The main objectives of the global green new deal are to reduce carbon dependency and ecosystem degradation, revive world economy, promoting sustainable inclusive growth and create new jobs. Climate change policy is not the only field where the forest sector can contribute to a green economy. Forest green economic opportunities include ecotourism, sustainable forestry and corporate driven oil palm plantations. Forestry can also contribute to the conservation of natural resources and to their sustainable growth in other important ways, for example, through the protection and delivery of water resources; through the protection and enhancement of biodiversity and the introduction of schemes of payments for environmental services which is promising to develop and promote, to better value, these functions.

Eco-tourism is a form of travel that aims to offer a unique tourist experience while at the same time improve the well-being of local communities and environment (Tsioumani, 2015). It offers a pathway to a more sustainable future for the local community while protecting the natural environment and achieving broad and equitable benefits. It is equally important that the communities be able and allowed to maintain control over the level and kind of tourism they want.

Sustainable forestry by virtue and design encourages investment in good forestry practices using financial and trade levers to promote improved management where it is needed and promoting forest certification such as that afforded by the Forest Stewardship Council (UNDESA, 2012). To assist corporate-driven palm production, the history of palm plantation and development in Nigeria should be revisited and the potential for oil palm expansion explored with degraded soils and vegetation that may offer the best prospects. Such development should also take advantage of areas that have low biodiversity and other environmental values. Industry-endorsed mechanisms such as roundtable on sustainable palm oil (RSPO) and its principles for sustainable palm oil production could be adopted to invoke new economic opportunities in the oil palm sector to take care of unsustainable forest conversion practices. When industries and corporations adhere to credible global standards, palm plantation enterprise would promote greater economic activities while decreasing the rate at which forest areas are converted to agricultural lands.

The foregoing are opportunities that Nigerian forests must explore to advance transition to a green economy and greener jobs. These are remarkable, so also is the need to place greater emphasis on the social aspects of forests and the forest sector. Chronic structural flaws are however noticeable in current economic models and assumptions focused on increasing GDP above all other goals. The extant paradigms might have improved incomes and reduced poverty for hundreds of millions, but it comes with significant and potentially irreversible social, environmental and economic costs. Poverty persists for as many as two and a half billion people worldwide, and the natural wealth of the planet is rapidly being depleted. In a recent global assessment, approximately 60 percent of the world's ecosystem services were found to be degraded or used unsustainably. The gap between the rich and poor kept increasing and the gap between the highest and lowest income earners widens daily. While the prevailing economic growth model focuses on increasing GDP above all other goals, a green economy promotes a triple bottom line arrangement that sustain and advance economic, environmental and social well-being.

The persistence of poverty and degradation of the environment can be traced to a series of market and institutional failures that make the prevailing economic model far less effective than it otherwise would be in advancing sustainable development goals. These market and institutional failures are well known to economists, but little progress has been made to address them. For example, there are "missing markets" – meaning that markets do not systematically account for the inherent value of services provided by nature like carbon sink, microclimate impacts, land protection *etc*. There are also insufficient mechanisms to ensure that polluters pay the full cost of their pollution.

We certainly need economic development to thrive. At the same time, we need a healthy environment to survive. Green growth is the pursuit of economic development in an environmentally sustainable manner. The ultimate goal is improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. It is an economic development model based on sustainable development and knowledge of ecological economics (UNECE, 2009; UNEP, 2010). The anchoring pillars of sustainability are social equity, economic viability and environmental compliance that consider natural capital and ecological services as having economic value. Green economy is a component of the ecosystem in which it resides and it accounts for biodiversity while providing surplus value to the human economy. Forest green economy, in particular, embraces Renewable energy, Waste management and Land management.

GLOBAL GREEN ECONOMY INDEX

The Global Green Economy Index™ (GGEI/ http://www.dualcitizeninc.com/ggei, 2012), elucidated four primary measures for assessing and referencing a national green economy as (1) Leadership and the extent to which national leaders are champions for green issues on the local and international stage (2) Domestic policies and the success of policy frameworks to successfully promote renewable energy and green growth in home market (3) Clean technology ; the perceived opportunities and corresponding investment climate in each country (4) Green tourism and government commitment to promoting sustainable tourism. Clean technology includes green energy generation based on renewable energy to substitute for fossil fuels and energy conservation for efficient energy use. Investment in these directions is capable of attenuating global greenhouse gas emissions (Hoffman, 2011). Green economy may need government subsidies as market incentives to motivate firms to invest and produce green products and services. Green strategies can be highly profitable for corporations that understand the business case for sustainability and can market green products and services beyond the traditional green consumer. In circumspect, 'green sticker' and 'eco-labeling' are currently being adopted by industries as forest standards for promoting greening practices in a globalizing economy.

Harnessing the Vision

The transition to Green Economy is a trending issue of international dimension with long range perspective and many countries are already demonstrating leadership by adopting national "green growth" or "low carbon" economic strategies. There is deeper appreciation today by many governments, companies, civil society and the public that we are reaching planetary limits, not just in terms of greenhouse gas emissions but also in our use of forests, wetlands and other natural resources. National dialogues have conjectured that lasting transition to green economy must be built on 'SERAC': i.e. Sustainable development, Equity, Resilience, Accountability and Citizen empowerment. According to the Green Economy Coalition (GEC, 2011), a green economy must necessarily (1). Improve governance and measurements (2). Drive investment and financial flows (3). Invest in natural capital (4). Invest in people and (5). Deliver sustainable development. The environmental and social costs of the current economic model are becoming more and more apparent and there are many examples of successful, large-scale programs that increase growth or productivity in a sustainable manner. For example, the Republic of Korea adopted a national strategy and a five-year plan for green growth for the period 2009–2013, allocating 2 per cent of its gross domestic product to investment in several green sectors such as renewable energy, energy efficiency, clean technology and water. The government of Korea also launched the Global Green Growth Institute established to help developing countries specially to develop green growth strategies. The United States Forest Service endorsed the American Recovery and Reinvestment Act of 2009, which directed $1.15 billion towards capital and maintenance improvement in forest areas and wild land fire management.

Namibia in Africa has started managing its natural resources to generate economic, social, and environmental benefits. Local communities across that country are granted the right to use and capitalize on the benefits of using wildlife and other natural resources within the boundaries of "communal conservancies." With an economic incentive to sustainably manage these areas, food and employment is being provided for hundreds of thousands of Namibians in rural areas. More than half of the jobs are filled by women while the wildlife populations is enhanced. South Africa started looking at carbon tax and, in the process, announced 1.1 million Rands over three years for green projects. Tanzania also initiated the Southern Agricultural Growth Corridor of Tanzania (SAGCOT), which has leveraged public-private sector and multi-donor catalytic investment of over $2bn. The idea came up during the World Economic Forum Africa summit in 2010 and founding members included Unilever, USAID, Government of Tanzania, Tanzania Sugarcane Growers Association and Confederation of Tanzanian Industries. The SAGCOT approach raised agricultural productivity and ensured necessary infrastructure, policy environment and access to knowledge to create efficient and well-functioning agricultural value chain.

Building a green economy is not about throwing out the old system and starting from scratch, it is about making choices according to the full cost and not just the financial cost of all activities. Intensive logging can seem attractive because it yields a high profit. In a 'brown' economy, the cost of cutting down a forest only includes the cost of buying the land, hiring labor, purchasing machinery and tools, and manufacturing a final product. Alternatively, in a green economy, the full cost of cutting down a forest includes damage to habitats and biodiversity, reduction in carbon-storing tree cover, loss of the social and cultural value of the forest, as well as the inability of future generations to reap these and other benefits from the forest. Under the green economy model, therefore, it makes economic sense to manage the forest sustainably rather than cut it down all at once to maintain these non-financial benefits. Waste products could ultimately become manufacturing inputs to enhance recycling and resource use efficiency. With reference to a sustainable product, such as sustainably harvested timber products, a message need be sent to producers to transit to sustainable practices to win over potential customers.

Emerging Challenges

Implementing a green economy requires accounting for the contribution of nature to GDP and rethinking capital allocations, incentives, markets and development indicators. Projects on "payment of environmental services" implicit in REDD+, according to Bond *et al*. (2010), have so far mixed results. We price forest products and services, but not ecosystem functions that make those products and services available. According to Masiero *et al*. (2019), this is a fundamental flaw. For example, if the price of carbon is low, it would not reflect the magnitude of the problem or the urgency to contain it, even the cost of supporting the ecosystem functions.

Forest industry position

The forest industry sees its future as a central player in the new green bio-economy. Promoting harvested wood products, such as wood for construction or furniture, or biomass for energy is an important strategy for maximizing the economic, social, and environmental potential of the forest sector (Climate Investments Fund, 2018). In Nigeria, the sector provides jobs for not less than 10,000 full time employees. Achieving a green economy that both protects forests and improves livelihoods will require technological advances towards a green bio-economy within the forest industry, and much more concerted investment in locally-controlled forestry. While both are necessary, supporting community forestry will be a strong foundation to achieving a fair, green economy. Forest certification systems play a significant role to regulate harvest and demonstrate that sustainable forest management is commendable. The importance of sustainable forest management and on-going efforts to reduce deforestation are helpful to fully realize the benefits of forests in a green economy. Governments will need to take an active role, including through policy reforms, to create incentives to maintain and invest in forests and introduce disincentives to modify market signals and associated rent-seeking behavior. Examples of policies include national regulations, smart subsidies and incentives, information management, supportive international markets, legal infrastructure, and conducive trade and aid protocols.

Deforestation and fire alerts

There were 879 Global Land Analysis & Discovery (GLAD) deforestation alerts reported in the week of the 6th of January 2020 which falls into the dry season. The seasonal trend is normal compared to figures for the same period in previous years. As for fire alerts,14,102 Visible Infrared Imaging Radiometer Suite (VIIRS) fire incidences were reported by NASA in the week of the 30th of December 2019 but this was unusually low compared to the same week in previous years. More deforestation and fire alerts are usually experienced in the dry seasons and should be tackled headlong.

Dignified engagement

Decent green jobs are desirable in the forest sector. Green economy means reducing social disparities, which implies that green jobs in the wood and forestry sector must provide adequate social protection, appropriate working conditions, respect of rights of workers, including participation and dialogue. The forestry sector must ensure an adequate level of reward for services provided by forest entrepreneurs to attract decent wages and generate investments. Policy measures that guarantee such investment and commensurate incentives must be inserted in future update of the extant National forest policy (2006).

Considering the challenges so outlined, the transition to a green economy will therefore not be easy because even when emerging solutions make economic sense, they may be politically challenging. Nonetheless, we must stop to see sustainability as a cost or hindrance but a key driver to innovation and progress. The bigger challenge is how we move towards an economic system that will benefit more people over time. Transitioning to a green economy will require a fundamental shift in thinking about growth and development, production of goods and services, and consumer habits. Green growth is relevant to the forestry sector; yet, challenges to large-scale adoption of green growth policies remain. This transition will not happen solely because of better information on impacts, risks or good economic analysis; ultimately, it is about politics and changing the political economy of how big decisions are made.

Forests in the 21st Century Nigeria

Analyzing the prospects and perspectives, it is evident that forest resources have a lot to contribute in diverse ways to green economy in Nigeria. Over-harvesting and unsustainable forest management due to illegal Logging are mundane challenges facing Nigeria's forest management today. Nigeria forestry is also challenged by issues of soil degradation, rapid deforestation, urban air and water pollution, desertification, periodic droughts and flooding, loss of arable lands and rapid urbanization. The concerns about depletion of forest resources also apply to NTFPs threatened by deforestation and over-harvesting. Many NTFPs that have found niches as important marketed products are now recording lean availability because of over-harvesting or inappropriate harvesting techniques.

Deforestation has negative implications on the environment in the form of soil erosion, loss of biodiversity, loss of wildlife and increased desertification. The annual rate of deforestation in Nigeria was estimated at 3.5% which is about 350,000 – 400,000 hectares per year (Odjugo, 2010). Industrial roundwood demand is on the increase to satisfy rising population and construction as well as fuelwood markets. Despite export restrictions on roundwood, the market for illegal flitches is on the rise to satisfy domestic demands. It is therefore essential to arrive at solutions aimed at sustainable management of existing forests while thinking of value addition.

Strategic cocktails for sustainability

- Forestry professionals must communicate better on the sector's role since public perception surveys show a lack of awareness about the potential of wood for mitigating climate change. In the transition of the forest sector to a green economy, communication and education must be encouraged to increase the attractiveness of the forest sector and the products and services it provides. Politicians and decision makers should be made to see green economy as a viable economic paradigm, driving growth of income and jobs, while reducing environmental risks and scarcities.

- Ensure best possible use of forest and forest products certification to promote the sector's contribution to greening the economy. Deal effectively with increased competition for different uses of wood. Increasing overall demand for wood may lead to situations where sustained availability of raw material becomes critical. We must promote the rational use of wood, with highest values first, cascading downwards, and eventually completely using wood residues.

- Ensure intra- and inter-sectoral coherency between policies that promote green economy because economic stimulus efforts can only provide short-term benefits to the forest sector. Governments' long-term visions are needed to enable a real shift as energy and climate change policies, for example, will likely have longer term effects on the forest sector. Design the best possible mix and balance of different types of policy measures and instruments, including regulations, subsidies and taxes, public procurement, trade measures.

- Ensure adaptation of forests and forest management to climate change. This is a prerequisite for a long-term contribution of the forest sector to climate change mitigation.

- There should be b*road collaboration and coordination among the Nigeria's leading forestry* institutions *and experts who must access and disseminate in a timely version latest* knowledge *and* data *to inform policy choices.*
- Greater visibility of the transition process can motivate voters and consumers not just because of the costs but also the economic benefits generated by a green economy, such as new jobs and new markets. People will not adopt policies because they are green. They will do so when they believe it is in their interest.

- Identify and take advantage of political leadership when available as this will be crucial to limit the undue influence of "dirty" economic holdouts.

- Green Economy advocates must be ready when that window of opportunity presents itself. A generalized projection is that a 2% of GDP investment in green economies could create 9.6 million new and decent green jobs.

Figure 2: Green economy' is a new economic paradigm, driving growth of income and jobs, while reducing environmental risks and scarcities—in short, delivering sustainable development. (*Diagram after Wagner et al. 2002)*

In short, green economy should deliver sustainable development (Figure 2) that would sharply reduce or even reverse environmental damage while also mitigating climate change or aiding adaptation to it. It is an alternative economy based on acknowledgement of the value of nature to people and incorporation of natural capital into economic policy and private sector decision making. The concept of a green economy has developed largely in response to the need for low-carbon development strategies. In addition to being dramatically less carbon intensive, a green economy in Nigeria must fully value natural capital as an engine of sustainable development.

Green Economy Opportunities in the Forest Ecosystem

Because of its specific characteristics as a sector dependent on multifunctional renewable resources that provide many goods and services, which are not marketed in a conventional economy (UNECE/FAO, 2013), the forest sector is influenced by, and should play an important role in a green economy. Decoupling economic growth from environmental degradation is embodied in the UN Sustainable Development Goals (SDGs). Green growth seeks to spur investment and innovation in ways that give rise to new, more sustainable sources of economic activity and jobs (Figure 3).

Environmental services from forests go beyond timber production. Many values and services provided by forests should be better recognized and compensated. For example, wildlife and nature-based tourism could constitute major economic activities in the national parks. In Yankari and Borgu games reserves, revenue from tourism is significant but human costs and factors associated with tourism such as displacement of communities and proper stewardship need also to be accounted for.

Figure 3: Green growth knowledge platform

Source: https://www.greengrowthknowledge.org/sites/default/files/ SDG_and_Green_Growth_Infographic.pdf

Urban and community forest strategies may need to include urban landscapes and green corridors as add-ons. Other important services provided by forests in Nigeria are protecting watersheds and regulating climate. Forest cover is important for maintaining good water quality by minimizing soil erosion, regulating flow, and providing protection from floods. All of these have significant implications for the economy.

Concerning fuelwood plantations/ biomass energy, wood currently represents the most important source of bio energy in Nigeria. When fossil fuel prices are high, wood energy is seen as a growing opportunity for wood utilization. To diversify into renewable energy, primarily bioenergy is based on our ability to guarantee fuelwood supply, because of demand, in terms of land ownership, but this depend considerably on financial incentives expected from public authorities. Biomass energy can play a significant role in future energy supply. Second generation biofuels could be competitive with oil in a future with oil prices ranging between $70 and $100 per barrel (UNECE/FAO, 2013). In contrast to other perennial crops, wood energy has a better public image than biofuels derived from annual crops and especially investment in oil palm, which has been accused of contributing to deforestation, reducing food supply and subsequently driving up food prices. How the price of wood energy compares with the prices of competing energy sources is crucial. So also, the prospect of technological advancement enabling more efficient use and possibly easier transport of wood energy.

In Nigeria, millions of wildlife dies from blazing fires attributed to cultural burning every year. The emerging standpoint is that forest resources, even if not further developed, must be preserved and sustainably managed. That means, protected against excessive exploitation and against other disturbances of biotic and abiotic nature. This is very important as climate change is likely to bring more frequent and intense threats in the form of fires, insect invasions and storms.

Private forests ownership in Nigeria is still nominal and yet to be adapted clearly into the landscape. Private forest ownership by individuals, business entities, institutions, local, indigenous and tribal communities must be encouraged and targeted to contribute to climate change adaptation, given its various positive externalities, such as its role in water resources protection and many other environmental services. Certification of private forest establishments are useful for ensuring proper management, but the cost of certification may be limiting to small forest owners who cannot afford certification rates and therefore must regroup and cluster themselves to demand necessary acknowledgement.

Non-timber forest products viz: - Edible fruits; Honey; Medicines; Fodder for Livestock's are also viable dividends of forest investments. Studies have shown the importance of NTFPs, both marketed and non-marketed, for people's livelihoods in Nigeria with wild foods and fodder for animals being important uses after fuel wood (Larinde *et al.*, 2017).

CONCLUSIONS

Rapid economic development has been a boom to human well-being. It has lifted millions out of poverty, raised standards of living, and increased life expectancies. But economic development comes at a significant cost to natural capital—the fertile soils, forests, coastal marshes, farmland etc. that support all life on earth. Economic and environmental protection are two sides of the same green coin. The dilemma of our times is to figure out how to improve the human condition without destroying the natural capital. If ecosystems collapse, so eventually will human civilization. In the developing world and the tropics, the links between economic and environmental activities appeared as concerns over deforestation and land degradation. One answer is *inclusive green growth*—the efficient use of natural resources. Inclusive green growth minimizes pollution and strengthens communities against natural disasters while reducing poverty through improved access to health, education, and services. Its genius lies in working with nature rather than against it. A range of approaches used around the globe to conserve and restore earth's forest ecosystems, include (1). Government subsidies (2). Regulatory-driven mitigation (3). Voluntary conservation (4). Water catchment conservation funds (5). Market-based transactions (5). Bilateral and multilateral payments

Nigeria's forest capital is acknowledged to have significant social and economic value at local, national and global levels. This includes social values related to traditional knowledge, the value of biodiversity and ecosystems in creating resilience to a changing climate and the value of ecosystem goods and services used as inputs within multiple sectors of the economy. The natural forest capital has gradually declined over years with concomitant decline in ecosystem goods and services. Climate change, coupled with deteriorating ecosystems and biodiversity from land use change is having further impacts that gravely affect human wellbeing. The unsustainable practices of one economic sector are however having downstream impacts on other sectors and on the local people. Few industries are considering the high costs of degraded forest or lost ecosystem services, which are eroding their long-term economic prospects and viability. Thus, shifting to a green economy that values and invests in natural capital would sharply reduce many of these negative trends while supporting climate change mitigation and adaptation. Its creation depends on the incorporation of natural capital values into economic policies and private sector decision making.

The potential benefits of such a shift include reduced poverty, more rapid growth, stronger local economies and enhanced resilience to climate change. A green economy is essential to ensuring long-term, sustainable economic growth and development. However, urgent action is still required by governments and other stakeholders working in partnership, because the cost of action is far less than the cost of inertia. Up till now, the Nigerian forest sector has not taken advantage of existing green stimulus packages introduced by governments to boost weakened economies.

- A forest contingent green economy would ultimately increase human well-being and social equity while significantly reducing environmental risks and ecological scarcities. It would deliver inclusive growth while sustaining natural capital to provide NTFPs, food, water, climate, soil and resource security. Deliver on development priorities of local and national governments for the benefit of society, particularly its most impoverished segments and secures more natural stocks for future use, enhances the provision of goods for revenue generation opportunities and avoids costs associated with damaged ecosystem services.
- We must be consistent in championing fairness, inclusion and ecological limits within the green economy narrative. We must also focus on resilient dynamism while championing equity and environmental limits.
- Sustainable Forest Management (SFM) is key to containing deforestation and forest degradation. Managing forests with an additional objective of reducing emissions could gradually be promoted as a regular good forestry practice that generates green and decent jobs for all.
- Better use of National Forest Programmes is key to forest policy formulation, planning and implementation. We must improve efficiency in harvesting, processing and use of forest products (e.g. fuelwood, timber, and non-timber products); increase the supply of forest and tree products and services (e.g. plantation forestry, conservation agriculture with trees, agroforestry); enhance the capacity to assess forests for their ability to maintain or increase human resilience to climate change and create/develop markets for environmental services, like carbon.
- Forest governance should be strengthened to include rights of indigenous people and forest dependents while significantly increasing support for multilateral initiatives and programmes.
- Greening of the economy is possible in the process of reconfiguring businesses and infrastructure to deliver better returns on natural, human and economic capital investments, while at the same time reducing greenhouse gas emissions, extracting and using fewer natural resources, creating less waste and reducing social disparities.
- We must reduce carbon dependency and ecosystem degradation, revive the nation's economy, promote sustainable inclusive growth and create new jobs. The challenge will be how to find a balance between food, fiber and fuel production which can meet people's needs without compromising the ability of the planet to absorb safely the consequent carbon emissions generated from human activity.
- The wood and forestry sectors can make a significant contribution towards meeting green economy objectives, linked to climate change policies, mainly through the abatement of greenhouse gas emissions and expansion of renewable energy objectives. Having recognized the potential that forests offer as a carbon sink, it becomes necessary to preserve and expand, when possible, the area occupied by forests.
- Wood energy represents the most important source of bio energy in Nigeria. When fossil fuel prices are high, wood energy is seen as a growing opportunity for wood utilization. For these reasons, it is meaningful to diversify into renewable energy with increased and sustainable use of renewable biomaterials that have additional benefit as they sequestrate carbon during their life time.
- Main threats to the forest resource base in Nigeria include overlapping rights to forest resources; informal rights associated with traditional systems of governance that are rarely given official recognition thereby undermining local users' incentives to invest in good management. There is need to develop a 'business-as-usual' scenarios for years to come, incorporating likely demand trends for wood and wood fuel materials based on expected population growth and gross domestic product (GDP). These are to be matched with estimates of the potential supply of industrial roundwood given the outlook for planted forests and deforestation. These scenarios may project that demand for industrial roundwood could be two to three times the current levels. To meet such demand from the existing natural forest designated for production will require harvesting intensities well above sustainable yield, putting severe strain on the forest resource base already threatened by deforestation. Additional pressures from other sectors, agriculture particularly, would have deleterious effects on the ability of forests to deliver key ecosystem services while carbon emissions will increase, and biodiversity will be threatened.
- There must be improvement in forest governance through wider stakeholder participation in forest decision-making processes; encompassing informal users of forest resources; working towards local control and new models of engagement with local people and forest communities; promoting access to finance; improving inter-sectoral coordination so that policy measures in sectors that affect or are affected by forests are coherent with those in the forest sector; and improving information on forest assets to document the contribution made by forest ecosystem services to different sectors.
- Forest Green economic opportunities include (1). Ecotourism which is a form of travel that aims to offer a unique tourist experience while at the same time improve the well-being of local communities and the environment. It also offers a pathway to more sustainable future for local communities. It provides an

alternative way to generate income for communities while protecting the natural environment. Involving communities in ecotourism development is particularly important to achieve broad and equitable benefits. Equally important is that the communities maintain control over the level and kind of tourism they want in their land. (2). Sustainable forestry that encourages investment in good forestry practices, using financial and trade levers to promote improved management where it is needed and promoting forest certification.

In context, effort is made in this paper to examine diverse ways in which the identified forest resources could contribute to a green economy in Nigeria – providing wood products, generating income and jobs, meeting needs for food, energy and medicinal plants and delivering other key ecosystem services. The ecological footprint of the forest ecosystem provides essential environmental, social values and services beyond their contribution as a source of wood such as biodiversity conservation; protection against erosion; watershed protection and employment in often fragile rural areas. Policy development and monitoring of the forest sector is therefore imminent and the goal would be to achieve proper valuation of and payment for forest ecosystem services while ensuring ongoing sustainability and building resilience to climate change.

Deriving from UNEP (2015) recommendations for Africa, green economy approach to forests in Nigeria will ultimately result in better, more secure lives for people and a more productive natural capital base. Nigerian people's welfare derived from forest ecosystem services such as decent jobs, secure livelihoods and income, health, freedoms, and culture will improve. Nigeria forest ecosystems will be more productive, secure and restored; the productivity of forests will increase, enabling the aforementioned benefits. The ecological limits of forest removal or use will be identified and respected; keeping climate, biodiversity and other planetary boundaries at bay and enabling a safe operating space for humanity. Resilience will be built into the Nigerian forest landscapes, societies and economies also forest institutions capability to manage risks and scarcities, adapt to climate change, and diversify economic activity that will offer much to society. This is fundamentally a human agenda informed by the environmental assets and hazards connected to forests and the urgent need to improve people's wellbeing. As such, it emphasizes inclusion of stakeholders in forest decision-making processes and equitable distribution of costs and benefits. The emerging calculus offers inclusion of stakeholders in decision making; good governance and accountability; a better quality of life for the citizenry; delivers ecosystem sustainability; supports equity; genuine prosperity and wellbeing for all; biodiversity restoration and rehabilitation of degraded habitats to achieve socio-economic and environmental resilience.

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KEYNOTE ADDRESS II

ADAPTATION STRATEGIES ASSOCIATED WITH AGRICULTURE AND TREE PRODUCTS IN THE GAMBIA: PANACEA FOR GREEN AND CIRCULAR ECONOMY

DELIVERED

BY

Professor Sidat YAFFA

Dean,
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The Vice-Chancellor,

Deputy Vice-Chancellor (Development),

Deputy Vice-Chancellor (Administration),

Deputy Vice-Chancellor (Academic),

President and other Executive Officers of CFA Nigeria Chapter,

All guests of honour present,

Ladies and Gentlemen and the Press,

I am delighted to be identified and associated with Commonwealth Forestry Association (CFA) Nigeria Chapter on this 3rd CFA Conference at the Federal University of Agriculture Akure (FUTA), Ondo State, Nigeria. I would like to first of all bring good greetings specifically from my Vice-Chancellor (Professor Muhammad Anjum) and generally from The Gambia to Nigeria and the Vice-Chancellor of FUTA in person of Professor Adeola Fuwape who is the Chief Host of this auspicious Conference. I would like to also extend my warm greetings to my colleague-Professor Busuyi Olasina Agbeja, the President, CFA Nigeria Chapter who invited me to this august gathering today. I quite believe Professor Agbeja is a dynamic leader who aims at expanding the frontier of knowledge in Forestry and environmental professions as well as other allied professions like Agriculture, Wildlife and Ecotourism, etc. I am also grateful to other executive officers of CFA Nigeria Chapter, the Local Organising Committee of CFA FUTA 2020 and all scholars seated here today. We all know that 52 countries around the world are members of Commonwealth of Nations. The Gambia is one of those fifty-two countries. Therefore, I look forward to receiving Professor Agbeja in The Gambia very soon to kick start the establishment of Commonwealth Forestry Association, The Gambia Chapter with me.

Location of the Gambia in West Africa

The Gambia is the smallest country in West Africa in terms of land size (11,300 Km^2). It is bordered by Senegal on all sides but the west, where you have the Atlantic Ocean. The borders generally follow River Gambia, which flows through the middle of the country from Fouta Jallon Highlands in the east and empties into the Atlantic Ocean in the west. The Gambia is located on Latitudes $13^0\ 4.5^1$ N and $13^0\ 48^1$ N and Longitudes $13^0\ 48^1$ W and $16^0\ 48^1$ W (Figure 1). The current population of The Gambia is estimated to be 2,405,249 (https://countrymeters.info/en/Gambia). Based on the rainfall pattern, there are 3 major agro-ecological zones in The Gambia, namely Sahelian, Sudan-Sahelian and Sudan-Guinean zones. The Sahelian Zone has a Sahelian micro-climate with open dry season savannah vegetation. There are twenty-two cities in The Gambia, namely: Serekunda, Brikama, Bakau, Banjul, Farafenni, Lamin, Sukuta, Basse Santa Su, Gunjur, Soma, Sabi, Bansang, Abuko, Essau, Barra, Demba Kunda, Koina, Diabugu, Georgetown, and Kerewan.

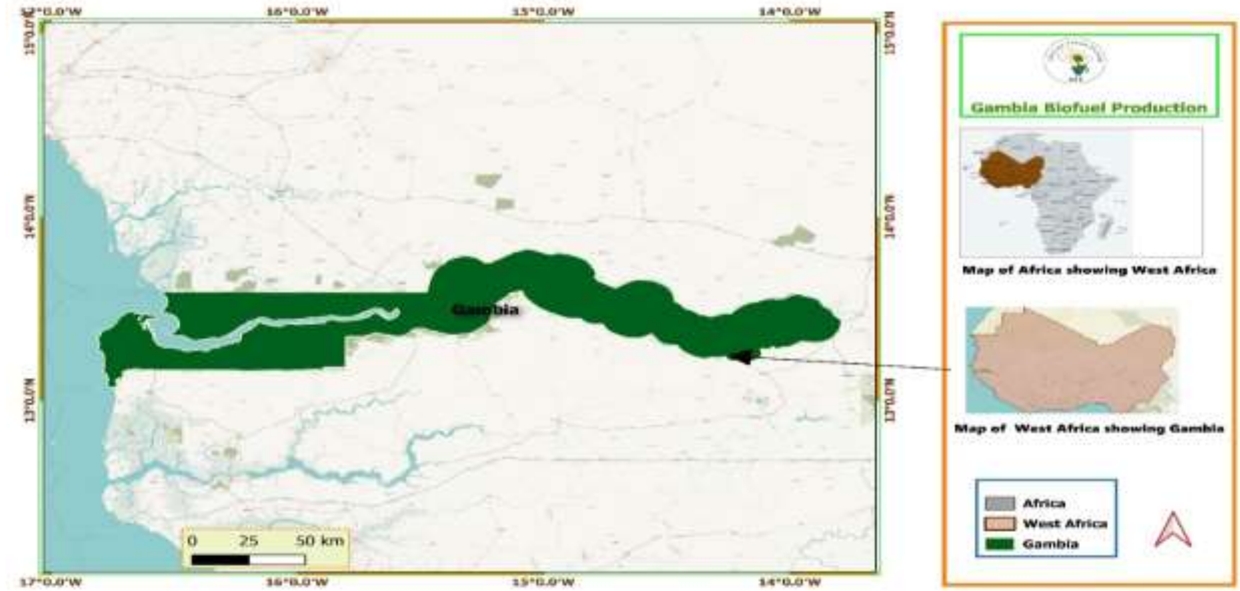

Figure 1: Map of The Gambia with Latitudes and Longitudes

Forest Ecosystem Potentials in The Gambia and the opportunities for a Green Economy

A Green Economy is a system of economic activities connected with production, distribution, and consumption of goods and services that results in improving the livelihood of human beings in the long term. A Green Economy also avoids exposing the future generations to significant environmental risks and ecologic storage, while the circular economy represents a development strategy that provides for the economic growth without increasing the consumption of resources and reducing the impacts on the environment.

The Gambia's commitment to a green economy is predicated on the realization of the economic importance of its natural resources for wealth creation, employment, livelihoods, poverty reduction, and sustainable improvement of the welfare of the population. The government of The Gambia has had dynamic focus on restoring degraded forests and agricultural landscapes with climate-resilient plants, establishing natural resource-based businesses, and strengthening capacity and policies to implement eco-based adaptation systems. Large scale ecosystem adaptation is necessary to build climate resilience of rural Gambian communities, whose livelihoods are threatened by the impacts of climate change. In order to respond to this threat, The Gambia is transitioning towards a sustainable green economy based on climate-resilient livelihoods and rigorous, evidence-based management of natural resources.

Implementing Ecosystem-based Adaptation (EbA) is a significant part of these strategies and its implementation will be enabled through The Green Climate Fund (GCF) investment. EbA will both protect the environment and facilitate the development of the sustainable natural resource-based economy to the benefit of local communities. EbA will be integrated into planning national, district, and village levels. Agricultural landscapes and degraded ecosystems including forests, mangroves, and savannahs will be restored using climate-resilient tree and shrub species across an area of at least 10,000 hectares. This will be complemented by the establishment of natural resource-based businesses managed by local communities.

The project has since 30th June, 2016 been approved and to be completed on 8th August, 2023. The Gambia's potentials for a green economy have been experimented with various strategies to adapt to climate change impacts. In the agricultural sector, 29.5% introduced new cultivars of crops that they were not growing before, 15.4% have tested new crop cultivars, 23% stopped growing crops totally, 16.8% stopped growing some crops seasonally, 15% introduced tree species as better means of adapting, 9.1% tested new tree species, and 3.7% stopped growing some tree species. These were the most common changes identified by the communities to reduce losses occurring or to improve gains from agricultural activities. For instance, in Lower River Region (LRR), 50.7% of the households stated introducing a new crop cultivar and about 44.2% also stated that they stopped growing some crop cultivars totally.

Still in the same Region, 35.8% of the households mentioned introducing tree species into their farms as a means of adaptation. The changes in crop cultivars focused mainly on introducing: short cycle crops (49.1%), high quality cultivars that are adaptable to climate change (38.7%), drought tolerant species (26.8%) and pretreated or improved seeds (21.1%). Introduction of fruit trees (17.9%) and timber trees planting (14.4%) were among other adaptation strategies the communities emphasized.

Off-farm sourcing of food is among the most common adaptation strategies adopted in the Region. Of particular attention are the LRR and Upper River Region (URR) where reliance on off-farm sources of food extend for over seven months in a year. Across all the Regions, from May to October, are critical times when communities become most vulnerable. This is termed the “hungry” season in The Gambia. These food insecure months of the year (May to October) are when the households have no food to harvest from their own farms.

Besides the off-farm sourcing options, communities have also described how they collect wild fruits and edible plant parts as means of coping. 48.7% of the households in the study area reported that they collect wild fruits and edible plants to cope with the food shortage in various months (mainly May to October) of the year.

Key Considerations for Project Implementation

1. Enhancing tree cover on the landscape does not only solve the wood crisis that is happening but also provides protection of the agricultural areas against soil erosion. Increasing the proportion of nitrogen-fixing trees also helps to restore the land that is already degraded by replenishing nitrogen and other nutrients. Hence, trees growing in agricultural landscapes should be given high priority. The choices of species should be done carefully in such a way that they adapt to the projected climate changes in the Regions. From the social aspects of the choices of species, it is also important that community perspectives on what they want to grow be part of the discussions. ICRAF’s approach of The Right Trees, at the Right Places and for the Right Purpose offers a guiding principle.

2. Wild, edible plants play a key role in minimizing the effects of food shortage. Hence, any tree growing scheme in the community forests and agricultural areas should give emphasis to ensuring this natural supply source of food does not become extinct due to overexploitation. Regional authorities should invest in replenishing forests in the form of enrichment planting, degraded area plantings and even in ANR activities. In the agricultural areas, such wild plants could even be domesticated to increase the benefits the communities get from such species.

Nevertheless, in The Gambia, considerable achievements have been made in implementing major strategic issues such as legislation review, the second national forest inventory, community forestry expansion and awareness creation, and forest park management. Based on the National Forest Action Plan (NFAP) in The Gambia, the following entail the major institutional strategies for Sustainable Forest Management in the Forestry Department of The Gambia:

- Ensure development of policy implementation tools;
- Reserve, maintain, and develop forestland resources covering at least 30% of the total land areas;
- To ensure that 75% of the forest lands are managed;
- Ensure active participation of the public in community forest management;
- Define principles for forest management planning for state, community, and private forests;
- Develop new strategies for the prevention and control of bushfires;
- Ensure suitable wood supply to forest produce for urban and rural population;
- Ensure that licenses, permits, royalties, stumpage fees reflect the replacement cost of the forest produce;
- Ensure co-ordination of all forest activities at all levels through the Forestry Department;
- Contribute co-ordination and harmonization of forestry and related costs;
- Support applied forestry research to acquire baseline data;
- Support tree planting in the urban areas;
- Maintain a forestry service with an adequate number of institutions at all levels;
- Institutionalize in country training for state, villages, and NGOs;
- Improve Forestry Department’s physical infrastructure and equipment; and
- Provide adequate funding for the Forestry Department.

In conclusion, on 3-5 June, 2019, the third annual World Circular Economy Forum (WCEF) 2019 in Helsinki, Finland, organized by the Finnish Innovation Fund Sitra brought together over 2,200 of the world's top business leaders, policymakers, researchers, and innovators from more than 90 countries to work towards implementing a circular economy. The forum included a dedicated session on Africa to discuss the goal of scaling up the circular economy in the continent. Almost 70 African representatives from different parts of the continent attended the forum.

Therefore, The Gambia has a forest ecosystem with potentials to fully engage in green economy in Africa.

I wish you all happy deliberations in your 3rd Commonwealth Forestry Association Conference.

Thank you.

KEYNOTE ADDRESS III

THE LIMITLESS OPPORTUNITIES IN NIGERIAN FOREST ECOSYSTEM FOR GREEN ECONOMY IN THE TWENTY FIRST CENTURY

DELIVERED

BY

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INTRODUCTION

Humanity faces serious challenges in the coming decades from climate change, biodiversity loss, growing inequality, and more. These systemic global crises cannot be tackled in isolation. To solve these problems, a new economic vision is required (Green Economy Coalition, 2019).This has necessitated the concept of green economy. According to UN Environment Programme, a green economy is defined as low carbon, resource efficient and socially inclusive. In a green economy, growth in employment and income are driven by public and private investment into such economic activities, infrastructure and assets that allow reduced carbon emissions and pollution, enhanced energy and resource efficiency, and prevention of the loss of biodiversity and ecosystem services. Bapma and Talberth (2011) regards Green Economy as an alternative vision for growth and development; one that can generate growth and improvements in people's lives in ways consistent with sustainable development. A Green Economy promotes a triple bottom line: sustaining and advancing economic, environmental and social well-being.

THE STATE OF NIGERIAN FORESTRY

Borrowing from Mensa Otabil (2002) in his book "Buy the Future", part of the reasons why forestry in Nigeria is what it is today may be due to two vital factors. These are, first the values developed for the sector by the colonial masters which unfortunately has not changed even after over sixty years of independence. Secondly, the way that forestry in Nigeria has viewed the larger world around it and its response the challenges. Rather than expand its frontiers, forestry went into "recession." Every new government in Nigeria sees forestry only from the view of generating money through logging. In this way, forestry cannot effectively play any role in the green economy. These two factors have ultimately shaped all the important decisions about forestry so far. For instance, agroforestry appeared a viable option to forest regeneration at its inception, but it has since remained inefficient in driving the momentum of forestry development in Nigeria especially in the last decades of the twentieth century. Farmers with connivance with government agencies and officials invade the forests for the establishment of ill-conceived agricultural projects. After a few seasons of planting, the farmers often experience a steep decline in their crop production. The answer by forestry should be to regrade agroforestry by encouraging urban agriculture and forestry, and indoor agriculture and forestry.

Charcoal production is a major problem to the survival of forests in Nigeria. Answers by forestry should include the encouragement of Terra Cota farming by using charcoal dust to improve soil fertility, and carbon sequestration. There are many positive implications of this. Farmers will experience better crop production, better product prices as a result of high Brix degree crops that are nutritionally-efficient. In addition, charcoal can be processed into graphene, a light weight material stronger than diamond. Graphene is the latest in technology that can be deployed in construction industries, and electronics among others. Biomass can also be converted into graphene. For forestry to take its place in a green economy, it must leverage on science and technology. There must be "start-ups" in the sector. Innovation is an unlimited resource. Innovation is one of the foundations of long-term competitiveness. Growth produced by "meta-ideas" increase the generation and spread of ideas (Dan Senor and Saul Singer, 2009).
For a developing nation as Nigeria, certain basic assumptions are required with regards to the role of forestry in a green economy.

1. What is the role of governments in forestry in Nigeria?
2. What is the current scientific and technological outlook of the forest sector?
3. What are the problems confronting the sector?
4. What is the current scientific and technological knowledge exposure of forestry personnel?
5. What is the role of indigenous knowledge in forest management?
6. What are the prospects of forestry in addressing emerging problems in Nigeria?

The answers to these questions/assumptions will provide a focus for the role of forestry in a green economy for the nation.

I. The democratic governance in Nigeria has produced an unstable environment for a sustainable forestry development. The forests are usually the first casualty of any newly elected government especially States that still have pockets of forest reserves. Government actions are characterized by low or no funding of forest projects, ambitious revenue targets that eventual ruin the forests, and political overbearing influence on forestry policies. Forest reserves are unilaterally de-gazetted by governments for ambiguous projects such as for agriculture, road and housing infrastructure.

II. The current scientific and technological outlook of the forest sector in Nigeria consists only in the establishment of new departments of forestry in a few Nigerian universities and monotechnics. However, there is only one research institute for forestry in the country. This has stifled research and human development in the forestry sector. It can be said today that forestry has stagnated in all forms in the country.

III. The problems confronting the sector are numerous. There are negative political influences, inadequate funding, loss of forest estates, and personnel that are not up to date in terms of scientific and technological development. No establishment of new plantations, and management plans are lacking.

IV. The current scientific and technological knowledge exposure of forestry personnel is abysmally poor. There are no laboratories in forest departments, no exposure to new orientations in forest management.

V. The role of indigenous knowledge in forest management in the country is nonexistent. The British colonial model of forestry still being practiced totally excluded indigenous knowledge in its programmes.

VI. The prospects of forestry in addressing emerging problems in Nigeria are bright and numerous. Forestry can be used to adequately address such problems.

3. 0 To save the forests from destruction, and use them in green economy, the problems confronting the sector can also spell out the solutions. They solutions lie in innovative start-ups.

I. Agriculture pressure on forest land:
Solutions: Encourage urban forestry, indoor forestry, and urban and indoor agriculture; anti-weevil, anti-aflatoxin plants; values from raw cow milk – buttermilk, ghee, butter. These are high economic, nutritional, and medicinal products. These will help open up herders to more productive ventures and act as a tool to dampen crime.
Forestry should have an inroad into agriculture. There are forest plants that have the potentials to stimulate crop production. The plant formulations are applied on plant tops to stimulate crop yields. This example can help make farmers not to keep moving to forest lands.

II. Pressure of infrastructure pressure on forests;
Solution: Urban and indoor forestry; establishment of healing forests in cities and country sides. These in turn will help in forest conservation, and enhance bio tourism.

III. Pressure on forestry as a result of urban terrorism. Forests have become casualties in government's fight against terrorism. Forests along Benin-Ijebu-Ode were ordered cleared by a Police Commissioner when it was alleged that kidnappers and robbers were using t6he forests as shields. The forests in Borno, Kaduna, Katsina, Zamfara, and other states have suffered worst destructions.
Solution: A major solution is to declare the plants under such circumstances as internally displaced plants (IDPs). The plants should be assessed, and many moved to new areas as IDPs for their preservation.
Research into pollen morphology; studies in forensic botany. These will widen the scope of forestry research in the country. In warfare, there are forest plants effective in expelling bullets lodged in the human body, and also for wound healing.

IV. The current scientific and technological knowledge exposure of forestry personnel is abysmally poor. There are no laboratories in forest departments, no exposure to new orientations in forest management. Forest research must deliberately go into Cold plasma pyrolysis. Oils can be produced from saw dust (see YouTubes).

V. Exploitation:
Solution: Scientific and technological utilization of forest resources. Tropical plants with high lignin values; ethanol production from harvested leaves, grasses, especially from Anchormanes difformis; Hoslunda opposite as a versatile plant for the cure of adenopathy, menta illness (boil the leaves and the roots, inhale the steam for fever and mental illness); earthworm cultivation (vermiculture); utilization of earthworm casts into fluvic and humic acids for various medicinal purposes; earthworm cast fertilizer, new product for enhancing high performance agriculture; fulvic acid is employed in cancer cure, and as an antiviral product (fluvic acid envelopes and destroys viruses); production of "gundruk"

VI. Loss of culture and language due to deforestation (loss of indigenous knowledge).
Solution: -rain making; -medicinal applications; -forest healing; induced crop production methods; weather forecasting; soil classification; animal breeding; traditional musical instruments; household utensils; traditional clothe weaving. Indigenous knowledge is a practical approach to problem-solving. Indigenous knowledge includes knowledge accumulated over thousands of years, making it particularly useful for problem-solving. Communities have vetted solutions and knowledge systems over time, retaining only the efficacious ones. When the December 2004 tsunami struck the Andaman and Nicobar Islands of India, it was feared that local tribal communities would have perished. But this was not the case: they had correctly read the signs of an impending tsunami and retreated to high ground (Sahai, 2013). Sahai (2013) further counselled that countries that are repositories of indigenous scientific expertise should make this mainstream. Investing adequate resources in indigenous science and expanding the base of education and training in traditional knowledge systems will help to neutralise the bias against them and assist their inclusion in official policy.
People and governments have to move away from the narrow thinking that the Western style of science is the only sciencethereis.

VI. Destruction of forest soils:
Solution: Forest soils may hold the key for future war against pandemic diseases, agricultural revolution, and food security. Forest soils are loaded with micro-organisms. A teaspoon of a productive soil generally contains between 100 million and one billion bacteria (Eliane R. Ingham; Soils 4 Teachers).
Organisms in the soil are both numerous and diverse. They range in size from the one-celled bacteria, algae, fungi, and protozoa, to the more complex nematodes and micro-arthropods, and to the larger organisms such as earthworms, insects, small vertebrates, and plants. Soil microbes (or microorganisms) are too small (i.e., smaller than 0. 1 mm) to be seen with the unaided eye. Bacteria are the most abundant microorganisms in soil, with a population of 10^{10}–10^{11} individuals and 6,000–50,000 species per gram of soil and a biomass of 40-500 grams per m^2 (It's Alive! Uncovering the roots of life in forest soils)
A handful of soil contains about 10 billion bacteria, but at the time, earth scientists knew very little about what these microbes were and what they did.
Soil microbes are not just carbon processors and not only do the vast microbial communities underfoot affect air quality and global temperatures, they can also affect the taste and quality of the food grown (Elizabeth Svoboda, 2015).
Forest soils are sources of probiotics, and potential drugs. For instance, earthworm casts are sources of varied hormones, potential drugs, fulvic acid, and fertilizer in high performance agriculture.

VIII. The prospects of forestry in addressing emerging problems in Nigeria are bright and numerous.
Solution: Forestry and forest plants can be adapted to address the problems of overcrowding in the cities. Nigeria houses some of the largest Christian congregations in the world. This has social and health consequences. Today, the Churches and mosques have not been allowed to re-open in many places in Nigeria because of the fear of Covid-19. But forest plants have the potential to purify the air in such congregations. Plants have potential usefulness for large congregations. *Sanseviera trifasciata* is one plant with numerous potentials for this. Sanseviera plants are originally from Africa. They have many health and beauty benefits. Each leaf of Sansevieria contains pregnane glycoside that is able to decompose toxic compounds into organic ones. They can also decompose toxic substances, such as carbon dioxide (CO2), benzene, formaldehyde, chloroform, and tri-cotylene (Endah, 2018). Commonly known as Snake plant, Mother-in-law's tongue, and Viper's bowstring hemp, out of so many houseplants to plant, snake plant is a must-have. Several studies have shown that indoor air pollution can be as deadlier as outdoor air pollution, and Sanseviera is one of the most oxygen producing houseplants (Balcony Garden Web7).

Sanseviera trifasciata

In addition, the plant improves air quality for it is a great air purifier. Snake plant can turn carbon dioxide into oxygen at night, which is contrast different to the other plant. The plant also improves sleep quality. The plant, in addition, alleviates sick building syndrome. This is a syndrome where a person tends to be experience illness while he or she inside a building. The person may generate some reactions such as nose and throat irritation, coughing, itching, dizziness, and nausea. But the person is usually getting better when he or she leave the building. A research found that this syndrome strongly related to the air condition in a building. Sanseviera this case, the benefits of snake plant as air purifier can help people with sick building syndrome to alleviate the reaction (Dian Paramita Ayuningtyas, 2018).
The cities and suburbs have become noisy and polluted. Forest plants have the potentials to absorb noise and particulate matters in the air.

RECOMMENDATIONS

The Nigerian forestry sector must develop avenues to make forestry relevant in the green economy of the twenty first century. Areas have been highlighted for exploration. The Commonwealth Forestry Association, Nigeria Chapter (CFA), perhaps along with other forestry associations in Nigeria must become the voice of forestry. The vast array of opportunities in forestry must be vigorously researched into and the opportunities tapped.

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KEYNOTE ADDRESS IV

CLIMATE CHANGE BATTLE RANGES: ANY HOPE FOR HUMANS?

DELIVERED

BY

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Protocols

1.0 Introduction

I wish to express my profound appreciation to the organizers for their kind invitation to this important event. Firstly, it is a great honour to present the key note address for this 3rd Annual Conference of the Commonwealth Forestry Association (CFA). The drive of the CFA for a sustainable forest management is a notable one and their mode of achieving this is very commendable. The International Forestry Review Journal along with the CFA Newsletter have afforded us with the latest innovations in the world of forestry. They have also facilitated networking of professional members and organizations, as we all know that nobody is an island of knowledge; these professional networks have the potentials of birthing cutting-edge researches.

The theme of this workshop, "Forest Ecosystem Potentials in Nigeria: Opportunities for Green Economy in the 21st Century", cannot be more apt than this time when our forest ecosystem is most threatened by human activities such as deforestation. According to FAO, Africa's tropical forests lost 10 million ha between 1990 – 2000, and 20 million ha between 2000 and 2010 (FAO, 2017). Consequently, in choosing the lead topic, I have carefully considered that the phenomenon of climate change is an important fundamental global challenge which is highly connected to forest ecosystem and upon which the argument for green economy rests.

2.0 The Global Climate Change

It was not until the last decade of the previous century that any serious attention was paid to the phenomenon of climate change by the entire world and indeed, scientists, even though its effects had been silently felt across the globe. The industrial revolution that started during the middle of the last century led to increasing release of greenhouse gases (GHG) to the atmosphere, global warming and climate change. According to the Intergovernmental Panel on Climate Change (IPCC, 2007), *climate change is defined as any change in the state of climate that is identifiable (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that continues for a prolonged period, usually decades or longer. Climate change may also be defined as any change in climate over a period of time, either due to natural variability or as a result of human activity.* In recent years, occurrence of climate change has been proved by rising surface temperatures, increases in atmospheric carbon dioxide concentrations and extreme precipitation events such as floods and droughts (IPCC, 2007; 2013). Generally, the impacts of climate change on regional basis could include increased frequency and magnitude of droughts and floods, and long-term changes in average renewable water supplies caused by changes in precipitation, temperature, humidity, wind intensity, duration of accumulated snowpack, nature and extent of vegetation, soil moisture and runoff (Christensen *et. al.*, 2007).

However, while the impacts of climate change are global, its effects are expected to be regional. There appears to be a general agreement that developing nations, such as those in Africa, are more expected to be affected by the global impacts of anthropogenic GHG emissions given their low adaptive capabilities caused by lack of technical knowhow and poverty (Callaway, 2004; IPCC, 2007). The United Nations Framework Convention on Climate Change (UNFCCC, 2007) further observed that regions of the world that are least blameworthy for climate change are the most vulnerable to the projected climate change impacts. For instance, whereas the African region contributes less to global warming because of the general low level of industrialization, warming is likely to be larger than the global annual average over the continent (Christensen *et. al.*, 2007).

Drivers of climate change are natural and man-made substances and processes that change the Earth's energy budget (IPCC, 2013). They are the elements that contribute to GHG emissions, directly or indirectly (Blanco *et al*., 2014). As reported in literature, the major drivers of GHG emissions are consumption (Hertwich and Peters, 2009), international trade (Jakob and Marschinski, 2013), population growth (O'Neill *et al*., 2010), economic growth (Carson, 2010; Lim *et al*., 2009), structural change to a service economy (Nansai *et al*., 2009) and energy consumption (Malla, 2009). These drivers have been so documented because of their capacities to heighten GHG emissions within the global environment.

3.0 Recipients of Effects of Climate Change

Unfortunately, however, as human activities exacerbate climate change, mankind also faces the consequential negative impacts of climate change. For instance, during the last century (between 1906 and 2005), the average global temperature rose by about 0.74 °C in two phases- from 1910s and 1940s and more strongly from 1970s to the present (IPCC, 2007). However, the increase has been more rapid (about 0.18°C per decade) in last 35 years, with the decade

2001–2010 being the warmest decade on record (Figure 1, WMO, 2011). IPCC (2018) also reported that if greenhouse gas emissions continue at the current rate, the temperature of the atmosphere will increase by 1.5 °C above preindustrial levels by 2040, intensifying droughts (Figures 2 & 3) and increasing poverty especially in developing countries. A direct result of this may be heat wave which also can lead to heat stress in livestock and plants thereby resulting in poor yield. The consequences can even be more severe for humans, causing death. The United States of America recorded 2,190 deaths from excessive heat between 1992 and 2001 alone (Sree *et al.*, 2016). Nigeria has also experienced extreme heat, with temperature reaching 42.2 °C in Minna in April 2019 (Al Jazeera, 2019). Climate change has also been largely responsible for the displacement of people in many parts of the word. In 2012 alone, 98% of all displacement was related to climate and weather related events (IDMC, 2013). Marzeion and Levermann (2014) predicted that a temperature increase of 3 °C would create a sea level rise that would force 600 million people to find new homes.

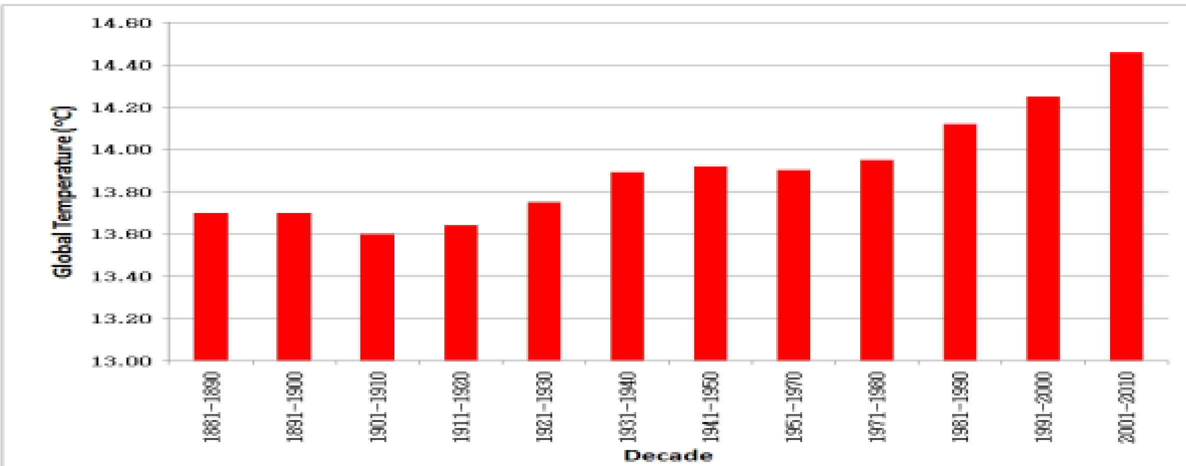

Figure 1: Decadal global average combined land-ocean surface temperature (°C), redrawn from WMO (2011).

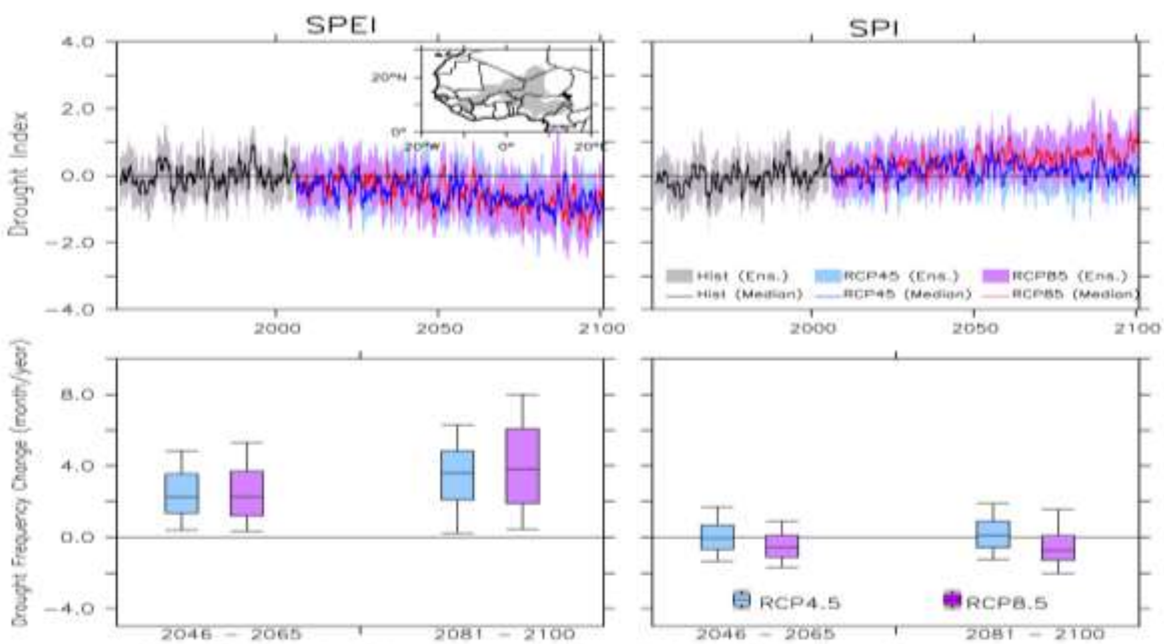

Figure 2: Projected future changes in 12-month drought intensity (top panels) and frequency (lower panels; number of months per decade) over the Niger River Basin for RCP4.5 and RCP8.5 forcings. The droughts are characterized with SPEI (left panels) and SPI (right panels) (Oguntunde *et al.*, 2018).

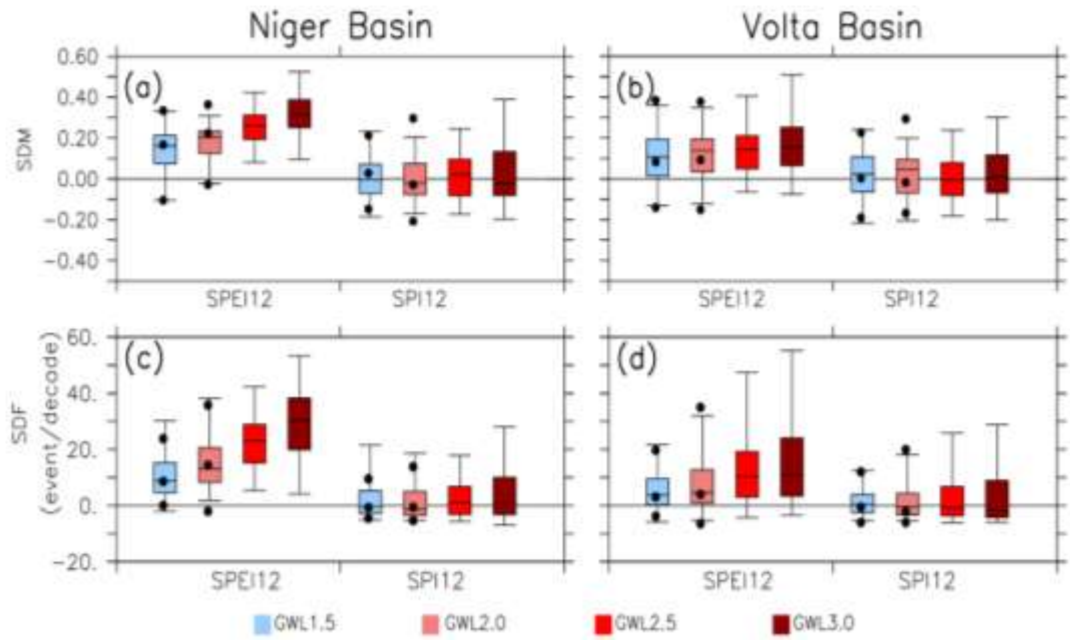

Figure 3: Projected changes in severe drought magnitude (SDM; upper panels) and severe drought frequency (SDF; lower panels; months decade^{-1}), averaged over the basins (NRB and VRB) under different GWLs for RCP8.5 scenario (bars) and RCP4.5 scenario (dots), (Oguntunde et al., 2020).)

More disasters are predicted to occur across the world if climate change is not efficiently tamed. Climate change may lead to increase in hurricane intensities due to warm waters which is a catalyst for storms. According to GFDL (2020), an 80 year build-up of atmospheric CO_2 at 1%/yr (compounded) will lead to about one-half category increase in potential hurricane intensity on the Saffir-Simpson scale and an 18% increase in precipitation near the hurricane core. Globally, crop yields have been projected to decrease due to climate change events such as reduced rainfall and high temperatures. According to IPCC (2014), global wheat and maize yields are already being negatively impacted by climate change. This trend will continue unless prevented and could lead to food scarcity and political unrest. With a 0.5 m rise in sea-level by 2070, there will be devastating potential losses in coastal cities around the world according to a study (OECD, 2008). Cities like Calcutta, India would have 14 million people and US$ 2 trillion assets at risk, while Miami, US, would have 4.8 million people and US$ 3.5 trillion assets at risk. Even Lagos, Nigeria, according to the study, will have 10.9 million people and US$ 117 billion assets at risk. Climate change could have a devastating impact on hunger and malnutrition.
Coming down to Africa and the sub-regional West Africa, desertification has expanded, continuous shrinkage of Lake Chad Basin has been reported (Lienou, 2013) and part of the Niger River Basin (NRB) has dried off with only nine out of its original ten countries covered, now active (Anderson and Golitzen, 2005; Sherbinin *et al*., 2013). As important as the NRB is to the economy of West African countries, several studies (e.g. Conway and Mahe, 2009; Van Vliet *et al*., 2013; Oguntunde *et al*., 2018; 2020) have also reported its high susceptibility to the influence of climate change. According to the International Food Policy Research Institute (IFPRI), the risk of hunger as a result of food production decline will increase by 20% in 2050. Developing nations would be worst hit as calorie intake will drop, resulting in an additional 24 million malnourished children by 2050, almost half of whom will be living in sub-Saharan Africa (Nelson *et al*., 2009).

Within the context of Nigeria, extreme climate events such as flood and droughts have been on the increase (Oloruntade *et al*., 2017) with serious devastating effects on the economy of the country. For example, the flood which ravaged some parts of Kogi State during the summer of 2012 alone was reported to have led to the loss of properties valued at over 40 billion Naira (219.6 million USD) with many inhabitants of over three hundred communities affected also put at a further risk of diseases outbreak (The Punch, 2012). There has been intermittent yearly washing off of water control and storage infrastructures such as bridges, dams and reservoirs especially in the northern part of the country. Desert encroachment has been further intensified leading to the migration of many herdsmen from their traditional abodes, thus, precipitating feuds and clashes between the herdsmen and farmers in many parts of the country. Of course, the list can go on! In the area of food production, Adebisi-Adelani and Oyesola (2014) reported that as a result of climate change, there was decline in the production of tomato across the different agro-ecological zones of the country between 2000 and 2009. It is not also unlikely that climate change may have caused the development and spread of new diseases and pests which farmers have to contend with during agricultural production. Some destructive impacts of climate change (Leslie Baehr, 2014) that threatens the existence of humans on earth are presented in Table 1.

Table 1: Destructive Impacts of Climate Change that Threatens the Existence of Humans on Earth

S/N	Climate Change Impact	Specific Impacts	Source
1.	Increase in flooding	• High precipitation of longer duration • Flooding of low-lying coastal areas	Leslie Baehr (2014)
2.	Decrease in global crop yields	• Reduced rainfalls • High temperatures	IPCC (2014)
3.	Displacement of millions of people	• A temperature increase of 30C would displace 600 million people	Marzeion and Levermann (2014)
4.	Heat waves	• Heat stress in livestock and plants • Death of humans	Sree et al., 2016
5.	Elimination of historic places	• 40 UN world heritage sites will be at risk	Marzeion and Levermann (2014)
6.	Increase in Hurricanes	• Increase in potential hurricane intensity • Increase in precipitation near the hurricane core	GFDL(2020)
7.	Decrease in fisheries	• Reduction in the population of fishes • Reduction in catch of fishes in some areas	IPCC (2014)
8.	More risk for people and assets in coastal areas	• Millions of people will be at risk • Billions of assets will be at risk	OECD (2008)
9.	Extinction of some reptile species	• Difficulty in producing offspring in some reptile species that depend on ambient temperature will threaten their survival	Leslie Baehr (2014)
10.	Millions of people may go hungry	• There will be an additional 24 million malnourished children by 2050	Nelson et al. (2009)
11.	Increase in costs due to climate change	• Global climate change costs will reach $US700 billion annually by 2030	DARA (2012)
12.	Increase in scarcity of water	• Some areas may enter a state of “new or aggravated water scarcity”	Gerten et al. (2013)
13.	Increase in droughts	• Increase in frequency of dry days in some areas • Water pollutant concentrations could rise	IPCC (2014)
14.	More water sources will dry up	• Meltwater yields from stored glacier ice will increase, causing lack of water in the long-term	IPCC (2014)
15.	Small island nations could be eliminated	• Existence of some island nations is threatened by rising sea levels	IPCC (2014)

4.0 Some Empirical Climate Change and Impacts Studies

Mr. President of the CFA in Nigeria, you will recall our discussion leading to this invitation was hinge on sharing our climate change experiences with the participant. I have tried to summarise, in this presentation, a few results from our research work in this area as presented in Table 2. Permit me to state that these studies varied from local or field scale to country-wide, basin-wide and regional scales.

5.0 The Conference Theme and Some Recommendations

So, any hope for mankind? This is why the ingenuity of the leadership of your Association deserves some accolades by coming with the right theme for this year's conference. According to Nabuurs *et al.* (2007), deforestation in the tropics and forest regrowth in the temperate zone and parts of the boreal zone remained the major factors responsible for emissions and removals, respectively, during the last decade of the 20th century, while Alo and Wang (2010) stated that changes in vegetation structure may modify the climate and hydrological processes at a rate equal or higher than global warming effects. It is should be noted that West Africa has lost almost 12 million hectares (two times the size of Togo) of tropical forest (FAO, 2009) and that the annual deforestation rate is 1.17 percent of the total land per annum. Deforestation rate in Africa is more than six times the world's average (FAO, 2009). The IPCC estimates that deforestation produces 5.9 billion tonnes of CO_2 per annum, which account for about 18% of global CO_2 whereas, the tropical forests across the globe store about 428 Gt of carbon in vegetal cover and soils (IPCC, 2000). Oyenkwelu (2017) reported that globally, forest and forest soils store about one trillion tonnes of carbon, which is about twice the amount resident in the atmosphere.

From the foregoing, it is obvious that without deliberate efforts at changing the narrative as exemplified by the theme of today's conference, mankind will continue to suffer the devastating impacts of climate change. If we say there is hope, yes, it is doable if the right efforts are put in place. The effort must go beyond the rhetoric of planting one three at a time to a holistic sustainable forest management actions.

Table 2: Selected Empirical Climate Change and Impacts Studies

S/N	Research/ study title	Study type / Scale /Location	Key findings	Reference
1.	Trends and variability in pan evaporation and other climatic variables at Ibadan, Nigeria, 1973-2008.	Assessment / Local / Ibadan	• Significant reduction in Pan Evaporation with slight increase in rainfall. • overall reduction in aridity index	**Oguntunde P.G.,** Abiodun B.J., Olukunle O.J., Olufayo A.A. (2012), *Meteorol. Applications* 19: 464-472.
2.	Solar dimming or brightening? Radiative climate change with discussion of its possible agricultural implications at Ibadan, Nigeria.	Assessment / Local / Ibadan	• Solar dimming observed • Linked to widespread biomass burning, industrial and vehicular activities and/or migrated dust haze from Sahara desert.	**Oguntunde P.G.**, Babalola T. E. and Abiodun B.J. (2015), *Journal of Meteorology and Climate Science* 13 (1): 1-9.
3.	Relationship between rice yield and climate variables in southwest Nigeria using multiple linear regression and support vector machine analysis,	Assessment & Effects / Local / Ibadan	• empirical evidence of the link between reduced rice yield and climate variables especially solar radiation	**Oguntunde P.G.**, Lischeid G., Dietrich O. (2018), *International Journal of Biometeorology* 62:459-469.
4.	Modeling the effects of climatic variability on cocoa yield in Ondo State, Nigeria (1976-2009).	Assessment & Effects/ Local / Ibadan	• Model change in climate impacts on cocoa yield	Oguntunde S.O., Ajibefun I.A., **Oguntunde P.G.** (2013, *Applied Tropical Agriculture* (2): 52-57)
5.	Analysis of trends and association between climatic variables and Cocoa yield in Ondo State, 1976-2009	Assessment & Effects/ Local / Ibadan	• empirical evidence of the link between reduced Cocoa yield and climate variables	Oguntunde S.O., Ajibefun I.A., **Oguntunde P.G.** (2014), *J. of Meteorol. and Climate Science* 12(1): 7-13.
6.	Rainfall trends in Nigeria, 1901-2000,	Assessment / Country-wide / Nigeria	• Empirical evidence that Nigeria landscape was dryer during the last four decades of the 20th century.	**Oguntunde P.G.,** Abiodun B.J., Lischeid G. (2011), *Journal of Hydrology* 411: 207-218.
7.	Spatial and temporal temperature trends in Nigeria, 1901-2000.	Assessment / Country-wide / Nigeria	• Average annual temperature has risen by 0.3°C during the last century	**Oguntunde P.G.,** Abiodun, B.J., Lischeid G. (2012), *Meteorology and Atmospheric Physics* 118: 95-105
8.	Implications of Trends and Cycles of Rainfall on Agriculture and Water Resource in the Tropical Climate of Nigeria"	Assessment & Effects / Nigeria	• Empirical evidence trends and Cycles of Rainfall for different stations	Alli A.A., **Oguntunde P.G.,** Olufayo A.A., Fasinmirin J.T. (2012), *Hydrology for Disaster Management* 1:188-200
9.	Analysis of spatial and temporal patterns in onset, cessation and length of growing season in Nigeria.	Assessment / Country-wide / Nigeria	• Empirical evidence that about 50.0% of Nigeria landscape exhibit reduction in the length of growing season	**Oguntunde P.G.,** Lischeid G., Abiodun B.J., Dietrich O. (2014), *Agriculture and Forest Meteorology* 194:77-87.
10.	Analysis of long-term dry and wet conditions in Nigeria	Assessment / Country-wide / Nigeria	• 40 - 50% of the land area is manifesting persistent shift towards aridity.	**Oguntunde P.G.,** Abiodun B.J., Lischeid G., Dietrich O. (2017), *International Journal of Climatology*. 37, 3577-3586

S/N	Research/ study title	Study type / Scale /Location	Key findings	Reference
			• semi-arid zone is becoming arid while humid is shifting to sub-humid regime	
11.	Hydroclimatology of the Volta River Basin in West Africa: Trends and Variability from 1901-2002..	Assessment / Volta River Basin	• Significant changes in hydroclimatology of the basin • climate and land use changes linked to the observation	**Oguntunde P.G.**, J. Friesen, van de Giesen N., Savenije H.H.H. (2006), *Physics and Chemistry of the Earth*, 31: 1180-1188
12.	The impact of climate change on the Niger River Basin hydroclimatology, West Africa.	Impacts / Niger River Basin	• warmer basin in all the months, drier during the rainy months transition months • reduction in peak rainfall and runoff, possible increases in length of growing season that may lead false start/ cessation of rains	**Oguntunde P.G.,** Abiodun B.J. (2013), *Climate Dynamics* 40:81-94.
13.	Impacts of climate change on hydro-meteorological drought over the Volta Basin, West Africa,	Impacts / Volta River Basin	• Significant increase in drought intensity, frequency and area extent is projected	**Oguntunde P.G.**, Abiodun B.J., Lischeid G. (2017), *Global and Planetary Change* 155: 121-132
14.	The impact of reforestation on the Niger River Basin hydroclimatology, West Africa	Mitigation / Niger River Basin	• Reforestation reverses the predicted future impacts of GHG on rainfall, mean basin air temperature and soil moisture	**Oguntunde P.G.**, Abiodun B.J, Lischeid G., Merz C. (2014), *Ecohydrol*. 7: 163-176
15.	Impacts of climate variability and change on drought characteristics in the Niger River Basin, West Africa.	Impacts / Niger River Basin	• Significant increase in drought intensity, frequency and area extent is projected	**Oguntunde P.G.,** Lischeid G., Abiodun B.J. (2018), *Stoch Environ Res Risk Assess*, 32:1017-1034.
16	Future projection of droughts over major river basins in Southern Africa at specific global warming levels.	Impacts / four River Basins / Southern Africa	• Robust increase in drought intensity and frequency over Southern Africa with increasing GWLs, especially over the various river basins.	Abiodun B.J., Makhanya N., Petja, B., Abatan A.A, **Oguntunde P.G**. (2019), *Theor and Applied Climatol.*, https://doi.org/10.1007/s00704-018-26
17	Droughts projection over the Niger and Volta River Basins of West Africa at specific global warming levels..	Impacts / Two River Basins / West Africa	• Significant increase in severe drought magnitude and frequency are projected • increase grows with higher warming levels	**Oguntunde P.G.,** Abiodun B.J., Lischeid G., Dietrich O. (2020), *International Journal of Climatology*. https://doi.org/10.1002/joc.6544
18	Modeling the impacts of reforestation on future climate in West Africa	Mitigation / West Africa	• the West African climate would be warmer in all the months, drier during the rainy months • the warming and drying would be more pronounced in the western part of the Sahel	Abiodun B.J., Adeyewa Z.D., **Oguntunde P.G.,** Salami A.T., Ajayi V.O. (2012), *Theoretical and Applied Climatology*, 110:77-96
19	Simulating the impact of deforestation and forest regeneration on crop yield in West Africa.	Mitigation / West Africa	• deforestation could reduce rainfall and hence cowpea, millet and maize yields • reforestation would mitigate the impact of climate change and enhance grain yield	Abiodun B. J., **Oguntunde P.G**. and Babalola T. E. (2015), *Applied Tropical Agriculture* 20 (2): 110-120

S/N	Research/ study title	Study type / Scale /Location	Key findings	Reference
20	Simulating the Impacts of Tree, C3, and C4 Plant Functional Types on the Future Climate of West Africa	Adaptation/ Mitigation / West Africa	• Agri-silviculture could provide a win-win solution to climate change impacts in West Africa by acting as a mitigation and adaptation strategy	Olusegun C.F., **Oguntunde P.G**. and Gbobaniyi E.O. (2018). *Climate* 2018, *6*(2), 35; https://doi.org/10.3390/

Now coming to the theme of this conference and as it touches the challenges of climate change, especially in Nigeria, there is the need to understand what green economy entails. Green economy is an economic system that places emphasis on the use of non-fossil fuels (alternative and renewable energy). As mentioned previously, the warming of the globe has been hugely blamed on the use of fossil fuels which releases excess carbon to the atmosphere. Thus, with green economy, there is an attractive framework to deliver more resource efficient, lower carbon, less environmentally damaging, more socially inclusive societies (Georgeson *et al*., 2017). As of today, the concepts of green economy and frameworks have influenced discourses and policy in many countries. These include the UK, France and China with a greater focus on growth (Bailey and Caprotti, 2014), a number of countries in Africa (such as Rwanda, Morocco, Ethiopia, Senegal and South Africa) with emphasis on its ability to deliver transformations that go beyond current high-pollution development paradigms (UNEP, 2015).

With the continuous rise in global warming and its resultant impacts, it is extremely important that a cost effective solution be developed fast. Fortunately, experts have proposed that moving to a green global economy will not only help to protect our planet from severe effects of climate change, but is also affordable (WWF, 2009). Green economy is based on five principles which are the:

- ✓ ***wellbeing principle:*** everyone is enabled to create and enjoy prosperity,
- ✓ ***justice principle***: there is promotion of equity within and between generations,
- ✓ ***planetary boundaries principle***: nature is safeguarded, restored and invested into,
- ✓ ***efficiency and sufficiency principle***: sustainable consumption and production is supported and,
- ✓ ***good governance principle***: green economy is guided by integrated, accountable and resilient institutions.

For Nigeria to adopt a green economy, a strategic policy framework must be developed which will provide a road map for the next 20-30 years. According to International Energy Agency (2009), the policy and regulatory frameworks established at national and international levels determine whether investment and consumption decisions on energy are steered towards a low carbon option. Before the development of this policy, a convention of stakeholders must be launched to outline objectives and scope transition pathways. We must be able to discuss what we want and how we want to achieve it. Capacity building of people should also be done continuously to create awareness and for sustainability. Three important elements that should be included in the policy are:

(a) ***Sustainable energy***: switching from fossil fuels to renewable energy offers so many benefits, from reduction in emission of greenhouse gases to cleaning the air and reducing the pollution. Similarly, renewable energy is fast becoming cheaper as compared to fossil fuels. Government must provide funds for companies dedicated to providing renewable sources of energy such as solar, wind and biofuel.

(b) ***Energy efficiency***: energy efficiency can play a germane role in reducing the amount of greenhouse gases emission to the atmosphere. Energy wastage ranges from lights in unoccupied rooms, poorly insulated buildings to gas flaring in oil industries. Therefore, energy efficiency regulations and standardization need to be established and enforced.

(c) ***Sustainable forest management***: sustainably managed forests have important social and environmental benefits. These benefits include climate change mitigation, conservation of biodiversity, prevention of erosion, maintenance of watershed and employment in rural areas. Government must therefore provide incentives that would encourage investments in businesses that ensure sustainability of forests. Previous studies have highlighted the challenges of sustainable forest management to include (Onyekwelu, 2017; Wale *et al*., 2000): (i) Deforestation; (ii) Outdated forest management plan; (iii) Lack of forest certification; (iv) Ineffective forest policy instrument; (v) Irregular national forest inventory; (vi) Poor investment in forest enterprises; (vii) Ownership issues with respect to immediate economic gains from the Forest Reserves; (viii) Weak institutions and lack of enforcement; (ix) Poor incentive for Agroforestry; and (x) Lack of capacity to benefit from Carbon/Emission market or trading. Thus, CFA experts need continuous engagement of relevant stakeholders to evolve strategic actions that will turn the above listed challenges to opportunities.

6. 0 Conclusion

The most viable and affordable option to mitigating climate change risks remains transitioning to a green economy. In order to achieve this transition, all stakeholders must meet and formulate a strategic policy that should include factors such as sustainable energy, energy efficiency and sustainable forest management. We are at a stage where our actions or inactions will determine if humans will continue to exist on the planet earth or not. There is no better forum to address this problem than among scholars like you who are consultants to governments in formulating policies on sustainable development. There is also no better time to discuss this problem than now when we have the opportunity to act and leave a better world for generations coming.

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SUB-THEME 1

Status and Extent of Nigeria's Forest Ecosystem in Different Ecological

Gardenia jasminoides and *Galphimia gracilis:* The Growth and the Bloom

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Abstract

The effects of different growing media on the growth and bloom of Gardenia jasminoides (Jasmine) and Galphimia gracilis (Gold shower) in order to determine the most suitable potting mix was evaluated. Three different growth media which include coconut coir, top soil and saw dust were used. Mixture of top soil + saw dust (1:1); coconut coir + top soil (1:1); saw dust + topsoil + coconut coir (1:1:1) and top soil as control were used for growing Gardenia jasminoides and Galphimia gracilis. The experiment was laid out in Completely Randomized Design (CRD). Numbers of blooms, leaf count, stem diameter, plant height were determined and there is no significant difference among them. Top soil performed best on both plant species (cuttings) in all parameter assessed. The study confirmed that selection of the appropriate medium of growth for potted flowering plants were important from aesthetic and marketing view. Therefore, top soil is appropriate for raising both Gardenia jasminodes and Galphimia gracilis cutting because of its economic and easy adoption.

Keywords: *Galphimia gracilis*, *Gardenia jasminodes*, CRD, marketing and bloom.

INTRODUCTION

Soil is a highly valuable resource to man and it is the medium for plant growth and development. It doubles as substratum that provides support for natures diverse. Flora and fauna also serve as a medium from which most nutrient and water are supplied to the plants and supported mechanically. However man's activities in search of means of livelihood and in developmental process such as agricultural production, quarrying, and mining and many others have subjected the soil to various degradation, thus threatening its potential as a sustainable medium of agricultural production (FAO, 2015). Apart from soil, saw dust has also been used to raise species of trees at the nursery stage (Afor, 2001).

Soils in containers do not behave the same as soil in the field. Potting media is defined as the mean where the roots of cultivated plant-grow and their primordial function is to .give support for plant growing (Kampf, 2000). Commercially available potting media and soilless mixes are usually made up of different organic ingredients including varying proportions of peat moss, sphagnum peat moss, shredded bark, and sawdust, as well as mineral ingredients such as vermiculite, perlite, calcanei clay and sand. Some alternative materials that are being used include shredded coconut husks (coir), composted yard waste and animal wastes, composted cotton gin wastes, composted hardwood bark, mushroom compost, municipal compost, rice hulls, peanut, hulls, and pecan shells. Some packages even contain fertilizer. This soil less mixes are typically lightweight, and weed and disease free. Many different brands and types of mixes are offered in garden stores, and quality varies widely (Linda and Riddick, 2010). There is no regulation by state or federal agencies over the content of these mixes and there are no standards that defined what constitutes a good potting mix. There are requirements to label the product with the names of the ingredients in decreasing order of volume.

However because organic nutrients are supplied slowly over time, meeting seedling nutrient needs can be difficult (Klein and Hammer, 2006). Microbial breaks down organic material, releasing plant-available nutrients that are slowly available for the plant. Decomposition of materials would provide additional nutrients to the growing medium which may lead to higher uptake of nutrient by the plant and subsequently high yield. The interest in logical grown cut flower is blooming. Cut flowers specialty business may fit well into a small scale and part time farming operation. New growers can control start-up costs by entering' the business slowly through increasing investment and production as their business and market grow. Cut flower includes basically anything that can be placed in a bouquet or vase. It is one of the most profitable products one can grow in-a field. There are about 250,000 different types of plants, varying from giant trees to tiny mosses. They grew almost everywhere on land and in the sea, on plains or mountains, even in deserts and snowy wastes. About 40% of land is covered by trees and grass. The Plant chosen for this research is Gardenia and Galphimia. The fruits of trailing Gardenia are small, ovate berries that are relatively inconspicuous. It can be used as ground cover, container and above ground planter, mass planting, cascading down a wall.

Gardenia species are widely practiced as an ornamental flower in bouquets, as house plants, and as outside plants. This plant is known as one of the most valuable plant species in traditional Chinese medicine and is considered highly effective as a haemostatic agent, drains fire, and is effective in treating injuries to the muscles, joints, and tendons (Dhamananda and Gardenia, 2003). *Gardenia jasminoides* is not only used as Chinese medicine for hundred years, but extract of gardenia fruit have been scientifically studied and proven to be effective for many of same conditions for which Chinese medical practitioners have been prescribing it for centuries. Zhizi, as *Gardenia jasminoides* is called bitter, cold herb that helps within deficiency. In conventional western medicine, the medicinal plant has been shown effective in reducing inflammation and exhibits anti-antigenic properties.

In traditional Chinese medicine, the kernel of the *Gardenia jasminoides* berry is made into a paste and used to treat redness and swelling for conditions like rheumatoid arthritis. It is considered effective for relieving anxiety and agitation, so it is frequently prescribed for depression and insomnia. Some aroma therapists prescribe gardenia oil for anxiety and nervous tension owing to its calming effects. *Gardenia jasminoides* may also be used to treat physical and emotional menopausal symptoms. Traditional Chinese medicine practitioners use it to cool and detoxify the blood, stop bleeding, and help injuries to heal more quickly. Due to this ability, it is used to treat nosebleeds and other bleeding conditions, such as blood in the urine. It also lessens inflammation in the body by raising glutathione levels. In 2006, a study showed that a compound in gardenia is able to inhibit an enzyme in the body that prevents diabetics from making sufficient insulin. Although more research is needed to back up these results, the study suggests that *Gardenia jasminoides* may help diabetics to increase blood insulin levels. Higher insulin levels allow those with diabetes to regulate blood sugar. (Klein and Hammer, 2006).

Galphimia gracilis is native to eastern Mexico, deciduous lowland forest, acahuales, road sides, often in wet situation such as stream banks and ditches but widely cultivated throughout the tropical and sub-tropical regions and has become naturalized in many areas. It is known as gold shower or shower of gold and available in all parts of Bangladesh. It is a cultivated attractive ornamental shrub (4m long) in flowering season November to February. It has some medicinal properties and is used as a source of vitamins .It has been widely misapplied to many other species of Galphimia, particularly to those with deciduous petals. It is often confused with the partly sympatric *Galphimia glauca,* which is easily separated by its persistent petals and smaller fruits (2.5mm long vs. 4.5-5mm long in *Galphimia gracilis.* (Anderson 1995, 2003, 2007) and (Anderson 1978)

The cultivation and practise of rising cut flowers forms a part of horticulture called floriculture which the degradation in soil nutrients has led to reduce production of cut flowers in Nigeria. A mix of top soil saw dust and coconut coir should provide a suitable nutrient for raising plants with sufficient water holding capacity, nutrient content and aeration for plant growth and development. This fact outlines basic recipes for potting media and the research to know the best and suitable mixtures for planting cut flowers in Nigeria because vast majority of cut flowers are imported from overseas. Therefore, this study was carried out to evaluate the effect of potting materials or media on the growth and bloom of *Gardenia jasminoides* and *Galphimia gracilis* grown in different potting media using pot culture technique and also select a best potting medium for the growth and bloom of *Gardenia jasminoides* and *Galphimia gracilis* in pots.

MATERIALS AND METHOD

Materials

The materials used were *Gardenia jasminoides* (cuttings), *Galphimia gracilis* (cuttings), Topsoil, Saw dust, Coconut coir, Watering can, Notebook, pen, Metre rule, Polythene pots, Veneer Calliper, Hoe and cutlass, Secateurs, Hand trowel.

Methods

The sawdust was sieved to obtain the finest of the samples of the desired quantity required for the experiment. The coconut husk was shredded to get the required fine particles (coconut coir) for the experiment and the top soil was also sieved to remove unwanted lumps and stones from the soil sample. The top soil, coconut coir and the sawdust were measured using the same ratio (at ratio 1 each). Forty polythene pots were filled with top soil, top soil and sawdust (1:1), top soil and coconut coir (1:1); and top soil, sawdust, and coconut coir (1:1:1). The cuttings of the plant species was planted in a shady area (little sunlight and rainfall) as required by the plant to survive and watering was done when needed over 6weeks and weekly readings were taken to get the result for the experiment.

Treatments

The treatments used are as follows: top soil (control); top soil + saw dust (1:1); top soil + coconut coir (1:1); top soil + saw dust + coconut coir (1:1:1).

Parameter Assessed

The parameters assessed for the period of 6 weeks were leaf counts, total plant height, stem diameter and number of bloom.

Method of Data Collection

The initial readings were recorded immediately after procuring the cuttings of *Gardenia jasminoides* and *Galphimia gracilis* on the growth and bloom rate. Original readings were recorded a week after planting the cuttings and was at weekly basis or interval.

Data Analysis

Data collected was subjected to Analysis Of Variance (ANOVA). The experimental design used is Completely Randomised Design since the plants were being potted.

The Statistical Model used is $y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$

Where y_{ij} = jth observation in group *i*

μ = grand population mean

α_i = effects of group *i*

ε_{ij} = random error, (Samuel *et al*., 2012)

RESULTS AND DISCUSSION

Table 1 shows that Top soil has the highest mean value in all the parameters assessed of *Galphimia gracilis*. This is in line with Klein and Hammer (2006) that categorically stated that Top soil performed appropriately for raising cuttings and seeds.

Table 1: The Weekly Grand Mean Result for Parameters Assessed of *Galphimia gracilis* (cuttings) at the end of 6 weeks.

Treatments	Number of Leaves (cm)	Plant height (cm)	Stem diameter (cm)	Number of Bloom (cm)
Top soil (control)	49.66	22.76	0.30	3.11
Top soil + Saw dust	47.46	22.37	0.26	2.51
Top soil + coconut coir	33.77	21.87	0.23	2.77
Top soil + saw dust + coconut coir	46.83	22.65	0.24	2.80

Table 2 shows that top soil has the highest mean value in the number of leaves and bloom; Top soil + saw dust + coconut coir has the highest value on plant height while Top soil + coconut coir has the highest value in stem diameter on parameters assessed of *Gardenia jasminoides*. This is supported by Kampf (2000) that supported Top soil as the best medium of raising the cuttings.

Table 2: The Weekly Grand Mean Result for Parameters Assessed of *Gardenia jasminoides* at the end of 6 weeks.

Treatments	Number of Leaves (cm)	Plant height (cm)	Stem diameter (cm)	Number of Bloom (cm)
Top soil (control)	17.08	12.83	0.84	0.66
Top soil + Saw dust	14.14	12.58	0.84	0.49
Top soil + coconut coir	16.13	13.29	0.86	0.40
Top soil + saw dust + coconut coir	13.94	13.85	0.73	0.29

CONCLUSION AND RECOMMENDATION

From the result obtained, Top soil performed best on both *Gardenia jasminoides* and *Galphimia gracilis* (cuttings) in all parameter assessed. It was concluded that top soil is appropriate for raising both cuttings since it is economical and readily available. High and healthy production of cut flowering plants is pertinent for production of cut flowers and landscape designs to meet the demand for the populace.

It was recommended that top soil should be used for raising *Gardenia jasminoides* and *Galphimia gracilis* cuttings in other to improve the growth, survival and bloom of both plant species.

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Appendix 1: Analysis of variance table for plant height, stem diameter, leaf count and number of blooms of *Galphimia gracilis.*

		Sum of Squares	***df***	***Mean Square***	***F***	***Sig.***
Leaf count	between groups	779.224	3	259.741	15.664	.000ns
Within groups		265.306	16	16.582		
Total		1044.531	19			
Plant	between groups	2.560	3	853	1.100	.378 ns
Height	within groups	12.413	16	776		
Total		14.973	19			
Stem .	Between groups	1.611	3	537	.922	.452 ns
Diameter .	Within groups	9.313	16	582		
Total		10.924	19			
Number of	between groups	.906	3	302	1.374	.287 ns
Bloom	within groups	3.518	6	220		
Total		4.424	19			

Appendix 2: Analysis of variance table for plant height, stem diameter, leaf count and number of blooms of *Gardenia`jasminoides.*

		Sum of Squares	df	Mean Square	F	Sig.
Leaf	between groups	35.268	3	11.756	2.132	.136 ns
Count	within groups	88.212	16	5.513		
Total		123.481	19			
Plant	between groups	4.872	3	1.624	.690	.571 ns
Height	within groups	37.662	16	2.354		
Total		42.534	19			
Stem	between groups	056	3	019	1.955	.161 ns
Diameter	within groups	153	16	010		
Total		210	19			
Nb .	Between groups	313	3	104	1.256	.323 ns
Within groups		1.331	16	083		
Total		1.644	19			

Appendix 3: Result of Chemical Analysis of Soil and Coconut Coir Sample Used

Parameters	Values (Soil)	(Coconut coir)
pH in H_2O	5.60	
Organic carbon (g/kg)	2.330	9.55
Total Nitrogen (g/kg)	0.241	1.68
Available phosphorus (mg/kg)	2.88	0.015
O.M (%)		33.71
Exchange acidity (ml/kg)	0.40	
Cacmol/kg	0.78 ,	0.07
Mg cmol/kg	0.56	0.8
K cmol/kg	0.25	2.06
Na cmol/kg	0.22	2.62
Mn mg/kg	81.0	0.007
Fe mg/kg	68.0	0.25
Cu mg/kg	0.80 ,	0.002
Zn- mg/kg •	4.28	0.048
Sand (g kg)	75.8	
Silt (g kg)	11.4	
Clay (g kg).	12.8 !	

Source: Agronomy Department, University of Ibadan for soil sample and Bioscience Department Soil Lab. for Coconut coir (Forestry Research Institute of Nigeria).

Plate 1: Seedlings of *Gardenia jasminoides* and *Galphimia gracilis. At* 6th week after planting

The Potential of Agroforestry in Biodiversity Conservation in the Tropics

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Abstract

Agroforestry ecosystems incorporate perennial trees into agriculture, such as those typified by smallholder farmer dominated areas in the tropics (typically 0.01 to 5 ha), and this can be a fundamental component of both biodiversity conservation and socio-ecological resilience, also Agroforestry represents the pinnacle of sustainable development and abundance of its uses. Tropical forest conversion to pasture, which drives greenhouse gas emissions, soil degradation, and biodiversity loss, remains a pressing socio-ecological challenge. This problem has spurred increased interest in the potential of small-scale agroforestry systems to couple sustainable agriculture with biodiversity conservation, particularly in rapidly developing areas of the tropics. In addi tion to providing natural resources (i.e. food, medicine, lumber), agroforestry systems have the potential to maintain higher levels of biodiversity and greater biomass than lower diversity crop or pasture systems. However, this paper highlights biodiversity conservation value of agroforests, the role of agroforestry to biodiversity conservation such as, habitat for species, preserve germplasm of sensitive species; reduce the rates of conversion of natural habitat, conserve biological diversity and provides connectivity between agroforestry and biodiversity.It also identifies the different agroforestry practices used in biodiversity conservation for sustainable protection of the floras and fauna resources.

Keywords: Agroforestry, biodiversity conservation, germplasm, habitat

INTRODUCTION

Agroforestry is increasingly being identified as an integrated land use that can directly enhance plant diversity while reducing habitat loss and fragmentation Together; crop- and pasture-lands comprise one of the largest biomes on earth, representing 40% of global terrestrial area (Foley *et al.* 2005). While agricultural innovations have greatly increased food production, they have also caused extensive environmental degradation; nearly half of global croplands are impacted by soil erosion, declines in soil fertility, reduced biodiversity, and other socio-ecological concerns. (Wright *et al.* 2012). In the tropics, deforestation for agricultural expansion accounts for 8% of anthropogenic carbon dioxide (CO_2) emissions–nearly all global land-use change emissions–and is the primary cause of species extinctions worldwide (Gullison, 2007). Coupling sustainable agriculture to biodiversity conservation through small, diversified farms, such as those typified by traditional tropical agroforestry ecosystems, may be a viable complementary land use strategy in rapidly developing areas of the tropics .(Nair *et,al* 2009) Despite the potential socio-ecological benefits of agroforestry systems and the possibility for them to support conservation efforts in ecologically fragile areas of high biodiversity, tropical conservation policy remains dominated by efforts to reduce intact forest conversion and promote natural reforestation in lieu of supporting more socio-ecologically integrative practices (Lamb, 2005). Increasing our understanding of the ecosystem service benefits of traditional agroecosystems could help encourage policy that supports a broader range of conservation objectives (Norris, 2008).

Agroforestry ecosystems that incorporate perennial trees into agriculture, such as those typified by smallholder farmer-dominated areas in the tropics (typically 0.01 to 5 ha), can be a fundamental component of both biodiversity conservation and socio-ecological resilience (Nair *et al.* 2009). In addition to providing natural resources (i.e. food, medicine, and building materials), agroforestry ecosystems have the potential to maintain higher levels of biodiversity and greater biomass than conventional agriculture. Relative to monoculture or pasture techniques, agroforestry ecosystems may also enhance soil quality, including C content and nutrient status, by increasing litter inputs and soil organic matter accumulation (Kirby and Potvin, 2007). In many tropical systems, agricultural productivity is constrained by low nutrient availability due to highly leached acidic soils. This problem is amplified because many subsistence farmers in these areas often cannot access mineral fertilizer (Glaser *et al.*, 2002)

Positive relationships between plant diversity and ecosystem functions such as C sequestration which can be driven by either niche complementarily or the greater likelihood of including functionally important species in more diverse assemblages have been identified in a number of model ecosystems (Lambers *et al.*, 2004) although these relationships are complex and positive species/functional diversity relationships are not always observed (Cadotte *et al.*, 2011). Both plant community functional diversity and phylogenetic diversity, rather than simply the number of taxonomic units (e.g. species or functional group richness), appear to underlie observed biodiversity–ecosystem-service relationships (Flynn *et al.*, 2011) However, the nature of these relationships remains equivocal in human-managed systems, such as smallholder agroecosystems typical in developing areas of the tropics (Guo and Gifford, 2002)

Synopsis in Agroforestry

Agroforestry is a concept of integrated land use that combines elements of agriculture and forestry in a sustainable production system. An emphasis on managing rather than reducing complexity promotes a functionally biodiversity system that balances productivity with environmental protection. Agroforestry systems are classified according to the components present. Trees with crops are referred to as silvoarable, trees and animals as silvopastoral, and trees with crops and animals as agro –silvopastoral.

In the UK, traditional agroforestry systems include wood pastures such as the New Forest, browsing of acorns and beech mast (pannage), parklands, orchard grazing and hedgerows. Modern systems include silvoarable and silvopastoral systems, and woodland chicken and egg production. There are both ecological and economic interactions between the trees and crops and livestock. Total productivity of agroforestry systems is usually higher than in monoculture systems due to complementarily in resource capture i.e. trees acquire resources that the crops alone would not. Agroforestry systems support the production of a wide range of products including food, fuel, fodder and forage, fibre, timber, gums and resins, thatching and hedging materials, gardening materials, medicinal products, craft products, recreation, and ecological services

The Future of Agroforestry

This synopsis highlights the multiple benefits of integrating trees and agriculture and demonstrates the potential of agroforestry to reconcile the need for increased productivity with protection of the environment and delivery of ecosystem services including soil, water and air quality regulation, biodiversity support and cultural services. However, there are three key areas of activity essential for promoting agroforestry into the mainstream are research, dissemination of information and policy.

Scientific research on agroforestry systems started in the late 1970's, and focused on tropical systems; studies on temperate systems only starting to appear in the literature from the early 1990's (Young, 1997) .The long time scale needed for such research is a limiting factor, with very few examples yet available of complete cycles of the systems through to tree harvest. Research needs range from studies at the fine-scale (species interactions), the farm scale (economic as well as environmental benefits) right up to the landscape scale (e.g. watershed impacts on nitrate leaching, biodiversity enhancement), national scale (e.g. home grown timber and fuel to reduce imports and increase renewable energy production) and global-scale (climate change mitigation and adaptation).

Another primary barrier to wider adoption of agroforestry is limited awareness among farmers and landowners of agroforestry practices (Graves *et al.*, 2008). For agroforestry to be adopted on a wider scale, economic viability and practical management skills need to be demonstrated to farmers and landowners. This relies crucially on effective information dissemination and therefore outreach support and extension projects are essential (Current, 2009)

Supportive policies are seen as instrumental in providing incentives and removing constraints to wider adoption of agroforestry (Current, 2009). Agroforestry systems often fail to qualify for subsidies under either agricultural or forestry policies, although there have been a number of recent developments in policy reforms (e.g in France) that adopted options for payments to establish new agroforestry systems. Raising awareness of the potential of agroforestry among policy makers is essential for promoting agroforestry as a mainstream land-use system. In temperate systems, the general belief seems to be that the high cost of manual labour in /Europe necessitates a greater reliance on agrochemical input and intensive management, particularly in the industrialized northern countries. Many temperate agroforestry systems are only one step up from conventional, intensive monocultures; while these systems benefit in a number of ways from integrating trees with crops or livestock, the full potential of agroforestry as a low-input, biodiverse approach to sustainable production and ecosystem service delivery is yet to be realized.

Biodiversity conservation value of Agroforests is context dependent

The biodiversity of agroforestry systems, and of agroecosystems in general, consists of planned and unplanned components. By their very nature, agro-forestry systems contain more planned diversity (i.e., more planted and selected plant species) than the corresponding monoculture crops, although not necessarily more than some traditional mixed cropping systems (Thurston *et al*., 1999). Certain agroforestry systems such as tropical homegardens, which may contain several dozen species and varieties of trees and crops, are seen as important reservoirs of tropical tree and crop germplasm (Torquebiau, 1992). However, not all agroforestry systems have much planned diversity; for example, certain shaded coffee plantations essentially consist of one crop and a single, sometimes exotic shade tree species, and live fences typically consist of only a handful of tree species.

Of similar or greater importance for the conservation value of agroforestry systems than their planned diversity is their unplanned diversity, that is, the plants and animals that colonize or use the structure and habitat formed by the planted species. Structurally heterogeneous perennial vegetation can provide more niches for native flora and fauna than structurally simpler mono-cultures and pastures (Thiollay, 1995). A humus-rich soil that is not regularly disturbed by tillage and the permanent litter layer that usually develops under agroforestry may also provide appropriate habitat. For a diverse soil fauna and micro flora that may not be present in simpler and regularly disturbed agricultural systems, although little is known about such below ground biodiversity benefits of complex land use systems (Lavelle *et al*., 2003).

The role of agroforestry systems as refugia for forest-dependent species is most relevant in landscapes that is largely devoid of natural vegetation. In such deforested and often densely populated landscapes, agroforestry systems may maintain more species of plants, animals, and microorganisms from the original ecosystems than corresponding agricultural monocultures and pastures and therefore could be a better compromise between production goals and biodiversity conservation (Thiollay, 1995). It should be stressed that one cannot evaluate this role for an agroforestry system by simply counting the species present because these will invariably include species that are adapted to disturbed conditions and may not need special protection. Instead, it is necessary to determine whether forest-dependent and threatened species use the agroforestry areas, the degree to which they depend on these areas for habitat or food, and whether their populations are viable over the long term.

AGROFORESTRY PRACTICES IN BIODIVERSITY CONSERVATION

Agroforestry can be separated into three sub-system classifications - agrisilviculture, silvopastoral and agrosilvopastoral (Weiwei, 2014).

- *Agrisilviculture* combines annual and perennial crops with woody perennials (trees, shrubs, vines),
- *Silvopastoral* combines trees with pastures and animals, and
- *Agrosilvopastoral* combines crops, pastures, animal and trees

Silvopasture is a system in which forests are managed for timber production along with domesticated animals being raised on the same plot of land (King, 1979). This system utilizes several agronomic principles such as fertilization, native pasture grasses, and rotational grazing systems with short grazing periods that maximize plant growth and harvest while avoiding damage to the tree crop. Silvopasture is a highly intensive agroforestry method that requires grazing and timber management that can involve tree pruning, grazing, haying, fertilization and more. There are several benefits of silvopasture, which have led to its increased use. It can also create high value timber products (resulting from pruning and tree management) that lead to higher diversification of income for farmers and increased income opportunities. While considerable scientific research depicting beneficial animal/tree interactions has been conducted, the issue of soil compaction and animal/soil interactions in silvopastures has not been scientifically evaluated to a great extent (Sharrow, 2007).

Alley Cropping

Alley cropping is an agro forestry practice where in rows of trees or shrubs are planted at a spacing that provides an “alley” where perennial or annual agricultural crops are then grown. Agricultural crops within an alley cropping system are often referred to as intercrops. In this system, special care must be taken to ensure that crops and trees are compatible with one another as well as local climatic and geologic conditions. Alley cropping requires careful maintenance and pruning to limit the lateral spread of tree branches and to ensure that trees will provide the desired level of shade. The typical intercrops for this agro forestry system are row crops (corn, wheat, barley), forage crops (bluegrass, clover, alfalfa), specialty crops (dogwood, Christmas trees) and biomass crops (willows, birches) (Hodge, 1999). According to the USDA, alley cropping can be used for short-rotation woody crops or fast-growing woody plants that are then combined with forage to produce fuel wood and fodder. Alley cropping improves crop health through the creation of tree canopies that protect against wind damage and pests and also aid in pollination activities. It also improves soil health in areas prone to erosion, adds carbon to improve soil health, and enhances nutrient recycling. As with most other agro forestry techniques, alley cropping diversifies income for landowners who are able to harvest trees and other crops at different times throughout the year (Wotjkowski, 2006)

ROLE OF AGROFORESTRY IN BIODIVERSITY CONSERVATION

Generally, agroforestry systems are closer to the natural forest systems (Schroth and McNeely 2011). Agroforestry helps in conservation of ecosystem through improving soil and microclimate properties, reduced erosion, improved water quality and carbon sequestration (Schroth and Sinclair 2003; Schroth *et al*. 2004; Nair *et al*. 2009; Sarvade 2014).

Farmers practice agroforestry for gaining livelihood, income generation, risk management, food security and optimal use of available land, labour and capital (Arnold and Dewees, 1997). It is estimated that about 1.2 billion people (20%) of the world population depends directly on agroforestry products and services in developing countries which can provide goods and services, that can offset 5-20 per cent of deforestation (Leakey and Sanchez 1997; Dixon 1995).

Agroforestry represents the pinnacle of sustainable development and plethora of its uses has made it closer to the people. Many effective conservation organizations are now including agroforestry as a component in their programmes. In general, agroforestry plays five major roles in conserving biodiversity: (1)It provides habitat for species that can tolerate a certain level of disturbance; (2)It helps to preserve germplasm of sensitive species; (3) helps to reduce the rates of conversion of natural habitat by providing a more productive, sustainable alternative to traditional agricultural systems that may involve clearing natural habitats; (4) provides connectivity by creating corridors between habitat remnants which may support the integrity of these remnants and the conservation of area-sensitive floral and faunal species; and (5) helps conserve biological diversity by providing other ecosystem services such as erosion control and water recharge, thereby preventing the degradation and loss of surrounding habitat (Jose 2009).

Agroforestry systems are considered as diversity enhancing land use system especially in the context of inter-species diversity as it brings together crops, shrubs, trees and in some cases livestock on the same piece of land (Atta-Krah *et al*., 2004). A well designed agroforest can spontaneously attract and support higher biodiversity. Agroforestry provide expanded habitat for a wide range of species, from soil micro life to insects to mammals and have diversified and intensified agro-ecosystems to maintain and enhance biodiversity (Sanchez and Leakey 1997; Sanchez *et al*., 1997). Agroforestry systems have potential to support as high as50-80 per cent of biodiversity of comparable natural system (Noble and Dirzo 1997).

Agroforestry conserve biodiversity within deforested, fragmented landscapes by providing habitats and resources for plant and animal species. It makes the landscape less harsh for forest dwelling species by reducing the frequency and intensity of fires and providing buffer zones to the protected areas (Pandey, 2002). Harvey and Gonzalez Villalobos (2007) characterized bat and bird assemblages occurring in forests in two types of agroforestry systems (cacao and banana) and plantain monocultures in the indigenous reserves of Talamanca, CostaRica. Agroforestry systems had bat assemblages that were as (or more) species-rich, abundant, and diverse as forests, contained the same basic suite of dominant species, but also contained more nectarivorous bats than forests. Agroforestry systems also harbored bird assemblages that were as abundant, species-rich, and diverse as forests. Kumar and Nair (2004) reported species richness of tropical home gardens varying from27 (Sri Lanka) to 602 (West Java). In an extensive survey of floristic and structural diversity of 402 home gardens from six regions across south-western Bangladesh, Kabir and Webb (2009) reported 419 species (59%native), including six species of conservation concern. Das and Das, 2005have reported 122 species in home gardens of Barak valley of Assam, India. Similarly, 68 species were found in home gardens of Karnataka (Shastrin *et al*., 2002) and 127 species in Kerala (Kumar *et al*., 1994). 74species of different plants had been reported in the home gardens of North Bengal in addition to poultry, various milch and meat animals which are linked socially and economically to the owner (Panwar and Chakravarty 2010).

In addition to biodiversity conservation, agroforestry provide food security and enhances farm income through enhancement in the yield of products and services from biodiversity rich agro-ecosystems. In Indonesia 4 million of agroforests not only yield rubber of US $ 1.9 billion but also contain 250-300 spp. of plant (Leakey 1998; Mc Neely and Scherr, 2001). In San Jose - the Milpa, three types of traditional agroforestry systems viz., slash-and-burn agriculture, cacao cultivation under shade trees and home gardens were found to meet the entire family requirements of food and wood and generated 62 per cent of family income in Maya community of Belize (Levasseur and Olivier, 2000). Deb *et al*., (2014) recorded 44 woody and 49 herbaceous species in the traditional agroforestry system of Tripura, North East India and these documented plants meets community day to day needs of food, timber as well as ethno-medicinal purposes.

In addition to plant diversity, agroforestry systems also play an important role in increasing microbial, avian and faunal diversities. The greater diversity of birds and insect in agroforestry systems provide the beneficial service of pest reduction to adjacent crops (Gillespie *et al*., 1995; Schultz *et al*., 2000). Trees grown with crops improve the insect pest management options by providing habitat that can foster populations of natural enemies. CAST (1999) estimated natural enemy populations that live in natural and semi natural areas adjacent to farmlands can control more than 90 per cent of potential crop insect pests. Bugg *et al*. (1991) observed that cover crops (e.g. annual legumes and grasses) sustained lady beetles (Coleoptera: Coc-cinellidae) and other arthropods that are useful in the biological control of pests in pecan. Price and Gordon (1999) reported that earthworm densities were greatest next to poplar and white ash tree-rows, due to greater litter contributions. Although the population decreased during the summer period, but was still significantly greater than those from a comparable conventionally maize cropped field. Trees in agroforestry systems support cavity nesting birds, and offer forage and habitat to many species of birds (Pandey1991; Pandey and Mohan 1993). The number of bird species like *Streptopelia chinensis, Psittacula krameri, Eudynamys scolopaceus, Micropternus brachyurus, Dinopium benghalense, Oriolus xanthornus, Dicrurus macrocercus, Acridotheres tristis, Corvus splendens, Turdus cafer, Orthotomus sutorius, Copsychus saularis, Nectarinia zeylonica, Anthus campestris, Passer domesticus, and Ploceus philippinus* attracted to collect their food from fruit tress like *Aegle marmelos, Annona squamosa, Areca catechu, Averrhoa carambola, Carica papaya, Carissa carandas, Cocos nucifera, Dillenia indica, Elaeocarpus floribundus, Mangifera indica, Phyllanthus acidus, Phyllanthus emblica, Psidium guajava, Spondia spinnata, Syzygium cumini, Tamarindus indica and Zizyphus mauritiana* from homestead gardens(Roy *et al*., 2013).

CONCLUSION

The overall conclusion that emerges from this review is that agroforestry generally produces biodiversity benefits that are intermediate between monocrop agriculture and primary forests. The overall contribution of agroforestry to biodiversity conservation depends on the type of land use that it replaces and on the attributes of the specific agroforestry system. The effectiveness of agroforestry in biodiversity conservation depends on the design of the system and the nature of the biodiversity to be conserved. Agroforestry is not a stand-alone approach to conservation. Rather, it needs to be seen as an element of conservation strategies, which also include policy and institutional changes, and spatial configurations that emphasize maintenance of habitats.

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Contemporary Status of Some Selected Forests in Ondo State, Nigeria

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Abstract
This study assessed the present status, such as trees species diversity, abundance and volumes, of some selected natural forest in Ondo State, Nigeria. The forest selected were Igbo Olodunmare located at Okeigbo, Idanre forest reserve and Idanre hill both in Idanre. Eight plots of 25 by 25m were laid in each forest reserve where there were forest patches. All living trees with diameter at breast height (dbh) ≥ 10cm were identified and their total height, diameter at breast height, diameter at the base, middle and top were measured in each plot. These variables were used to compute the basal area, volume, relative frequency and relative density. Shannon-Weiner and species evenness indices were also used to assess and compare tree species diversity and abundance of each forest. The results obtained from this study showed that a total of 207 stem ha^{-1} in 30 tree species from 15 families were encountered in Igbo Olodunmare, 148 stem ha^{-1} which span through 61 tree species from 25 families were encountered in Idanre forest reserve and 151 stem ha^{-1} in 44 tree species from 19 families were encountered in Idanre hill. In Igbo Olodunmare, Hidegardia barteri had the highest number of stem per hectare (141 stem ha^{-1}). The diameter at breast height (DBH) distribution curve of tree species in the selected forests followed inverse J-shaped pattern. Although there was no continuous forest in the study areas, the species diversity and abundances obtained in the study areas compared favorably with the ones obtained in similar ecosystem except for Igbo Olodunmare that was dominated by Hildegardia barteri. Information provided in this study could be used by the government to avert further deforestation and forest degradation in the study areas

Keywords: Contemporary status, Natural forest, sacred grove and Tree diversity

INTRODUCTION
The total land area of the country excluding area under inland water bodies (13,000 km^2) remained stable at around 910,770 km^2. Initially, 39 percent, which is about 355,200km^2, of Nigeria's land area was covered with the tropical rainforest (NEST, 1991). This forest area fell gradually from 143,661 km^2 in 1997 to 65,834 km^2 in 2016. As at 2006, the Federal Government of Nigeria, through its body responsible for the management of forest resources, puts deforestation rate per annum to be 3.5% (Oyebo, 2006). By implication, Nigeria lost an average of 12,432km^2 of forest cover every year. Therefore, it could be deduced that between 2016 and 2019, a total of about 49,728 km^2 of Nigeria forest was lost, while today Nigeria is left with about 8% (28,538km^2) forest cover. Deforestation is the process of clearing, removal of forest trees where the land is converted to other types of activities for non-forest use, like conversion of forest reserves areas to residential or industrial areas, removing of forest trees as a result of road or rail construction, conversion for agricultural purposes and cutting down of forest trees for domestics and industrial use like fire-woods, timbers, paper production and charcoal production (Emeodilichi, 2018). Considering the rate at which forests cleared and trees are cut down without regeneration efforts, Nigeria may likely lose all its valuable trees if the

current unsustainable harvesting remains unchecked. A large proportion of Nigerians are living in the rural areas and they depend majorly on fuel-wood to meet their daily domestic energy requirements and other needs. Subsequently, forests are cut down to support human survival. This has wide range implications on environmental protection as well as the sustainable management of forest resources. Therefore, over-exploitation and encroachment are therefore great threats to the survival of an important tree species and the sustainable supply of products that previously come from it. Forest reserves are established to protect, as much of the original forests, as possible. However, these reserves are poorly monitored and there is a great threat to the survival of the present patches of forest in them. Forest reserves should be monitored and managed to ensure preservation for future generations. Information on the nature, extent and limitations of the various natural resources is pre-requisite for achieving this. Presently, there is little or no effort to address the threats to the survival of forest reserves. Part of the problem is that decision-makers do not have access to necessary information on the resources. Therefore, this project is designed to assess the volumes and tree species diversity and abundances of the selected Natural forest in Ondo State, Nigeria.

METHODOLOGY

Study Sites

Idanre forest reserve is located in Idanre local government, Ondo State. It is 148m above sea level and covers about 561km^2. It falls on latitude 6°51'27.72'' and longitude 5°6'19.84''. The Annual mean rainfall is between 1400 –2000 mm. The wet season spreads over eight months, from April to November while the dry season spreads over the remaining four months, from December to March. The temperature is fairly moderate and ranges between 21°C and 30°C depending on the time of the year. The Idanre Hill is located in Idanre town in Idanre local government, Ondo State. Idanre hill is one of the most beautiful natural landscapes in Nigeria. It includes such cultural sites as "Owa's Palace, Shrines, Old Court, Belfry, Agbooogun footprint, thunder water (Omi Apaara) and burial mounds and grounds". It is about 900m above sea level and houses a unique ecosystem upon which the cultural landscape has integrated. Idanre Hills is located on a Precambrian igneous batholith that is about 500 Million years old, and is cut by several large fracture that form deep valleys within the rocks. Igbo Olodunmare is located at Oke-Igbo in Oke-Igbo/Ile-Oluji local government, Ondo State. The forest is on a landmass of about 698 km^2. The forest is believed to be a place for deities, demons, monsters, spirits, kobolds, Gnomes, Ghosts, Ghommids, Trolls and gods who sometimes performed magic of appearing and disappearing (Aumeeruddy and Bakels, 1992).

Methods of Data Collection

Owing to the nature of these forests, eight plots of 25m x 25m were laid where there were forest patches in each study site. In each sample plot, all trees with Diameter at Breast Height (DBH) ≥ 10 cm were tagged and identified. Their diameters at the base, middle, top and the total height were measured. Where a tree's botanical name was not known, the tree was identified with its local or trade name. Parts (such as leaves, backs and fruits) of trees that cannot be identified were collected and taken to the herbarium for identification.

Method of Data Analysis

Basal Area Estimation

$$BA = \frac{\pi D^2}{4} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where BA = Basal area (m^2), D = Diameter at breast height (cm) and π = Pie (3.142).

Volume Estimation

The volume of individual trees was estimated using the Newton formula $V = \frac{\pi h}{24}\left(D_b^{\,2} + 4D_m^{\,2} + D_t^{\,2}\right)$

……………………………………………………………… (2)

Where: V = Volume of tree (m^3), D_b = Diameter at the base (cm), D_m = Diameter at the middle (cm), D_t = Diameter at the top (cm), H = height (m)

Biodiversity Indices and Tree Species Classification

All trees were assigned to families and the number of species in each family was obtained for tree species diversity classification. Frequency of occurrence was obtained for species abundance/richness. This was repeated for all the trees encountered in all the forests used in this study. The following biodiversity indices were used to compare tree species richness and evenness in each forest reserve. It was also be used as indices for comparing biodiversity among the selected forests.

(i) **Species relative density** was computed as

$$RD = \frac{n_i}{N} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where: RD (%) = species relative density;

ni = number of individuals of species i;

N = total number of all tree species in the entire community

(ii) **Species relative dominance (RDo (%)** was computed using the equation:

$$RD_O = \frac{\sum Ba_i \times 100}{\sum Ba_n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where**:** Ba_i = Basal area of individual tree belonging to species i and

Ba_n = Stand basal area

(iii) **The Shannon's maximum diversity index** was determined using the Shannon–Wiener diversity index equation (Kent & Coker, 1992), was employed to calculate the tree species diversity in the ecosystems because it takes into account the richness and abundance of each species in different ecosystems (Prince 1997)

$$H' = \sum_{i=1}^{S} p_i \ln(p_i) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Where H' = Shannon diversity index,

S = the total number of species in the community,

pi = proportion S (species in the family) made up of the ith species and

ln = natural logarithm.

(iv) **Species evenness (E)** in each community Shannon's equitability equation was used (Kent and Coker 1992).

$$E_H = \frac{H'}{H_{Max}} = \frac{\sum_{i=1}^{S} P_i \ln(P_i)}{\ln(S)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

(v) **Importance Value Index (IVI)**: The Importance Value Index for each species was obtained by summing up the RD and RDo divided by 2 (RD x RDo/2) (Brashears *et al*., 2004; Yang *et al*. 2008). This was used to express the share of each species in the tree community

(vi) **Family Importance Value (FIV)**: This was used to understand a family's share in the tree community. This is the sum of the relative dominance (RDm), relative density (RD) and relative frequency (RF).

RDm= (Total Basal area for a family ÷ Total Basal area of all families) X 100

RD= (Number of individual a of family ÷ Total number of all individual) X 100

RF = (Frequency a of family ÷ Sum frequencies all of s families) X 100

Therefore, the FIV was be calculated as: RDm+ RD+ RF………………………………….. (7)

Number 1 of Hill diversity index

N1 = exp(-Σpi(lnpi))……………………………………………………..………………..(8)

pi = ni/N …………………………………………………………………………………….(9)

Where: pi: is the proportional abundance of ith species,

ni: number of individuals of ith species,

N: total number of individuals

Number 2 of Hill diversity index

N2: Reciprocal of Simpson's dominance Index;

N2 = 1/Σ pi2 ……………………………………………..…………………………... (10)

(vii) **Shannon max diversity index** was determined using

Hmax = LnS…………………………………………………………………………… (11)

Where S = the total number of species in the community

(viii) **Sorensen's species similarity index** between all sites was calculated using the equation

$$SI = \frac{2c}{a+b+c} X\ 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

C is the total number of species in three communities (i.e. aggregate of all species encountered in the entire study area); while a, b, & c are the number of species in Forest reserve 1, 2 & 3 respectively.

RESULTS

Tree species diversity and abundance

The tree species diversity and abundances obtained in this study are presented in table 1, 2 and 3. The study revealed that 1012 stem ha^{-1} was encountered in all the study sites. A total of 414 stem ha^{-1} in 30 tree species from 15 families were encountered in Igbo Olodunmare, 296 stem ha^{-1} which span through 61 tree species from 25 families were encountered in Idanre forest reserve and 302 stem ha^{-1} in 44 tree species from 19 families were encountered in Idanre hill. In Igbo Olodunmare, *Hidegardia barteri* had the highest number of stem per hectare (282 stem ha^{-1}). This was followed by *Sterculia rhinopetala* (26 stem ha^{-1}) and *Spondias pinnata* (12 stem ha^{-1}). Idanre forest reserve had *Celtis mildbreadii* as the most abundance tree species (32 stem ha^{-1}). This was closely followed by *Celtis zenkiri* (18 stem ha^{-1}) and *Drypetes polyantha* (16 stem ha^{-1}). *Casia siemen* was recorded as the most abundance tree species in Idanre hill with (38 stem ha^{-1}).This was followed by *cola gigantean* and *Albizia zygia* with (28 stem ha^{-1}) and (22 stem ha^{-1}) respectively. In this study, about 39% of all the species were represented by single individual ha^{1}. Only two tree species (*Diospyrous monbuttensis and Ficus mucoso*) were common to all the study area. The results for Family Importance Value (FIV) for the selected forests are presented in Table 4 - 5 and 6. The results revealed that 32 different families were encountered in the three forest ecosystem, 15 families from Igbo-Oledumare, 25 families from Idanre Forest Reserve and 19 families from Idanre Hill natural forest. The Family *Malvaceae* had the highest Family Importance Value (218.61%) in Igbo-Olodumare. The family *Fabaceae* (94.02 %) and *Ulmaceae* (78.91%) had the highest FIV in Idanre Hill and Idanre forest reserves respectively.

Biodiversity indices

The summary of the various biodiversity indices for the purpose of assessing the abundance, level of diversity and evenness of all the tree species encountered is presented in Table 7. Idanre forest reserve had the highest Shannon-Weiner index (3.76). This is an indication that it has the highest species richness when compared to the other two locations. This was closely followed by Idanre hill natural forest (3.33) and the lowest Shannon-Weiner index was recorded for the Igbo Olodunmare (1.58). Idanre forest reserve had the highest species evenness (0.91) according to Pielous, followed by Idanre hill (0.88) and Igbo Olodunmare (0.46). A high N1 (57.39) and N2 (29.52) of hill diversity were recorded for Idanre forest reserve, followed by Idanre hill (40.83 and 19.73) and Igbo Olodunmare (28.49 and 2.13).

Table 1: Tree Species, Abundance/ha, Diversity Indices and Tree Growth Variables of the Idanre Forest Reserve.

S/N	Species Name	N/Ha	MDBH (cm)	MHt (m)	MBA (m^2)	MVol. (m^3)	PiLnpi	RD
1	*Allanblackia floribunda*	2	88	16.5	0.61	3.32	-0.03	0.68
2	*Antrocaryon micrasta*	2	37.46	25.6	0.11	1.24	-0.03	0.68
3	*Baphia nitida*	4	12.65	8.25	0.01	0.14	-0.06	1.35
4	*Berlinia grandiflora*	6	13.67	10.8	0.01	0.12	-0.08	2.03
5	*Brachystegia eurycoma*	12	43.54	21.32	0.18	2.59	-0.13	4.05
6	*Brachystegia nigerica*	2	75	18.6	0.44	2.66	-0.03	0.68
7	*Celtis mildbreadii*	32	50.53	19.4	0.27	1.62	-0.24	10.81
8	*Celtis philippensis*	4	36.54	18.05	0.11	1.21	-0.06	1.35
9	*Celtis zenkeri*	18	33.71	13.93	0.17	0.78	-0.17	6.08
10	*Cleistopholis patens*	4	122.8	32.05	1.21	16.36	-0.06	1.35
11	*Cola acuminate*	2	13.43	10.5	0.01	0.1	-0.03	0.68
12	*Cola gigantean*	10	87.99	22.6	0.68	5.87	-0.11	3.38
13	*Cordia millenii*	6	91.2	13.17	1.1	2.79	-0.08	2.03
14	*Coula edulis*	4	36.07	18.5	0.11	1.07	-0.06	1.35
15	*Desplatsia subericarpa*	10	30.29	17.28	0.1	0.97	-0.11	3.38
16	*Diospyros biondii*	4	52.37	12.65	0.3	0.93	-0.06	1.35
17	*Diospyros dendo*	4	22.22	10	0.04	0.27	-0.06	1.35
18	*Diospyros mespiliformis*	2	13.97	16.2	0.02	0.12	-0.03	0.68
19	*Diospyros monbuttensis*	4	17.81	15	0.03	0.22	-0.06	1.35
20	*Diospyros spp*	2	74	15.5	0.43	1.28	-0.03	0.68
21	*Diospyros suaveolens*	2	80	13.1	0.5	2.26	-0.03	0.68
22	*Diospyros zenkeri*	4	13.21	11.9	0.01	0.14	-0.06	1.35
23	*Draceana spp*	2	137	23.5	1.47	8.3	-0.03	0.68
24	*Drypetes afzelii*	2	11.97	8.5	0.01	0.06	-0.03	0.68
25	*Drypetes polyantha*	16	33.8	16.01	0.09	0.78	-0.16	5.41
26	*Enantia chloranta*	2	23.59	4	0.04	0.11	-0.03	0.68

27	*Entandrophragma cylindricum*	2	18.25	11.2	0.03	0.09	-0.03	0.68
28	*Entandrophragma utile*	6	51.6	21.87	0.32	2.87	-0.08	2.03
29	*Ficus mucosu*	2	117	24.8	1.08	10.75	-0.03	0.68
30	*Ficus sur*	4	72.66	17	0.44	2.36	-0.06	1.35
31	*Fiscus amplissima*	4	14.5	12.5	0.02	0.27	-0.06	1.35
32	*Harungana madagascariensis*	4	17.33	14.45	0.03	0.17	-0.06	1.35
33	*Hildegardia barteri*	14	55.9	16.2	0.4	1.69	-0.14	4.73
34	*Hormalium longistulus*	2	10.16	11.8	0.01	0.07	-0.03	0.68
35	*Hunteria umbellate*	4	45	16.45	0.26	2.76	-0.06	1.35
36	*Hypodaphinis zenkerii*	4	26.51	12.6	0.06	0.43	-0.06	1.35
37	*Ixora guineensis*	2	17.65	12.4	0.02	0.15	-0.03	0.68
38	*Khaya grandifoliola*	2	10.1	12.9	0.01	0.06	-0.03	0.68
39	*Lannea welwitschii*	2	42	25.9	0.14	2.98	-0.03	0.68
40	*Leucaniodiscus cupanoides*	2	44.13	18.5	0.15	1.42	-0.03	0.68
41	*Malacantha alnifolia*	2	130	19	1.33	4.79	-0.03	0.68
42	*Mansonia altissima*	10	32.58	21.52	0.09	1.09	-0.11	3.38
43	*Musanga cecropoides*	4	117.3	14.55	1.62	4.84	-0.06	1.35
44	*Pterocarpus erinaceus*	2	190	20.5	2.84	10.68	-0.03	0.68
45	*Pterygota macrocarpa*	2	33.08	19.5	0.09	0.97	-0.03	0.68
46	*Pycnanthus angolensis*	2	125	16.6	1.23	5.12	-0.03	0.68
47	*Rhabdophylum arnoldianum*	2	78	22.4	0.48	3.96	-0.03	0.68
48	*Ricinodendron heudelotii*	4	38.8	14.95	0.12	0.87	-0.06	1.35
49	*Rothmannia longiflora*	4	12	9.25	0.01	0.08	-0.06	1.35
50	*Rothmannia whitfiedii*	2	10.79	11.7	0.01	0.09	-0.03	0.68
51	*Sterculia oblonga*	2	12.06	12.2	0.01	0.08	-0.03	0.68
52	*Sterculia rhinopetala*	8	37.05	19.88	0.14	1.62	-0.1	2.7
53	*Sterculia trigacantha*	4	23.15	16.5	0.05	0.43	-0.06	1.35
54	*Strombosia fasae*	6	15.19	15.87	0.02	0.17	-0.08	2.03
55	*Strombosia pustulata*	4	24.24	11.7	0.05	0.24	-0.06	1.35
56	*Tectona grandis*	2	115	23.5	1.04	7.65	-0.03	0.68
57	*Trichilia retusa*	2	29.71	21.5	0.07	0.68	-0.03	0.68

58	*Trichilia welwitschii*	4	31.17	18.65	0.08	0.86	-0.06	1.35
59	*Trilepisium madagascariense*	2	36.83	18.6	0.11	0.68	-0.03	0.68
60	*Triplochyton scleroxylon*	2	47.74	21.5	0.18	2.46	-0.03	0.68
61	*Vitex doniana*	10	61.57	16.32	0.37	1.91	-0.11	3.38

MDBH-Mean diameter at breast height, MHT-Mean height, MBA-Mean Basal area, RF-Relative frequency

Table 2: Tree Species, Abundance/ha, Diversity Indices and Tree Growth Variables of Igbo Olodunmare.
MDBH-Mean diameter at breast height, MHT-Mean height, MBA-Mean Basal area, RF-Relative frequency

S/N	Species	N/ha	Mean Dbh (cm)	Mean Ht (m)	Mean BA (m2)	Mean Vol. (m3)	piLnpi	RD
1	*Amphimas pterocarpoides*	2	31.50	21.80	0.08	0.82	-0.03	0.48
2	*Anthonotha macrophylla*	2	11.00	7.70	0.01	0.04	-0.03	0.48
3	*Blighia sapida*	2	13.20	10.00	0.01	0.07	-0.03	0.48
4	*Brachystegia nigerica*	2	45.50	16.80	0.16	1.37	-0.03	0.48
5	*Ceiba pentandra*	2	31.20	14.90	0.08	0.62	-0.03	0.48
6	*Celtis mildbreadii*	2	33.50	16.80	0.09	0.96	-0.03	0.48
7	*Celtis philippensis*	2	11.50	11.30	0.01	0.07	-0.03	0.48
8	*Celtis zenkeri*	4	22.85	13.75	0.05	0.50	-0.04	0.97
9	*Cola millenii*	6	28.67	13.37	0.07	0.49	-0.06	1.45
10	*Cordia mellenii*	2	46.50	22.40	0.17	2.17	-0.03	0.48
11	*Diospyros monbuttensis*	2	12.20	11.40	0.01	0.10	-0.03	0.48
12	*Drypetes spp*	4	22.50	14.15	0.05	0.46	-0.04	0.97
13	*Ficus exasperate*	2	21.50	14.60	0.04	0.27	-0.03	0.48
14	*Ficus sycomona*	2	117.00	25.80	1.08	12.22	-0.03	0.48
15	*Funtumia elastic*	8	15.45	12.88	0.02	0.17	-0.08	1.93
16	*Hildegardia barteri*	282	34.47	13.10	0.11	0.71	-0.26	68.12
17	*Khaya grandifoliola*	6	31.23	15.20	0.12	1.25	-0.06	1.45
18	*Leucaniodiscus cupanioides*	2	25.00	14.40	0.05	0.35	-0.03	0.48
19	*Mansonia altissima*	6	35.53	17.20	0.11	0.77	-0.06	1.45
20	*Millettia thonningii*	2	10.20	7.20	0.01	0.02	-0.03	0.48

21	*Nesogordomia*	4	12.75	10.20	0.01	0.07	-0.04	0.97
22	*papaverifera*							
23	*Pterigota macrocarpa*	2	14.00	13.40	0.02	0.15	-0.03	0.48
24	*Ricinodendrum heudelotii*	8	57.45	20.33	0.29	2.08	-0.08	1.93
25	*Rothmannia whitfieldii*	2	16.00	13.80	0.02	0.15	-0.03	0.48
26	*Spathodea campanulata*	8	13.83	13.55	0.02	0.17	-0.08	1.93
27	*Spondias mombin*	12	29.60	12.62	0.08	0.48	-0.10	2.90
28	*Spondias pinnata*	6	38.43	15.17	0.12	0.85	-0.06	1.45
29	*Sterculia oblonga*	26	16.55	10.60	0.02	0.15	-0.17	6.28
30	*Sterculia trigancantha*	2	28.50	17.40	0.06	0.54	-0.03	0.48
31	*Voacanga Africana*	2	12.50	9.60	0.01	0.09	-0.03	0.48

Table 3: Tree Species Abundance/ha, Diversity Indices and Tree Growth Variables of Idanre Hill Natural Forest.
MDBH-Mean diameter at breast height, MHT-Mean height, MBA-Mean Basal area, RF-Relative Density

S/N	Species name	N/Ha	MDbh (cm)	MHt(m)	MBA (m2)	MVol. (m3)	pilnpi	RD
1	*Adansonia digitata*	2	88.00	14.70	0.61	4.62	-0.03	0.66
2	*Albizia ferruginea*	12	24.77	13.75	0.05	0.47	-0.13	3.97
3	*Albizia lebbeck*	8	29.25	13.83	0.08	0.50	-0.10	2.65
4	*Albizia zygia*	22	20.83	12.88	0.04	0.41	-0.19	7.28
5	*Alsonia boonei*	2	127.50	24.90	1.28	12.55	-0.03	0.66
6	*Amphimas pterocarpoides*	4	24.60	12.85	0.06	0.51	-0.06	1.32
7	*Anthocleista vogelii*	4	29.60	13.45	0.07	0.55	-0.06	1.32
8	*Antiaris Africana*	8	21.28	12.73	0.04	0.41	-0.10	2.65
9	*Baphia nitida*	2	10.00	4.50	0.01	0.02	-0.03	0.66
10	*Blighia sapida*	4	27.85	15.30	0.06	0.61	-0.06	1.32
11	*Brachystagia eurycoma*	2	71.50	23.60	0.40	6.22	-0.03	0.66
12	*Bridelia micrantha*	2	36.20	14.10	0.10	0.77	-0.03	0.66
13	*Casia siemen*	38	27.85	14.74	0.07	0.87	-0.26	12.58
14	*Chrysophylum albidum*	4	50.85	17.15	0.21	1.47	-0.06	1.32
15	*Cola gigantean*	28	42.41	18.39	0.17	1.73	-0.22	9.27

16	*Dialium guineensis*	6	27.10	10.17	0.07	0.46	-0.08	1.99
17	*Diospyros dendo*	2	17.60	8.50	0.02	0.09	-0.03	0.66
18	*Diosypros mobutensis*	2	10.00	10.40	0.01	0.05	-0.03	0.66
19	*Ficus exasperate*	2	23.20	13.30	0.04	0.35	-0.03	0.66
20	*Ficus mucuso*	10	50.42	16.50	0.23	2.40	-0.11	3.31
21	*Funtumia elastic*	2	13.40	9.80	0.01	0.07	-0.03	0.66
22	*Holarrhena floribunda*	14	25.26	11.30	0.06	0.48	-0.14	4.64
23	*Khaya grandifoliola*	2	27.80	16.10	0.06	0.56	-0.03	0.66
24	*Kigelia africana*	2	15.00	7.50	0.02	0.08	-0.03	0.66
25	*Manikara obovata*	2	40.80	13.60	0.13	1.43	-0.03	0.66
26	*Margaritaria discoidea*	16	21.64	10.25	0.04	0.37	-0.16	5.30
27	*Milicia excels*	10	68.10	19.38	0.51	6.34	-0.11	3.31
28	*Millettia thonningii*	8	30.30	15.10	0.08	0.71	-0.10	2.65
29	*Monodora tenuifolia*	2	24.00	18.20	0.05	0.24	-0.03	0.66
30	*Morus mesozygia*	2	16.00	12.30	0.02	0.16	-0.03	0.66
31	*Pipterdeniastrum africanum*	2	46.70	18.00	0.17	1.82	-0.03	0.66
32	*Pterocarpus mildbraedii*	2	10.20	9.70	0.01	0.07	-0.03	0.66
33	*Pterygota macrocarpa*	6	16.80	10.40	0.02	0.14	-0.08	1.99
34	*Spathodea campanulata*	4	18.00	13.00	0.03	0.23	-0.06	1.32
35	*Spondia mombim*	16	25.11	11.05	0.07	0.48	-0.16	5.30
36	*Sterculia oblonga*	2	32.00	13.10	0.08	0.59	-0.03	0.66
37	*Terminalia superba*	2	63.20	22.40	0.31	2.82	-0.03	0.66
38	*Tetrapleura tetraptera*	12	25.75	15.58	0.06	1.02	-0.13	3.97
39	*Trema orientalis*	2	21.20	10.10	0.04	0.18	-0.03	0.66
40	*Trichilia monadelpha*	2	12.00	8.30	0.01	0.06	-0.03	0.66
41	*Trichilia welwitschii*	14	17.04	8.30	0.02	0.15	-0.14	4.64
42	*Triplochiton scleroxylon*	4	44.60	20.65	0.16	1.48	-0.06	1.32
43	*Albizia labbeck*	2	17.50	15.20	0.02	0.23	-0.03	0.66
44	*Ceiba pentandra*	8	63.58	18.13	0.41	3.25	-0.10	2.65

Table 4: Families' Importance Index for Igbo Olodunmare.

S/N	Family	Count	Dbh(cm)	M Ht(m)	M BA (m^2)	M Vol. (m^3)	RF%	RD%	RDo%	FIV
1	*Anacardiaceae*	9	32.54	13.47	0.09	0.60	4.35	4.35	3.89	12.59
2	*Apocynaceae*	5	14.86	12.22	0.02	0.15	2.42	2.42	0.45	5.28
3	*Bignoniaceae*	4	13.83	13.55	0.02	0.17	1.93	1.93	0.28	4.15
4	*Boraginaceae*	1	46.50	22.40	0.17	2.17	0.48	0.48	0.79	1.76
5	*Caesalpinioideae*	1	11.00	7.70	0.01	0.04	0.48	0.48	0.04	1.01
6	*Ebenaceae*	1	12.20	11.40	0.01	0.09	0.48	0.48	0.05	1.02
7	*Euphorbiaceae*	6	45.80	18.27	0.21	1.54	2.90	2.90	5.88	11.68
8	*Fabaceae*	3	29.07	15.27	0.08	0.73	1.45	1.45	1.16	4.06
9	*Malvaceae*	147	34.17	13.15	0.11	0.70	71.01	71.01	76.58	218.61
10	*Meliaceae*	3	31.23	15.20	0.12	1.25	1.45	1.45	1.63	4.53
11	*Moraceae*	2	69.25	20.20	0.56	6.24	0.97	0.97	5.20	7.13
12	*Rubiaceae*	1	16.00	13.80	0.02	0.15	0.48	0.48	0.09	1.06
13	*Sapindaceae*	2	19.10	12.20	0.03	0.20	0.97	0.97	0.29	2.23
14	*Sterculiaceae*	18	19.09	11.59	0.03	0.22	8.70	8.70	2.72	20.11
15	*Ulmaceae*	4	22.68	13.90	0.05	0.50	1.93	1.93	0.91	4.77

MDBH-Mean diameter at breast height, MHT-Mean height, MBA-Mean Basal area, RF-Relative frequency RD-Relative frequency, FIV-Family importance Value

Table 5: Families' Importance Index for Idanre Forest Natural Forest

S/N	Family	No	MDbh (m)	MHt (m)	MBA (m^2)	MVol. (m^3)	RF	RD%	RDo%	FIV
1	*Anacardiaceae*	2	0.40	25.75	0.12	2.11	1.35	1.35	3.142678	5.85
2	*Annonaceae*	3	0.90	22.70	0.82	10.94	2.03	2.03	4.714016	8.77
3	*Apocynaceae*	2	0.45	16.45	0.26	2.76	1.35	1.35	3.142678	5.85
4	*Boraginaceae*	3	0.91	13.17	1.10	2.79	2.03	2.03	4.714016	8.77
5	*Cecropiaceae*	2	1.17	14.55	1.62	4.84	1.35	1.35	3.142678	5.85
6	*Clusiaceae*	1	0.88	16.50	0.61	3.32	0.68	0.68	1.571339	2.92
7	*Dracaenaceae*	1	1.37	23.50	1.47	8.30	0.68	0.68	1.571339	2.92
8	*Ebanaceae*	11	0.34	13.08	0.16	0.62	7.43	7.43	17.28473	32.15
9	*Euphorbiaceae*	11	0.33	15.14	0.09	0.73	7.43	7.43	17.28473	32.15
10	*Fabaceae*	13	0.46	16.61	0.34	2.27	8.78	8.78	20.4274	37.99
11	*Guttiferae*	2	0.17	14.45	0.03	0.17	1.35	1.35	3.142678	5.85
12	*Irvinginaceae*	2	0.27	12.60	0.06	0.43	1.35	1.35	3.142678	5.85
13	*Lamiceae*	6	0.70	17.52	0.48	2.87	4.05	4.05	9.428033	17.54
14	*Malvaceae*	18	0.42	18.27	0.22	1.37	12.16	12.16	28.2841	52.61
15	*Meliaceae*	9	0.35	18.57	0.15	1.32	6.08	6.08	14.14205	26.30
16	*Moraceae*	5	0.58	16.76	0.40	3.20	3.38	3.38	7.856694	14.61
17	*Myristicaceae*	1	1.25	16.60	1.23	5.12	0.68	0.68	1.571339	2.92
18	*Ochnaceae*	1	0.78	22.40	0.48	3.96	0.68	0.68	1.571339	2.92
19	*Olacaceae*	7	0.24	15.43	0.05	0.45	4.73	4.73	10.99937	20.46
20	*Rubiaceae*	4	0.13	10.65	0.01	0.10	2.70	2.70	6.285355	11.69
21	*Samydaceae*	1	0.10	11.80	0.01	0.07	0.68	0.68	1.571339	2.92
22	*Sapindaceae*	1	0.44	18.50	0.15	1.42	0.68	0.68	1.571339	2.92
23	*Sapotaceae*	1	1.30	19.00	1.33	4.79	0.68	0.68	1.571339	2.92
24	*Sterculiaceae*	14	0.50	19.12	0.30	2.70	9.46	9.46	21.99874	40.92
25	*Ulmaceae*	27	0.44	17.48	0.23	1.31	18.24	18.24	42.42615	78.91

MDBH-Mean diameter at breast height, MHT-Mean height, MBA-Mean Basal area, RF-Relative frequency RD-Relative frequency, FIV-Family importance Value

Table 6: Families' Importance Index for Idanre Hill Natural Forest

S/N	Family	No	MDBH (cm)	MHt (m)	MBA (m2)	MVol. (m3)	RF%	RD%	RDo%	FIV
1	*Anacardiaceae*	8	25.11	11.05	0.07	0.48	5.30	5.30	3.01	13.61
2	*Annonaceae*	1	24.00	18.20	0.05	0.24	0.66	0.66	0.26	1.58
3	*Apocynaceae*	9	35.30	12.64	0.19	1.77	5.96	5.96	9.98	21.90
4	*Bignoniaceae*	3	17.00	11.17	0.02	0.18	1.99	1.99	0.41	4.38
5	*Caesailpiniodeae*	3	27.10	10.17	0.07	0.46	1.99	1.99	1.19	5.16
6	*Combretaceae*	1	63.20	22.40	0.31	2.82	0.66	0.66	1.80	3.13
7	*Ebenaceae*	2	13.80	9.45	0.02	0.07	1.32	1.32	0.19	2.83
8	*Fabaceae*	55	26.32	14.23	0.07	0.77	36.42	36.42	21.17	94.02
9	*Loganiaceae*	2	29.60	13.45	0.07	0.55	1.32	1.32	0.80	3.45
10	*Malvaceae*	7	61.64	18.36	0.36	2.94	4.64	4.64	14.68	23.95
11	*Meliaceae*	9	17.68	9.17	0.03	0.18	5.96	5.96	1.40	13.32
12	*Mimosoideae*	1	46.70	18.00	0.17	1.82	0.66	0.66	0.99	2.31
13	*Moraceae*	16	44.81	15.99	0.25	2.86	10.60	10.60	22.68	43.87
14	*Papilionoideae*	1	10.20	9.70	0.01	0.07	0.66	0.66	0.05	1.37
15	*Phyllanthaceae*	9	23.26	10.68	0.05	0.41	5.96	5.96	2.57	14.49
16	*Sapindaceae*	2	27.85	15.30	0.06	0.61	1.32	1.32	0.70	3.35
17	*Sapotaceae*	3	47.50	15.97	0.18	1.46	1.99	1.99	3.14	7.12
18	*Sterculiaceae*	18	37.57	16.76	0.14	1.40	11.92	11.92	14.82	38.66
19	*Ulmaceae*	1	21.20	10.10	0.04	0.18	0.66	0.66	0.20	1.53

MDBH-Mean diameter at breast height, MHT-Mean height, MBA-Mean Basal area, RF-Relative frequency RD-Relative frequency, FIV-Family importance Value

Table 7: Summary of tree species diversity indices in the selected forest sites

Variables	Igbo Olodunmare	Idanre F.R	Idanre hill	All Locations
No of trees/ ha	207	148	151	506
No of Families (NF)	15	25	19	32
No of Species (NS)	30	61	44	100
Shannon-Weiner Index (H')	1.58	3.76	3.33	3.57
Pielou's Spp evenness index	0.46	0.91	0.88	0.78
Simpson's concentration	0.47	0.03	0.05	0.1
N1 of hill diversity (N1)	28.49	57.39	40.83	96.57
N2 of hill diversity (N2)	2.13	29.52	19.73	10
Margalef's index of Spp. richness (M)	5.44	12.01	8.57	15.90

The forest structure, based on diameter distribution of all the trees that were encountered in the selected forest reserves are presented in figure 1 below. As one of the peculiar features of a mature natural forest ecosystem, the DBH distribution curve of tree species in the selected forests followed inverse J-shaped pattern as represented. About 39.3% trees fall within the lowest diameter class (10-20cm) in each of the selected forest area.

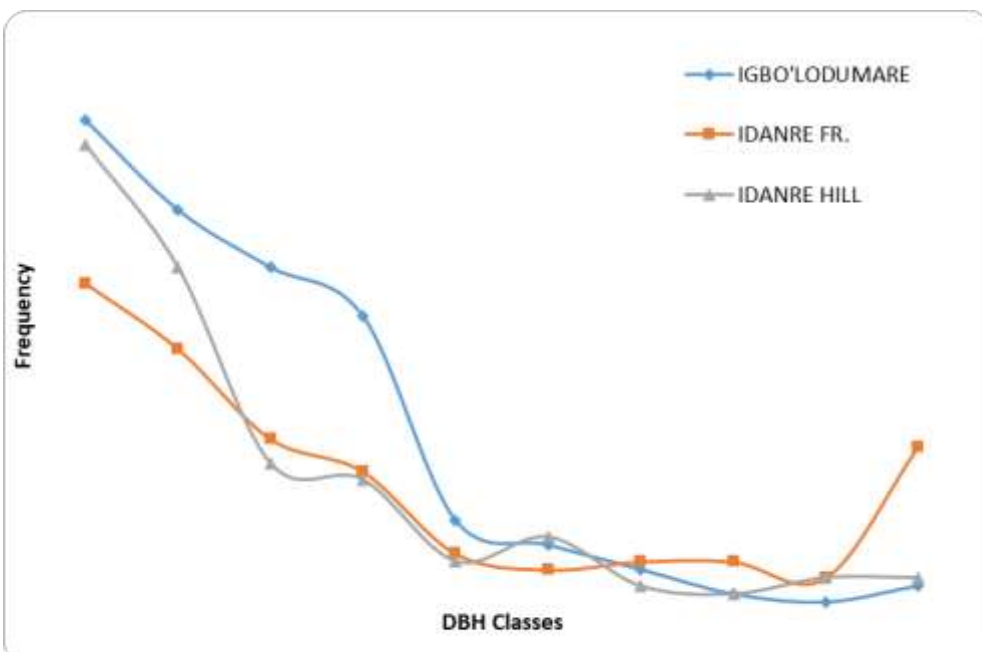

Figure 1: Diameter distribution curve for the selected natural forests.

DISCUSSION

The Nigeria rainforest ecosystem has been reported to be rich in diversity of trees than any other single forest community regardless of its plot size (Adekunle, 2006).This forest ecosystem is dominated by members of Sterculiaceae, Moraceae and Meliaceae (Isichei, 1995), which agrees with the result obtained in this study. Tree species richness is one of the biodiversity indexes. The result obtained in this study shows that 61 tree species were encountered in Idanre fo rest reserve and 44 tree species were recorded in Idanre hill, which was higher than the 31 species that was obtained in the Igbo Olodunmare. The values of species richness obtained in Idanre forest reserve and Idanre hill are comparable with the results of Lowe (1997) and Adekunle (2006) obtained for some natural rainforest sites in Nigeria and that of Abayomi (2001) who recorded 68 species in Cross river state of Nigeria. Several researchers had adopted the use of Shannon Weiner diversity index to investigate ecosystem diversity as it takes into account both species richness and evenness in a forest community (Onyekwelu *et al*., 2005). The trend of Shannon Weiner diversity indices shows that Idanre forest reserve was the most diverse of the three selected study areas, followed by Idanre hill and lastly Igbo Olodunmare. The Shannon Wiener value obtained in Idanre forest reserve (3.76) and Idanre hill (3.33) agrees with the findings of Adekunle (2006) that obtained H' values of 3.34-3.66 for some rainforest sites in Nigeria but higher than that of Igbo Olodunmare (1.58). This result is an indication that biological diversity could be adequately conserved through the establishment of natural forest. The value of tree species evenness according to Pielou obtained in Idanre hill (0.88) and Idanre forest reserve (0.91) was an indication that tree species in the forest was most evenly distributed in Idanre forest reserve and Idanre hill followed by Igbo Olodunmare (0.46) which was unevenly distributed.

Tree stem volume at stand level was reported to be one of the most important parameters in forest management, and its acquisition is very time consuming and expensive because it is normally obtained from field surveys (Tonolli *et al*., 2011). The high tree volume productivity obtained in the three natural forest (Igbo Olodunmare, Idanre hill and Idanre natural forest) could be attributed to the effect of conservation (Onyekwelu *et al*., 2005). About 90% of all the trees encountered in the Igbo Olodunmare fall in the lower height class of 10-20cm while 10% of them falls in the diameter class of 20-30cm. Similar trends were also noticed in Idanre forest reserve and Idanre hill. About 65% of the trees encountered in the all the selected natural forest could be regarded as matured or big trees (dbh≥40cm) while about 35 % of them were represented as small diameter logs. The proportion of big trees in this forest is more than 4.5 and 3.5% reported by Huang *et al*., (2003) and Lu *et al*., (2010). The number of stem in the site was inversely proportional to the diameter sizes in the DBH class frequency distribution which denotes a healthy recruitment of individual in an unlogged forest site. The distribution of number into DBH size classes for the study area is a typical inverted J-shape curve expected of tropical natural forest eco-system.

CONCLUSION

This study provided species diversity and abundance in Idanre forest reserve, Idanre Hill natural forest and Igbo - Olodumare. Idanre forest reserve had the highest Shannon-Weiner index (3.76) when compared with the other two locations. Although there was no continuous forest in the study areas, the species diversity and abundances obtained in the study areas compared favorably with the ones obtained in similar ecosystem except for Igbo -Olodunmare that was dominated by *Hildegardia barteri*. Information provided in this study could be used by the government to avert further deforestation and forest degradation in the study areas.

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Phytoecological Studies of a Protected Area in Lowland Humid Forest, Ondo State, Nigeria

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Abstract

The species rich tropical rainforests have been under intense pressure to satisfy demands for timber and non-timber products, the long-term effect being degradation in terms of quality and quantity of the forest ecosystem. This study was carried out to assess the potential of protected areas in biodiversity conservation. This was done by assessing the tree species diversity and abundance, and growth yield of a protected forest area. Systematic line transect was used for plot layout. All trees with dbh ≥10cm were identified, and classified up to family level and their diameter at the base (db), height, diameter at breast height (dbh), diameter at the top (dt) and height were measured. A total of 150 stems per hectare belonging to 46 tree species distributed among 27 families were encountered in this study. Hylodendron gabunense Taub. was the most abundant tree species with 19 $stemsha^{-1}$ .A total basal area and volume of 15.09m^2ha-^{1} and 107.72m^3ha-^{1} were recorded respectively for the study site. Only 45.3% of trees encountered in the study area fell in the lower diameter class of 10-20cm and 25.3% fell in diameter class above 40cm. Shannon-Weinner diversity index of 3.51 and Species evenness of 0.92 were obtained. The study concluded that protected areas are potential biodiversity hotspots and recommended that protected areas should be safeguarded from anthropogenic activities.

Keywords: Species diversity, Species Evenness, Tree Volume, biodiversity hotspots

INTRODUCTION

Due to population growth, exploitation of natural resources in the developing countries of the world is increasing at an alarming rate. Variations in structure and floristic composition in rainforests are attributed to ecological and evolutionary processes, geographic circumstances, and natural (e.g. fires, floods, wind throws) and human-induced disturbances e.g. clearing, burning, logging etc. (Okuda *et al*., 2003; Richards, 1952). As stated by Dengler (2017), Phytosociology is an aspect of science which study vegetation in terms of plant assemblages, classification and characterization of the vegetation types based on the floristic composition in the plant community. It is a veritable tool to characterize and classify plant community according to structure and composition for protecting the natural plant environment and proper management of the forest resources. Protected Areas (PAs) are potentially beneficial for carbon sink and environmental conservation. They help to conserve ecosystems that provide habitat, shelter, food, raw materials, genetic materials, a barrier against disasters, a stable source of resources and ecosystem goods and services and thus can have vital roles in helping species and people adapt to climate change. Strict Nature Reserve (SNR) is a common method of in situ conservation of biodiversity in Nigeria in particular and the world in general (Isichei,1995). Other common methods in Nigeria are Game Reserves, Sacred Groves, Biosphere Reserve. These areas are created to protect representative samples of natural ecosystems for preservation of biodiversity, ecological process and maintenance of genetic resources. About 10 million ha of rainforests are degraded each year, with exploitation, felling damage to residual forests and non-timber forest products collection being the chief causes. Forest degradation is usually accompanied by species extinction, reduction in biodiversity and decrease in primary productivity (Wilcox, 1995). Logging can generate negative impacts, with immediate effects that include reduction in tree density, basal area, commercial species, canopy area and climax species populations (Johns *et al*., 1992; Köhler and Huth, 2007; Marshall, 1992; McDonald *et.al*., 2008). Long-term effects result in changes in diameter and height distribution, basal area, volume, recruitment and floristic composition (Belote *et. al.*, 2012; Irwin *et.al.*, 2010; Kalacska *et. al*., 2004; Okuda *et al*., 2003), and can be difficult to separate from responses associated with site factors and natural processes (Cannon and Peart, 1998).

Many tropical forests are under great anthropogenic pressure and require management interventions to maintain the overall biodiversity, productivity, and sustainability (Kumar, *et al*.,2006*)*. Understanding tree composition and structure of forest is a vital instrument in assessing the sustainability of the forest, species conservation, and management of forest ecosystems. Kacholi (2014) reported that the long-term biodiversity conservation depends basically on the knowledge of the structure, species richness, and the ecological characteristics of vegetation. Information from this phytoecological studies of this PA will provide vital information for forest assessment and improve our knowledge in identification of ecologically useful species. In view of the above, this study was carried out in Oluwa natural forest to assess its tree species diversity and forest structure.

METHODOLOGY

The study area

Oluwa natural forest is within Oluwa Forest Reserve and lies between reserve latitude 6°55'–7° 20'N & longitude 3°45'–4°32'E. It covers an area of 87, 816 ha. The forest experiences the rainy season from March to November while the dry season occurs from December to February. The average annual rainfall is 1700mm, relative humidity of 80%, an annual temperature of 26^{0}C with an average elevation of 100 m above sea level. The soil texture in Oluwa Forest Reserve is sandy-loamy but gradually becomes heavier in depth. The soil of the area supports the growth of many tropical hardwood species with a great diversity.

Data Collection

Plot layout

Systematic line transect was adopted in the study area. Two parallel transects of 500m apart were laid in study site after a 50-meter offset has been measured. Thereafter, four sample plots of equal size (50x50m) were alternately laid on each transect. On each sample plot, all trees with Diameter at Breast Height (DBH) $\geq$ 10 cm were tagged and measured.

Tree growth measurement

Tree growth variables such as the diameter at the breast height(dbh), diameters at the base (Db), diameter at the middle (Dm), diameter at the top (Dt) and height of all trees in each plot were all measured.

Tree diversity

The frequency of occurrence and scientific names of all the tree species encountered in each plot were recorded. Where a tree species is difficult to identify the species, the local name was recorded, and plant specimens were collected and taken to Forestry Research Institute of Nigeria, Ibadan, Nigeria herbarium for identification.

Data Analysis

(i) *Basal Area Estimation:* The basal area of each tree was computed using:

$$BA = \frac{\pi D^2}{4} \quad \ldots\ldots \quad (1)$$

Where BA = Basal area (m^2), D = Diameter at breast height (m) and π = Pie (3.142).
Basal area per hectare was obtained by multiplying the mean plot basal area with the number of sampling plots in a hectare

(ii) *Volume Estimation*
The volume of individual trees was estimated using Newton formula

$$V = \frac{\pi h}{24}\left(D_b^{\ 2} + 4D_m^{\ 2} + D_t^{\ 2}\right) \ldots\ldots \quad (2)$$

Where: V = Volume of tree (m^3), D_b= Diameter at the base (cm), D_m = Diameter at the middle (m), D_t = Diameter at the top (m), H = height (m).
Volume per hectare was obtained by multiplying the mean plot volume with the number of sampling plots in a hectare

Tree Diversity Analysis
(i) Species Relative Density was computed as follows

$$RD = \frac{n_i}{N} \times 100 \ldots\ldots \quad ..(3)$$

Where: RD (%) = Species Relative Density; ni = number of individuals of species i; N = total number of all tree species in the entire community.

(ii) Species Relative Dominance (%) of each species was estimated using the following equation:

$$RD_O = \frac{\sum Ba_i \times 100}{\sum Ba_n} \ldots\ldots \quad ....(4)$$

Where: Ba_i = basal area of individual tree belonging to the i^{th} species and Ba_n = stand basal area.

(iii) The Shannon–Wiener diversity index equation (Kent & Coker, 1992), was employed to calculate the tree species diversity in the ecosystems because it takes into account the richness and abundance of each species in different ecosystems (Prince 1997).

$$H^{'} = \sum_{i=1}^{S} p_i \ln(p_i) \ldots\ldots \quad ...(5)$$

Where H' = Shannon diversity index, S = the total number of species in the community, pi = proportion S (species in the family) made up of the ith species and ln = natural logarithm.

(iv) To determine the Species evenness (E), in each community Shannon's equitability equation was adopted (Kent and Coker 1992)

$$\frac{H^1}{Ln(S)} \ldots\ldots \quad (6)$$

(v) Important Value Index (%): This was obtained using the equation below

$$IVI = \frac{(\mathrm{RD} + \mathrm{RDo})}{2} \ldots\ldots (6)$$

Where RD is relative density of the Species; RD_o is the relative dominance of Species

RESULTS
A total of 150 stems ha^{-1} distributed among 46 tree species and 27 families were encountered in this study (figure 1). *Hylodendron gabunense* Taub had the highest number of occurrence with 19stemsha $^{-1}$. So, it was referred to as the most abundant tree species. This was closely followed by *Cleistopholis patens* (Benth)Engl.& Diels with

$10 stems ha^{-1}$. The third most abundant tree species was *Ficus exasperata* Vahl with $8 stems ha^{-1}$.Some of the tree species represented by a single stem are *Diospyros spp*, *Macaranga barteri* Mull-Arg, *Newbouldia laevis* P. Beauv., *Hylodendron pabe Taub.*, *Picralima nitida* (Stapf) T. Durand & H. Durand, *Maesopsis eminii*, *Mitragyna ciliate* Myta, *Nuclea diderrichii* De wild. & Th. Dur., *Rothmannia spp*, *Zanthoxyllum leprieurii* Gril. & Perr. etc. *Baphia nitida* Lodd had the highest mean dbh of 68cm.This was followed by *Pycnanthus angolensis* (Welw.) Warb. with a mean dbh of 58.25cm while *Celtis mildbraedii* Engl. blanco had the lowest mean dbh of 10. 10cm.The highest mean height of 31.55m was recorded for *Lannea welwitschii* (Hiern) and the lowest was recorded for *Mansonia altisima* A. Chev and *Celtis mildbraedii* Engl. Blanco each with a mean height of 5.70m (table 1). Table 2 shows the IVI of tree species in the study area. *Hylodendron gabunense* Taub had the highest IVI of 10.77 while the lowest was recorded for *Blighia sapida* K Konig, *Celtis mildbraedii* Engl. Blanco, *Maesopsis eminii*, *Mitragyna ciliate* Myta and *Nuclea diderrichii* De wild. & Th. Dur each with an IVI of 0.37. A basal area and volume of $15.09 m^2 ha^{-1}$ and $107.72 m^3 ha^{-1}$ were recorded respectively for the forest (Table 3). High **Shannon** Wiener diversity index of 3.51 and equitability index according to Pielou of 0.92 were recorded for the study area (table 4). The forest was dominated by trees that fell in the height class 11-20m (Figure 2). Most of the trees observed in this study fell in the lower diameter class of 10-20cm while few numbers fell in tree diameter class greater than 40cm (figure 3).

Table 1: Tree Species abundance and growth variables for the study area.

S/N	Family	Species	No of Stem	MDbh (cm)	MHt.(m)	BA/ha(m^2)	Vol./ha(m^3)	H[1]
1	Anacardiaceae	*Lannea welwitschii* Hiern	2	46	31.55	0.35	4.38	-0.06
		Pseudospondia microcapal spp	5	16.72	7.78	0.14	0.53	-0.11
2	Annonaceae	*Cleistopholis patens* (Benth) Engl.& Diels	10	24.15	12.13	0.59	6.47	-0.18
3	Apocynaceae	*Rauvolfia vomitoria* Afzel.	3	11.13	6.1	0.03	0.1	-0.08
4	Bignoniaceae	*Newbouldia laevis* P. Beauv.	1	23.4	16.7	0.04	0.47	-0.03
5	Burseraceae	*Canarium schweinfurthii* Engl.	2	33.85	17.15	0.18	1.39	-0.06
6	Capparaceae	*Bucholzia corrazea* Engl.	6	27.9	11.05	0.57	2.77	-0.13
7	Cecropiaceae	*Musanga cecropioides* R. Br.	4	23.88	11.23	0.22	1.83	-0.10
8	Combereteceae	*Terminalia superba* Chev	3	18.8	14.4	0.09	0.68	-0.08
9	Ebenaceae	*Diospyros dendo* Welw.ex Hiern	4	24.78	7.93	0.27	0.85	-0.10
		Diospyros mespilifomis Hochst	3	25.77	9	0.23	1.9	-0.08
		Diospyros spp	1	30.8	18.5	0.07	1.06	-0.03
10	Euphorbiaceae	*Macaranga barteri* Mull-Arg	1	13	8.5	0.01	0.07	-0.03
		*Rhesinodendron heudelotti (*Baill.) Pierr	3	18.83	8.97	0.08	0.4	-0.08
11	Fabaceae	*Hylodendron gabunense* Taub	18	28.1	14.98	1.44	10.98	-0.25
		Hylodendron pabe Taub.	1	16	18.7	0.02	0.24	-0.03
12	Guttifereae	*Picralima nitida* (Stapf) T.Durand & H.Durand	1	17.3	10.1	0.02	0.19	-0.03
13	Loganaceae	*Anthocleista vogelii* Planch.	3	24.9	10.57	0.19	1.73	-0.08
14	Malvaceae	*Ceiba petandra*(L) Gaertn	1	28.5	24	0.06	0.68	-0.03
15	Meliaceae	*Trichilia heudelottii* Planch. ex. Oliv.	6	34.92	15.33	0.8	6.25	-0.13
16	Moraceae	*Ficus exasperata* Vahl	8	50.1	17.06	2.14	16.79	-0.16
		Milicia excels (Welw.) C. Berg	1	55	11	0.24	0.96	-0.03
		Myrianthus arboreus P. Beauv	3	24.27	15.2	0.15	1.5	-0.08
		Pycnanthus angolensis (Welw.) Warb.	4	58.25	13.13	1.35	7.48	-0.10
17	Olacaceae	*Strombosia pustulata* Oliv.	1	25	14.3	0.05	0.32	-0.03
18	Pandaceae	*Microdesmis puberula* Hook.f. ex Planch	2	35.95	15.8	0.21	2.22	-0.06
19	Papilionoideae	*Pterygota macrocarpa* Craib	4	18.33	10.05	0.12	0.53	-0.10
20	Papinonaceae	*Baphia nitida* Lodd	3	68	21.63	1.21	7.77	-0.08

		Blighia sapida K Konig	1	12	6.7	0.01	0.06	-0.03
		Nochocarpus sericeus (Poir) HB & K.	1	25.3	14.7	0.05	0.6	-0.03
21	Phylianthaceae	*Spondiathus preussii* Engl.	3	12.43	9.93	0.04	0.32	-0.08
22	Rhamnaceae	*Maesopsis eminii*	1	10.4	6.2	0.01	0.03	-0.03
23	Rubiaceae	*Mitragyna ciliate* (Myta)	1	10.5	7.1	0.01	0.04	-0.03
		Nuclea diderrichii De wild. & Th. Dur.	1	11.3	9.7	0.01	0.07	-0.03
		Rothmannia spp	1	85	13.7	0.57	2.31	-0.03
24	Rutaceae	*Zanthoxyllum leprieurii* (Gril.& Perr.)	1	44	18.3	0.15	1.06	-0.03
25	Sapotaceae	*Cola heterophylla* (P. Beauv.) Schott & Endl.	4	37.83	17.98	0.5	5.55	-0.10
		Macaranga barteri Mull-Arg	1	18.5	8.2	0.03	0.1	-0.03
		Malacanta alnifolia(Baker) Pierre	3	28.27	8.5	0.24	1.14	-0.08
26	Sterculiaceae	*Cola exasperata* Vahl.	1	31.9	7	0.08	0.17	-0.03
		Cola gigantea A.Chev.	4	34	15.4	0.64	3.03	-0.10
		Mansonia altisima A. Chev.	1	16.1	5.7	0.02	0.03	-0.03
		Sterculia rhinopetala K. Schum	8	31.41	11.59	0.85	6.13	-0.16
		Sterculia tragacantha K. Schum	2	36.5	18.85	0.22	1.83	-0.06
		Triplochiton scleroxylon K. Schum	5	19.8	11.06	0.19	1.25	-0.11
27	Ulmaceae	*Celtis mildbraedii* Engl. Blanco	1	10.1	5.7	0.01	0.02	-0.03
		Celtis zenkeri Engl	6	30.3	11.45	0.58	3.42	-0.13
		Total	**150**					**3.51**

MDBH-Mean Diameter at the Breast height, MHt-Mean height, MBA-Mean basal area, MVol.-Mean Volume,H^1-Shannon Wiener diversity index, RD-Relative Density.

Table 2: Importance value index of tree species in the study area

S/N	Species	RD (%)	RDo (%)	IVI (%)
1	*Anthocleista vogelii* Planch.	2.00	1.19	1.60
2	*Baphia nitida* Lodd	2.00	7.96	4.98
3	*Blighia sapida* K. Konig	0.67	0.07	0.37
4	*Bucholzia corrazea* Engl.	4.00	3.58	3.79
5	*Canarium schweinfurthii* Engl.	1.33	1.19	1.26
6	*Ceiba petandra*(L) Gaertn	0.67	0.40	0.53
7	*Celtis mildbraedii* Engl. Blanco	0.67	0.07	0.37
8	*Celtis zenkeri* Engl	4.00	3.98	3.99
9	*Cleistopholis patens*(Benth)Engl.& Diels	6.67	3.98	5.32
10	*Cola exasperata*	0.67	0.53	0.60
11	*Cola gigantea* A.Chev.	2.67	4.24	3.46
12	*Cola heterophylla* (P. Beauv.)Schott & Endl.	2.67	3.18	2.93
13	*Diospyros dendo* Welw.ex Hiern	2.67	1.86	2.26
14	*Diospyros mespilifomis* Hochst	2.00	1.59	1.80
15	*Diospyros spp*	0.67	0.46	0.57
16	*Zanthoxyllum leprieurii* (Gril.& Perr.)	0.67	0.99	0.83
17	*Ficus exasperata* Vahl	5.33	14.32	9.83
18	*Hylodendron gabunense* Taub	12.00	9.55	10.77
19	*Hylodendron pabe* Taub.	0.67	0.13	0.40
20	*Lannea welwitschii* (Hiern) Engl.	1.33	2.25	1.79
21	*Macaranga barteri* Mull-Arg	1.33	0.27	0.80
22	*Maesopsis eminii*	0.67	0.07	0.37
23	*Malacanta alnifolia* (Baker) Pierre	2.00	1.59	1.80
24	*Mansonia altisima* A. Chev	0.67	0.13	0.40
25	*Mitragyna ciliata* (Myta)	0.67	0.07	0.37
26	*Microdesmis puberula* Hook.f. ex Planch	1.33	1.33	1.33
27	*Milicia excelsa* (Welw.) C. Berg	0.67	1.59	1.13
28	*Musanga cecropioides* R. Br.	2.67	1.33	2.00
29	*Myrianthus arboreus* P. Beauv	2.00	0.99	1.50
30	*Newbouldia laevis* P. Beauv.	0.67	0.27	0.47
31	*Nochocarpus sericeus* (Poir) HB & K.	0.67	0.33	0.50
32	*Nuclea diderrichii* De wild. & Th. Dur.	0.67	0.07	0.37
33	*Picralima nitida* (Stapf) T.Durand & H.Durand	0.67	0.13	0.40
34	*Pseudospondia macrocarpa* (A. Rich.) Engl	3.33	0.99	2.16
35	*Pterygota macrocarpa* Craib	2.67	0.80	1.73
36	*Pycnanthus angolensis* (Welw.) Warb.	2.67	9.02	5.84
37	*Rauvolfia vomitoria* Afzel.	2.00	0.20	1.10

38	*Ricinodendron heudelotii* (Baill.) Pierr	2.00	0.60	1.30
39	*Rothmannia spp*	0.67	3.78	2.22
40	*Spondiathus preussii* Engl.	2.00	0.20	1.10
41	*Sterculia rhinopetala* K. Schum	5.33	5.84	5.58
42	*Sterculia tragacantha* K. Schum	1.33	1.46	1.39
43	*Strombosia pustulata* Oliv	0.67	0.33	0.50
44	*Terminalia superba* Chev	2.00	0.60	1.30
45	*Trichilia heudelottii* Planch. ex. Oliv.	4.00	5.17	4.59
46	*Triplochiton scleroxylon K. Schum*	3.33	1.33	2.33
	Total	100.0	100.0	100.0

RD-Relative Density RDo-Relative Dominance, IVI-Importance Value Index

Table 3: Summary of tree growth variables for the study Area

Growth Variables	Values
Basal area/ha (m^2)	15.09
Volume/ha (m^3)	107.72
Mean DBH (cm)	29.43
Dominant DBH (cm)	92.3
Dominant height (m)	29.5

Table 4: Tree Species diversity Indices for the study area

Biodiversity Indices	Values
No of stem/ha	150
No of Species (NS)	46
No of Family (NF)	27
Shannon-Wieners (H^1)	3.51
Pielou's Spp. evenness index(E)	0.92

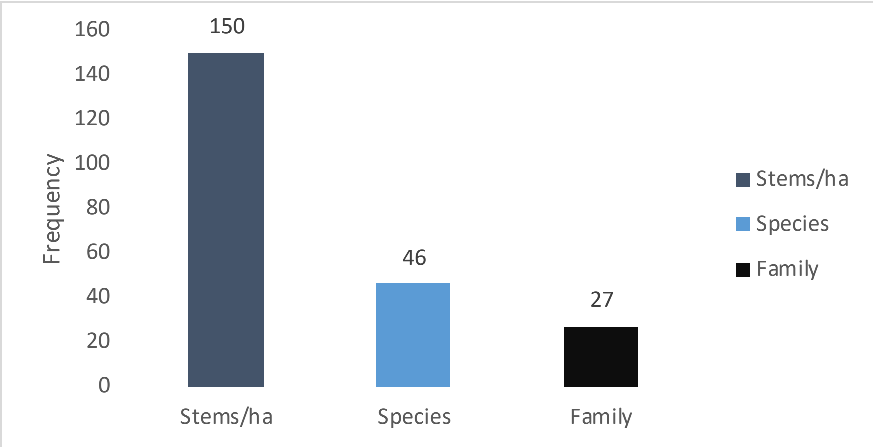

Figure 1: No of stemha-1, species and family

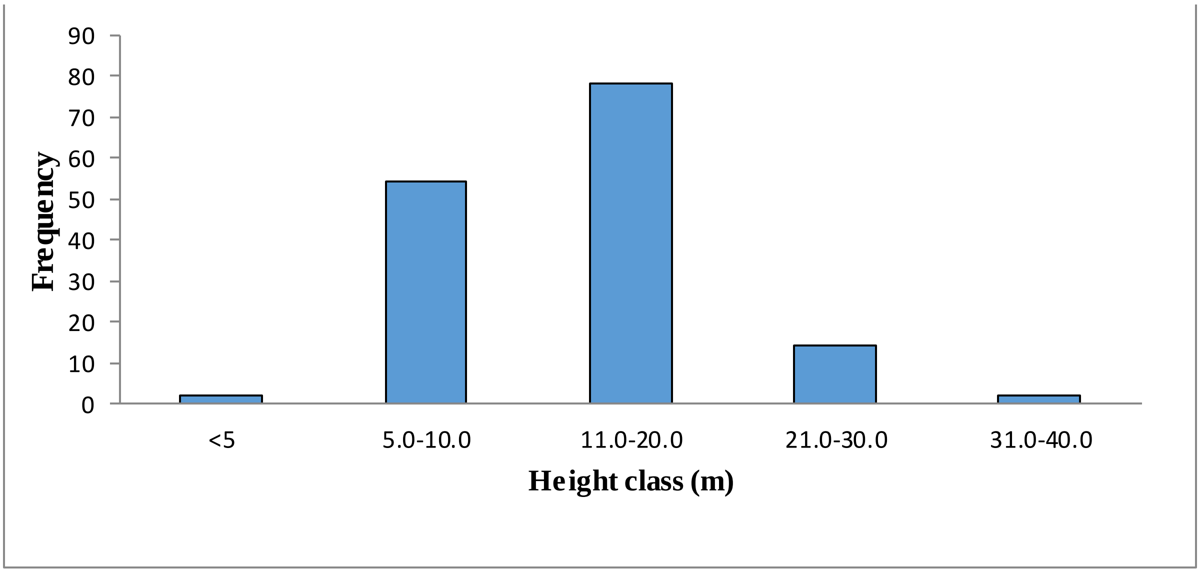

Figure 2: Height distribution of tree species in the study area

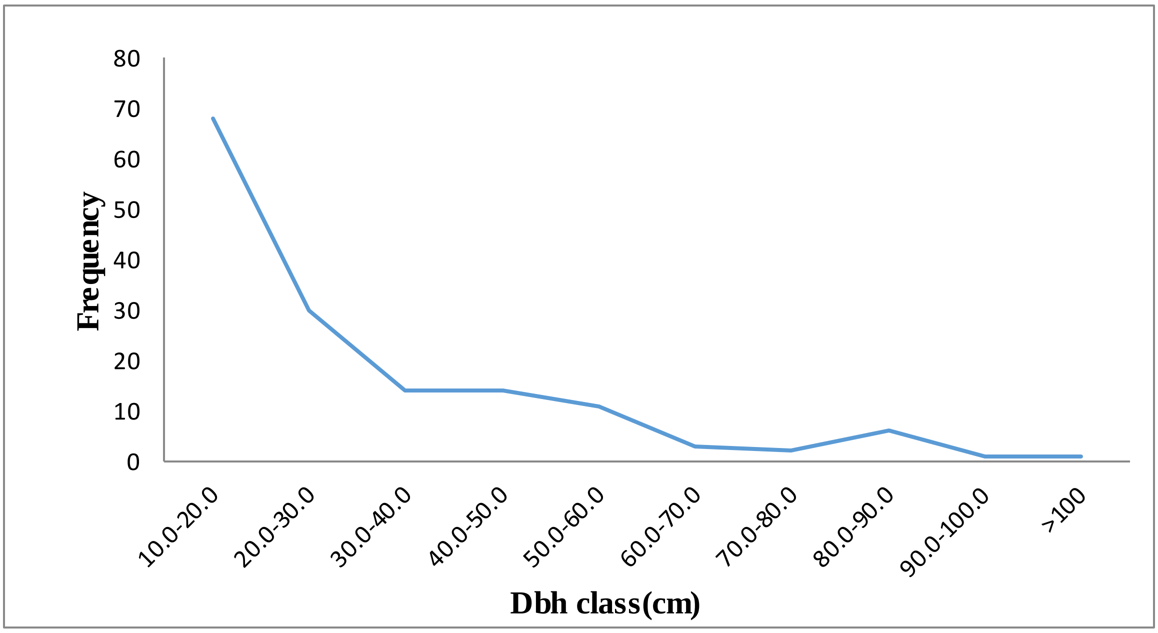

Figure 3: DBH distribution of tree species in the study area

DISCUSSION

Tropical rainforests are greatly rich in biodiversity. It has the highest of number of tree species when compared to any other community. Understanding Tree species diversity and abundances, composition and structure are very important in assessing forest sustainability, species conservation and ecosystems management (Kacholi, 2014). The tree species encountered in this study are majorly of tropical hardwood species and are of high economic values especially to rural dwellers and source of revenue for national development. The density, abundance and distribution of individual species are measurable indicators of plant diversity (Wattenberg and Breckle,1995). The 46 tree species obtained in this study area corresponds with the result of Adekunle *et al*. (2010) who obtained 46 tree species in the undisturbed forest of Akure Forest Reserve and Onyekwelu (2007) who recorded 45 tree species in Oluwa Forest Reserve. Biodiversity indices are generated to investigate ecosystem diversity as it takes into consideration of both the species richness and evenness in a community (Onyekwelu, Adekunle, & Adedutan, 2005).The high Shannon Wiener index of 3.51 obtained in this site revealed a forest with high tree species diversity and abundance and agrees with the values (3.34-3.66) reported for some tropical rainforest sites (Adekunle 2006; Adekunle and Olagoke, 2007).The high floristic composition of this forest site could be attributed to conservation, noting that the forest has not been disturbed within a living memory. The high species evenness is an indication that tree species encountered in this study area are evenly distributed. The total volume obtained in this study is less than the value reported by Adekunle *et al*., (2010). The difference in the values may be as a result of method used in tree volume computation. The mean dbh obtained in this study is greater than the values reported by Adekunle *et al*., (2013) who worked in a similar tropical rainforest ecosystem. The distribution of stems into dbh classes showed a J-shaped pattern which is an indication of healthy recruitment of individuals in the forest. The study revealed that the number of trees reduces as the tree diameter increases which is a common characteristic of tropical rainforest. The distribution of trees into height classes in this study revealed a forest that will continue to grow till maturity if proper managements are put in place (Adekunle *et al*., 2013).

CONCLUSION AND RECOMMENDATIONS

The results of this study revealed that protected areas play vital roles in biodiversity conservation. The high Shannon wiener value obtained in this study was a result of conservation. Therefore, there is need to act upon and embrace forest conservation and to ensure our forests and forest land are being managed in a way that maintain their biodiversity, regeneration potential and productivity. Proper forest management and practices should be encouraged through trainings. Rural communities should be involved in the management of the forest and they should be rewarded inform of incentives by the government agency responsible for management of protected areas.

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The Genus *Sterculia* Linn. In Nigeria: Taxonomic Significance of Morphological and Foliar Epidermal Characters

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Abstract

The genus Sterculia is an important taxon of indigenous tree in the family Malvaceae utilised for ethnomedicinal purposes in Nigeria. However, there is limited recent information on the morphological and foliar epidermal characteristics of the genus Sterculia in Nigeria which contribute to the taxonomic description and optimum use of the species in the genus. This study therefore investigated the morphological and epidermal characteristics of the genus Sterculia to provide information for the taxonomic relationship of the species in the genus. Data were collected on the morphological and epidermal characters on the samples of Sterculia tragacantha and Sterculia rhinopetala, Sterculia oblonga and Sterculia setigera obtained from Onigambari, Olokemeji forest reserves and Department of Forest production and Products, University of Ibadan. Data were analysed using descriptive statistics, ANOVA, Principal component analysis and Phylogenetic analyses. Leaf shape of the species varied from elliptic, obovate, ovate to oblong. Leaf base was largely lobate and rounded, flower colour was dull red, reddish-pink and cream colour. The leaf morphometrics of the trees in the Genus Sterculia was significantly ($p<0.05$) different. The epidermal cells varied from either polygonal or irregular shapes on the two epidermal layers. Trichomes were usually many and located along the veins on the epidermis of Sterculia setigera and S. tragacantha but absent on Sterculia oblonga and Sterculia rhinopetala. Paracytic stomata were identified on S. tragacantha and Sterculia rhinopetala while anomocytic and anisocytic stomata were discovered on Sterculia setigera and S. oblonga respectively. Epidermal cell length was 26.4 µm – 32.4 µm while cell width, stomata length, stomatal width, guard cell width and guard cell area on the abaxial epidermal layer were respectively 13.9 µm – 20.4 µm, 12.9 µm – 23.5 µm, 9.1 µm – 15.3 µm, 3.9 µm – 10.5 µm and 50.3 – 154.5 µm^2. First two principal components accounted for approximately 85.4% of the total variation among the taxa at 7.5 eigenvalues. Stomata and epidermal cell variables were highly loaded to the first two principal components. The phylogenetic tree indicates that Sterculia oblonga is the earliest evolved species, followed by S. rhinopetala while S. tragacantha and S. setigera are the most recent Sterculia species having strong branch support of 60% bootstrap value. This study has provided basic information on the morphological and leaf epidermal characters that could be used for proper discrimination and identification of the Sterculia species in Nigeria. Taxonomic keys to the species were generated based on the epidermal characters.

Keywords: Morphological characters, epidermal peel, Taxonomy, *Sterculia*

INTRODUCTION

Sterculia is one of the largest genera of flowering plants in the family *Malvaceae*. This taxon was named after the Roman god of privies, Sterculius as a result of foul-smelling flowers of the plants in the group. It comprises of about 150 species distributed into different parts of the tropics and 4 species have been identified in Nigeria some of which have significantly contributed to human wellbeing (El-Sherei *et al*., 2016). The genus *Sterculia* is ethnomedicinally useful. This is based on the fact that the species are a rich source of flavonoid, alkaloids, saponins and glycosides, which are well-known for their broad range of bioactivity, including antimicrobial, antifungal, insecticidal, antioxidant, cytotoxic, and anti-inflammatory activities (Judd and Manchester, 1997). In China and Thailand, the leaves of some of the species are taken as a tea (Inta *et al*., 2008). Oil extracted from *Sterculia setigera* seeds has been utilised for frying and in the production of biscuit (Hassan *et al*., 2016).

Despite the aforementioned importance, *Sterculia* is poorly known taxonomically in Nigeria. This has accounted for many unidentified and misidentified specimens as well as nomenclatural problems, including synonymy, in most of the herbaria (Ayodele and Olowokudejo, 2006). According to El-Sherei *et al.* (2016), there is confusion on the systematic position and classification of the genus *Sterculia,* which has greatly limited the optimum utilisation of the species. This genus was previously placed in the family *Sterculiaceae* and later transferred to the family *Malvaceae* due to its unsettled taxonomic position. *Malvaceae, Sterculiaceae, Bombacaceae* and *Tiliaceae* now constitute the order *Malvales.* Hence, there is presently paucity of recently published information on the taxonomic characteristics of the genus from Nigeria using morphology and epidermal characters. This study, therefore, examined the taxonomic significance of morphological and leaf epidermal characters with a view to contributing to the knowledge of the taxon and providing necessary information for the classification and identification of the genus.

METHODOLOGY

Study Area

A reconnaissance survey was carried out to determine the distributional range in Nigeria using the previous collection records obtained from the herbarium and Floras. Ten (10) samples of leaf were randomly collected at a uniform position on the matured mother trees in their distributional range from two (2) trees of each species based on availability. *Sterculia tragacantha* and *Sterculia rhinopetala* were obtained from Onigambari Forest Reserve Ibadan while samples of *Sterculia setigera* were sourced from the Department of Forest Production and Products, the University of Ibadan based on availability. Samples of *Sterculia oblonga* were collected from Olokemeji forest reserve. The fresh specimens were divided into two; 5 matured leaves were used for macro morphology while the remaining portion was preserved with 50% ethanol in the specimen collection bottle immediately. The preserved samples were used for the description of leaf epidermal characters at the laboratory of the Department of Forest Production and Products, University of Ibadan.

Data Collection

Morphological characterisation

Qualitative variables such as the position of petiole attachment, leaf apex shape, leaf margin, leaf surface, leaf venation, tree bark type, flower colour and fruit colour were determined and translated into numerical codes. Morphological characters that were measured include leaf length, leaf width, petiole length, lamina length, leaf width at base, leaf width at the middle, leaf width at the top, leaf acumen length (apex), petiole width and space between successive secondary veins were measured using Vernier calliper, thread and 30cm meter rule.

Leaf epidermal characterisation

The procedure described by Soyewo *et al* (2015) was adopted for the leaf epidermal characterisation. Portions of about 2–5 cm were cut from the standard median part of the leaf lamina near the mid-rib of the fresh leaf and subsequently soaked in concentrated trioxonitrate (v) acid (HNO3) in capped specimen bottles for about 8–24 hours depending on the leaf texture to macerate the mesophyll. The appearance of air bubbles on the soaked leaves indicated the readiness of the epidermises for separation. The specimens were then transferred into Petri dishes containing water for the separation of epidermal layers. The abaxial and adaxial epidermises were separated with the aid of forceps and dissecting needles. The leaf surfaces were cleared to remove the mesophyll layer using camel-hair brush and washed in several changes of water. Cleared epidermises were transferred into different grades of ethanol, 50 % – 100 % in Petri- dishes to dehydrate the cells. The epidermal peels were stained with Safranin O for about five minutes mounted in glycerin on glass slides with the uppermost surfaces facing up, covered with cover-slips and ringed with nail varnish to prevent dehydration.

The slides were labelled appropriately and studied under the x40 objective magnification of CIWA XSP-35TV Biological microscope number of stomata and epidermal cells per unit area, types of stomata, epidermal cell type, cell shape, presence of trichomes and type of trichomes on the epidermises. Epidermal cell length, guard cell length, guard cell thickness, stomata length, stomata width was measured using ocular micrometre installed in the microscope eyepiece and photomicrographs were captured using 200W Electronic Eyepiece.

Stomata index was calculated according to Ayodele and Olowokudejo (2006) as:

Stomata index (I) = S/S+E × 100, S=number of stomata per unit area, E=number of epidermal cells per unit area.

Guard cell area was estimated as: GCA = Length × Width × K, (K = Franco's constant =0.78524).

Data were analysed using descriptive statistics, analysis of variance (ANOVA) and principal component analysis (PCA). Phylogenetic analysis was carried out using Treecon at 500 bootstrapping replicates.

RESULTS AND DISCUSSION

Results

Morphological characteristics of the genus Sterculia

The result obtained from the summary of the qualitative variable (Table 1) of the four *Sterculia* species shows that the leaf shape varied from elliptic, obovate, ovate to oblong. Leaf base was largely lobate and rounded, flower colour was dull red, reddish-pink and cream colour. Leaf apex varied from mucronate to acuminate while the leaf venation was reticulate and palmate. The leaf morphometrics of the trees in the Genus *Sterculia* was significantly ($p<0.05$) different (Table 2). Leaf total length ranged from 13.7 cm (*S. oblonga*) to 33.4 cm (*S. rhinopetala*), lamina length 7.3 cm (*S. oblonga*) – 18.1 cm (*S. setigera*), leaf width at base 6.8 cm (*S. oblonga*) – 17.6 cm (*S. setigera*), leaf width at middle 7.0 cm (*S. oblonga*) – 14.9 cm (*S. tragacantha*), leaf width at top 4.1 cm (*S. oblonga*) – 12.5 cm (*S. tragacantha*), acumen length 0.5 cm (*S. tragacantha*) – 2.2 cm (*S. setigera*), petiole length 4.9 cm (*S. oblonga*) – 14.3 cm (*S. setigera*), petiole width 1.3 mm (*S. oblonga*) – 3.2 mm (*S. setigera*), number of secondary veins 3 (*S. setigera*) – 15 (*S. rhinopetala*) and space between secondary veins 0.5 cm (*S. setigera*) – 2.8 cm (*S. tragacantha*). *S. tragacantha*, *S. oblonga* and *S. rhinopetala* had equal leaf width ratio of 1.0 while the maximum value was recorded for *S. setigera* (1.5).

Epidermal characteristics of the genus Sterculia

The Summary of the qualitative characteristics of adaxial and abaxial epidermal layers of the four *Sterculia* species studied (Table 3) shows that there were no stomata on the adaxial layer. The four species also lack crystals. The epidermal cells varied from either polygonal or irregular shapes on the two epidermal layers. Variations were also observed on the cell wall type of the species, which includes straight wall, straight thick wall, straight to wavy and wavy. Trichomes were located along the veins on the epidermis of *Sterculia setigera* and *S. tragacantha*. Trichomes were not found on *Sterculia oblonga* and *Sterculia rhinopetala* on the two layers.

On the abaxial layer (Table 3), paracytic stomata were identified for both *S. tragacantha* and *Sterculia rhinopetala* while anomocytic and anisocytic stomata were discovered on *Sterculia setigera* and *S. oblonga* respectively (Plate 1). The stomata were either multidirectional and few or multidirectional and many. All the four *Sterculia* species lack stomata on the adaxial layer of the epidermis (Table 4). The tree species were significantly ($p<0.05$) different by stomatal length, stomatal width, guard cell width and guard cell area on the axial surface. On the abaxial layer, epidermal cell length ranged from *S. setigera* (26.4 µm) to *S. rhinopetala* (32.4 µm). The least cell width (13.9 µm), stomata length (12.9 µm) and stomatal width (9.1 µm), was assessed in *S. rhinopetala* while the least guard cell width (3.9 µm) and guard cell area (50.3 μm^2) on the abaxial epidermal layer were discovered in *S. tragacantha*. On the other hand, *S. tragacantha* had the highest cell width (20.4 µm) and stomata length (23.5 µm), while the maximum stomatal width (15.3 µm), guard cell width (10.5 µm) and guard cell area (154.5 μm^2) (Table 4). Stomatal frequency ranged from 16 (*S. tragacantha*) to 60 (*S. rhinopetala*) while the stomatal index increased from 23.6 % (*S. oblonga*) to 37.7 % (*S. rhinopetala*) on the abaxial surface (Figure 1). Stomatal density varied from 39.2 mm^2 (*S. tragacantha*) to 147.3 mm^2 (*S. rhinopetala*) on the abaxial layer (Figure 1). Epidermal cell length ranged from *S. setigera* (26.1 µm) to *S. tragacantha* (36.4 µm) while the cell width was from *S. rhinopetala* (13.9 µm) to *S. tragacantha* (24.0 µm) on the adaxial leaf surface (Table 4).

Table 1. Summary of Sterculia species morphological variables

Qualitative Variables	*S. setigera*	*S. tragacantha*	*S. oblonga*	*S. rhinopetala*
Leaf base	Lobate	Rounded	Rounded	Rounded
Petiole attachment	Central peltate	Marginal	Marginal	Marginal
Leaf apex shape	Acuminate	mucronate	Mucronate	Acuminate
Teeth shape	Concave	Straight	Straight	Straight
Leaf surface	Hairy	Glabrous	Glabrous	Glabrous
Leaf venation	Palmate	Reticulate	Reticulate	Reticulate
Tree bark type	Smooth with thin scales	Smooth	Smooth	Flaking in small square pieces
Flower colour	Dull red	Reddish pink	Cream	Cream
Fruit colour	Green to Brown (ripe)	Red to Brown (ripe)	Green to Brown (ripe)	Brown
Crown shape	Layered	Layered	Broad	Vase
Branching pattern	Alternate	Whorled	Alternate	Alternate
Leaf arrangement	Alternate	Opposite	Alternate	Alternate
Leaf shape	Elliptic	Elliptic-oblong	Lanceolate	Oblong-lanceolate

Table 2. Leaf macro-morphometrics of *Sterculia* species

Species	LTL	LL	LWB	LWM	LWT	AL	PL	PW	NSV	SBSV	LWR
S. setigera	15.3±2.8c	18.1±2.5a	17.6±2.9a	12.0±1.8a	4.7±0.9c	2.2±0.4a	14.3±3.2a	3.2±0.2a	3	0.5±0.08c	1.5±0.4a
S. tragacantha	23.0±4.7b	14.9±3.1ab	12.8±3.0b	14.9±3.2a	12.5±2.2a	0.5±0.3c	9.1±4.0b	2.3±0.4b	10	2.8±0.3a	1.0±0.02b
S. oblonga	13.7±2.2c	7.3±1.2c	6.8±1.2c	7.0±1.1b	4.1±0.9c	1.2±0.1b	4.9±1.0b	1.3±0.2c	6	1.7±0.4b	1.0±0.04b
S. rhinopetala	33.4±6.8a	12.5±2.1b	9.9±1.1bc	12.4±2.1a	9.2±1.7b	0.9±0.2bc	9.9±2.6ab	1.8±0.5bc	15	2.2±0.4ab	1.0±0.01b
p-value	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.001*	0.000*	0.001*	0.000*	0.002*

LTL= leaf total length (cm), LL= lamina length (cm), LWB= leaf width at base (cm), LWM= leaf width at middle (cm), LWB= leaf width at top (cm), AL= acumen length (cm), PL= petiole length (cm), PW= petiole width (mm), NSV= number of secondary veins, SBSV= space between successive veins (cm), LWR= leaf width ratio

Table 3. Summary of the qualitative characteristics of adaxial and abaxial epidermal layer of the four *Sterculia* species

Characteristics	Layer	*S. setigera*	*S. tragacantha*	*S. oblonga*	*S. rhinopetala*
Stomata(P/A)	Adaxial	Absent	Absent	Absent	Absent
Stomata type	Adaxial	Nil	Nil	Nil	Nil
Stomata direction	Adaxial	Nil	Nil	Nil	Nil
Stomata abundance	Adaxial	Nil	Nil	Nil	Nil
Cell wall alignment	Adaxial	Anticlinal	Anticlinal	Anticlinal	Anticlinal
Cell shape	Adaxial	Polygon	Polygon	Polygon	Irregular
Cell wall type	Adaxial	Straight wall	Straight thick wall	Straight to wavy	Wavy
Trichome (P/A)	Adaxial	Present	Present	Absent	Absent
Trichome types	Adaxial	Glandular	Non glandular	Nil	Nil
Crystal (P/A)	Adaxial	Absent	Absent	Absent	Absent
Stomata(P/A)	Abaxial	Present	Present	Present	Present
Stomata type	Abaxial	Anomocytic	Paracytic	Anisocytic	Paracytic
Stomata orientation	Abaxial	multidirectional	Multidirectional	Multidirectional	Multidirectional
Stomata abundance	Abaxial	Many	Few	Many	Many
Cell wall alignment	Abaxial	Anticlinal	Anticlinal	Anticlinal	Anticlinal
Cell shape	Abaxial	Polygon	Polygon	Polygon	Irregular
Cell wall type	Abaxial	Straight wall	Straight thick wall	Straight to wavy	Wavy
Trichome (P/A)	Abaxial	Present	Present	Absent	Absent
Trichome types	Abaxial	Glandular	Non glandular	Nil	Nil
Crystal (P/A)	Abaxial	Absent	Absent	Absent	Absent

Table 4. Leaf epidermal Micro-Morphometrics of *Sterculia*species

Species	ECL	ECW	SL	SW	GCW	GCA
S. setigera Ab.	26.4±4.4	19.2±6.1	15.8±2.7b	9.6±1.8b	4.8±1.7b	63.7±32.0b
S. tragacantha Ab.	30.4±2.8	20.4±4.0	23.5±1.3a	12.2±2.7ab	3.9±1.4b	50.3±20.1b
S. oblonga Ab.	29.7±6.0	15.3±4.9	15.3±4.0b	15.3±3.6a	10.5±2.7a	154.5±43.6a
S. rhinopetala Ab.	32.4±2.4	13.9±2.4	12.9.5±2.7b	9.1±2.0b	5.7±2.4b	60.1±33.7b
p-value	0.193ns	0.125ns	0.000*	0.007*	0.001*	0.000*
S. setigera Ad.	26.1±5.5	16.5±2.7bc	-	-	-	-
S. tragacantha Ad.	36.4±9.2	24.0±2.9a	-	-	-	-
S. oblonga Ad.	30.4±2.8	20.4±4.0ab	-	-	-	-
S. rhinopetala Ad.	27.1±4.9	13.9±2.7c	-	-	-	-
p-value	0.065ns	0.001*	-	-	-	-

ECL=epidermal cell length (µm), ECW=Epidermal cell width (µm), SL=Stomatal length (µm), SW= Stomatal width (µm), GCW= guard cell width (µm), GCA = Guard cell area ($µm^2$), Ad.= Adaxial epidermal layer, Ab.= Abaxial epidermal layer, *= significant at 0.05 probability level, Ns= not significant at 0.05 probability level

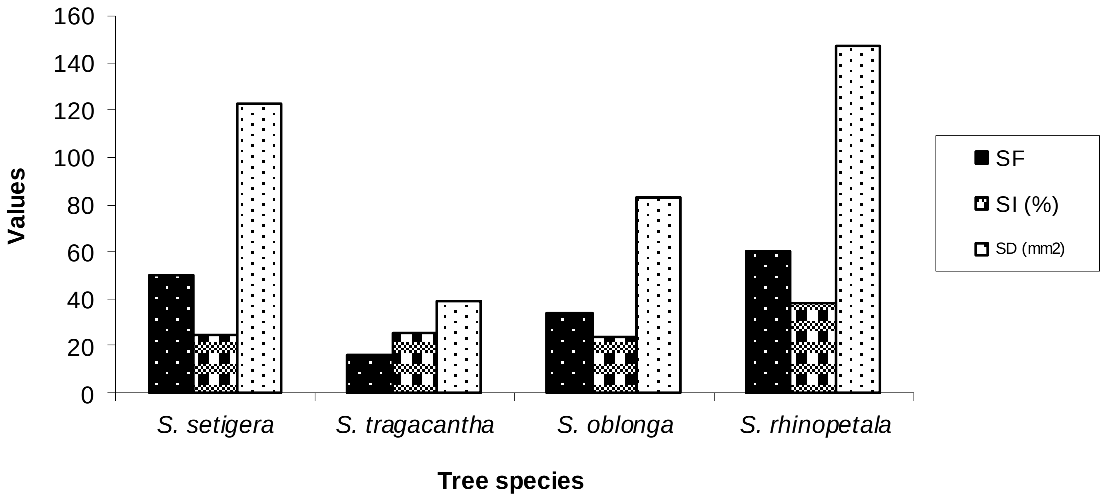
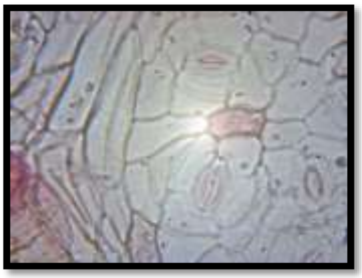
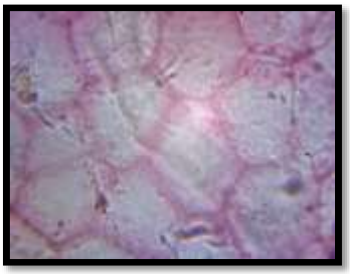


Figure 1. Summary of Stomatal frequency, Stomatal index and Stomatal density on the abaxial surface of *sterculia* species

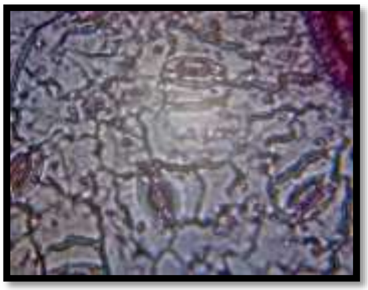
S. Oblonga (Adaxial)



S. Oblonga (Abaxial)



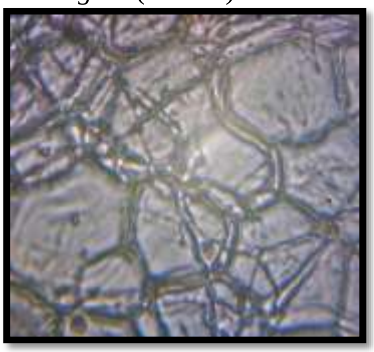
S. rhinopetala (adaxial)



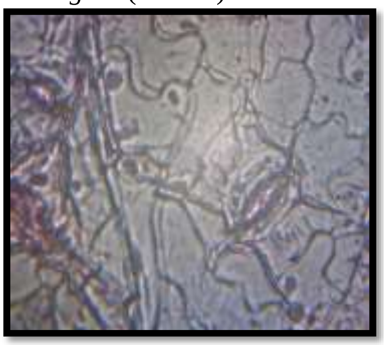
S. rhinopetala (abaxial)

S. *setigera* (adaxial)

S. setigera (abaxial)



S. tragacantha (adaxial)



S. tragacantha (abaxial)

Plate 1. Photomicrographs of Sterculia species epidermal layers

Principal Component Analysis and Phylogenetic tree for Taxonomic delimitation of the genus *Sterculia*

Principal component analysis result (Table 5) shows that the first two principal components accounted for approximately 85.4% of the total variation among the taxa at 7.5 eigenvalues. Variables such as leaf total length, lamina length, lamina width at base, lamina width at the top, acumen length, petiole width, leaf width ratio, leaf base, petiole attachment, leaf margin, leaf surface, leaf venation, flower and fruit colour were significantly loaded at the first two principal components. Similarly, epidermal cell length epidermal cell width, stomatal abundance, cell wall type, presence of trichome, types of trichome were also highly loaded epidermal characters at the first two principal components.

The four species were taxonomically differentiated into clusters based on the scatterplot and phylogenetic tree (Figure 2 and 3). The phylogenetic tree indicates that *Sterculia oblonga* is the earliest evolved species, followed by *S. rhinopetala* while *S. tragacantha* and *S. setigera* are the most recent *Sterculia* species having strong branch support of 60% bootstrap value. The morphologic and epidermal characterization of the species indicated that the highest similarity (29%) is between *S. setigera* and *S. tragacantha* (Table 6). Closely following this was *S. rhinopetala/S. tragacantha* and *S. oblonga/ S. tragacantha* having about 25% and 24% similarity respectively. The least similarity was discovered between *S. oblonga* and *S. setigera*, which had a 13.8% similarity.

Table 5. Eigen-Value, percentage variance and factor loadings of the taxonomic characters in *sterculia* species

Principal components	1	2
Eigen value	4.4	3.1
Percentage variance	61.9	23.5
Taxonomic characters	Loadings	
Epidermal cell length (Abaxial)	**-0.23**	0.06
Epidermal cell width (Abaxial)	**0.20**	0.22
Stomatal length (Abaxial)	-0.03	**0.28**
Stomatal width (Abaxial)	-0.17	0.15
Guard cell width (Abaxial)	-0.14	-0.13
Guard cell area (Abaxial)	-0.14	-0.13
Epidermal cell length (Adaxial)	-0.17	0.15
Epidermal cell width (Adaxial)	-0.17	0.15
Stomatal abundance (Abaxial)	0.03	**0.28**
Cell shape (Abaxial)	0.06	0.08
Cell wall type	**0.20**	0.22
Pr/Ab of Trichome	**0.20**	0.22
Trichome type	**0.20**	0.22
Leaf total length	-0.09	**0.20**
Lamina length	**0.20**	0.22
Lamina width at base	**0.20**	0.22
Lamina width at middle	0.14	0.13
Lamina width at top	-0.09	**0.20**
Leaf acumen length	0.09	**0.20**
Petiole length	0.17	-0.15
Petiole width	**0.20**	0.22
Number of secondary veins	-0.09	0.20
Space between successive veins	-0.09	0.20
Leaf width ratio	**0.23**	-0.06
Leaf base	**0.23**	-0.06
Position of petiole attachment	**0.23**	-0.06
Leaf acumen shape	0.17	-0.15
Leaf margin	**0.23**	-0.06
Leaf surface	**0.23**	-0.06
Leaf venation	**0.23**	-0.06
Tree bark type	0.17	-0.15
Flower colour	**-0.20**	-0.22
Fruit colour	0.09	**0.20**

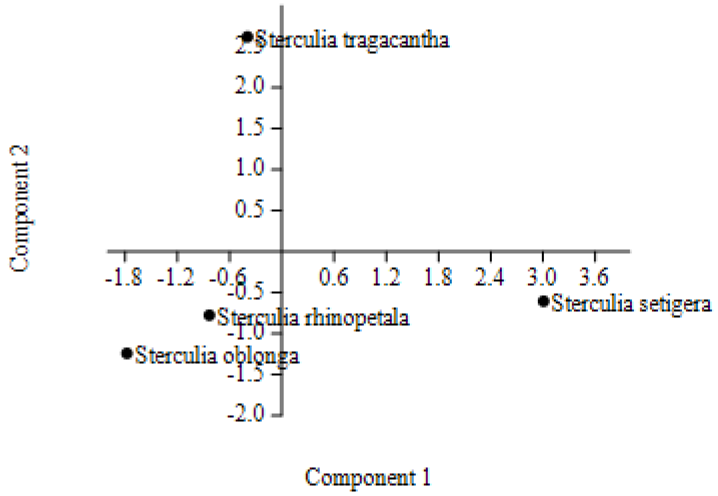


Figure 2. Scatterplot generated from the principal components of the sterculia species

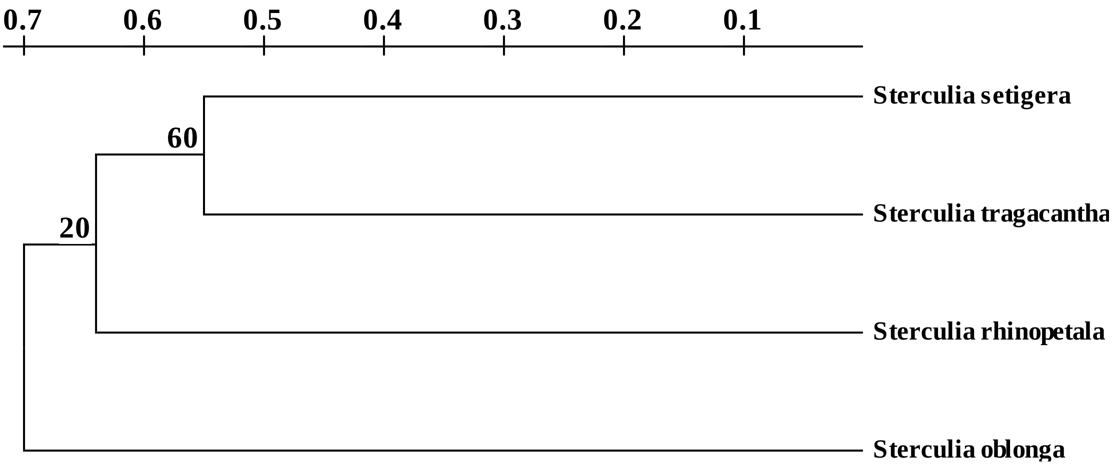


Figure 3. Phylogenetic tree of the *Sterculia* species

Table 6. Jaccard's similarity index among the sterculia species

Tree species	*S. setigera*	*S. tragacantha*	*S. oblonga*	*S. rhinopetala*
S. setigera	100.0			
S. tragacantha	29.0	100.0		
S. oblonga	13.8	24.0	100.0	
S. rhinopetala	18.5	25.0	15.0	100.0

DISCUSSION

The study has shown that taxonomy of plant depends greatly on the morphology for a natural classification of taxa of which leaf morphometrics cannot be overemphasized in plant taxonomic and systematic studies (Viscosi and Cardini 2011). The wide significant variation observed in the leaf morphometrics of the genus *Sterculia* is an indication that the traits are informative and are of taxonomic significance in delimiting the taxa. *Sterculia setigera* and *Sterculia oblonga* had the extreme values on the average in terms of leaf macro-morphometrics and this would have contributed to the resulted delimitation in their phylogeny. According to Evarte-Bundere and Evarts-Bunders (2013), leaf morphometrics constitutes important taxonomic markers due to their easy assessment procedure. Morphological features such as leaf total length, lamina length, lamina width at base, lamina width at the top, acumen length, petiole width, leaf width ratio, leaf base, petiole attachment, leaf margin, leaf surface, leaf venation, flower and fruit colour contributed to the delimitation of the four species. The flower and fruit colour identified in this study as informative characters have been used for the separation of various taxa, especially at the generic level (Leeuwenberg, 1994; Nwokocha *et al*., 2012). The implication of the absence of stomata on the adaxial folia surface of all the *Sterculia* species is that stomata are only restricted to the lower surface of the leaves, which is referred to as hypostomatic leaves. According to Shokefun *et al.* (2017), absence of stomata on the abaxial layer of leaf in plant signifies adaptation to water loss, which is usually beneficial to the ecological survival of the perennial plants. The hypostomatic epidermis has been reported for the genus *Pterygota*¸which shares the same order *Malvales* with *Sterculia* (Chukwuma *et al*., 2017).

The unique stomata types identified in *S. oblonga* and *S. setigera* delimited them from the other taxa. The significant variation recorded for the stomata variables on the adaxial and epidermal cell size on the abaxial represents an important diagnostic key for identifying the taxa even when there is an absence of fruit or flower. The irregular cell shape that is peculiar to *Sterculia rhinopetala* could be useful in solving taxonomic classification among the *Sterculia species.* Comparison of species within a plant genus has been successfully achieved using trichome as a marker (Sonibare *et al.,* 2005; Shokefun *et al.,* 2017). In this study, the glandular type of trichome was uniquely observed on the epidermal peels of *S. setigera*. All the *S. species* were devoid of crystals on both epidermises. A similar finding was reported for the genus *Desplatsia* by Shokefun *et al.* (2017). Based on the principal component analysis, the most significant epidermal characters for delimiting the genus are epidermal cell length and width; cell wall type; stomatal abundance; the presence of trichome and types of trichome. On this basis, the most closely related species in this genus are *Sterculia setigera* and *Sterculia tragacantha*.

CONCLUSION

This study has provided basic information on the morphological and leaf epidermal characters that could be used for proper discrimination and identification of the *Sterculia species* in Nigeria. It was discovered that stomata and epidermal cell variables are very important characters for the understanding of the taxonomy of the genus *Sterculia*. The taxonomic key to the species based on the epidermal characters are presented below.

Taxonomic key to the *Sterculia* species based on leaf epidermal characters

1a. Trichome present on abaxial and adaxial surface
2a. Stomata is many on the abaxial surface……………..3
2b. Stomata is few on the abaxial surface………………*tragacantha*
3a. Trichome is many and scattered……………..*setigera*
3b. Trichome is few and it is located along the veins
1b. Trichome absent on both abaxial and adaxial surface
4a. Cell shape is polygon………………………………...*oblonga*
4b. Cell shape is irregular……………………………….5
5a. Leaf epidermal cell wall type is straight
5b. Leaf epidermal cell wall type is wavy………*rhinopetala*

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Structural Diversity of Tree Stems of Elephant Camp Natural Forest in Omo Forest Reserve

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Abstract

Tree size diversity is an indicator for biodiversity values of a forest. Microsite conditions of forest determine the survival and growth of tree. However, the contribution of variable habitats to tree size hierarchy and segregation is poorly understood. Variation in size of trees in a population is caused by different mechanisms. Therefore, size distribution and spatial pattern of trees can identify the process governing the growth of resources utilization in the forest. The objective of the study was to determine the structural diversity of tree stems of Elephant Camp natural forest in Omo Forest Reserve with a view to provide information on how environmental heterogeneity influence forest structure. Three and four 0.09ha sample plots were established in Riparian (RF) and Old-growth forests (OF) of Elephant camp, respectively. The tree stems (Dbh≥5cm) were identified to species level and enumerated within each plot and stem density was computed. The diameter-at-breast height (Dbh) was measured with diameter tape. Species diversity was assessed using Shannon-Weiner (H´) and Simpson indices (1-D´) while size inequality was assessed using Gini coefficient (GC), Coefficient of Variation (CV), H´ and I-D´. The performance of single two- and three-parameter Weibull models were evaluated; Kolmogorov-Smirnov (K-S) Chi-Square (χ^2), Root Mean Square Error (RMSE), Bias and Coefficient of determination (R^2). Data were analysed using descriptive statistics. A total of 27 and 24 tree species were identified in RF and OF, respectively. Stem density of RF was significantly higher than OF. The value of species diversity (H´, 1-D) and Evenness (E´) were higher in OF than RF while richness (Margalef and number of species) was higher in RF than OF. The Dbh were 38.30±21.4 and 42.87±19.2cm in Riparian and Old-growth forests, respectively. Diameter distributions of both forests were positively skewed and expressed exponential pattern. The two forest types of Elephant Camp natural forest comprise different proportion of tree sizes and structural diversities.

Keywords: Biodiversity, Natural forest, Diameter distribution, Elephant camp and Diversity.

INTRODUCTION

The structure of plant populations in the forest can be described by ages, sizes and forms of individual plants (Shaltout *et al.*, 2009). However, it is better to classify the plant by size because fecundity and survival of plants are often related to plant size than age (Shaltout *et al.*, 2009). The diameter and height indicate the stem size. Therefore, diameter and height distributions are effective tools to describe forest structure. Diameter is easy to measure and closely related to height (Loetsch *et al.*, 1973) other tree attributes (Podoga *et al*, 2020) of forest trees. Conversely, structural diversity of forest indicates the degree of variation of stem diameter and height and the spatial distribution (Pach and Podlaski, 2014). Data attributes of stem diameters provide detail information about the stand (Podoga *et al*, 2020) and suggest the underlying mechanisms controlling regeneration and mortality (Alessandrini *et al.*, 2011). Hence, tree size diversity can be used as an indicator for biodiversity values (Shaltout *et al.*, 2009). However, the contribution of variable habitats to tree size and segregation is limited. Knowledge of effect of variable habitat is critical for understanding the factors controlling forest structure. It is require to determine tree species and size diversity of two adjacent forest areas with different water regimes.

Therefore, the study provided information on how environmental heterogeneity influence forest structure. The objective of the study was to investigate the structural diversity of Elephant camp natural forest with a view to provide information on how environmental heterogeneity influence forest s tructure.

MATERIALS AND METHODS

The study area

The study was conducted in Elephant Forest Reserve of Omo Forest Reserve. Omo Forest Reserve is located between Latitude 06°51′00″N and 06°91′00″N; and Longitude 04°22′48″E and 04°32′48″E at altitude 150 above sea level (asl) in the Ijebu area of Ogun State in Southwestern Nigeria (Figure 1). It is one of the remaining protected forests in Southwestern Nigeria. Elephant Camp forest covers approximately 55,000 ha.

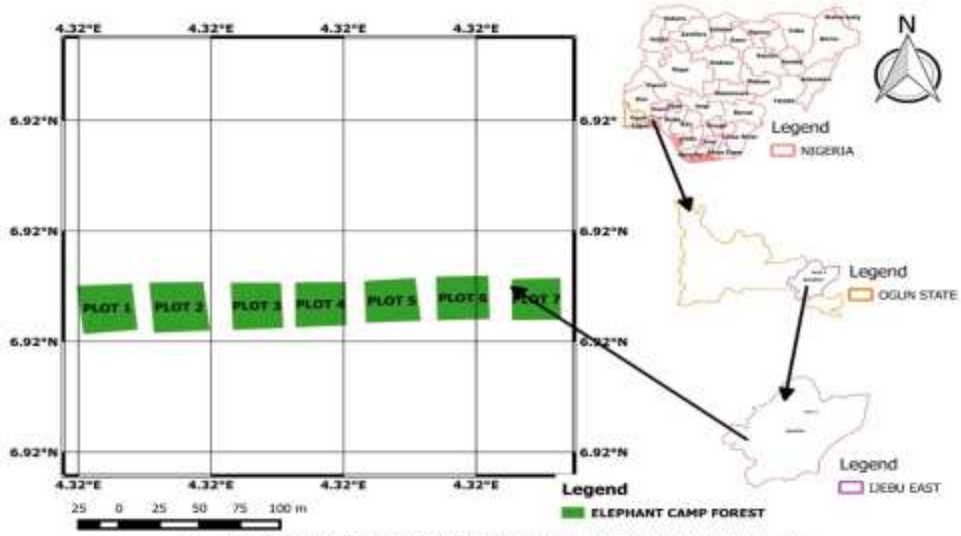

FIG. 1: MAP OF ELEPHANT CAMP NATURAL FOREST OF OMO FOREST RESERVE

A preliminary survey was conducted to observe general physiognomy of the forest reserve and it was observed that the forest was heterogenous based on its water regime. Therefore, Elephant Camp was divided into two parts based on its water regime. A part of the forest with close proximity to the river course was referred to as Riparian forest and the upper part which was relatively far from the river course was referred to as Old-growth forest.

Demarcation of sample plots and method of data collection

Four and three (30m×30m^2) sample plots were established in the Riparian and Old-growth forests, respectively, using a hand compass and cloth tape. The corners of each sample plots were marked with wooden peg and the boundary with red twine. Tree stems with diameter-at-breast height (dbh≥5cm) were identified to species level and enumerated in sample plots. Flora of West Tropical African and Woody plants of western African forests (Hutchison *et al*., 2014 and Hawthorne and Jongkind, 2006, respectively) will be used for the identification of plants species composition on the field with the assistant of taxonomists and authenticated with collection of reference samples available in the Herbarium of the Forestry Research Institute of Nigeria.

Forest structure of Riparian and Old-growth were estimated using tree species and size diversity indices and tree diameter distribution. The species diversity indices were Shannon-Weiner and Simpson and Margalef indices (Peet, 1975).

Shannon-Wiener species diversity index is expressed as:

$$H = -\sum_{i=1}^{n} P_i \ln P_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, ln $is\ natural\ logarithm$; P_i is the percentage of individual trees represented by species i and is estimated by;

$$P_i = \frac{n_i}{N_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, n_i = number of individuals of the ith species and N_i = total number of individuals.

The Simpson species diversity index is expressed as:

$$D = 1 - \left[\frac{\sum_{i=1}^{n} n_i(n_i-1)}{N(N-1)}\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where, n_i = number of individuals of the ith species and N= total number of individuals
The Margalef's index of species richness (Ma) is expressed as:

$$Ma = \frac{(S-1)}{\ln N} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad .(4)$$

Where
S = total number of species in the community
N = total number individual trees
*l*n = natural logarithm

Stem diameter distribution

The stem diameter of trees in Riparian and Old-growth forests were categorized into size classes of 3cm dbh width, starting from the smallest to the largest. Histogram of the dbh classes was produced and single two- and three-parameter Weibull distributions were used for fitting size-density distributions of Riparian and Old-growth forests. The two- and three-parameter Weibull functions are expressed as:

$$f(x) = \frac{c}{b}\left(\frac{x}{b}\right)^{c-1} \exp\left(-\left(\frac{x}{b}\right)^{c}\right)\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

$$f(x) = \frac{c}{b}\left(\frac{x-a}{b}\right)^{c-1} \exp\left(-\left(\frac{x-a}{b}\right)^{c}\right)\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Where: x = tree diameter, a, b and c are the location, scale and shape parameters of the distribution, respectively. Also, a = 0 in two-parameter Weibull function.

Data analysis

Tree species diversity was calculated using Shannon-weiner and Simpson indices. The tree species richness was computed as the number of species present and Margalef index. Important value index (IVI) was calculated for the tree species following standard method (Gilliam *et al.*, 1995 and Houchanou *et al.*, 2013). The degree of size inequality of the diameter distribution of Riparian and Old-growth forests was characterized using Gini Coefficient (GC), Coefficient of variation (CV), dissimilarity coefficient, Shannon-Weiner (H´), Simpson diversity and Margalef indices (Weiner and Solbrig, 1984). The size-density distribution of Riparian and Old-growth forests were fitted with single two- and three-parameter Weibull models and parameter estimation of Weibull models was performed using maximum likelihood estimate (MLE) techniques because studies have shown that MLE is superior to other parameter estimation methods (Zhang *et al.*, 2003). Also, the performance of single two- and three-parameters Weibull models were evaluated using Goodness-of-fit tests such as Kolmogorov-Smirnov (K-S), Anderson-Darling (A-D), Root Mean Square Error (RMSE), Bias and Coefficient of determination (R^2). The Gini coefficient (G) is expressed as:

$$G = \sum_{i=1}^{n}\sum_{j=1}^{n} \left|x_i - x_j\right| / 2xn^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where i= 1,….., n and j=1,….., n and χi, χj are the sizes of ith and jth plant, respectively.
G ranges from 0 (all individuals equal) to a theoretical maximum of 1.

RESULTS

Tree species diversity attributes of Riparian and Old-growth forests

A total of 27 and 24 tree species were identified in the Riparian and Old-growth forests, respectively (Table 1). *Milicia excelsa* had the highest important value index (41.0%), followed by *Terminali superba* (27.0%), *Cordia millenii* (26.0%).in the Riparian Forest. Also, *Irvigia garbonensis* had the highest important value index (36.0%), followed by *Khaya ivorensis* (30.0%), *Baphia nitida* (23.0%) in the Old-growth forest. Therefore, these six tree species were ecologically important and most widely distributed tree species in Elephant Camp of Omo Forest Reserve. *Milicia excelsa, Terminali superba* and *Khaya ivorensis* are pioneer and belong to the upper canopy while *Cordia millenii* belong to the lower canopy (Table 1).

Table 1. Tree Species Distribution in Riaparian and Old-Growth Forests

Riparian Forest			*Old-growth Forest*		
Species	**Stems/ha**	**IVI**	**Species**	**Stems/ha**	**IVI**
Funtumia elastica	3.0	1.97	*Cynnometra megalophylla*	4.0	1.24
Baphia nitida	3.0	2.00	*Entandrophragma utile*	4.0	2.80
Ficus thonningii	3.0	2.04	*Antiaris africana*	4.0	3.22
Detarium macrocarpum	3.0	2.17	*Musanga cecropioides*	4.0	3.37
Celtis integrifolia	3.0	2.63	*Hunteria umbellata*	7.0	5.87
Macaranga barteri	3.0	2.63	*Dracaena fragrans*	7.0	6.59
Musanga cacropioides	3.0	2.76	*Uapaca guinensis*	7.0	7.74
Hunteria umbellata	6.0	3.36	*Albizia glaberima*	7.0	8.22
Pterigota macrocarpa	5.0	3.46	*Pterigota macrocarpa*	11.0	8.31
Okoubaka aubrevillei	6.0	3.59	*Ceiba petandra*	7.0	8.76
Ficus exaspirata	6.0	4.75	*Milicia excelsa*	7.0	9.40
Nauclea diderrichii	6.0	5.01	*Ficus exasprata*	15.0	9.76
Stylochiton hypogaeus	8.0	5.08	*Strombosia pustulata*	11.0	10.52
Khaya ivorensis	6.0	5.16	*Nauclea diderrichii*	11.0	10.72
Pycnanthus angolensis	11.0	6.98	*Cordia Millenii*	11.0	11.66
Entandrophragma utile	11.0	7.14	*Funtumia elastica*	15.0	11.85
Antiaris africa	8.0	7.42	*Sida acuta*	15.0	12.09
Sida acuta	11.0	8.31	*Alstonia boonei*	11.0	16.34
Pausinystalia johimbe	17.0	12.95	*Terminalia superba*	15.0	17.04
Ceiba petandra	17.0	20.71	*Ficus thonningii*	19.0	20.43
Ficu capensis	25.0	21.67	*Gossypium arboreu*	19.0	20.94
Irvingia gabonensis	28.0	22.03	*Baphia nitida*	29.0	20.35
Albizia glaberima	28.0	25.03	*Khaya ivorensis*	26.0	30.19
Dracaena fragrans	33.0	25.19	*Irvingia garbonesis*	37.0	36.73
Cordia millenii	28.0	26.93			
Terminalia superba	33.0	27.86			
Milicia excelsa	28.0	41.07			

Important value index; IVI

Riparian Forest contained more tree stems per ha (338.89±9.80 stems/ha) compared to Old-growth forests (296.30±8.92 stems/ha). The values of Shannon-Weiner and Simpson indices were higher in Old-growth forest than Riparian Forest (Table 2). However, values of Evennes and Equitability indices of tree species were higher in Riparian Forest than Old-growth Forest (Table 2). A comparison of Riparian and Old-growth forests at species level using Sorensen similarity index showed high (74.50%) similarity with 9 tree species shared by two forests.

Table 2. indices of tree species diversity in Riparian and Old-growth forest of Elephant camp

Diversity indices	Riparian forest	Old-growth forest
Tree species richness	27	24
Shannon-weiner	2.963	2.98
Simpson	0.937	0.939
Margalef	5.412	5.249
Evennes (H/S)	0.717	0.82
Equitability	0.899	0.937
Sorensen similarity index		75.0%
Stem density (stem/ha)	338.89±9.80	296.30±8.92

Diameter Distribution of the Tree Stems

The mean diameter of Old-growth forest (42.87±18.90cm dbh) was significantly higher than Riparian forest (38.30±21.35cm dbh) (Table 2). The size-density distribution of Old-growth forest ranged from 9.65 to 90.63cm dbh while Riparian forest had extended distribution ranged from 6.43 to 104.96 cm dbh. The diameter distribution of Riparian and Old-growth forests are positively skewed. The values of skewness and kurtosis of Riparian forest (skewness=0.90, kurtosis= 0.65) were higher than Old-growth forest (skewness= 0.49, kurtosis= 0.53), respectively. However, both had the highest peak in size class 27.9-30.0cm dbh.

Table 3. Descriptive statistics of stem diameter of Riparian and Old-growth forests of Elephant Camp forest

Forest	N/ha	Mean±Std (cm)	Minimum (cm)	Maximum (cm)	Skewness	Kurtosis
Riparian	338.0	38.30±21.35	6.42	104.96	0.895	0.646
Old-growth	296.0	42.87±18.90	9.65	90.63	0.485	0.527

Standard deviation (Std), Stand density (N/ha)

Gini-coefficient (GC) and Coefficient of Variation (CV) and dissimilarity coefficient (DC) measure plant size inequality in a population (Weiner and Solbrig, 1984). The Coefficient of variation (CV) and Dissimilarity Coefficient of Riparian forest was relatively higher compared to Old-growth forest and dissimilarity coefficient follow the same pattern (Table 4). However, the value of Gini coefficient of diameter distribution of Old-growth forest (0.91) was higher compared to Riparian forest (0.82) (Table 4). The values of size diversity (Shannon-Weiner; H´, Simpson; 1-D and Evenness; E´) were higher in Riparian forest compared to Old-growth forest while richness (Margalef and tree richness) was higher in Riparian forest than Old-growth forest (Table 4).

Table 4. Indices of diameter diversity in Riaprian and Old-growth forest of Elephant camp

Diversity indices	Riparian forest	Old-growth forest
Shannon-Weiner (H´)	3.038	3.007
Simpson (!-D)	0.942	0.940
Margalef index	5.204	5.705
Evennes (e^H´/S)	0.802	0.778
Equitability_J	0.932	0.923
Gini-coefficient	0.825	0.915
Coefficient of Variation (CV)	0.557	0.44
Dissimilarity Coefficient	0.557	0.466

The values of Kolmogorov-Smirnov (K-S) and Anderson-Darling (A-D) test criteria for goodness of fit showed no significant difference between single three-parameter Weibull function and size-density distribution of Riparian and Old-growth forests. Therefore. single three-parameter Weibull distribution provided a good approximation than single two-parameter Weibull distribution, for the diameter distribution of Riparian and Old-growth forests. Also, the values of model selection criteria (Root mean square error (RMSE), Bias and Coefficient of determination (R^2)) of single three-parameter Weibuill model that fit size-density distribution of Old-growth forest is much less than the Riparian forest. Three-parameter Weibull model provided better approximation to diameter distribution of Old-growth forest than Riparian forest. Therefore, data properties and forest type affected the fit of diameter distribution. The two size-density distributions were not significantly different from single three-parameter Weibull distribution as shown by Kolmogorov-Smirnov (K-S), Anderson-Darling (A-D), Root Mean Square Error (RMSE), Bias and Coefficient of determination (R^2) test (Table 5).

Table 5. Statistics of diameter distributions of Riparian and Old-growth forests of Elephant Camp forest

Forest	**Distributions**	**A**	**β**	**γ**	**K-S**	**A-D**	**RMSE**	**Bias**	**R^2**
Riparian	2-p Weibull	-	2.037	42.434	0.099	0.991	2.474	1.610	0.5064
	3-p Weibull	5.508	1.565	36.472	0.073	0.463	2.359	1.551	0.4603
Old-growth	2-p Weibull	-	2.324	47.777	0.089	0.615	1.936	1.414	0.6651
	3-p Weibull	7.452	1.831	39.813	0.075	0.511	1.910	1.386	0.6474

Kolmogorov-Smirnov (K-S), Anderson-Darling (A-D), Root Mean Square Error (RMSE) and Coefficient of determination (R^2)

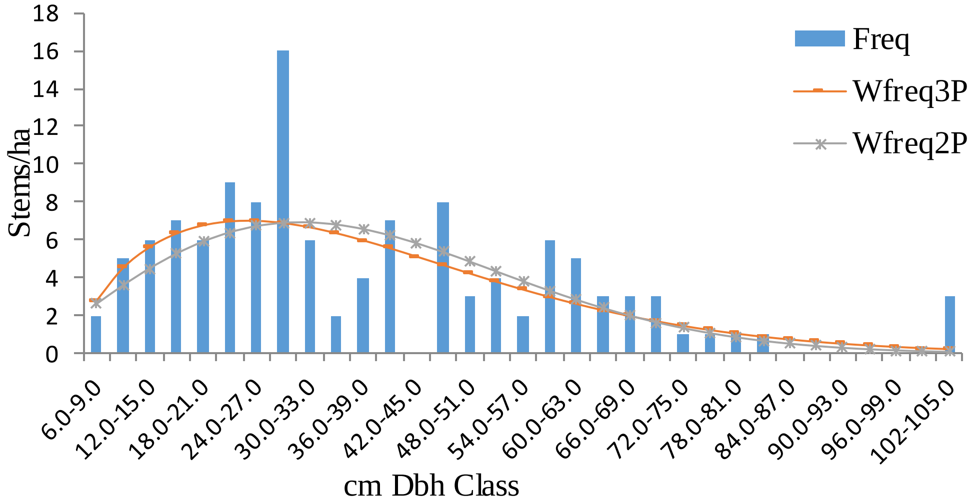

Figure 2. Observed and expected diameter distribution of Riparian forest of Elephant Camp forest in Omo Forest Reserve

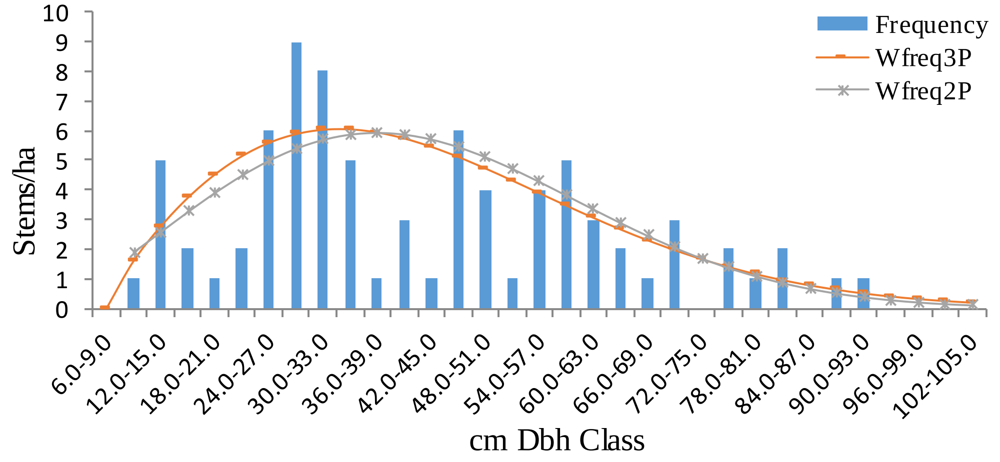

Figure 3. Observed and expected Dbh distribution of Old-growth forest of Elephant Camp in Omo Forest Reserve

DISCUSSION

Tree species diversity and richness

A total of forty two (42) tree species was identified in Riparian forest (27 tree species) and Old-growth forest (24 tree species) of Elephant camp natural forest. However, both forests had nine (9) tree species in common. The present study showed that Riparian forest contained more tree species than Old-growth forest and also, Riparian forest had higher values of tree species diversity indices than Old-growth. Most diversity indices combine measurement of eveness and richness. Therefore, tree species in Old-growth forest had almost equal proportion of stems than Riparian forest. The availability of water in most times of the year probably created conducive micro-sites for growth and survival of most tree species in Riparian forest while induced disturbance in Old-growth forest probably created enormous space for growth of individual stems (Sharma *et al.*, 2020). Similarity index was used to measure similarity of tree species in the two forests. Applying the benchmark threshold of Bradley and Crow (2010), the two forests can be considered to be of the same vegetation type due to high degree of similarity (≥50%) by Sorensen index. However, both forests have nine tree species in common. Out of forty-two (42) tree species identified in Elephant camp natural forest of Omo Forest reserve, *Milicia excelsa, Terminali superba,Khaya ivorensis,Cordia millenii, Irvigia garbonensis* and *Baphia nitida* are widely distributed and ecologically important for biodiversity conservation while the infrequent and sparse species require proper protection and regeneration

Size-density distribution of the Elephant camp natural forest

The mean tree density of Riparian forest was significantly higher than Old-growth forest. Gini coefficient (GC) and Coefficient of variation (CV) can be used to measure tree size diversity (Wiener and Solbrig, 1984). High value of Gini coefficient (GC) in Old-growth forest indicated a higher structural diversity and stability in Old-growth forest. The result showed that Riparian forest and Old-growth forest exhibited stem size inequality and structural diversity and stability, respectively. Therefore, stem size diversity may not indicate structural diversity and stability. Structural diversity and stability indicates capacity to endure difficult environmental and biologically stressful conditions (Chivulescu *et al.*, 2020). The CV increases with increase in stem density (Liu and Burkhart, 1993). Conversely, the presence of large stems was a distinctive feature that was noticeable lacking in Old-growth forest. This implied that Old-growth forest had experience exogenous or endogenous disturbances. Tree size diversity is an indicator for biodiversity values of a forest. The mean stem diameter of Old-growth forest (42.87±18.90cm) was significantly higher than Riparian forest (38.30±21.35cm). Therefore, high mean diameter of Old-growth forest resulted from few mid-size stems (38≤dbh≤81cm) because Riparian forest had extended diameter distribution with few largest trees. The size-density distribution of two forest types expressed irregular exponential distribution. The shape of the two diameter distributions is not different from each other as shown by Goodness-of-fit tests but with different value of skewness and kurtosis. This is probably because both forest types experienced the same environmental conditions except different water regime. However, Toledo (2012) stated that similar size-density distribution could be shaped by different mechanisms. Therefore, size-density distribution of trees of two forests was hypothetical similar but may be shaped by different processes. The Riparian forest expressed extended irregular exponential distribution to ≤104.96cm dbh with high density of small size trees (5.0-39cm dbh) while size-density distribution of Old-growth forest is truncated at ≤90.63cm dbh with high density of mid-size trees (39≤dbh≤ 60cm dbh). The result of high value of skewness and kurtosis of size distribution in Riparian forest may be caused by high density of small size trees (5.0-40cm dbh). Therefore, Riparian forest had sufficient density of small size trees (5.0-40cm dbh) to replace the mid-size trees while Old-growth forest has sufficient mid-size trees (39≤dbh≤ 60cm dbh) to replace the adult trees. Therefore, Elephant camp natural forest is showing good growth and adequate self-replacement of adult tree species. High stem density of mid-size trees (39≤dbh≤ 60cm dbh) may cause low density of small size trees (5.0-40cm dbh) in Old-growth forest because high tree diversity decreased light interception through structural complexity of the canopy (Rissanen *et al*. 2019).

The best result of approximation for positively skewed exponential distribution of Riparian and Old-growth forests was obtained with the single three-parameter Weibull distribution base on the result of goodness-of-fit tests (Kolmogorov-Smirnov (K-S), Anderson-Darling (A-D), Root Mean Square Error (RMSE), Bias and Coefficient of determination (R^2). Moreover, single three-parameter Weibull model provide better approximation to diameter distribution of Old-growth forest compared to Riparian forest. Therefore, data properties and forest type affected the fit of diameter distribution. Exponential pattern is expected when individual mortality and growth are independent of tree size (Muller-Landau *et al.*, 2006). It showed that tree growth and mortality are related to random events in both forest types. Riparian forest contained high density of small-size stems (6.0≤dbh≤39.0cm) while Old-growth forest contained high density of mid-size stems (39.0≤dbh≤60.0cm). Therefore, Riparian forest represented reproductive success and survival of the tree stems while Old-growth forest represented rapidly growing population with high reproductive capacity

CONCLUSION

Riparian forest and Old-growth forest exhibited stem size inequality and structural diversity and stability, respectively. Therefore, stem size diversity may not indicate structural diversity and stability. Size-density distribution of trees of two forests was hypothetical similar but may be shaped by different processes. Riparian forest had sufficient density of small size trees to replace the mid-size trees while Old-growth forest has sufficient mid-size trees to replace the adult trees. Riparian forest represented reproductive success and survival of the tree stems while Old-growth forest represented rapidly growing population with high reproductive capacity. The Elephant Camp natural forest is showing good growth and adequate self-replacement of adult tree species. Data properties and forest type affected the fit of diameter distribution. The protection of the study area is required for conservation of its plant resources and biodiversity components.

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SUB-THEME 2

New Technologies and Approaches to Sustainable Forest Management in Nigeria

Dead Organic Matter and Carbon Assessment in Okomu National Park, Edo State, Nigeria

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Abstract

Dead organic matter (DOM) which consist of dead wood and litter represent two of the major carbon pools considered for forest carbon stock accounting. However, information on carbon contents of dead wood and litter is very scanty because most studies have focused on live biomass pools. The study therefore assessed dead organic matter carbon contents of a lowland rainforest in Nigeria, Okomu National Park. The main objective of the study was to estimate biomass and carbon contents in dead wood including both Standing dead tree (SDT) and lying dead wood (LDW) as well as litter at the study site. To achieve this, fourteen temporary sample plots size of 50m X 50 m were laid using line transect method. All dead standing trees and lying dead wood were enumerated within the plots and a quadrant of 1 m X 1 m dimension was used to collect litter samples from each plot. Wood samples were collected from all dead tree enumerated while sub-samples were also collected for litter. The samples were dried in the laboratory and further analysis was carried out. The average biomass estimated for SDT was 174.41 kg/ha while that of LDW was 101.07 kg/ ha. Estimated carbon stock for dead wood was 6.05±1.56 tons/ha out of which SDT constituted 2.92± 0.65 tons/ha while lying dead wood accounted for 3.13±1.16 tons/ha. Litter was estimated to be 4.02± 0.0001 tons/ha. The carbon content in dead organic mass of the study area was significant. It is therefore recommended that more studies on dead organic matter of Nigerian forests should be carried to provide the much needed information on these carbon pools.

Keywords: Carbon Stock, standing dead wood, lying dead wood, litter, national park

INTRODUCTION

Dead organic matter (DOM) is a term used to refer to the combination of dead wood and forest litter (Ravindranath and Ostwald, 2008). Dead wood are standing and fallen dead trees and shrubs which includes all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil (Cienciala *et al*, 2010; Genene *et al*., 2013; Assaye, 2015; Tadesse, 2015). According to Genene *et al*., (2013), dead wood with diameters greater or equal to 10cm are generally referred to as Coarse Woody Debris (CWD). Litter on the other hand includes all non-living biomass with a size greater than the limit for soil organic matter (suggested 2 mm) and less than the minimum diameter chosen for deadwood (*e.g.* 10 cm), in various states of decomposition above or within the mineral or organic soil (Tadesse, 2015). Studies on dead organic matter has received attention in recent times because of the growing knowledge on its importance and contribution to ecological processes (Thomas 2002; Krishna and Mohan, 2017). For example, dead trees, lying dead wood and litter play important role in forest ecosystems by aiding nutrient cycling and soil fertility process, plant regeneration, erosion control, wildlife habitat provision, maintenance of biodiversity, *etc* (Paletto *et al*., 2012; Wuerthner, 2018; Ewa *et al*., 2019). In addition, it also play a major role in climate change amelioration because it has been established that it constitute two of the major carbon pools. A carbon pool is a system that is capable of accumulating and releasing carbon, and the mass of carbon stored in a pool is referred to as carbon stock (FAO, 2003). According to IPCC (2006), the main carbon pools in tropical forest ecosystems are the living biomass of understorey vegetation and trees, the dead mass of litter, dead wood and soil organic matter. However, in spite of its recognition as major carbon pools in forest ecosystems, studies on dead wood and litter are still scarce (Merganičová and Merganič 2010; Pfeifer *et al*., 2015) and this is especially true in Nigeria. This study therefore focused on assessing the carbon content of dead wood and litter of Okomu National Park, a low land rainforest in Nigeria.

MATERIALS AND METHOD

Study Area

The study area was Okomu National Park located in Ovia South-West Local Government, Edo State, Nigeria. The site had a total size of 202.24 km^2 (Nigeria Park Service 2016). Okomu National Park lies between longitude 5.187 °E and 5.431 °E and latitude 6.278 °N and 6.435 °N as shown in Figure 1. The park constitutes four different ranges namely; Igowan range, Arakhuan range, Julius creek range and Babui creek range (Ijeomah *et al*., 2015).

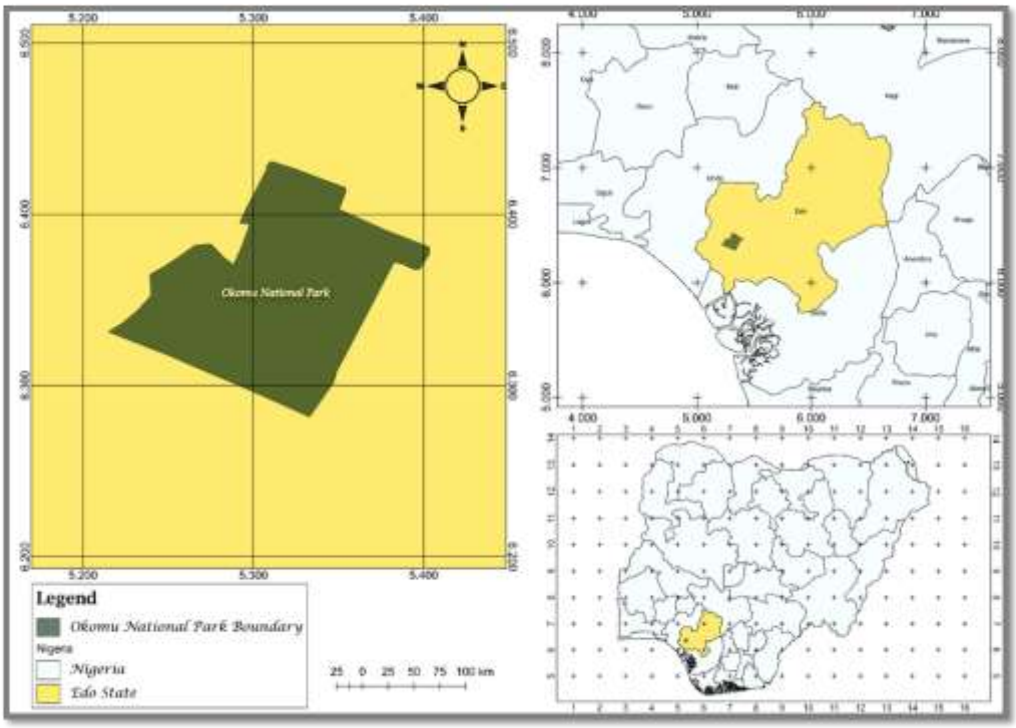

Figure 1: Boundary Map of Okomu National Park

Sampling Procedure

Line transect method was used in mapping out the temporary sample plots. Plots were laid alternately with 50 m interval between alternate plots after a distance of 50 m was measured along the transect to avoid edge effect. Nested plot design was used in laying sample plots for collection of data on dead wood and litter. Fourteen (14) temporary sample plot sizes of 50 m X 50 m were laid for enumeration of all dead wood in the plot (both standing and lying) while quadrants of size 1 m X 1 m were used for litter sample collection in each plot.

Standing Dead Trees (SDT)

Dead standing trees within the 50 m X 50 m plots were identified and classified into three categories as recommended by Genene *et al.,* (2013). The classification was based on the presence or absence of branches, twigs and leaves. They were:

i. Category 1: with big branches, twigs but no leaves;
ii. Category 2: with big branches but no twigs and leaves; and
iii. Category 3: with only boles, no branches, twigs nor leaves.

Tree variables that were measured were Diameter at Breast Height (dbh), diameter at base (db), diameter at middle (dm), diameter at top (dt), and height (h) of the trees. Samples were also collected from the bole of each of the trees. The volume of the wet/fresh samples were measured using water displacement method and this was carried out on the field, they were then kept in polythene bags and labelled appropriately for onward drying in the laboratory.

Downed/Lying Dead Wood (LDW)

All lying dead wood within the 50 m X 50 m temporary sample plots were enumerated. Using the machete test, they were classified into three classes (based on their healthiness) namely:

i. Class 1-Sound: when wood was hit by a machete, the wood repelled it
ii. Class 2-Intermediate: when wood was hit by machete, the machete entered slightly
iii. Class 3-Rotten: wood crumbled into pieces when hit by a machete

Variables measured on them included diameter at the base (db), diameter at the top (dt) and length of the log. Samples were also collected from the logs and their fresh/wet volumes were measured using water displacement method. The samples were kept in polythene bags for moisture preservation and labelled appropriately for oven-drying at the laboratory.

Litter

All litter within the 1 m X 1 m sub-plots, which were marked out using a quadrant, was collected and weighed on field using the electronic weighing balance. Sub-samples were then collected, weighed, placed in a polythene bags, labelled appropriately and taken to the laboratory for oven-drying. The sub-samples were dried at a constant temperature of 105 °C until constant weight was attained.

Data Analyses

Biomass of Dead Standing Trees and Carbon Estimation

The carbon contents in the dead standing trees were computed based on the different categories stated earlier.

Categories 1 and 2 Estimation

The volume was computed using Equation 1 while density was estimated using Equation 2.

$$\boldsymbol{V = \frac{\pi}{24} h\ (d_b^2 + 4d_m^2 + d_t^2)} \quad \ldots\ldots \quad \text{Equation 1}$$

Where V is Volume (m^3), h is height (m), d_b is Diameter at the base (m), d_m is Diameter at the middle (m), d_t is Diameter at the top (m), and π is 3.142.

The volume of individual trees were summed up to obtain volume per plot. The mean volume per plot was used to compute volume per hectare by multiplying it with the number of sample plots in a hectare (*i.e.* four for 50 m X 50 m plots).

$$D = \frac{M}{V} \quad \ldots\ldots \quad \text{Equation 2}$$

Where D is Density of Wood (g/cm^3), M is Mass of the dry sample that was obtained from the tree (g), and V is Volume of wet sample (cm^3).

The resulting values were then expressed in kg/m^3. The biomass was computed using Equation 3, after which 3 % of the total biomass obtain was subtracted from the resulting values to correct for absence of leaves. The discounted biomass value was then divided by 2 to obtain the carbon content in kg which was divided by 1000 to obtain the value in tonnes (tons).

$$B = V \times D \times BEF \quad \ldots\ldots \quad \text{Equation 3}$$

Where B is Biomass (kg), V is Stem Wood Volume (m^3), D is Wood Density (kg/m^3) and BEF is Biomass Expansion Factor (2.292). The mean BEF value of 2.292 was used for this study as prescribed by Nigeria R-PP (2013) for lowland Rainforest National Parks.

Category 3 Estimation

The density of the tree was calculated using Equation 2 and the volume of the bole was calculated using Smalian's Formula given in Equation 4.

$$V = \pi h \frac{d_b^2 + d_t^2}{8} \quad \ldots\ldots \quad \text{Equation 4}$$

Where V is Volume of bole (m^3), h is height (m), d_b is Diameter at the base (m) and d_t is Diameter at the top (m)

The biomass was then estimated using Equation 5.

$Biomass(kg) = Density\ (kg/m^3) \times Volume\ (m^3)$…………………….. Equation 5

Half of the resulting value gave the carbon content for each tree. This was then divided by 1000 to obtain the carbon value equivalent in tonnes.

The mean plot values (for all the categories) were multiplied by four to obtain the carbon in tonnes per hectare.

Carbon Estimation of Downed/Lying Dead Wood

The volume of the log was estimated using Equation 4 while the density was computed using Equation 2. The biomass was then calculated using Equation 5. Half of the resulting value gave the carbon content for the tree which was divided by 1000 to give the tonnes equivalent of the carbon.

Carbon Estimation of Litter

The dry mass of the litter sample was estimated from the dry to wet ratio of the sub-sample using Equation 6.

$Dry\ Mass\ of\ sample(kg) = \frac{sub-sample\ dry\ mass\ (kg)}{sub-sample\ wet\ mass\ (kg)} \times Fresh\ Mass\ of\ sample(kg)$ ……… Equation 6

The result obtained was divided by 2 to obtain the amount of carbon in the litter, this was then expressed in tonnes per plot by dividing it by 1000. The resulting value was multiplied by 10,000 (the number of 1m X 1m in a hectare) to obtain the amount in tonnes per hectare.

RESULTS AND DISCUSSION

Out of the fourteen (14) temporary sample plots laid, Standing Dead Tree (SDT) were encountered in twelve (12) while Lying Dead Wood (LDW) were seen in thirteen (13). For standing dead trees, four trees were enumerated for class one, while class two and class three had seven and twenty-two trees respectively. Lying dead wood had more logs in class two (32) than class one and three which had 15 and 14 logs respectively. The presence of dead wood (whether standing or lying) is an important indicator of forest's health as it helps to provide the habitat and structure needed to maintain and sustain biodiversity (Bujoczek *et al.* 2018; Parisi *et al.* 2018; Monaco *et al.* 2020). Standing dead tree had a wide dbh range, it ranged from 7.5 cm to 115.2 cm. The highest average height (16m) was recorded for trees in plot 12 while the lowest was recorded in plot 5 (2.45m). The overall average height for the plots was 12 m. The lowest volume per plot (0.01 m^3) was estimated for plot 5 while plot 8 had the highest volume per plot which was 10.50 m^3. Plot five also had the lowest basal area of 0.01 m^2 while the highest value was 0.59 m^2 estimated for plot 4. The average basal area per hectare estimated for the entire plot was 0.04 m^2. Biomass estimated for standing dead tree ranged from 1.80 kg to 3088.43 kg. Overall, the mean dbh was 33.93 cm with an average volume of 0.49m^3/ha while the average biomass was estimated to be 174.41 kg/ha as shown in Table 1. The average and total carbon per hectare estimated for SDT was 0.088 tons/ha and 2.92 tons/ha respectively while the estimated value for the entire stand was 59047.37 tons.

A total of 62 LDW was encountered in the sampled plots. The highest number (12) was encountered in plot 1, while least numbers were encountered in plots 11, 12 and 14. None was found in plot 10. Biomass estimated for LDW ranged from 1.87kg to 5404.42 kg, giving an average biomass of 101.07 kg/ ha for the entire sample plots. The average carbon estimated was 0.05 tons, while the total carbon for LDW was estimated to be 3.13 tons/ha. The value of carbon in LDW for the entire stand was estimated to be 63367.54 tons. Overall, dead wood had 6.05±1.56 tons/ha out of which SDT constituted 2.92±0.65 tons/ha while LDW was 3.13±1.16 tons/ha as shown in Table 1 and Table 2. The values obtained for SDT and LDW fell within the range of values, that is, 6.6 tons/ha, 8.3 tons/ha and 9.0 tons/ha, reported by Sierra *et al.* (2007), Ngo *et al.* (2013) and Lü *et al.* (2010) respectively. It was higher than the 1.2 tons/ha reported by Glenday (2006) for a tropical forest in Kenya but lower than 13.97tons/ha recorded by Berta *et al.* (2015). This indicates that the carbon content of dead wood in the study area compare favourably with those from other similar site.

Table 1: Biomass and Carbon Stock of Enumerated Standing Dead Tree

Plot No	Freq	MDbh (cm)	Avg Ht (m)	AV (m^3)	MBA (m^2)	Avg B (kg)	Avg C (kg)	Avg C (tons)	Avg C (tons/ha)	Total C (tons)	Total C (tons/ha)
1	2	44.55	12.70	1.31	0.16	510.06	258.07	0.258	1.032	0.52	2.06
2	4	34.15	10.45	1.08	0.11	922.29	467.65	0.468	1.871	1.87	7.48
3	7	47.50	17.45	2.39	0.21	440.59	222.70	0.223	0.891	1.56	6.24
4	2	78.30	18.65	4.03	0.59	3088.43	1591.97	1.592	6.368	3.18	12.74
5	2	8.20	2.45	0.01	0.01	1.80	0.91	0.001	0.004	0.00181	0.01
6	-	-	-	-	-	-	-	-	-	-	-
7	3	16.70	20.23	0.42	0.02	120.52	60.26	0.060	0.241	0.18078	0.72
8	2	68.90	19.15	10.50	0.50	2579.76	1289.88	1.290	5.160	2.57976	10.32
9	3	22.07	10.63	0.32	0.04	62.17	31.90	0.032	0.128	0.10	0.38
10	-	-	-	-	-	-	-	-	-	-	-
11	1	18.46	6.00	0.10	0.03	17.80	8.90	0.009	0.036	0.01	0.04
12	2	16.23	16.00	0.21	0.02	78.25	39.12	0.039	0.156	0.078247	0.31
13	1	16.50	2.50	0.03	0.02	6.04	3.02	0.003	0.012	0.00	0.01
14	4	16.70	8.93	0.13	0.02	70.53	35.26	0.035	0.141	0.141055	0.56
Per ha	9			0.49	0.04	174.41	88.47	0.088	0.088	2.92	2.92
Total for stand											59047.37
C1 (95%)											0.65

Freq=Frequency, MDBH=Mean Diameter at Breast Height, Avg Ht=Average Height, AV=Average Volume, MBA=Mean Basal Area, Avg B= Average Biomass, Avg C=Average Carbon, Total C=Total Carbon

Table 2: Biomass and carbon of enumerated downed/ lying dead wood

Plot No	Freq	Avg B (kg)	Avg C (kg)	Avg C (tons)	Avg C (tons/ha)	Total C (tons)	Total C (tons/ha)
1	12	209.81	104.90	0.105	0.42	1.26	5.04
2	3	282.25	141.12	0.141	0.56	0.42	1.69
3	2	223.37	111.68	0.112	0.45	0.22	0.89
4	3	5404.42	2702.21	2.702	10.81	8.11	32.43
5	10	5.13	2.56	0.003	0.01	0.03	0.10
6	10	13.33	6.67	0.007	0.03	0.07	0.27
7	2	15.84	7.92	0.008	0.03	0.02	0.06
8	3	129.43	64.71	0.065	0.26	0.19	0.78
9	10	1.87	0.94	0.001	0.00	0.01	0.04
10	-	-	-	-	-	-	0.00
11	1	94.89	47.45	0.047	0.19	0.05	0.19
12	1	220.70	110.35	0.110	0.44	0.11	0.44
13	4	11.28	5.64	0.006	0.02	0.02	0.09
14	1	924.56	462.28	0.462	1.85	0.46	1.85
Total	62	353.76	176.88	0.177	0.71	10.97	43.87
Per ha	17.71	101.07	50.54	0.05	0.05	3.13	3.13
Total for Stand							63367.54
C1(95%)							1.16

Freq=Frequency, Avg B= Average Biomass, Avg C=Average Carbon, Total C=Total Carbon

Litter Carbon

The value of biomass estimated for litter ranged between 0.26 kg and 1.39 kg, with plots 7 and 10 having the least while plot 4 had the highest as shown in Table 3. The average biomass per plot was 11.24 kg, while the average biomass per hectare was estimated to be 8032.06 kg. Estimated carbon also followed the trend with an average per hectare value of 4016. 03 kg. The average value of carbon expressed in tonnes per hectare was 4.02, accumulating to a total of 56.22 tons/ha and 81220.19 tons for the entire stand. Litter forms an integral part of the forest ecosystem because of its role in carbon and nutrient cycling, as well as protection of soil and habitat provision for some species of animals and microorganisms (Giweta, 2020). The estimated value of carbon content of litter (4.02± 0.0001 tons/ha) obtained for this study was higher than the value (1.4 tons/ha) reported by Lü *et al*. (2010) and those (1.8 tons/ha, 2.0 tons/ha) reported by Sebastian *et al*., (2015). It was however lower than the 5.4tons/ha estimated by Glenday (2006) and 8.87 tons/ha reported by Berta *et al*. (2015). This difference might be due to some factors that affect litterfall production which in turn affects its carbon content. Some of these factors include difference in tree species composition and vegetation type (age, species and density); climatic condition of the study area; and the season of the year when the samples were collected (Lopes, *et al*. 2015; Paudel, *et al*. 2015; Krishna and Mohan 2017; Ifo, *et al*. 2018).

Table 3: Biomass and carbon of litter

Plot No	Dry Biomass (kg)	Carbon (kg)	Carbon (tons)	Carbon (tons/ha)
1	0.48	0.24	0.0002	2.39
2	1.01	0.51	0.0005	5.06
3	0.85	0.42	0.0004	4.24
4	1.39	0.70	0.0007	6.97
5	1.02	0.51	0.0005	5.08
6	1.24	0.62	0.0006	6.19
7	0.26	0.13	0.0001	1.32
8	0.77	0.39	0.0004	3.86
9	1.04	0.52	0.0005	5.19
10	0.26	0.13	0.0001	1.32
11	1.03	0.51	0.0005	5.15
12	0.58	0.29	0.0003	2.92
13	0.72	0.36	0.0004	3.60
14	0.59	0.30	0.0003	2.95
Total	11.24	5.62	0.0056	56.22
Per ha	8032.06	4016.03	4.02	4.02
Total for Stand				81220.19
C1(95%)				0.0001

CONCLUSION

The study provided information on dead wood and litter biomass and carbon content of Okomu National Park. The total Carbon estimated for Dead Organic Matter (DOM) for the study area was 203,635.10 tons out of which dead wood and litter accounted for 122,414.91 tons and 81,220.19 tons respectively. The park, though small in size, has the capacity to be a major carbon sink in Nigeria which can compare favourably with similar tropical forest, as shown from the results obtained from the two carbon pools considered. Therefore, good conservation effort should be sustained and improved upon, and management objective should be extended to incorporate carbon management.

RECOMMENDATION

Studies on carbon content on dead wood and litter are scarce in Nigeria as observed during literature review in the course of this study. It is therefore recommended that more in depth study should be carried out for Nigerian forests by exploring these important carbon pools. This will help position Nigeria to benefit from carbon funding such as is available under REDD+ (Reducing Emissions from Deforestation and Forest Degradation, and foster conservation, sustainable management of forests, and enhancement of forest carbon stocks) programme.

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Efficacy of Saw Dust from Three Different Species as Growth Media for Cashew (*Anacardium occidentale* L.)

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Abstract

The rate of pollution increases every day due to non-use of waste generated by Timber Companies in Nigeria. Most of the waste are burnt, which releases pollution to the atmosphere. This has negative effects on quality of rain which is the backbone of our nursery and forest plantation. The top soil in our communities are also affected, this reduce the quality of soil nutrients. This lead to experiment on three selected saw-dust from sawmill in Edo state Nigeria. There is little work on the nursery aspect of cashew across Nigeria. This experiment compared the different sawdust as growth media on seedling emergence, growth and prospect of Anacardium occidentale. The practical was carried out in Forestry Technology Nursery at Federal College of Agriculture, Akure. The project practical was carried out between April and July, 2019. The site is fairly gentle slope. The relative humidity is moderately high all the year. The research were carried out with four treatments which are, Top soil, Gmelina arborea sawdust, Milicia excelsa and Swietemia macrophylla sawdust A,B,C and D respectively. Materials used were cutlass, bamboo, palm front, and polythene pot. All the treatments were analysis using means different to know the best responses among the treatments. Experimental study, show that top soil of natural forest and Gmelina arborea sawdust have the shortest days of germination, within fourteen days after planting while, Milicia excelsa and Swietenia macrophylla saw dust germinated sixteen days after planting. The treatments mean for plant height are 23.13cm, 22.50cm, 22.53cm and 22.50cm for Top soil, Gmelina arborea sawdust, Milicia excelsa and Swietemia macrophylla sawdust respectively at 12 weeks after planting. It was discovered after the experiments that, top soil performed very well but the other media like saw dust can be used for raising of cashew seedling in our nursery in Nigeria instead of burning them.

Keywords: *Milicia excelsa*, *Swietenia macrophylla*, *Gmelina arborea*, Treatment, Cashew.

INTRODUCTION

Cashew (Anacardium occidentale L.) is a fast growing, Hardy and drought resistant multi-purpose species cultivated in many tropical countries. It is one of the most well-known species for its nut in the world, although all parts of the tree are useful (Hamad, 2015). It is an important tropical tree crop and in terms of international trade for major edible nuts, it ranks third after coconut tree (Mofa, 2001). It is also a well-known agro-forestry species. The tree produce fruits when they are about four years old and maximum production is from 10-30 years. Trees are also suitable for use in the rehabilitation of degraded lands, afforestation of barren, slash-and-burned farmland and coastal saline Sandy land. The trees are easily cultivated, vigorous and required little care (Rex *et al*., 2019).

According to Montealegre, (1999) explained that, Establishment of cashew plantation is essential for economics, environmental and domestic uses. The main producer countries are Brazil, India, Mozambique and Tanzania. Limiting factors for the species are the inability to tolerate Frost and extreme cold for a long term, reduction of nuts yields due to anthracnose fungal disease, and the damaging effect of heavy rainfall during the flowering period (Dorthe, 2003). Flowering is affected by weather conditions and also varies from tree to tree, but continue for a period of three months. High temperature leads to earlier flowering. Both male and bisexual flowers Bourne on one clusters. The flowers are very susceptible to mildew and control thereof on the leaves and flowers is a prerequisite for good production. After pollinations it takes 6-8 weeks for the fruits to develop. The nut develops first while the apple develops and enlarges only 2 weeks before fruit fall. Nuts should be harvested and should be dry before storage (Dorthe Joker, 2003).

The nut is attached to the lower portion of the cashew apple which is conically shaped. The cashew nut (seed) hangs at the bottom of the apple, and is C-shaped .The cashew seed has within the outside shell the edible kernel or nut. In its raw form the cashew kernel is soft, white and minty. When roasted it changes colour and taste. Cashew apple and cashew nuts are excellent source of nutrition. The cashew apple contain five times more vitamin C than an orange and contain more calcium, iron and vitamin B1 than other fruits such as citrus, avocados and bananas (Franco and Janzantti, 2005; Soares *et al*., 2007; Sivagurunathan *et al*., 2010). Cashew nut shell oil (CNSL) extracted from the shell is caustic and causes burns on the skin. The mucous membrane of the month and throat are severely affected when it comes Iinto contact with shell oil or the irritating fumes emitted during roasting (Temilade, 2008). The oily shell liquid has many uses. Cashew tree are genuinely tropical and very fast sensitive. The tree grows in a wide spectrum of climatic region between 25 degree North and South latitudes. Although the cashew can withstand high temperature, a monthly mean of 25 degree Celsius is regarded as optimal. The cashew tree has a well-developed for production but 1500 – 2000mm can be regarded as optimal (Grieve, 2004) .The cashew tree has a well-developed root system and it can tolerate drought conditions. Rain during the flowering season causes flowers and overcast due to anthracnose and mild. During harvesting, while nuts are on ground, rain and overcast weather causes the nuts to root or start germinating. The cashew is a strong plant that is renowned for growing in soils, especially Sandy soils that are generally suitable for other fruits tree. For the best production deep, well drained Sandy or Sandy loam soil is recommended. Cashew tree will not grow in poorly drained soil (Dorthe, 2003).

The surviving rate of seedling at nursery is partly dependent on the nutritional condition of the medium in which they developed. Poor nutrition for seedlings at the juvenile stage may result in growth and developmental defects, poor establishment of seedling on the field, slow growth, reduced survival percentage etc. The use of saw dust as alternative medium to know the present of essential nutrients which are Nitrogen, Phosporus and Potassiun in forest waste like saw dust of trees. Instead of burning, it should be used as organic sources. The saw-dust can be used as organic materials for growing tree seedlings (Ellen, 2011). Therefore, the present study seeks to investigate different saw dust as growth media for seedling emergence parameter of *Anacardium occidentale* and to determine the growth and prospect of cashew.

MATERIALS AND METHODS

The practical was carried out in Forestry Technology Nursery at Federal College of Agriculture, Akure. Duration for the project is between April and June, 2019. The site is fairly gentle slope. The temperature ranges from 25°C-28°C. The relative humidity is between 80-90% which is high during rainy season and favour the growth of forest tree. Seed of cashew were obtained from cashew plantation of Federal College of Agriculture, Akure. The three different species of sawdust were obtained from sawmill at Ibillo in Edo State. The site was cleared with the use of hoe and Cutlass, the debris were packed and remove from the site. Shade was constructed with the use of bamboo and Palm front. Top soil was collected in nursery site to fill the polythene bag pot for the experiment. The polythene pots were arranged on the site according to the different species of saw dust and the top soil. According to Zake *et al*., (2000) recommended that, planting of one nut per pot with diseases free gives good outcome. There are four treatments which are natural plantation top soil (A), *Milicia excelsa* saw dust (B), *Gmelina arborea* saw dust (C), and *Swietenia macrophylla* saw dust (D). Stem girth, plant height, and number of leave were measured and recorded at every fortnight for 12th weeks after planting before the experiment were terminated. The data were subjected to statistical analysis using tables with means different of each treatment to know the most efficient medium and the least.

RESULTS

Soil Analysis of top soil before planting

The result of soil analysis before planting is presented in table 1. The organic matter of the soil was 3.12% which is recommended for plant production in south-western Nigeria (Agboola and Corey, 1973). Nitrogen was 0.69% which is high above 0.15% for plant production in south-western Nigeria (Sobulo and Osiname, 1981). The soil pH was 5.06 showing that the soil is acidic. The soil N, P, K, Mg and Ca contents were 0.69, 12.90, 0.25, 1.93 and 4.61 Cmol/kg.

Table 1: Chemical and properties of the Top soil before planting

Parameters	Value
pH(H_2O)	5.06
% Organic Matter	3.12
% Nitrogen	0.69
% Phosphorus	12.90
% Potassium	0.25
% Magnesium	1.93
% Calcium	4.61
% Sand	85.7
% Silt	7.8
% Clay	6.7

Figure 1 shows that, the germination date of *Anacardium occidentale* was different with each treatment been used. In top soil and *Gmelina arborea* sawdust germination date was 14 days for the plant to sprout from the soil and sawdust respectively. However, in *Milicia excelsa*,and *Swietenia macrophylla*, sawdust germination date was 16 days before sprouting.

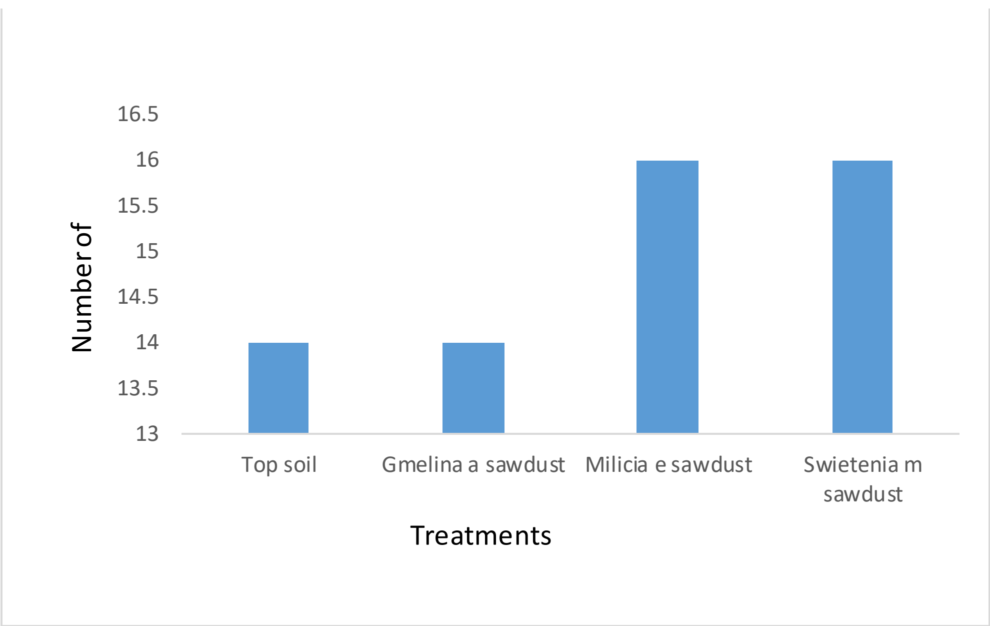

Fig 1: Germination day for each treatments

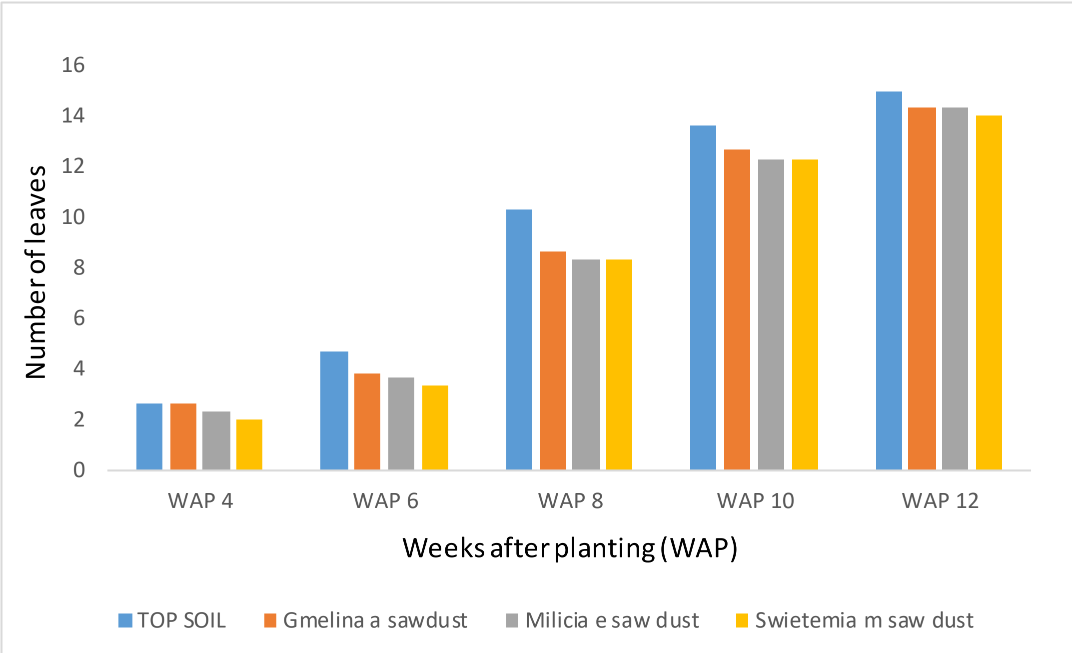

Fig 2: Effects of each treatment on number of leaves of Cashew seedlings over 12 weeks after planting

Figure 2 shows that, the mean number of leaves produce by *Anacardium occidentale* seedlings was highest in top soil (15.00) while the lowest number of leaves was (14.00) in *Swietenia macrophylla* sawdust. There is significant different between the number of leaves across the treatments in each week from 4 to 12 weeks after planting. Figure 3 shows that, the mean of plant heights have highest value in top soil at 12 weeks after planting (23.13cm). While the lowest mean recorded was in *Swietenia macrophylla* and *Gmelina arborea* sawdust (22.50cm) at 12 weeks after planting.

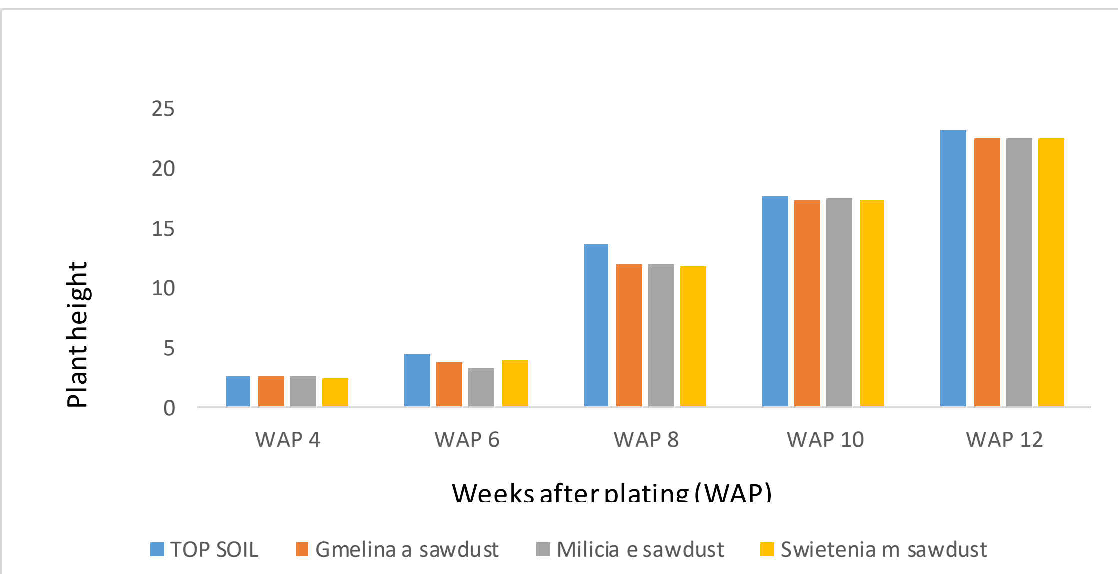

Fig 3: Effects of each treatment on plant height of Cashew seedlings over 12 weeks after planting

DISCUSSION

The result of the nursery experiment revealed that all the seeds of each treatments germinated 100% but the day of sprouting differ from one another. The fastest germinated seeds came from top soil and *Gmelina arborea* sawdust while *Milicia excelsa*, *Swietenia macrophylla* sawdust germinated lately. The top soil which were collected from natural forest performed very well in this study because, of some essential like Nitrogen, Phosporus and Potassium nutrients in higher quantities this corresponds to Owonubi (2005) which make pre-germination easier for seeds. Litters decomposition at the base of natural forest also contributed to the nutrients. *Gmelina arborea* sawdust also have some potential in retaining water and essential nutrients which helped in germination of *Anacardium occidentale* seeds. However, *Milicia excelsa, Swietenia macrophylla* sawdust also performed fairly in germination of *Anacardium occidentale* seeds. Number of leaves and plant height increase gradually in top soil medium, *Gmelina arborea* sawdust, *Milicia excelsa* sawdust while the least value occurred in *Swietenia macrophylla* sawdust.

CONCLUSION

In conclusion, the rate at which waste increases in Nigeria is alarming because of the non-use of our waste for organic fertilizer. Rather people do burn the waste materials which lead to pollution of the environment. Also, the pollution lead to increasing of global warming which change our seasonal pattern in Nigeria (Janzantti, 2005). Temilade (2008), said that the production of urban and industrial organic wastes is increasing worldwide; agricultural wastes are equally on the increase in most farms; sometimes to the level of becoming a menace in forest plantation. The analysis carried out for the 12weeks after planting, explained that, treatment A which is top soil have the highest record of number of leaves and height of plant. Treatment C which is *Gmelina arborea* saw dust perform well in 4nd, 8th and 10th week. Treatment B which is *Milicia excelsa* saw dust has the third highest records in terms of number of leaves and height of the plant. Treatment D which is *Swietenia macrophylla* saw dust has the least data recorded in number of leaves and height of plant.

RECOMMENDATION

The study recommended that top soil of natural plantation and waste of sawmills (sawdust) should be converted to planting media for raising seedlings in the forest nursery for full usage of our natural resources.

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Diameter Distribution Models For *Tectona grandis* Linn. F. Stands in Ado-Ekiti, Nigeria.

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Abstract

Diameter distribution functions play a vital role in determining the diameter structure of tree sizes in the forest. It also provides information about age structure and stand stability. This research assess the flexibility of five statistical models: Beta, Webull (3P), Gamma (3P), Johnson SB and Lognormal (3P) for fitting diameter at breast height (Dbh) of Tectona grandis Linn.F plantation in Afe-Babalola Plantation, Ado-Ekiti, Nigeria. The plantation was divided into four compartments. Each compartment was divided into five temporary sample plots (TSPs), each with plot size of 25x25m. A total of one thousand, two hundred and ninety five (1295) T. grandis species with diameter at breast height (Dbh) ≥10.0 cm in the twenty TSPs trees were measured. Data were analysed on five probability density function: Beta, Webull (3P), Gamma (3P), Johnson SB and Lognormal (3P). The distributions were ranked based on Kolmogorov smirnov, Anderson darling and Chi-Square. The five distributions were further tested with Kolmogorov smirnov (D) for fitting the diameter data. The results revealed that there are more trees in the middle diameter class than the lower and upper diameter class which make the diameter structure a nearly bell-shaped. Weibull 3P were more flexible and consistent when tested with the three statistical tests: Kolmogorov smirnov, Anderson darling and Chi-Square. The reason is because the calculated D-value (Weibull 3P = 0.03274) is lower than the tabulated D-value (0.03707) at p ≥0.05. This means that Weibull 3P appropriately provide a better fit for the diameter data in Afe Babalola Plantation.

Keywords: Afe Babalola Plantation, Tectona grandis, Diameter at breast height, Statistical models

INTRODUCTION

Teak is a tropical hardwood species belonging to the family Verbenaceae. Teak has been widely used both within and out of its natural distribution. At present, teak is one of the major planted tree species in Indonesia, tropical African countries like Nigeria, Ghana and Ivory Coast, South and Central American countries like Panama, Costa Rica, Brazil and others (Tewari and Mariswamy, 2013). The strength, durability, and ease of working without cracks are some properties that make teak so popular among the regions for forestry plantations (Koirala *et al*., 2017). Tree size distributions are simple yet effective tool to describe tree populations and forest stands (Ezenwenyi *et al*., 2018). They are used to value forests, plan harvest activities, predict forest growth, and thus, enhance forest productivity (Bailey and Dell, 1973; Burkhart and Tome, 2012).Diameter distributions also provide information about stand structure, age structure, stand stability, etc. and enable the planning of silvicultural treatments (Ige *et al.,* 2013). In forestry, a number of distribution functions such as normal, gamma, lognormal, Johnson's SB, beta, and Weibull have been developed to describe tree diameter distributions of forest stands (Palahi *et al*., 2007; Aigbe and Omokhua, 2014; Ogana *et al*., 2015; Alo, 2017). Weibull distribution is often and widely used owing to its simplicity and flexibility and its parameters are easy to estimate (Bailey and Dell 1973; Nord-Larsen and Cao 2006; Gorgoso *et al*., 2007).

Stand models that provide accurate estimates of stand growth and yield have become essential tool for evaluating the numerous management and utilization decision. No single type of stand model can be expected to provide information efficiently for all levels of decision making (Adesoye, 2002). Therefore, there is need for wide variety of models of varying degree of complexity for the management of natural forest and plantation (Ige *et al*., 2013). This research work aim to assess the flexibility of five statistical models: Beta, Webull (3P), Gamma (3P), Johnson SB and Lognormal (3P) for fitting diameter at breast height (Dbh) of *Tectona grandis* Linn.F plantation in Afe Babalola Plantation, Ado-Ekiti, Nigeria

METHODOLOGY

Study Area

This study was carried out in the Teak stands at Afe Babalola Plantation, Ado- Ekiti, Ekiti State. It is geographically located within the Latitude 7.5689°N and 7.5608°N and Longitude 5.2033°E and 5.2107°E. The plantation is divided into four compartments. It is 33.1 Ha in size and the first, second and third compartment was established in 2002 while compartment four was established in 2003. The vegetation of the study area is a moist semi-evergreen tropical rainforest. The focus of forest management is timber production. However, some other economic activities such as fish farming, apiculture and production of crops such as banana, palm nuts are practiced in the forest.

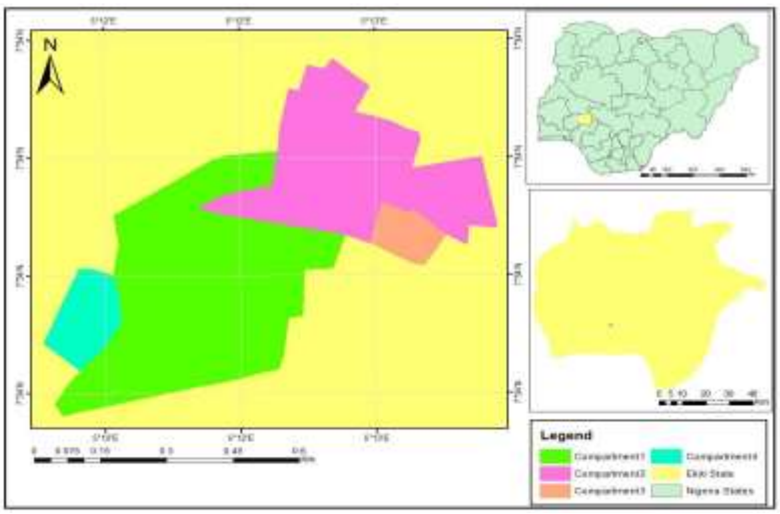

Figure 2: Map of Afe-Babalola Plantation
Source: (Muniru, 2017)

Data Collection

Plot layout and data collection

The plantation was divided into four compartments. Each compartment was divided into five temporary sample plots (TSPs) each with plot size of 25x25m. A total of one thousand, two hundred and ninety five (1295) *T.grandis* species with diameter at breast height (Dbh) ≥10.0 cm in the twenty TSPs trees were measured.

Data Analysis

Diameter fitting procedure

In this study, Five Diameter distribution functions were fitted using Kolmogorov Smirnov, Anderson Darling and Chi-Square. Beta, Gamma (3P), Lognormal (3P), Weibull (3P) and Johnson S_B were used in characterizing the Dbh of *T.grandis* trees enumerated in the study area. The statistical distribution models considered is represented below

Beta Distribution

The beta distribution function (Krishnamoorthy, 2006) is expressed as:

$$f(x) = \frac{1}{B(\alpha_{1,}\alpha_2)} \frac{(x-a)^{\alpha_1-1}(b-x)^{\alpha_2-1}}{(b-a)^{\alpha_1+\alpha_2-1}} \quad (1)$$

Where: α_1 and $\alpha_2$are shape parameters (α_1, α_2 >0), a, b, are the limits of the distribution (a<b)
$B(\alpha_1, \alpha_2)$ is the beta function. It has the formula:

$$B(\alpha_1, \alpha_2) = \int_0^1 t^{\alpha_1 - 1} (1-t)^{\alpha_2 - 1} dt (\alpha_1, \alpha_2 > 0) \quad (2)$$

Weibull Distribution (3P)

The 3-parameters Weibull distribution (Weibull 1951) was used for this study. It is expressed as:

$$f(x) = \frac{\alpha}{\beta}\left(\frac{x-\gamma}{\beta}\right)^{\alpha-1} exp\left(-\left(\frac{x-\gamma}{\beta}\right)^{\alpha}\right) \quad (3)$$

$\alpha \geq 0, \beta > 0$, c $> 0\beta$ *is the shape parameter*, α *is the scale parameter*, γ *is the location parameter*

Where: *F(x)* is the Weibull probability density function; *x* is tree diameter to be measured, a, b and c are the location, scale and shape parameters of the distribution respectively.

Lognormal Distribution (3P)

The probability density function (pdf) of the three-parameter lognormal distribution (Aristizabal, 2012) is:

$$f(x) = \frac{1}{(x-y)\propto\sqrt{\pi}} exp\left(\frac{lnx-\mu}{\sigma}\right)2 \quad (4)$$

Where: $\sigma > 0, x > 0, 0 > \mu + \propto$

The Gamma Distribution (3P)

The 3-parameter gamma distribution function (Krishnamoorthy, 2006) is expressed as:

$$\frac{(x-\gamma)^{\alpha}}{\beta^{\alpha}\ \Gamma(\alpha)} e\left(-\left(\frac{x-\gamma}{\beta}\right)\right) \quad (5)$$

$$\Gamma(\alpha) = \int_0^1 t^{\alpha-1} e^{-t} dt \qquad (\alpha > 0) \quad (6)$$

Where:α is the shape parameter (α > 0), β is the scale parameter (β > 0), γ is the location parameter (γ ≡ 0, for a distribution with two parameters); x = diameter (Dbh)

Johnson's S_B Distribution

The S_B distribution is obtained by the following four-parameter logistic transformation of a standard normal variate, z. The $S_B$pdf is given as:

$$f(x) = \frac{\delta}{\lambda\sqrt{2\pi}z(1-z)} exp\left(-\frac{1}{2}\left(\gamma + \delta ln\left(\frac{z}{1-z}\right)\right)^2\right) \quad (7)$$

Where:

$$Z = \frac{\frac{x-\xi}{\xi+\lambda-x}) - \mu}{\sigma}$$

$$\mu = \frac{\gamma}{\delta} \quad \text{and} \quad \sigma = \frac{1}{\delta} \quad (8)$$

RESULTS AND DISCUSSIONS

The statistical summary of diameter at breast of the study area is presented in Table 1. The result revealed that the mean value of the diameter at breast height is 17.45 cm, which is far below the minimum merchantable size of 48cm stipulated by logging policy of southwestern Nigeria (Adekunle, 2006). The value of the skewness and kurtosis is 0.54 and 0.33 respectively. (Gadow, 1983) noted that high positive skewness and peakedness means that considerable numbers of trees are concentrated in the lower diameter classes. However, the result showed that the skewness fall below 1 (not high) which implies that the skewness is moderate and considerable numbers of trees were not concentrated in the lower dbh class. The Kolmogorov Smirnov, Anderson Darling and Chi-Squared were used to test the goodness of fit of the diameter distributions as shown in Table 2. Five distributions were selected and further tested with Kolmogorov Smirnov. The Kolmogorov Simonov test showed its statistical value and rank for the dbh in the study area. The result indicate that Weibull (3P) was the only distribution that provide a good fits for the diameter data, because it's calculated D-values (Weibull 3P: 0.03274) was less than its tabulated D-value (0.03707) at 0.05 significant level. Other distributions (Johnson SB; 0.03861: Beta: 0.04106: Lognormal 3(P): 0.04167 and Gamma 3P: 0.04367) were rejected because their calculated D-value was higher than their tabulated D-value (0.03707) at the same significant level. Same trend was noticed in Chi-square test, Weibull (3P) distribution was the only distribution that provides good fit at 0.05 significant level as its calculated value (18.16) was less than the tabulated value (18.307). Although, the result of the Anderson Darling test revealed that all the distributions can provide good fit, because their calculated value (Table 2) was less than the tabulated value (2.5018) at 0.05 significant level. It was observed that Weibull (3P) distribution was consistent for the three statistical tests in fitting diameter data of the study area. Hence, Weibull (3P) distribution was selected as the best model for the study area. Weibull distribution was adjudged more flexible in a research carried out in Gorazbon district of Kheyroudkenar forest by Namiranian (1990) and Mataji *et al*., (2000). Both scientists, using Kolmogorov-Smirnov tests showed that Weibull distributions could determine diameter distribution of trees. This observation was in agreement with the research of Alo (2017) who found that Weibull (3P) was more flexible when fitting diameter distribution functions for second rotation of *T. grandis* plantation in Eda Forest Reserve, Nigeria. Aigbe and Omokhua (2014) also found that Weibull (3P) was more flexible than Beta, Burr 4P, Gamma 3P, Johnson SB, and Lognormal distribution functions when tested with Kolmogorov Simonov and Chi-Square in modelling diameter distribution of the tropical rainforest in Oban Forest Reserve, Nigeria. Likewise, this study is also similar to the work of Ogana *et al*., (2015) who reported that three parameter Weibull distributions performed slightly better than the Beta and Gamma 3P distributions for Characterizing tree diameter in Oluwa Forest Reserve, Ondo State, Nigeria. Several authors (Adegbehin, 1985; Akindele and Abayomi, 1983; and Abayomi, 1983). have demonstrated the use of Weibull probability distribution functions for predicting diameter distribution in even – aged stand. Clutter *et al*., (1983) described Weibull function as the most popular frequency distribution model. Additionally, Gamma (3P) was ranked the least distribution provided to fit the dbh data in the study area due to its large values for the goodness of fit statistics. This is in concordance with Alo (2017) who found that the Gamma (3P) distribution was less appropriate for determining the structure of the second rotation plantation forest studied.

Table 1: Summary of Descriptive Statistics for Dbh class in the study are

Statistics	Value
Mean	17.45 cm
Standard Error	0.11
Standard Deviation	4.00
Sample Variance	15.99
Kurtosis	0.33
Skewness	0.54
Range	22.60
Minimum	10.00
Maximum	32.60
Total	1295

Table 2: Summary of Goodness of Fit of Distribution Functions for the study area

S/N	Distribution	**Kolmogorov Smirnov**		**Anderson Darling**		**Chi-Squared**	
		Statistic	Rank	Statistic	Rank	Statistic	Rank
1	Weibull (3P)	0.03274	1	1.359	1	18.298	1
2	Johnson SB	0.03861	2	1.408	2	30.398	4
3	Beta	0.04106	3	1.4809	3	30.109	3
4	Lognormal (3P)	0.04167	4	1.7379	4	25.142	2
5	Gamma (3P)	0.04367	5	1.7609	5	42.608	5

The parameter values of the five distribution functions are presented in Table 3 while Figure 1 shows the graphical analyses of observed numbers of trees and the predicted frequency by the five distribution functions. The distribution pattern of the models showed that there are more trees in the middle dbh class with decreasing frequency at both sides; given rise to the Bell-shaped structure. This is typical of a plantation forest, with most of the trees within the middle diameter class. This indicates that most of the trees in the plantation were growing at similar rate and with less competition (Ezenwenyi *et al*., 2018). This result is in concordance with Alo, (2017) and Ezenwenyi *et al*., (2018) who reported Bell shaped structure of *T. grandis* plantation in Eda Forest Reserve and *Nauclea diderrichii* in Omo Forest Reserves, respectively. The graphs of observed and estimated probability functions of dbh class of the distribution functions show that there is no significant difference ($p > 0.05$) between the observed and predicted diameter frequencies as shown in Figure 1.

Table 3: Distribution Parameter Estimates for Afe Babalola plantation

S/N	Distribution	Parameters
1	Beta	α_1=4.7271 α_2=16.185
		a=7.2168 b=52.221
2	Gamma (3P)	α=9.9398 β=1.2813 γ=4.6548
3	Johnson SB	γ=3.7662 δ=2.9321
		λ=68.892 ξ=2.0811
4	Lognormal (3P)	σ=0.20529 μ=2.9465 γ=-2.0532
5	Weibull (3P)	α=2.4693 β=10.495 γ=8.0841

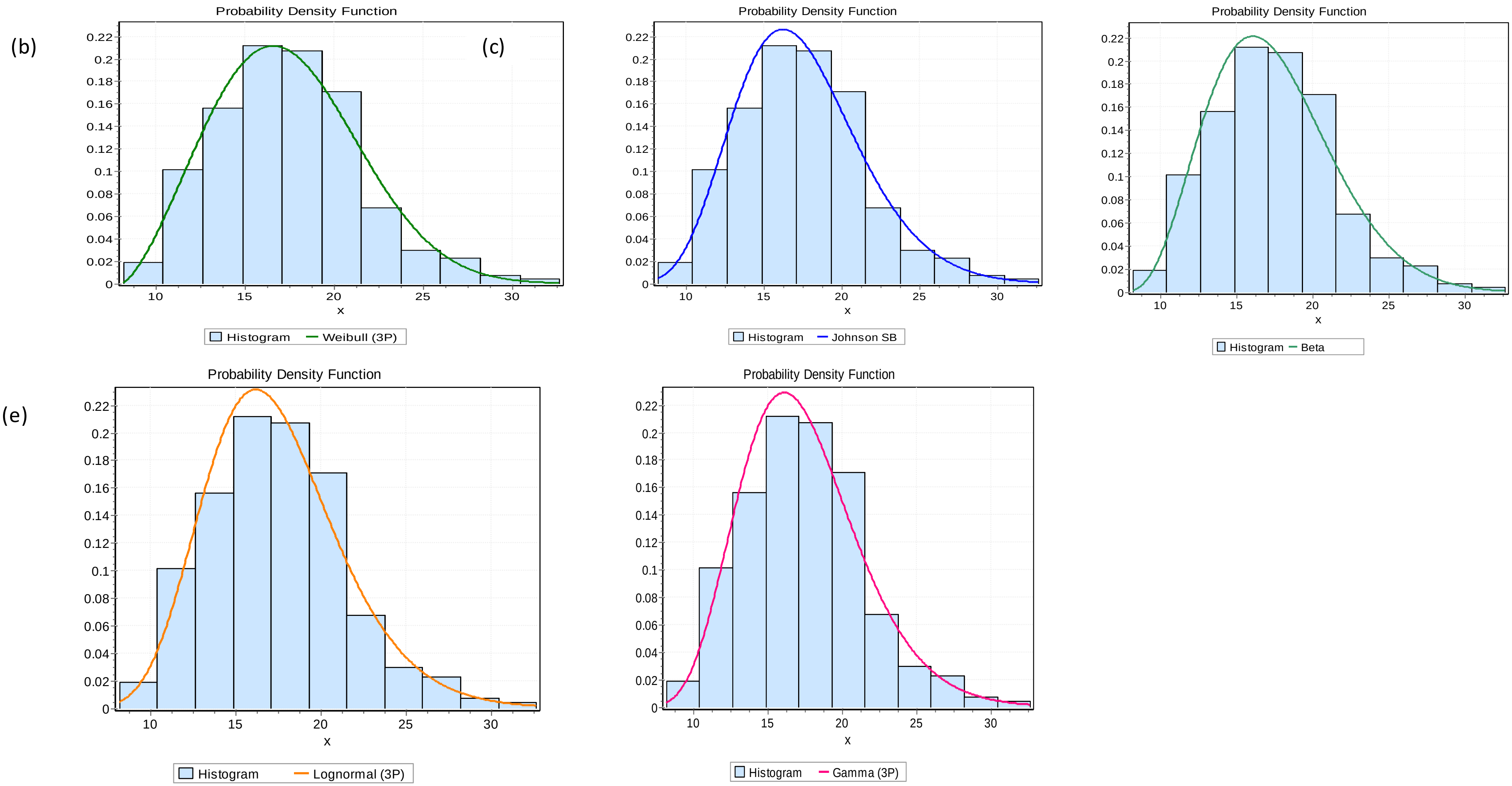

Fig. 1:Graph of observed and estimated probability function, of DBH class of T.*grandis* data in the study area (a)Weibull (3P) (b) Johnson SB (c) Beta (d) Lognormal (3P) (e) Gamma (3P)

The distribution's description results of 1295 trees in the observed diameter class and their evaluation with Weibull (3P) probability distribution was shown in Table 4. The result showed that there are more in the middle dbh class than the lower and upper dbh class. Table 5 showed the result of the t-test carried out between observed frequencies and predicted frequencies. The result showed that there is no significant difference between the observed and predicted frequencies as the t-statistical value (0.03) is less than the t-critical value (2.23). The correlation between the observed and predicted frequencies was 0.98.

Table 4: Frequency distribution in the observed diameter class and evaluation with Weibull (3P) distribution of *Tectona grandis* stand

dbh class	Observed frequencies	Predicted frequencies
9 -10.5	30	30
11 - 12.5	130	123
13 - 14.9	201	227
15 - 16.5	272	272
17 - 18.5	259	246
19 - 21.5	214	181
22 - 23.9	84	117
24 - 26.5	39	52
27 - 28.9	32	23
29 - 32.0	13	6
33 - 35.0	6	1

Table 5: Student T-test analysis for Weibull (3P) Distribution Model

	Observed Frequencies	Predicted Frequencies
Mean	116.36	116.18
Pearson Correlation	0.98	
t Stat	0.03	
P(T<=t) one-tail	0.49	
t Critical one-tail	1.81	
P(T<=t) two-tail	0.97	
t Critical two-tail	2.23	

CONCLUSION

It is important to use appropriate probability theories to foresee trees distribution by estimating their diameter distribution. The study made use of five statistical models to describe diameter data of *T. grandis* plantation in Afe Babalola Plantation, Nigeria. The outcome showed that Weibull (3P) distribution best described the stem diameter when tested with Kolmogorov Simonov. Hence, Weibull (3p) are recommended for application in the prediction of diameter distribution in similar ecosystem for *T. grandis* species.

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Modelling the Growing Space of *Parkia biglobosa* Benth for Agroforestry Project

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Abstract

Parkia biglobosa is a leguminous tree that plays a significant role in the socio-economic wellbeing of people especially in rural communities of sub-Saharan Africa. The trees are maintained on farms by farmers because of the benefits derived from it. Its inclusion in agroforestry practice is often limited because of scanty information on appropriate growing space or planting distance. Agroforestry practice often requires the determination of planting distance in the form of alleys to reduce the effect of canopy cover. Therefore, in this study the growing space requirement of P. biglobosa for agroforestry project was determined. The data sets used consist of 288 trees measured from P. biglobosa plantation in Markurdi, Nigeria. Quantile regression technique was used to establish a simple relationship between tree crown width (Cw) and diameter at breast height (DBH) of the species. This relationship was used to estimate the growing space required for the establishment of agroforestry project. The limiting density and stand basal area were also estimated. The result shows that the relationship of the form: Cw = 2.674 + 0.095DBH, explained 56.2% of the variation in crown width with a mean bias of 0.985. Also, the study shows e.g., that P. biglobosa trees of 10 cm DBH would each require 3.2 m of growing space with limiting density and basal area of about 982 trees/ha and 6.06 m^2/ha, respectively. Furthermore, trees of 50 cm DBH would each require 6.6 m of growing space with limiting density and basal area of about 232 trees/ha and 35.86 m^2/ha, respectively. In agroforestry practice, alleys are predetermined from the onset of the project, and as such, information from this study could be used to determine the planting distance and the limiting density of the specie. Thus, arable crops can be integrated between the alleys.

Keywords: Crown width; quantile regression; stand density; stand basal area, *Parkia biglobosa*

INTRODUCTION

A land use management systems where woody perennial such as tree and shrubs are deliberately combined with arable crops and/or animals on the same piece of land in a spatial or temporal arrangement is known as Agroforestry (Lundgren and Raintree, 1982). Maintaining increase production while conserving the potential of the resource base are some of the attributes of agroforestry (Nair, 1993). Although all trees are multipurpose, however, multipurpose trees/shrubs in Agroforestry are referred to as "those trees and shrubs which are deliberately kept and managed for more than one preferred use, product, and/or service; the retention or cultivation of these trees is economically and sometimes ecologically motivated, in a multiple-output land-use system." (Nair, 1993).

Among the several multipurpose tree species used in agroforestry is *Parkia biglobosa*. *P. biglobosa* belongs to the family Fabaceae and sub-family Mimosoideae, it is commonly referred to as the locust bean but its trade name is dadawa or dawa-dawa. *P. biglobosa* is a perennial deciduous tree which can attain the height of 7 to 20 m when matured, in rare case it can reach 30 m. The crown is generally large and has a wide spread with a stout bole (Orwa *et al*., 2009). *P. biglobosa* thrives in different agro-ecological zones. *P. biglobosa* is usually retained on farm land even after felling other tree species because of the diverse benefits associated with it (Amoako, 2012). It utilisation ranges from medicinal, glaze for ceramic pots, fodder, firewood, charcoal production (Kwon-Ndung, *et al*., 2009). In agroforestry system, *P. biglobosa*, helps in breaking wind, providing shade for both crops and animal as well as fodder for animal. The soil benefits through improves nutrients uptake efficiency because of the activities of endomycorrhizal fungi (Amoako, 2012).

Growing space as defined by Foli *et al*. (2003) refers to the availability of all resources required for the survival of tree in a site. For optimal growth and development of any tree, a definite amount of growing space is essential (Foli *et al*., 2003). The optimal or ideal growing space of a plant may be defined as the adequacy in all available resources that are necessary for the growth and survival of the plant. The amount of growing space maintained in an agroforestry system would likely contribute to the growth and size of trees and subsequently arable crops incorporated. Wider spacing generally results in larger tree and wider canopies and vice versa. It has been shown that concentration of minerals increases with increase in tree size (Kater *et al*., 1992; Tomlinson *et al*., 1995). This implies that maintaining wider space in an agroforestry system may lead to increase in mineral concentration; in consequence, increase arable crops yield. Therefore, the aim of the study was to determine the growing space requirement of *P. biglobosa* for the establishment agroforestry project.

METHODOLOGY

Study Area

This study was carried out in the *P. biglobosa* plantation, Makurdi, Nigeria. It is located between latitudes 7°21′ and 8°0′N and longitudes 8°21′ and 9°0′E with an area of about 7,978 km^2 (Chukwu *et al*., 2017). The data set consist of 288 trees measured from 9 sample of a hectare size. Diameter at breast height (DBH, measured at 1.3 m above the ground), tree height and crown width (Cw) were measured to the nearest 0.1 cm, 0.1 m and 0.3 m, respectively. Diameter tape and hypsometer were used to measure DBH and height, respectively. Cw was measured as the linear distance of the projected tree crown in four directions i.e., north-south and east west. The mean value of these measures was recorded the crown width (Cw). The data set was randomly split into 75% fitting and 25% validation data set. The descriptive statistics of the data are presented in Table 1.

Table 1: Descriptive statistics of the fitting (75%) and validation data sets (25%)

Variables	Fitting data (n = 216)				Validation data (n = 72)			
	Mean	Max	Min	SD	Mean	Max	Min	SD
DBH (cm)	40.4	95.4	15.3	14.83	40.1	79.8	14.6	14.83
Height (m)	6.8	17.8	2.1	1.89	6.6	12.0	3.3	1.89
CD (m)	6.5	12.6	2.8	1.97	6.6	10.8	3.4	1.97
BA (m^2)	0.15	0.72	0.02	0.11	0.14	0.49	0.02	0.11
N = 288 trees								

CD = Crown diameter; BA = Basal area; SD = Standard deviation; N = Number of trees

Modelling Crown width and DBH

A quantile regression technique was used to model the linear relationship between tree crown and DBH of *P. biglobosa*. The relationship is of the form:

$$Cw_i = b_0 + b_1 DBH_i + \epsilon_i \quad (1)$$

Where Cw = crown width (m), DBH = diameter at breast height (cm), b_0 and b_1 = intercept and slope, respectively, ϵ = error term in the model. The error is assumed to be normal and independent with zero mean and constant variance that is, $\epsilon_i \sim NID(0, \sigma^2)$. The subscript i = individual tree i. In quantile regression, the estimate of the regression parameters (b_0 and b_1) were obtained by minimizing the sum of absolute error. The 0.5 (i.e., median) was used in this study; expressed as:

$$\hat{\beta}_{(0.5)} = \text{argmin}_{\beta \in R^2} \sum_{i=1}^{n} \rho_{0.5}(y_i - x_i'\beta)$$

(2)

Where $\hat{\beta}$ = parameter b_0 and b_1; ρ = rho. This method was recently used by Raptist *et al.* (2018), Ozcelik *et al.* (2018) and Ogana (2019). The fitting method was assessed based on coefficient of determination ($\bar{R}^2$), root mean square error (RMSE) and mean absolute bias (MAB). The analysis was carried out in R (R Core Team, 2017).

Determination of growing space (GS, m) requirement

The growing space requirement of *P. biglosbosa* was estimated from these relationships:

$$N(tree/ha) = \frac{40000}{\pi(b_0 + b_1 DBH)^2} \quad (3)$$

$$GS\ (m) = \frac{100}{\sqrt{N(tree/ha)}} \quad (4)$$

Where π is pi (3.142); b_0 and b_1 are the estimated regression parameter from equation 1. N is the number of trees per ha (i.e. the limiting density) which was derived from the estimated crown width. The basal area per ha of the stand at any given diameter was also estimation with this expression:

$$G(m^2/ha) = 10000\left(\frac{0.7854}{K}\right) \quad (5)$$

Where G is the stand basal area in square meter per ha and K is the ratio of crown width to DBH.

RESULT AND DISCUSSION

The result of the fitted model for the relationship between crown width and DBH is presented in Table 2. The model has positive intercept and slope value with relatively high adjusted coefficient of determination, low root mean square error and mean absolute bias. Positive intercept and slope are expected for most Cw-DBH relationships irrespective of the modelling method used. The implication of positive intercept (b_0) is that the stand basal of *P. biglobosa* can grow to maximum i.e., maturity since the Cw-DBH ratio (K-ratio) decreases with tree size (Foli, 2003).

The graphical relationship between K-ratio and tree size (i.e., DBH) is presented in Figure 1. The graph showed that *P. biglosbosa* has higher K-ratio for younger trees (smaller DBH) and reduces with increase tree size. And then began to stabilize around DBH of 45 cm but never increases. It dropped by about 75% from DBH of 0.1 to 0.45 m (10 to 45 cm). Hemery *et al.* (2005) reported a drop of K-ratio around DBH of 30 – 40 cm for 11 temperate tree species. This K-ratio can be used to estimate the mean crown with of the stand (K x DBH) from which other stand variables including growing space can be determined.

Table 2. Estimated parameters and fit indices

Data	b_0	b_1	$\bar{R}^2$	RMSE	MAB
Fitting	2.674	0.095	0.562	1.287	0.985
Validation				1.296	1.047

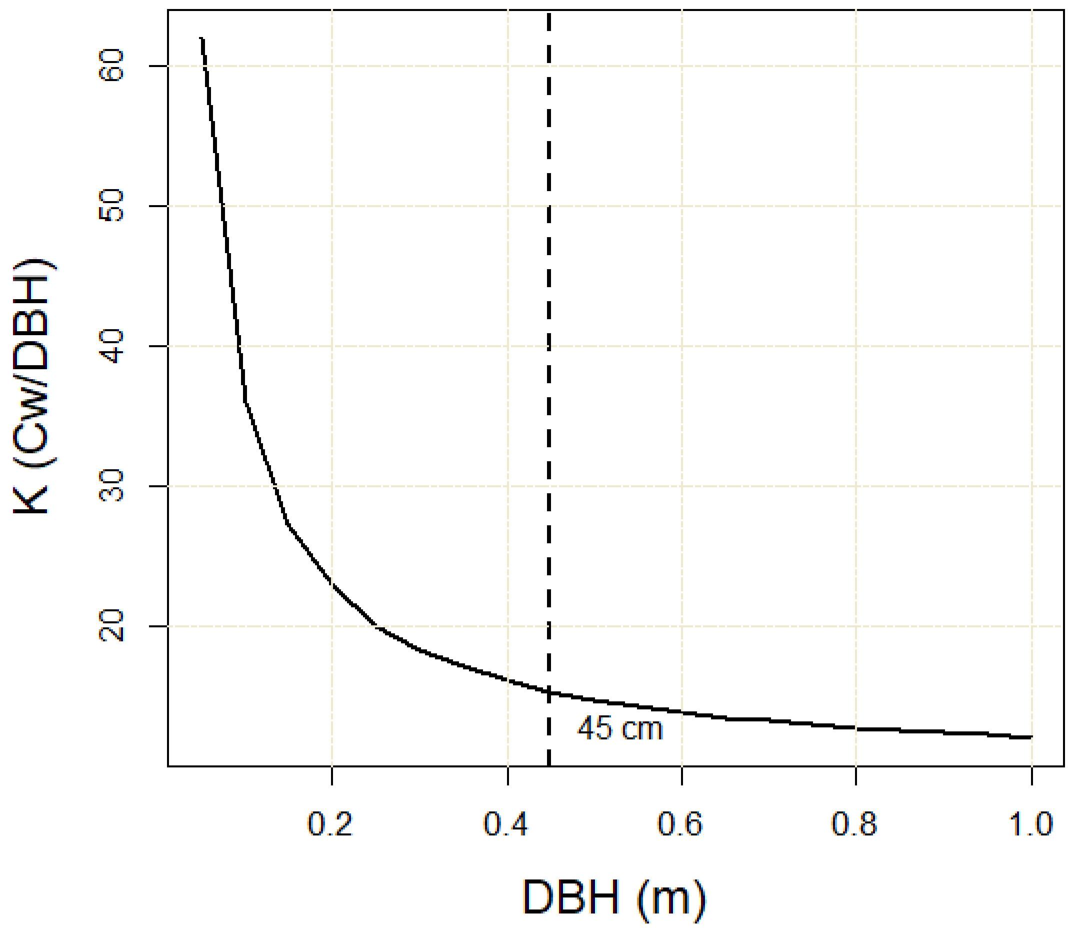

Fig 1. Crown width-DBH ratio at different DBH for *P. biglobosa*

The results of the estimated growing space (GS), limiting density (N, trees/ha) and the stand basal area (G, m^2/ha) for different DBH of *P. biglobosa* are presented in Table 3. Predictions of GS, N and G within 10 – 100 cm DBH range were presented. From the table, *P. biglobosa* trees of 10 cm DBH would each require 3.2 m of growing space with limiting density and basal area of about 982 trees/ha and 6.06 m^2/ha, respectively. Also, trees of 50 cm DBH would each require 6.6 m of growing space with limiting density and basal area of about 232 trees/ha and 35.86 m^2/ha, respectively. Furthermore, trees of 100 cm DBH would each require 10.8 m of growing space with limiting density and basal area of about 86 trees/ha and 53.64 m^2/ha, respectively. This information can be used as a guide for the establishment of agroforestry project.

Agroforestry practice often requires the determination of planting distance in the form of alleys to reduce the effect of canopy cover. These alleys are predetermined from the onset of the project. Thus, if *P. biglobosa* trees would be used in agrosilviculture (tree and arable crop) project and that the diameter of the tree at the establishment stage is 5.0 cm say, a growing space of about 2.7 m would be required. The stand density and basal area per ha would be 1324 trees/ha and 2.04 m^2/ha, respectively. Arable crops such as maize (*Zea mays*), cassava (*Manihot* spp.), etc. can be planted between the alleys. Inappropriate specification of planting distance will lead to competition for space, nutrient, light, etc. and in consequence low yield. Bazié *et al*. (2012) reported a decrease in the yield of sorghum and maize grown the under canopy of *P. biglobosa*. Furthermore, Kater *et al*. (1992) observed a decrease in the yield of cotton grown under the canopy of *P. biglobosa*, however, the yield of millet was less affected. Although the amount of growing space or distance in the studies was not stated, it is possible that the amount of distance maintained could be one of the contributing factors responsible for the observed difference in yield. Dau *et al*. (2016) reported a 4 x 4 m planting distance of *P. biglobosa* for plantation establishment. Foli *et al*. (2003) also determined the growing space for some tropical tree species in Ghana for the same purpose of plantation establishment.

Table 3. Limiting density (N), basal area (G) and growing space (GS) of *P. biglobosa*

DBH (cm)	CD (m)	N (tree/ha)	G (m^2/ha)	GS (m)
5.0	3.1	1324	2.04	2.7
10.0	3.6	982	6.06	3.2
15.0	4.1	757	10.52	3.6
20.0	4.6	601	14.85	4.1
25.0	5.0	509	19.63	4.4
30.0	5.5	420	23.38	4.9
35.0	6.0	353	26.73	5.3
40.0	6.5	301	29.74	5.8
45.0	6.9	267	33.42	6.1
50.0	7.4	232	35.86	6.6
55.0	7.9	203	38.09	7.0
60.0	8.3	184	41.06	7.4
65.0	8.8	164	42.84	7.8
70.0	9.3	147	44.47	8.2
75.0	9.8	132	45.98	8.7
80.0	10.2	122	48.31	9.1
85.0	10.7	111	49.55	9.5
90.0	11.2	101	50.75	10.0
95.0	11.7	93	51.75	10.4
100.0	12.1	86	53.64	10.8

CD = Crown diameter, DBH = Diameter at breast height (1.3m above the ground)

CONCLUSION

, this study has modelled the relation between crown width and diameter at breast height using quantile regression from which the growing space of *P. biglobosa* for agroforestry project was determined. Knowledge of the appropriate growing space or planting distance of a tree in an agroforestry system will not only ensured the optimal growth and development of the plant but also indirectly affect arable crop yield.

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Agroforestry as a Land Use Option for Sustainable Forest Management in Sokoto State, Nigeria

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Abstract

Despite its ubiquitous use by smallholder farm families, there is inadequate awareness about the potential of agro forestry toward achieving sustainable forest management particularly in Sokoto state of Nigeria. Although, several studies have been carried out on the role of agro forestry practices in achieving sustainable forest management. None has been carried out in Sokoto State which forms the basis of this study. Reconnaissance Survey (direct observation) was carried out at the initial stage of the research, in order to get acqu ainted with the study area with respect to agroforestry practices for sustainable forest management in some rural areas of the selected Local Government Areas of Sokoto State. A simple random sampling method was employed to select respondents from the study population. Survey questionnaires were issued to each respondent in order to collect data from them. The study revealed that 85 of out of 96 respondents were males (88.5%) while only 11 (11.4%) were females. This indicates a significantly less participation of women in agro forestry practice in Sokoto state, result also shows that farmers adopt agro forestry in the state for a variety of reasons the most popular of which is the improvement in soil fertility, offering them a variety of land use options. The result demonstrated that of all the different types of agro forestry, agri-silviculture is the most popular among the respondents having 42 out of 96 respondents which represents (43.7%). In the light of this challenge there is the need for sustainable management of the patchy forested areas that remains in the state to ensure that the goods and services derived from the forest meet present day needs while at the same time securing their continued availability and contribution to long term development. The implication of the finding is that agro forestry enhances management of forest resources, stability and production sustainability and present huge opportunities for raising food production and giving farmers options as per as land use is concerned in Sok oto state Nigeria. It's therefore suggested that for agro forestry to be truly effective as a means of enhancing land use options, forest management and sustainable use of forest resources, it should form part of the integrated rural development program an d there by meets more of farmer's basic needs than it does now.

Keywords: Agroforestry practice, forest management, production sustainability, land use and forest resources

INTRODUCTION

Agro forestry has been defined as a dynamic, ecologically based natural resources management system that through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels (Leakey, 1996). Agro forestry practices offer practical ways of applying various specialized knowledge and skills to the development of sustainable rural production systems. Agro-forestry is recognized as a land use option in which trees provide both products and environmental services. In agro forestry systems, the trees grown on different farmlands in the same locality when aggregated can bring about improved wooded situation thereby enhancing environmental protection (Otegbeye, 2002). Young (1989) reported that there are hundreds of agro-forestry systems but only so distinct practices. There are only 3 basic sets of components that are managed in all agro-forestry systems namely: - Woody perennials (usually referred to as "trees"), herbaceous plants or "crop" and animals. A logical step is to classify agro-forestry systems based on their components composition (Nair, 1991), thus, there are three basic types of agro-forestry systems Viz,

1. Agri-silviculture (crops + trees)
2. Silvopastoral (pasture/animals + trees)
3. Agrosilvopastoral (crops + pasture + trees)

Although several agro-forestry systems have been recorded from around the world, the distinct agro-forestry practices that constitute these systems in various biomass and locations are few of course, some of similar agro-forestry systems in different places. According to the World Agro forestry Centre (2012)"agro-forestry is uniquely suited to address both the need for improved food security and increased resources for energy, as well as the need to sustainably manage agricultural landscapes for the critical eco-systems services they provide.

Agro-forestry is already widely practiced on all continents using a 10 percent trees cover as threshold, agro-forestry is most important in Central America, South America, and South East Asia, but also occupies a large amount of land area in Africa. In addition to adaptation benefits, agro-forestry also has a function of carbon sequestration.

In most agro forestry systems, the trees grown do not have the usual silivicultural recommendations in terms of spacing (Owonubi, 2002). Given the reality of awareness among the farmers of multiple land use management, the need to improve on the existing agro forestry practices becomes necessary in the face of increasing population and limited nature of land. Agro forestry has both protective and socio-economic benefit. Kang (1993) reported that besides direct agricultural benefit, trees exhibit socio–economic values. The benefit of the tree components derived by farmers from agro forestry was evaluated from a socioeconomic and ecological perspective (Anderson and Sinclair, 1993). The social - economic benefits of agro forestry can be evaluated in terms of productivity, stability and sustainability.

Sustainability is a term that has gained much popularity in recent time. It means that a resource is used in such a way that it continues to be available. It is a general consensus that we must learn how to sustain our environmental resources including forest so that they continue to provide benefits for the people and other living things on our planet. One fundamental premise for sustainable development is the recognition that environment and development are not exclusive of one another but are complementary and inter-dependent and in the long run man mutually benefit from this interdependence (Ahmad and Sanny 1987). This complexity explains the difficulty in operationalizing the concept of sustainable development. Yet there has been ever increasing demand on the limited forest resources and the carrying capacity of the fragile forest ecosystem. Under the conditions of poverty for which Nigeria is known, the environment often exhibits the ravages of long years of mismanagement as illustrated by high rate of deforestation, overgrazing, desertification and endangering the forest species. Rural people have been discovered to have a wealth of indigenous knowledge and have incorporated trees in production systems in areas where they lived for a very long period of time (Evans and Alexander, 2004).

It should be noted that the attempts being made under agro forestry are to optimize the use of land for agricultural production in the state on a sustainable basis at the same time meeting other needs from forestry (Fagbemi, 2002). Nitrogen-fixing and non-nitrogen-fixing trees thrive adequately in agro forestry with annual crops, presents a farming system in which arable crop yields can be enhanced. The tree rooting system brings about stability that can lead to soil conservation. What is needed would be mutual interaction and proper management techniques that would reduce the adverse effects that may result when trees are integrated into agro-ecosystem (Connor, 1983). Various authors (Kang et al., 1990; Young, 1986; Rocheleau and Dianne, 1987) were of the view that successful agro forestry practices benefits the farmers in the following ways:

a. Consistent restoration of the fertility status of the depleted soil through the recycled litter deposition and nitrogen fixing mechanism of trees.
b. A variety of products, firewood, fodder, woodcraft, medicinal herbs and food for livestock and man respectively.
c. Prevention of wind and water erosion by trees acting as wind break and intercepting the raindrop impact on the soil respectively.
d. Improving the micro-climate effect of the immediate and adjourning environment.
e. Restoration of water table to an absorbable level for crops use.
f. Increased income opportunities.
g. Increased economic stability
h. Reduce cost for establishing plantation
i. Increased ability to manage for sustained yield.

METHODOLOGY

Study Area

The study area lies between latitude $13^{0}04'59.99''$ N, to longitude $5^{0}15'0.00''$ E. Sokoto state has 23 Local Government Areas:- 3 of which were selected for this study. The selected Local Government Areas include Wurno, Rabah and Goronyo Local Governments Areas.

Fig 1: Map of Sokoto state showing the study area

Reconnaissance Survey:

Reconnaissance Survey (direct observation) was carried out at the initial stage of the research, in order to get acquainted with the study area with respect to agro forestry practices for sustainable forest management in some rural areas of the selected Local Government Areas of the State.

Primary Source of Data:

Firsthand information was collected through the administration of questionnaire. This was administered to farmers to obtain information for the research. A total of 96 farmers were randomly selected and interviewed in sampled villages of the three purposively selected Local Government Areas (Table 1).

Vegetation

The study area falls within Savannah vegetation type. Tree species that are common in the area include *Azadirachata indica*, *Acacia species*, *Parkia biglobosa*, *Vitex duniana*, *Mangifera indica* etc. Herbaceous plants include lettuce and other grasses, such as gamba grasses and guinea grasses etc.

Population

According to 2016 Population projections, the 3 local governments that serve as the study area had a population of about 666300 (NPC 2016).

RESULTS AND DISCUSSION

Distribution of Demographic Characteristics of the Respondents

Gender:

Table 2 below shows that 85 of the 96 respondents were males (88.5%) while only 11 (11.4%) were females. This indicates a significantly less participation of women in agro forestry practice in Sokoto state.The study demonstrated that youth between the age of 31-50 years whose frequency were 39 out of 96 and represent 40.6% of the respondents are considerably involved in agro forestry practice in the study area, whereas adults between the age of 51 and above shows higher frequency and percentage42 (43.7%) respectively.

Educational level:

Is important in terms of exposure to information which help farmers understand the potential benefits of agro forestry and other relevant innovative practices. The frequencies and percentages are shown in the table 2 below. The table also shows the main occupation distribution of respondents and other sources of income. Thirty seven (37) people which represents (38.5%) of the respondents have farming as their occupation while petty trading take 24 (25%), civil service takes 17 (17.7%) while other small businesses got the remaining 18 (18.7 %) of the respondent's occupation.

Table 1 Demographic information of respondents

Parameter	Frequency	Percentages
Gender		
Male	85	88.5
Female	11	11.4
Age		
18-30	15	15.6
31-50	39	40.6
51-above	42	43.7
Level of education		
Non-formal education	22	22.9
Primary education	34	35.4
Secondary education	19	19.8
Tertiary education	11	11.4
Adult education	10	10.4
Occupation/source of income		
Farming	37	38.5
Civil servant	17	17.7
Petty trading	24	25
Others	18	18.7

Table 2 also indicates that 19 (19.7%) were large scale farmers while 35 (36.4%) respondents were medium scale farmers and the remaining 42 (43.7) were small scale farmers The table also shows that agro forestry is widely practiced among the respondents; this comes in variants including agri-silviculture and other traditional shifting cultivation systems.

There are different types of food and tree crops cultivated in the study area. This is especially important to the study for the inventory of both the food and tree crops in the state and degree of variability in cultivation among farmers.

The table also shows in years, the length of respondent's involvement in agro forestry. This information is particularly relevant as it depicts the extent of farmers experience on farm practices of agro forestry,

The table also indicates the main uses of trees on farm by the respondents. This is relevant to the study as it indicates the reasons why farmers chose to adopt agro forestry. Sources of labor for respondent's farm varies between hired labor, work group, and family labor this occur in varying combination

The table also indicates the impact of agro forestry practice towards reducing the level of bush fallowing practices in the state. While 41 (85%) out of 48 respondents spoke in the affirmative, 7 (15%) of the respondents said no.

Table 2: Scale of respondent's involvement in different agroforestry practices.

Characteristics	Frequency	Percentage
Scale of Farming		
Large scale	19	19.7
Medium scale	35	36.4
Small scale	42	43.7
Types of farming systems		
Agri-silviculture	42	43.7
Silvipastoral	30	31.2
Agri-silvi-pastoral	24	25
Types of food crops cultivated		
Millet-Sorghum-Cowpea	37	38.5
Sorghum-Cowpea	22	22.9
Cowpea-groundnut	14	14.5
Sorghum-groundnut	13	13.5
Millet-groundnut	10	10.4
Types of tree crops grown		
Cashew-mango-citrus	19	19.7
Neem-parkia-mango	23	23.9
Parkia-neem	31	32.2
Mango-guava	12	12.5
Parkia only	11	11.4
Period of involvement in agro forestry (in years)		

Not specific	32	33.3
1-3 yrs	29	30.2
3-5 yrs	22	22.9
5- 10 yrs	13	13.5
Main uses of trees on farm		
For soil improvement	25	26.0
Source of fruits	17	17.7
Source of fuel wood	31	32.2
Source of shelter	23	23.9
Source of labor on respondent's farm		
Family labor	41	42.7
Work group	29	30.2
Hired labor	26	27.0
Impacts of agro forestry on respondents livelihood		
Yes	69	71.8
No	27	28.1

CONCLUSION

The role of Agro forestry in sustainable forest management cannot be over emphasized. It evolves a synergy between agricultural production and forest management that is beneficial for increased food production, sustainable wood production and land use options. This is a win-win situation.

In the light of this there is the need for sustainable management of the patchy forested areas that remains in Sokoto state to ensure that the goods and services derived from the forest meet present day needs while at the same time securing their continued availability and contribution to long term development.

RECOMMENDATIONS

i. Provision of economic incentives to the farmers in Sokoto state

There is need for the provision of economic incentives by the Sokoto state's forestry department to farmers participating in agro forestry in the state. Such incentives should include viable and improved seeds and seedling provision through government nursery, regeneration and exploitation tools that are beyond the reach of peasant farmers.

ii. Empowering the extension workers in agro forestry

There is also the need for empowering forestry extension workers in the state who serve as intermediary between the research institutes and the rural dwellers. i.e. farmers and their families by educating and informing them on the role of agro forestry in achieving sustainable forest management and availability of alternatives that would better their lots in terms of production efficiency and income without disrupting the ecological equilibrium.

iii. Policy Reforms

The history of program design and implementation with regards to agriculture and forestry in Sokoto state and Nigeria in general shows that they are adhoc and reactionary in nature. Urgent matters such as deforestation, land degradation, natural hazards, climate change, food scarcity and rural poverty are only accorded topmost priority on the policy agenda when these problems have reached a disastrous proportion.

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Effects of Rock Dusts on the Early Growth of Cocoa (*Theobroma cacao*) L.

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Abstract

The early growth of cocoa (Theobroma cacao) was evaluated using rock dusts as soil remineralization agents. Experiments were conducted in pots to determine the effect of remineralization of soil using granite and basalt rock dusts. Seven treatments including control were used for the experiment and these were replicated four times. The treatments were T_1 (0.5 tons/ha of granite dust per 2kg of top soil), T_2 (0.5 tons/ha of basalt dust per 2kg of top soil), T_3 (1.0 tons/ha of granite dust per 2kg of top soil), T_4 (1.0 tons/ha of basalt dust per 2kg of top soil), T_5 (1.5 tons/ha of granite dust per 2kg of top soil), T_6 (1.5 tons/ha of basalt dust per 2kg of top soil), T_7 (Control). The experiment was laid out in Completely Randomized Design (CRD). Data were collected on number of leaves, plant height (cm) and stem diameter (mm) for 8 weeks. Watering was done twice daily both in the morning and evening. Data collected were subjected to Analysis of Variance (ANOVA) and there were no significant means among the treatments. The result however showed T_2 (0.5 tons/ha basalt) had the best mean performance of 20.00cm and T_3 (1.0 tons/ha granite) had the least mean performance of 16.30cm for plant height. For number of leaves T_5 (1.5 tons/ha granite) had the best mean performance of 12.00 and T_1 (0.5 tons/ha granite) had the least mean performance of 9.25, for stem diameter T_5 (1.5 tons/ha granite) had the best mean performance of 5.31mm while T_3 (1.0 tons/ha granite) had the least mean performance of 3.63mm, at 10 weeks after planting. However, there were no significant differences among the treatment at 0.05 level of significance. Observing the best performance from the parameter assessed using treatments including control, soil remineralization by rock dust should be encouraged to enhance the early of Theobroma cacao. These rock dusts are readily available at quarries and are environmentally safe.

Keyword: Rock dust, cocoa, early growth, measurement

INTRODUCTION

The cocoa plant was first given its botanical name by Swedish, Carl Linnaeus, where he called it *Theobroma* ("food of the gods") *cacao*. The cocoa tree is a small (13–26 ft tall) evergreen tree in the family Malvaceae (RBG, 2018), native to the deep tropical regions of the Americas. Its seeds, cocoa beans, are used to make cocoa powder and chocolate. It is a perennial tree crop that primarily comes from three tropical regions — Southeast Asia, Latin America, and West Africa. Côte d'Ivoire and Ghana are the single largest producers of cocoa. Other leading cocoa farming countries include Brazil, Cameroon, Ghana, Indonesia, and Nigeria (MCF Campaign, 2013-2020)**.** Cocoa trees grow in hot, rainy tropical areas within 20° of latitude from the Equator. Cocoa harvest is not restricted to one period per year and a harvest typically occurs over several months. In fact, in many countries, cocoa can be harvested at any time of the year. Pesticide are often applied to the trees to combat capsid bugs, and fungicides to fight black pod disease. The pods on a tree do not ripen together; harvesting needs to be done periodically through the year (Fawusi, 1983; Hawksley, 2001 and Hui, 2006). Harvesting occurs between three and four times weekly during the harvest season. The ripe and near-ripe pods, as judged by their colour, are harvested from the trunk and branches of the cocoa tree with a curved knife on a long pole. Cocoa is grown on millions of small (1-2 ha) and medium-sized (4-5 ha), family-run farms worldwide. It is a highly labor-intensive crop. It is an important cash crop providing income to more than 4.5 million families worldwide, yet the families who grow cocoa face challenges. Farmers must contend with severe crop loss due to disease, aging tress, outdated farming techniques, and limited organizational support. Many farmers have virtually abandoned their cocoa trees, only investing the bare minimum of time and money to maintain the crop (Sharaf *et al*., 2005). This neglect has exacerbated many pest and disease problems such as cocoa capsids, cocoa swollen shoot virus (CSSV), and black pod disease. The negative impact of agriculture on soil quality is commonly known and efforts must be made to mitigate and counter this effect especially conventional agriculture highly accelerates soil erosion. Soil fertility and the amount of arable land continue to be diminished by mismanagement of soil resources and bad agricultural practices (Pimentel *et al*., 1995). Soil remineralization creates fertile soils by returning minerals to the soil which have been lost by erosion, leaching, and or over-farming. Soils organic and sustainable farmers have long relied on rock dust, as an all-natural way to improve roots systems, increase yields, and promote general plant health in a wide variety of crops and conditions.

Rock dust mainly consists of finely crushed rock that has been processed either by natural or mechanical means. It is an important additive to our very leached and mineral depleted soils (Wolfe *et al*., 2005). The igneous rocks, basalt and granite, often contain the highest mineral content, whereas limestone, considered inferior in this consideration, is often deficient in the majority of essential macro-compounds, trace elements, and micronutrients. Basalt Rock dust is a natural soil additive that supplies many minerals, including magnesium, silicon, phosphorous, sulphur, potassium, calcium, manganese, iron, cobalt, copper and zinc to the soil. Rock dust increases the soil's moisture holding properties, improves the soil structure and drainage, and also improves the soil's cation exchange potential. It is full of nutrients and adding it to soil will replenish all of the nutrients that agriculture has taken out of our soil. Its ability to maintain soil biota environment makes it more suitable than chemical fertilizers. (Wood *et al*., 2001). There is a dearth of information on the effect of remineralization by rock dusts for the production of healthier cocoa seedlings and period spent in the nursery before transplanting. Hence, this study seeks to document the effect of remineralization by rock dust on the early growth of cocoa (*Theobroma cacao*).

METHODOLOGY

The experimental plot where the experiment was carried out is located at the Crop Production Technology Department at Federal College of Forestry, Jericho, Ibadan, situated at Jericho Hill under Ibadan Northwest Local Government Area of Oyo State. It lies at latitude7^0 54^1 N and longitude 3^0 34^1 E. The average annual rainfall range from 1300mm-1600mm with an average temperature of about 32^0C and average between humidity of 80-85%. (FRIN, 2019). The materials used for the experiment are cocoa seeds, granite rock dust, basalt rock dust, polythene pots, watering can, field book, pen, hand gloves, sacks, tape rule and vernier caliper. The seeds of cocoa (*Theobroma cacao*) was procured from Oyo State Agricultural Development Project (OYSADEP), Ibadan.

The basalt rock dusts and granite rock dusts were collected from the commercial quarries along Ibadan-Lagos express way. The rock dusts (residual minerals fines) were collected manually from the ground underneath the rock crushers where the finest dust tends to accumulate. After collections, the rock dusts were taken to Forestry Research Institute of Nigeria (FRIN) soil laboratory to determine its physical and chemical composition.

A total of 28 Polythene pots were filled with soils and placed on the experimental field. Basalt and granite rock dusts were added to 24 polythene pot filled with topsoil at different application rates (Boland *et al*., 2000), as shown in the experimental layout key below. The granite and basalt dusts were mixed together with the top soil and left for a day prior to planting. Four soil filled polythene pots were left undisturbed and these serve as control. Watering was done twice a day (early in the morning and evening). Regular weeding was also carried out as when necessary. The experimental layout was laid out in Completely Randomized Design (CRD), with four (4) replicates as shown below:

T_1R_1	T_3R_3	T_5R_3	T_2R_1
T_6R_1	T_4R_1	T_6R_3	T_4R_2
T_5R_4	T_1R_2	T_2R_2	T_3R_4
T_3R_2	T_7R_4	T_4R_4	T_7R_2
T_7R_3	T_2R_3	T_1R_3	T_6R_4
T_4R_3	T_5R_1	T_7R_1	T_5R_2
T_2R_4	T_6R_2	T_3R_1	T_1R_4

Where

T_1 =Topsoil + 0.5tons/ha of granite dust (85g of granite dust per 2kg of top soil).

T_2 =Topsoil + 0.5tons/ha of basalt dust (85g of basalt dust per 2kg of top soil).

T_3 =Topsoil + 1.0tons/ha of granite dust (170g of granite dust per 2kg of top soil).
T_4 =Topsoil + 1.0tons/ha of basalt dust (170g of basalt dust per 2kg of top soil).
T_5 =Topsoil + 1.5tons/ha of granite dust (255g of granite dust per 2kg of top soil).
T_6 =Topsoil + 1.5tons/ha of basalt dust (255g of basalt dust per 2kg of top soil).
T_7 =Top soil (Control).
The growth parameters measured include, number of leaves, plant height and stem diameter. The measurement of these parameters started by the third week after planting. Data collected were analysed using Analysis of Variance (ANOVA). Differences between means were determined using the Least Significant Difference (LSD) test at 5% level of significance.

RESULTS AND DISCUSSIONS
Pre planting soil analysis showing the physical and chemical properties of the soil is presented in table 1 above. From the analyzed result, the soil pH is slightly acidic (6.2), this is based on soil fertility classification established for Nigeria soil by Esu (1991). The total Nitrogen is low (0.64 gkg^{-1}) which is below the critical value of 1.50gkg^{-1}. The available phosphorus (3$mgkg^{-1}$) and organic carbon (3.62g/kg) are also said to be low when compare to their respective critical value of 7.0mg/kg and 10mg/kg respectively (Agboola and Ayodele,1985, FMANR, 1990).

The exchangeable cations of Na and K are also low while that of Mg (0.3$cmol/kg^{-1}$) can be said to be moderate using the critical value of Mg which is (0.28 $cmol/kg^{-1}$). The extractable micro nutrients analysis shows that Mn (96$mgkg^{-1}$), Fe (81 mg/kg^{-1}) and Cu (2$mgkg^{-1}$) in the soil were within the critical value of 5-100 $mgkg^{-1}$, 5-200 $mgkg^{-1}$ and 1.2 - 2.0 $mgkg^{-1}$ respectively . Zn (7$mgkg^{-1}$) was found to be higher than the critical value of 1-5 $mgkg^{-1}$ (Agboola *et al,* 1976).

Table 1 Typical Physical and Chemical Properties of the Soil used.

Soil parameters	Content in soil
pH (H_2O 1:1)	6.2
Organic Carbon (gkg^{-1})	3.62
Total Nitrogen (gkg^{-1})	0.64
Available Phosphorus ($mgkg^{-1}$)	3.0
Exchangeable cations ($Cmolkg^{-1}$)	
Na	0.4
K	0.1
Mg	0.3
Ca	3.0
Extractable Micronutrients ($mgkg^{-1}$)	
Mn	96
Fe	81
Cu	2
Zn	7
Particle size distribution (gkg^{-1})	
Sand	884
Silt	68
Clay	48
Textural Class	Loamy sand

Source: Soil & Tree Nutrition Laboratory, FRIN.

Analysis showing the physical and chemical properties of the rock dust is shown in table 2 above. The pH of the granite dust is 5.7 which are acidic and this is tantamount to the acidic nature of granitic rocks while the pH of the basalt dust is 8.1 which are also tantamount to the basic nature of basaltic rocks. Both rock dusts have a high iron (Fe) content (180 and 230$mgkg^{-1}$) because of the present of amphibole which is a mineral present in both granite and basalt rocks. In the exchangeable cations, the Mg content which is from pyroxene (a mafic minerals found in igneous) can be said to be higher in basalt dust (0.71$Cmol/kg^{-1}$) than the Mg content in granite dust (0.35Cmol/kg). The Na and the Ca contents are from the plagioclase feldspar minerals found in igneous rocks also. The Na content is higher in basalt dust (1.01$Cmol/kg^{-1}$) than in granite dust (0.98$Cmol/kg^{-1}$), also the Ca content is also higher in basalt dust (8.11$cmol/kg^{-1}$) than in granite dust (4.09$cmol/kg^{-1}$). The potassium content found in the dust are from orthoclase mineral (k-feldspar). The K content can be found to be higher in granite dust (0.45$Cmol/kg^{-1}$) than in basalt dust (0.30$Cmol/kg^{-1}$). Nitrogen is known to be of little content in rock dusts generally and in some cases are not found in them. This contributes to the little content of the total Nitrogen in the analysis of both rock dusts (0.26% and 0.28%). The organic matter content in the rock dust is found to be from the vegetations found on the rock which can be said to have affected few parts of the rock. The organic matter content of basalt dust (6.04%) is found to be higher than organic matter content of granite dusts (5.15%). The texture of the granite dust is phaneritic indicating coarse texture while the texture of the basalt dust is aphanitic indicating fine texture.

Table 2: Typical physical and chemical properties of rock dust used.

Parameters	Content.in Granite dust	Content in Basalt dust
pH (H_2O 1:1)	5.7	8.1
Organic Carbon (gkg^{-1})	2.99	3.82
Organic matter(gkg^{-1})	5.15	6.04
Total Nitrogen (%)	0.26	0.28
Available Phosphorus ($mgkg^{-1}$)	3.22	4.41
Exchangeable cations($Cmolkg^{-1}$)		
Na	0.98	1.01
K	0.45	0.30
Mg	0.35	0.71
Ca	4.09	8.11
Extractable Micro Nutrients ($mgkg^{-1}$)		
Mn	4.02	4.02
Fe	180	230
Cu	2.6	2.8
Texture	Phaneritic	Aphanitic

Source: Soil and Tree Nutrition lab, FRIN

The mean analysis of the plant height at 3 to 10 weeks after planting (WAP) as shown in table 4.2. The result obtained showed that there were no significant difference among the treatment of basalt, granite and control and also between the application rates of each treatment at 0.5tons, 1.0tons/ha, and 1.5tons/ha. Also there was no significant effect in the interaction of the treatment and the application rates. The 0.5tons/ha of granite produced the highest mean of plant height after 10 WAP having 20.00cm and this higher when compared with mean of plant height (17.69cm) of Prince *et al.*, 2019 in Ghana while the least plant height was recorded in 0.5tons/ha of granite at 3 to 10 WAP having 15.93 at 10 WAP. From the result obtained the 0.5tons/ha and 1.0ton/ha application rate in granite and have lower means when compared to the control at 3 to 10 WAP.

Table 3: Effect of Soil Remineralization by Basalt and Granite dusts on Plant Height of *Theobroma cacao*

Trt	App rate (tons/ha)	3	4	5	6	7	8	9	10
Basalt	0.5	12.63[a]	13.43[a]	15.25[a]	16.00[a]	17.83[a]	18.45[a]	19.40[a]	20.00[a]
	1.0	11.68[a]	12.60[a]	14.13[a]	15.05[a]	15.93[a]	16.55[a]	17.28[a]	17.93[a]
	1.5	12.98[a]	14.00[a]	15.08[a]	15.93[a]	16.45[a]	17.25[a]	17.75[a]	18.75[a]
Granite	0.5	19.03[a]	10.15[a]	11.05[a]	12.15[a]	12.95[a]	13.63[a]	14.38[a]	15.93[a]
	1.0	10.65[a]	11.33[a]	11.68[a]	12.75[a]	13.73[a]	14.60[a]	15.73[a]	16.30[a]
	1.5	13.50[a]	14.95[a]	15.68[a]	16.58[a]	18.50[a]	19.15[a]	20.03[a]	18.15[a]
Control	0	11.63[a]	13.10[a]	13.78[a]	15.05[a]	16.00[a]	16.90[a]	17.55[a]	18.45[a]
Sig	Trt	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
	App rate	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
	Trt & rate	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns

The result obtained showed that there were no significant differences among the treatment and among the application rates. Also there were no significance in the interaction effect between the treatment and the application rates. In the number of leaves the 0.5tons/ha and 1.0tons/ha of granite produce the least number of leave at 3 to 10 WAP and they are lower than the control treatments. The highest number of leaves was produced in the application of 0.5tons/ha of basalt at 7 to 9 WAP while at 10 WAP 1.5tons/ha of granite produced the highest number of leaves having 12.00 leaves, and this is slightly lower when compared with the number of leaves (12.33) of Olaiya and Fagbayide, 2016 in Abeokuta.

Table 4: Effect of Soil Remineralization by Basalt and Granite dust on Number of Leaves of *Theobroma cacao*.

Trt	App rate tons/ha	3	4	5	6	7	8	9	10 (WAP)
Basalt	0.5	2.75^{a}	4.25^{a}	4.50^{ab}	6.00^{ab}	8.25^{a}	9.50^{a}	11.25^{a}	11.25^{a}
	1.0	3.25^{a}	4.00^{a}	5.25^{a}	6.00^{ab}	7.00^{ab}	8.25$^{\mathbf{ab}}$	9.50^{ab}	10.50^{a}
	1.5	3.00^{a}	4.25^{a}	4.75^{ab}	7.25^{a}	7.75^{ab}	8.50^{ab}	10.25^{ab}	11.00^{a}
Granite	0.5	2.25^{a}	2.75^{a}	3.25^{b}	5.00^{b}	6.00^{b}	6.75^{b}	8.25^{b}	9.25^{a}
	1.0	2.75^{a}	3.75^{a}	4.25^{ab}	5.50^{ab}	6.50^{ab}	7.25^{b}	9.00^{b}	9.75^{a}
	1.5	3.00^{a}	4.25^{a}	5.00^{a}	5.25$^{\mathbf{b}}$	7.00^{ab}	8.50^{ab}	10.25^{ab}	12.00^{a}
Control	0	3.25^{a}	4.00^{a}	4.50^{ab}	5.75^{ab}	7.00^{ab}	7.75^{ab}	10.00^{ab}	10.75^{a}
Sig	Trt	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
	App rate	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
	Trt & rate	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns

Table 5: Effect of Soil Remineralization by Basalt and Granite dust on Stem Diameter of *Theobroma cacao*

		Weeks after planting							
Trt	App rate	3	4	5	6	7	8	9	10
Basalt	0.5tons/ha	0.33^{ab}	0.66^{ab}	1.02^{ab}	1.30^{a}	1.20^{a}	2.22^{ab}	3.34^{ab}	4.48^{ab}
	1.0tons/ha	0.29^{ab}	0.57^{ab}	0.86^{ab}	1.12^{a}	1.43^{a}	2.19^{ab}	3.14^{ab}	4.21^{ab}
	1.5tons/ha	0.39^{ab}	0.78^{ab}	1.16^{ab}	1.53^{a}	1.68^{a}	2.81^{ab}	3.26^{ab}	4.36^{ab}
Granite	0.5tons/ha	0.15^{b}	0.30^{b}	0.45^{b}	0.61^{a}	0.97^{a}	1.95^{ab}	2.92^{b}	3.88^{b}
	1.0tons/ha	0.19^{ab}	0.39^{ab}	0.57^{ab}	0.65^{a}	1.07^{a}	1.81^{b}	2.59^{b}	3.63^{b}
	1.5tons/ha	0.40^{a}	0.80^{a}	1.20^{a}	1.49^{a}	1.59^{a}	2.65^{a}	3.97^{a}	5.31^{a}
Control	s0	0.31^{ab}	0.61^{ab}	0.91^{ab}	1.23^{a}	1.51^{a}	2.28^{ab}	3.17^{ab}	4.25^{ab}
Sig	Trt	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
	App rate	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
	Trt & rate	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns

The result obtained showed that there were no significant difference among the treatments, application rate and the interaction effect. The mean performance in stem diameter showed that at 7 to 10 WAP the 1.0tons/ha of granite application produced the lowest stem diameter having 3.63 at 10WAP while 1.5tons/ha of granite had the highest at 5.31 at 10 WAP but this is lower when compared with stem diameter (7.00) of Olaiya and Fagbayide, 2016. The control treatment have higher means than 0.5tons/ha and 1.0tons/ha of granite application. (4.25)

CONCLUSION

Theobroma cacao seeds were planted at nursery stage using rock dusts (granite and basalt dusts) as soil remineralization agents. The parameters studied showed that basalt and granite dust performed better than the control when considering the days of emergence. For the plant height, basalt dusts performed best when compare with other treatments (granite and control). Granite rock dust (1.5tons/ha) performed best considering the number of leaves and the stem diameter when compared with other treatment media (basalt dust and control). It can thus be concluded that granite and basalt rock dust used for soil remineralization performs better than control in nursery stage preparation of *Theobroma cacao*. For the improvement of early growth of *Theobroma cacao* (cocoa), it is thus recommended that rock dust being a natural remineralization agent has the essential nutrient in enhancing the planting of *Theobroma cacao* at the nursery stage before transplanting to the field.

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New Technologies and Approaches to Sustainable Forest Management in Nigeria

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Abstract

Technological development creates new opportunities and structures while it modifies and adds value to existing ones. Despite the importance of technological development, it has rarely been the focus of research in the forestry literature. It is often taken with levity without depth. This is probably partly due to the difficulties related to the phenomenon itself. The scope of technological development and its impacts are often dauntingly large. Take for instance, Information Communication and Technology (ICT). How to study such a vast phenomenon? On the other hand, forest researchers are rarely experts on technology development issues and therefore, may find the topic out of their scope. This study sheds light on, Geographic Information System, Cut to Leng th System, Remote Sensing and Information Communication and Technology (ICT) as focus on new approaches and technologies in Sustainable Forest Management. We know however, that technologies such as ICT and biotechnology are having and will have transformational impacts to the global forest sector. For example, technological changes may alter forest industries, as well as forest management, utilisation and growth. It is an attempt to link forest governance, forest sector economics, policies, social issues, forest inventories and other forest issues in the modern world. The aim of this review is this is to analyse the impacts and challenges of technological change on the forest sector.

Keywords: Technological development, biotechnology, remote sensing, information, communication, technology

INTRODUCTION

It is well known that forests provide both tangible and intangible benefits. These benefits may be classified according to ecological values such as: climate stabilization, regulation of water cycles, improved biodiversity, purification of air, Carbon dioxide sinks, potential source of new products for the pharmaceutical industry, soil enrichment and protection, social values recreational and leisure area, landscape and employment, also economic values such as, timber, non-wood forest products and employment. Although forests have traditionally been managed by society, it is expected that the current growth in the world population (now > 7,000 million people) and the high economic growth of developing countries will lead to greater use of natural resources and of forest resources in particular.

The total forest area worldwide, previously estimated at 4 billion hectares, of the 51.01 billion hectare of the earth surface has decreased alarmingly in the last two decades. The rate of deforestation and loss of forest from natural causes has slowed down from 16 million hectares per year in the 1990s to around 13 million hectares per year in the last decade (FAO, 2011). Nevertheless, the loss of forest varies according to the region, and while the forest area in North America, Europe and Asia has increased in the past two decades (1990-2010), it has decreased in other regions such as Africa and Central and South America, and to a lesser extent Oceania. As of 2005, Nigeria has the highest rate of deforestation in the world according to the Food and Agriculture Organization of the United Nations (FAO, 2011) Between 2000 and 2005 the country lost 55.7% of its primary forests, and the rate of forest change increased by 31.2% to 3.12% per annum. Forest has been cleared for logging, timber export, subsistence agriculture and notably the collection of wood for fuel which remains problematic in western Africa. In 2005 12.2%, the equivalent of 11,089,000 hectares (27,400,000 acres) had been forested in Nigeria. Between 1990 and

2000, Nigeria lost an average of 409,700 hectares of forest every year equal to an average annual deforestation rate of 2.38%. Between 1990 and 2005, in total Nigeria lost 35.7% of its forest cover, or around 6,145,000 hectares

There is a growing public concern about the importance of the environment and its protection, as manifested by the fact that the total area of forest within protected systems has increased by 94 million hectares in the past two decades, reaching 13% of all the world's forests. Moreover, designated areas for conservation of biological diversity and for protection of soil and water account for 12 and 8% of the world's forests, respectively (FAO, 2010, 2011). Nevertheless, other statistics such as the disturbing decrease in primary forests (40 million hectares in the last decade) and the increase in planted forests (up to 7% of the world's forests) (FAO, 2011) appear to indicate that to achieve forest sustainability, we must go beyond analysis of the changes in the total forest area worldwide.

The concept of sustainability began to increase in importance at the end of the 1980s and at the beginning of the 1990s with the Brundtland report (1987) and the Conference on Environment and Development held in Rio de Janeiro, Brazil, in 1992 (the so-called Earth Summit), respectively. Nevertheless, the need to preserve natural resources for use by future generations had long been recognised. The negative influence of past use of forest resources, as well as the needs for continued use of these resources for future generations was already noted as early as the 17th century (Glacken, 1976, as cited in Wiersum, 1995). However, it was not until the 18th century that the concept of sustainability was specifically referred to, as follows: "every wise forest director has to have evaluated the forest stands without losing time, to utilize them to the greatest possible extent, but still in a way that future generations will have at least as much benefit as the living generation" (Schmutzenhofer, 1992, as cited in Wiersum, 1995). This first definition was based on the principle of sustainable forest yield, with the main goal being sustained timber production, and it was assumed that if stands that are suitable for timber production are sustained, then non wood forest products will also be sustained (Peng 2000). This assumption focused on the sustainability of the productive functions of forest resources, while other functions such as ecological or socio-economic functions were largely overlooked. This occurred because social demands for forests were mainly utilitarian. However, increased environmental awareness and improved scientific knowledge regarding deterioration of the environment have changed society's values and the global structural policy, which in turn have significantly influenced forest management objectives in 20th century (Wang and Wilson, 2007).

Nevertheless, nowadays more and more researchers think climate change is changing the paradigm and sustainability should not be referred to what we had before. Although there is no universally accepted definition of Sustainable Forest Management (SFM), the following concepts are widely accepted: "the process of managing permanent forest land to achieve one or more clearly specified objectives of management with regard to the production of a continuous flow of desired forest products and services without undue reduction of its inherent values and future productivity and without undue undesirable effects on the physical and social environment" (International Tropical Timber Organization: ITTO, 1992), and "the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfill, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems" (Second ministerial conference for the protection of the forest: MCPFE, 1993). The latter concept harmonizes ecological and socio-economic concerns at different scales of management and for different time periods. Nevertheless, both concepts are just refining the definition of sustainable development given by the Brundtland Commission (1987) "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" to apply it to forests.

MODERN TECHNOLOGIES AND APPROACHES IN SUSTAINABLE FOREST MANAGEMENT

Unprecedented technological development in the 21st century has led to its application in a number of fields and the forestry industry is not an exception. These new technologies are used world over, Nigeria is not an exception since the world is a global village. Technology has been relied on in the quest for sustainable forestry (recycling, shift from natural forests to plantations, reduced impact logging), biotechnology has been used for the genetic improvement of forests and plant cloning, while biomass conversion technologies have been used to turn biomass into energy. However, its impact on the forestry sector still has not been fully investigated, one of the reasons being that forest researchers are not so tech-savvy. In a similar vein, technological development can be too fast to track all of its impacts and its scope too large to keep an eye on all significant changes. Sequels to that fact, shown below are the new technologies in sustainable forest management in Nigeria:

Geographic Information System (GIS)

Geographic Information System is a computer system used for mapping and geographical analysis by capturing and displaying data related to positions on Earth's surface. Since it can make use of any information containing location it improves the process of decision-making as well as communication, so it is used across multiple industries, including forestry. The data it collects helps to discover: location of endangered species and habitat classification, the size of the forest area and forest cover type. This tool relies on Global Positioning System (GPS) making it suitable to operate with location data such as: latitude, longitude and altitude- each of them used in forest management.

Cut-To-Length System

Used primarily in Europe, it can also be adopted and adapted in Nigeria. It involves a cut-to-length system that has proven ecological and economic advantages when compared with more traditional harvesting systems. It operates with a harvester topped with a processor head, used to grab a tree and cut it off before it hits the ground. Its main component is a computer, measuring the tree and cut lengths, making it possible to delimb a tree and buck it while it is still gripped by a processor head. After that, a forwarder is used to pick up the logs, load them and remove them from the site instead of dragging them. The main advantage of this system is that it processes the tree right there, in the woods, causes less damage to other trees, improves personal safety and reduces erosion by picking up and loading instead of dragging.

Remote Sensing

This type of technology encompasses a number of different devices and approaches such as synthetic aperture radar, aerial photography or satellite images and what they all have in common is that they are used to measure objects by use of a photogramme without touching them. These methods are able to provide much more detailed images, but their downside is that they are mostly used only regionally and locally covering only leaf area development so, in order to improve remote sensing efficiency and scope, it should be combined with Geographic Information System and Geographic Positioning System (GPS) data.

Phytoremediation Technology

Phytoremediation refers to the use of woody plants to clean the environment by decontaminating it. Plants are used to "accumulate toxic metals and organic pollutants from contaminated soils and water for cleanup purposes" and as such, they are less invasive than traditional methods such as land filling (Das, P.K., 2018). Phytoextraction removes toxic metals by accumulating them in the biomass of plants while phytodegradation uses plants to degrade the pollutants. These two are the most commonly used forms of phytoremediation.

INFORMATION COMMUNICATION AND TECHNOLOGY (ICT)

Globally, monitoring and managing of forest resources have been effectively handled by establishing a robust Geographic Information Systems (GIS) that is now a cornerstone for most forest management information systems in the world (Jacob and Olajide, 2011). In Nigeria, the use of GIS is still limited to a few institutions and yet it could have wide impacts on the forest sector, from silviculture to the marketing of forest products and the recreational use of forests. New innovations such as mobile telephones have been widely adopted by institutions but there have been unexpected consequences. For example, illegal trade is on the increase because of introduction of mobile phones (improved communication among illegal dealers). At the international level, companies in the wood products industry use e-business solutions in many tasks right from design and product development through to supply chain management, promotion, and sales (Nsita, 2010). The launching of the internet has also seen the emergence of electronic magazines and increased electronic depositories of documents, and the reduced role of the library (Agyeman, 2007). Today, there are new insights into how ICT development could change strategies for acquiring information for preparing forest management plans: soil type, topography, wildlife, growth and yield, and marketing (Nsita, 2010). The tools used to collect and manage the information have changed dramatically over time, with ICT development assisting the rapid assessment and integration of data from multiple sources. ICT has been an essential driving force in putting across advocacy messages. With the help of electronic media and the Internet, issues such as degazettement of forests and public enlightenment will gain much wider audience and attention than the conventional print media.

Moreover, the forestry sector can utilize ICT to increase productivity and improve marketing. The Internet is becoming the primary method for sharing information, including forestry related information. The forest industry can use the internet to communicate with clients, share information about products, and support other business activities. E-mail and Web pages are becoming popular and will serve to increase productivity and competitiveness. Social communication facilities such as Facebook are also used for forestry businesses (Nsita, 2010). At the community level, there is a big "digital divide". Communities are continuously seeing themselves as secondary beneficiaries as there is limited access to internet and use of sophisticated technology such as GIS and GPS. However the most appropriate means to reach the communities is through FM Radios, which broadcast in local languages that are easily understood by the communities. There is also a proliferation of mobile phones that can be used as a means of reaching the communities.

FOREST INFORMATION DISSEMINATION AND ICT APPLICATION

The E-government strategy framework of the Nigerian government is aimed at improving the efficiency of and access to information. Furthermore, access to information in the forest sector has remained defective. Institutions with forestry information especially in developing countries seldom attach patent rights and ask for cost recovery fees, even for information already paid for by government and development partners (Nsita, 2010).

The Nigerian Telecommunications Act, 2003 established the Nigerian Communications Commission (NCC). They are saddled with the rights and duties of the state, enterprises, institutions, organizations and individuals in the use and management of the means of communication, in the establishment and management of communications networks, in rendering of communications services as well as the general responsibilities if there is violation of the law. The forest sector has not exploited this opportunity in the use and management of its information dissemination. For example dedicated radio systems, TV, Satellite and FM Radio Station can be used for publicizing and tracking illegal activities. The Press and Information Bill had been enacted into law since 2011, yet, forestry has the least share in the print and electronic media. There are ample opportunities for forest resources managers to advocate for more space to cover issues of forest sector development in the Nigerian media. However, the forest sector managers in the country have not exploited these opportunity to attract media coverage.

FOREST DECISION MAKING PROCESS AND ICT APPLICATION

With the above mentioned legal frameworks in place, one would assume there is a conducive environment for conducting forestry business electronically and using ICTs in facilitating improved governance of the forestry sector in the country. Logically, this should bring about efficiency in the forestry sector – minimizing costs, streamlining bureaucratic procedures, making operations more efficient, freeing up resources and enabling sector institutions to deliver services in a better organized and economic manner. Mainstreaming ICTs in the sector would promote effectiveness leading to better results and meeting development goals, increase the relevance of the sector by facilitating increased participation, resource allocation, responding to issues in a timely manner (Nsita, 2010).

Moreover, the use of ICTs would empower the public through increased awareness and increased contribution to the development process, thus, making ICT a partner of choice for economic and social development. It is also about opportunity for improved forestry business and attraction of investment. Considering the huge benefits that could be derived from the application of ICT in our decision making process in the forestry sector, the question is; why has the use of ICTs and ICT related products been neglected in our decision making process in the country? Who are those influencing the decision making process and what are their interests? This is food for thought.

IMPACTS OF NEW TECHNOLOGIES ON SUSTAINABLE FOREST MANAGEMENT

Technology and innovation are important features of sustainable forest management and the forest industry offering important contributions to achieve advancements in science and technology revolutionizing forest management, as well as forest products processing and production systems; delivering material efficiency, improving productivity, creating new products and monitoring forest areas including forest health – in real time. Innovations impacting forestry can be categorized into two types: (i) those developed outside the forestry sector, for example, information and communications technologies (ICTs) as well as geospatial technologies; and (ii) those developed within forestry, for example, production of new-generation wood-based materials such as engineered wood products, bioplastics, natural chemicals, bioenergy products and pharmaceuticals. For the past two decades, ICTs have significantly impacted on forests and forestry. ICTs have improved forest management, enhanced productivity and reduced production costs in forestry. ICTs have mainly been applied in mapping and monitoring of forest resources, and in communicating and raising awareness of key forestry issues contributing to sustainable forest management. However, their use for a wide range of other purposes is impacting on many other aspects of forestry. ICT-enabled timber tracking technologies (for example, radio frequency identification labels and chips) and platforms are being deployed to better track timber supplies and prevent illegally sourced timber from entering supply chains. ICT-enabled digital media and e-commerce are changing demand for paper and paperboard. For instance, as people increasingly access news from electronic media, global demand for newsprint has declined from 31 million tonnes in 2012 to 24 million tonnes in 2016(Source?. ICT-enabled mobile services, financial services and e-commerce are facilitating the ease of access to information on weather, pest recognition, transport and shipping logistics, price and market data, service innovations such as payment transfers, financial products (such as insurance and credit payments) and streamlining business to business value chain communications and interactions.

ICTs are key enablers for biotechnology, nanotechnology, and emerging technologies such as artificial intelligence, machine learning, drones or unmanned aerial vehicles (UAV), IOT (internet of things) sensors, and block chain. These technologies could potentially transform forest management in the future. Some are already being adopted and deployed in forestry, primarily in developed economies, though also in rapidly industrializing developing countries. As ICTs evolve and develop over time, their impacts on forestry are likely to accelerate and transform the sector. However, the scope and directions of these future impacts on forestry are unpredictable, especially changes at the cutting edge of forestry. The rate of uptake of new technologies, particularly in developing and least developed countries in Asia and the Pacific, will also be a significant factor in the overall development of forestry in the region. Among the greatest and potential beneficiaries from ICT developments in forestry are small, medium and micro enterprises (SMEs) and local communities. Sustainable Development Goals (SDG) target 9.3 aims at the integration of small scale enterprises into value chains and E-commerce potentially holds a key for linking SMEs to global niche markets; thereby increasing revenues and profitability. ICT developments that enable global communications, transactions and financial management to be carried out on a single portable device are offering tremendous prospects for small and isolated rural enterprises and communities to connect with the commercial world. In a separate development, greater use of the internet and mobile devices is empowering local communities to monitor forests and report forest crimes. ICTs also offer significant potential for management and information sharing among private sector and smallholder networks and for provision of rural advisory services.

Geospatial technologies in forestry

A distinct class of information technologies are geospatial technologies (remote sensing, global positioning systems and geographic information systems), which continue to play a significant role in forest and landscape management, enabling collation of detailed forest inventory data, monitoring of forest health, wildlife and natural disturbances and assessment of forest structures in support of sustainable forest management. Recent advances in cloud-based geospatial technologies, such as FAO's Open Foris and SEPAL (System for Earth Observation Data Access, Processing and Analysis for Land Monitoring) systems, have led to an increase in open scientific data for use beyond academia, by policymakers and field practitioners.

Risks and challenges inherent in adopting new technologies in forest management in Nigeria

Technological advances will continue to provide opportunities and offer novel solutions to challenges globally in the forest sector (FAO, 2010). However, the benefits and trade-offs arising from potential transformations (brought about by technological advances) in forestry, especially for the developing and least developed economies in the region, are yet to be fully analyzed. There is significant potential for new technologies to rapidly change labour markets, creating jobs in some areas and unemployment in others. For example, in many developed economies, especially, job losses in forestry 'mill towns' have eroded whole communities, often because forest resources have been depleted, but also where automation has substituted for human labour. The continuing rise of social media may similarly pose opportunities and challenges for sectors such as forestry. As social media has become a primary news source for literally billions of people, new ways of communicating on forestry aspects are available. This allows sharing of evidence-based information, to help shape and change public opinion, including the social acceptance of forestry management practices.

CONCLUSION

The importance of Information Communication and Technology (ICT) and other modern approaches highlighted for sustainable forest management are recognized globally and continued propagation of the ICT technologies is required in Nigeria. Increased penetration of ICT in forest sector could make a greater impact and change the status of forest management. However, such a realization could only be possible by overcoming the existing impeding constraints while taking advantage of the available opportunities. The forest sector in the country needs to take a systemic approach to ICTs application in its daily management. This will help in handling information, considering that most of the time data is not available. Forest sector agencies must be able to track the entire forest management and administration chain to ensure data delivered by ICTs is accurate and can actually be used and acted upon. It is also important that they become
information-centered, recognizing that the value of ICTs comes from their new abilities to handle information and make it readily available for decision making. This is the way forward if the forest sector institutions are to contribute towards improving governance of the sector and contributing meaningfully to the national economy.

There is also the need to reflect upon the complexity of the environment surrounding use of ICTs before investment. An integrated approach that requires the use of a full range of technologies to acquire, store, process and disseminate information is imminent. Not just digital ICTs but also the intermediate such as radio, TV, telephone, books, newspapers, manuals, internet based website and e-mail, and the use of telephone systems. In order to initiate action and develop lasting ICT activities in the forest sector, it is necessary to start with small management units learn from implementation the experiences and gradually expand to cover the entire country. The main approach would require decentralized trial runs to take advantage of the different local conditions.

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Assessment of Agroforestry Practices as Land Use System in Wukari Local Government Area, Taraba State, Nigeria

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Abstract

Agroforestry, a natural resources management system through the integration of trees on farms and in agricultural landscape diversifies and sustains production for increased socioeconomic and environmental benefits for land users was assessed. The study was carried out in Wukari LGA, Taraba state, Nigeria, situated in the Guinea Savanna ecological zone. Data were collected with pre-tested questionnaires administered to 120 farmers -household heads, randomly selected from twelve villages in Wukari local government area. Information was gathered on farmers' awareness and involvement in agroforestry systems, type of the system adopted, tree species commonly planted or retained and other information relevant to the study. Data were analyzed using a descriptive statistics, t-test and $\chi 2$ *model. Results revealed that the primary occupation of the majority of the respondents (83%) is farming. Land acquisition is majorly through inheritance (40%), followed by those who lease their land from land owners (34%). Farmers (96%) were aware of agroforestry practices, few farmers (26%) were involved in deliberate planting of trees on their farmland, while (93%) retain and take care of trees on their farmland for edible fruits production, shade during farming activities, and increased crop yield. Among the adopted agroforestry practices are alley cropping, improved fallow, scattered trees on farmland, live fences and home gardening. Agroforestry benefits in the study area are crop protection, increased soil fertility, generation of additional income, biodiversity conservation. There is a need to educate the farmers about the intricacies of agroforestry system and make available genetically improved seedlings that could address the issue of long gestation period.*

Key words: Agroforestry, gestation period, biodiversity, seedlings

INTRODUCTION

Agricultural production, mostly crop cultivation, has remained a significant and important component of the human population due to its strategic role of providing food supply to the entire human race (FAO, 2017). However, this system had severe repercussions on land resources, as the land's continuous tillage easily loosens the soil and results in soil erosion and large-scale environmental degradation (Tully, 2015). The breakdown of traditional systems of agriculture such as rotational bush fallow and shifting cultivation, due to population pressure, has compelled peasant farmers to continuously cultivate the land, damning the cons equences of loss in soil fertility, soil erosion, and reduced productivity (Beets, 1990; Kang *et al*., 1999). Besides, most traditional agriculture systems are largely characterized by clearance of vegetation, most especially woody perennial, are not without repercussions. These traditional systems have been confirmed to result in lower potential productivity, reduction in leaf area index, and groundwater recharge, disruption of soil ecology, breakdown of nutrient cycling and increase in soil erosion, siltation of dams and reservoirs, destruction of wildlife habitats, loss of plant and genetic diversity (Shihata, 1991). However, integration of trees with monoculture crops and animal rearing is considered an appropriate strategy capable of bringing about a balance in the ecosystem, especially in already degraded environments and areas threatened by land degradation (Chukwujekwu, 2010). The combination of tree production with annual crop cultivation and the rearing of animals on the same piece of land could enable interaction between the various components, which bring about stability of the soil and equally enhance increased productivity (in terms of harvests). Agroforestry is a dynamic, economically based, natural resources management system, through the integration of trees on farms and in agricultural landscape diversifies and sustains production for increased social, economic, and environmental benefits for land users at all levels (ICRAF, 1997). This system, known as agroforestry, therefore does not only ensure the stability of land resources but could also be used as a means of controlling large-scale erosion, reclaiming degraded lands, as well as improve food production (Sekhwela, 1990; Stocking *et al.*, 1990; Gordon *et al.*, 1997). It is against this background that this study aimed at assessing the agroforestry Practices as Land Use System with a view to gain insight into the level of adoption and possible ways of enhancing the system in Wukari Local Government, Taraba State, Nigeria.

METHODOLOGY

The study area: the present study was carried out in Wukari Local Government Area in Taraba State, Nigeria. The State is located in the northeastern part of Nigeria and is the second-largest in the country in terms of landmass (Oruonye and Bashir, 2011). It lies between latitude 6° 30' and 8° 30' north of the equator and longitude 9° 00' and 12° 00' east of the Greenwich meridian. The State has an area of 4,308km^2 with a population of 241,546 (NPC, 2006) and comprises sixteen Local Government Areas (LGAs) and three senatorial districts (Taraba North, Central, and South). Moreover, it is regarded as Nature's Gift to the Nation because of its abundant natural resource endowment. Agriculture is the major occupation of Taraba State people, particularly the rural dwellers hence it is regarded as agrarian community (Oruonye and Abbas, 2011). The State is blessed with a climate and vegetation types that cut across the country, ranging from a more humid climate and forest vegetation in the south to a more seasonal wet and dry climate and savanna vegetation in the north. The vegetation type favors the growth of tree crops such as palm oil, banana/plantain, and orange. Root crops in the State include cassava, potato, and yam, while cereals include maize, rice, millet, sorghum, and guinea corn. A multistage sampling technique was used for selection of sample site in Wukari Local Government Area of Taraba state. From the two existing constituencies, which has five wards each. 30% sampling intensity was used to select three wards from each of the constituencies. Two farming communities were randomly selected from each of the six selected wards making a total of 12 communities. Questionnaires were administered to a total of 120 farmers in the local government area. Data were collected through the administration of pre-tested and validated semi-structured questionnaires with a reliable correlation coefficient ($r = 0.85$). Data obtained were analyzed using descriptive statistics that include frequency distributions, means, and percentages. T-test and Chi-square ($\chi 2$) was used to test for the presence of associations in the variables obtained.

RESULTS AND DISCUSSION

Table 1 shows the gender, marital status, family size, educational qualification, land acquisition mode, farming experience, and farmers' farm size. The results show that (75%) of the respondents were male while (25%) of the respondents were female (Table1). The results of the t-test show a significant difference ($P<0.05$) in gender distribution among the respondents. The proportion of male respondents was significantly higher than those of females, which indicates that farming predominantly male occupation in the study area. More so, women are considered subordinate to their male counterparts in the study area and reflect cultural beliefs in the region These findings corroborate the assumption by Babalola (2014) that the most general opinion, especially in Northern Nigeria, is that women are better suited as home keepers and are less interested in farming activities than their male counterparts; thus, very few women approved to be interviewed. Sixty-five percent (65%) of the farmers were married, with only (9%) being single. The result revealed that divorcees and widows/widowers are also involved in farming activities in the study area. Forty-three percent (43%) of the respondents had a family size of above 13 persons, while 27 % had between 10-13 persons and the least represented range was 3-5 persons in the family. The size of the farming household in the study area reflects that of African settings where family members are large to provide sufficient labor for farm work. Sobola *et al*. (2015) and Adekunle (2009) also reported similar findings in Osun State and Ondo State respectively. Sixty-six percent (66%) of the farmers in the study area were above 31years of age, 24% were within the age group 21- 30 years, while 11% were below 20 years of age. It was noted that the key occupation of respondents in the study region was agriculture (83 %), followed by trade (8 %), and 6 % were civil servants, which only reinforces the assertion that the State of Taraba is an agrarian nation. Oruonye and Abbas (2011) also reported that agriculture is the main occupation of Taraba State people, especially in rural areas. Among the crops raised in the study area are; cassava, potato, yam, maize, rice, millet, sorghum, and guinea corn. Farmers with good land tenure systems also propagate and tend cash crops such as; coffee, tea, and groundnuts.

Education has been said to play a very important role in the growth of society, as it acts as a link to national development. The level of education can directly influence one's ability to respond to change and to embrace new ideas hence, the respondents' educational status in this study reflects that twenty percent (20%) had no formal education, (25%) had tertiary education, while 55% had one form of education. The $\chi 2$ test results (significant at $p<0.05$) show a significant difference in farmers' educational status in the study area. Variation exist in the mode of land acquisition in this study. (40%) of the farmers obtained their farmland through inheritance from their forefathers; such farmlands are usually very small as the initial parcel of land is normally shared among many children. Sixteen percent (16%) of the respondent farms on land owned by the community, while some (10%) indicated that they are farming on a parcel of land belonging to the government. However, land acquisition through personal purchase is very negligible (3%) in the study area.

Table 1: Socio-economic Characteristics of Respondents in the Study Area

Variables	Frequency	Percentages
Sex		
Male	90	75
Female	30	25
t.test results		
P value- 0.000, (df- 119)* significant (P<0.05)		
Marital Status		
Married	78	65
Single	11	9
Divorced	19	16
Widow/Widower	12	10
Family size		
3-5	7	6
6-9	27	24
10-13	32	27
Above 13	52	43
Educational qualification		
No formal education	24	20
Adult education	19	16
Primary education	11	9
Secondary education	36	30
Tertiary education	30	25
P-value – 0.004, (df – 4) * significant (P<0.05)		
Major Occupation		
Farming	100	83
Civil servant	7	6
Trading	8	7
Craft man	5	4
Mode of land acquisition		
Lease	41	34
Inheritance	48	40
Purchase	3	3
Government land	12	10
Communal land	16	13
Farming experience		
Below 5 years	14	12
5 - 10 years	32	27
11 - 15 years	22	18
16-20 years	40	33
Above 20years	12	10
Farm Size		
0 – 0.5ha	11	9
0.51 – 1.00ha	34	28
1.01 - 2.00ha	31	26
2.01 – 3.00ha	30	25
Above 3.00ha	14	12

Table 2 shows farmers' awareness of Agroforestry practices, tree retention, and deliberate planting of trees on cropland in the study area. Ninety-six percent (96%) of the farmers in the study area claimed to be aware of Agroforestry practices in the study area, while very few 4% confirmed that they were ignorant of the practice. The chi-square ($\chi 2$) result shows that farmers' educational status had a significant relationship (P<0.005) with the awareness of agroforestry practice in the study area. Since most of the farmers had one level of education or the other, this, in turn, had a positive effect on their awareness and eventual adoption of the practice. Similar work by Sobola *et al*. (2015) confirms that farmers with formal education are more involve and usually active in

Agroforestry practices in Osun state, Nigeria. The result also indicates that the awareness of agroforestry practice with its resultant benefits reflects the retention of trees on farmland during land preparation. Ninety-three percent (93%) of the respondents retain trees on their farmland, probably because they were aware of the socio-economics, ecological, and environmental potential of trees on farmland. Those who indicated no retention of trees on farmland were majorly those with very small landholdings, who held a view that trees occupy a large land area and could constitute hindrances to crop growth and productivity because of their canopy. These findings support Adekunle (2009) that some groups of farmers were unwilling to retain or plant trees because of the negative notion they had about the presence of trees on farmland. Deliberate planting was negligible (26%) in the study area; the retention of trees on farmland was the commonest agroforestry practice in the study area.

Table 2: Farmers Awareness of Agroforestry Practices

Awareness of Agroforestry Practice	Respondent	Percentage (%)
Yes	115	96
No	5	4
Deliberate retention of trees on farmland		
Yes	112	93
No	8	7
Deliberate planting of trees on farmland		
Yes	31	26
No	69	58

Adopted agroforestry practices in the study area are presented in Table 3. Deliberate retention of trees on farmland during land preparation was the most common agroforestry practice in the study area. The majority (96%) of the respondents usually retain valuable and economic trees on farmland during land preparation, most especially fruit trees that produce fruits, seeds, and nuts that could supplement feeding and generate income during the off-season of crops. Few of the species, which are timber species and some exotics, were also retained by farmers to serve as shade, erosion control, and protection for the crop. These findings align with Banjo *et al.*, (2013), who found out that deliberate retention of trees on farmland was the most common among farmers in Oyo State, Nigeria. Another system, widely adopted by farmers in the study area is home garden (83%). The high level of adoption can be attributed to the proximity to farmers' homes and the intimate mix of diversified crops and multipurpose trees that meets the fundamental needs of farmers' household. Nair's (2000) reported that high adoptability of home garden is because it has a greater diversity of production and higher net income, which is continuous throughout the year. However, 77% of the respondents adopted the scattered tree system on farmland, which is also referred to as the Parkland system and it's characterized by the deliberate retention of trees on cultivated or recently fallowed land.

Trees are an integral part of the system, providing food, fuel, fodder, medicinal products, building materials, and saleable commodities, contributing to the maintenance of soil fertility, water conservation, and environmental protection. Researchers (Nikiema, 2005; Fischer *et al*., 2010; Sobola, 2015) have identified that this system governs much of the biodiversity and ecosystem services on farmlands. Live fencing is another important agroforestry system adopted by 74% of farmers in the study area. This system enables farmers to demarcate and fence their farmland at minimal cost, protecting the farmland from intruders. The system has been reported by various authors (Vihi, 2019; Sobola, 2016; Adedayo and Sobola, 2014; Alao, 2014) as being capable of land use diversification, soil conservation, and improvement while ensuring an adequate supply of fuelwood and poles for the local community. Forty-two percent (42%) of the respondent also adopted improved fallow, which involves using fast-growing trees, shrubs, or vines on land during the fallow period; the resting period allows natural processes to restore productivity of degraded or damaged land. Authors (Oke, 2008; Adekunle, 2009 Sobola *et al.*, 2015) had observed that this method has become unsustainable as the pressure on land is increasing daily, leading to shortening of fallow period, consequently lack of adequate time for the resuscitation of lost soil fertility. Other systems adopted in the study area are; silvopastoral system (56%) and alley cropping (21%)

Table 3: Adopted Agroforestry Practices

Agroforestry Practices	**Respondent**	**Percentage (%)**
Alley Cropping	25	21
Improved fallow	50	42
Retaining trees on farmland	115	96
Live fences(boundary planting)	89	74
Home gardening	100	83
Apiculture	51	43
Silvopasture	67	56
Scattered trees on farmland	92	77

The major benefits derived from agroforestry practice is presented in Table 3. Farmers attested to the fact that trees in the agroforestry system give protection to crops (73%), control erosion (65%), serves as a windbreak (48%), generate additional income (82%), mitigate climate change (56%) and provides shade (85%) for crops and farmers during the heat period. Steffan-Dewenter *et al*. (2007) stated that the integration of trees into the farming system increases farm productivity when the various components occupy complementary niches and their associations are managed effectively. Species retained by farmers include *Prosopis africana, Albizia lebbeck, Daniella Oliveri, Vitellaria paradoxa, Detarium microcarpum*, while species such as *Citrus sinensis, Mangifera indica, Psidium guajava* were planted by farmers (Table 4).

Table 3: Benefit Derived from Trees in Agroforestry System

Benefit Derived from Trees in Agroforestry System	Respondents	Percentage (%)
Protection of crops	87	73
Control of erosion	78	65
Serves as wind break	57	48
Generate additional income	98	82
Mitigate climate change	67	56
Provision of shade for crops and farmers	102	85

Table 4: Agroforestry Tree Ppecies Retained/Planted in the Study Area

Tree Species	Family	Life Form
Daniella oliveri (Rolfe) Hutch. & Dalziel	Leguminosae	Tree
Prosopis africana (Guill. et Perr.)	Leguminosae	Tree
Albizia lebbeck (L) Benth	Fabaceae	Tree
Moringa oleifera Lam.	Moringaceae	Shrub
Detarium microcarpum Guill. & Perr.	Leguminosae	Tree
Vitex doniana Sweet	Verbenaceae	Tree
Annona senegalensis Pers.	Annonaceae	Shrub
Parkia biglobosa (Jack.)	Fabaceae	Tree
Perinari excelsa (Sabine)	Chrysobalanaceae	Tree
Tectona grandis L.f.	Lamiaceae	Tree
Elaeis guinensis Jacq.	Arecaceae	Tree
Citrus sinensis (L.)Osbeck.	Rutaceae	Tree
Treculia africana Decne.	Moraceae	Tree
Strychnos innocua Delile	Loganiaceae	Shrub
Nauclea latifolia Sm.	Rubiaceae	Shrub
Azadirachta indica A Juss	Meliaceae	Tree
Mangifera indica L.	Anacardiaceae	Tree
Gmelina arborea Roxb.	Lamiaceae	Tree
Crossopteryx febrifuga (Afzel.) Benth	Rubiaceae	Tree
Vitellaria paradoxa C.F.Gaertn.	Sapotaceae	Tree
Tamarindus indica L.	Leguminosae	Tree

Source: Field Survey, 2019

Problems influencing agroforestry practices in the study area are presented in Table 5. Lack of technical know-how, non-availability of tree seedlings, the long gestation period of trees, and fire outbreaks among others were major problems mentioned by the farmers in the study area. Among all these problems, lack of technical know-how ranked highest (98%) in the study area. Similar findings were reported by Adedayo and Sobola (2014) on farmers' perception and adoption of agroforestry practices in Osun state, they found out that lack of technical know-how was the highest ranked hindrance to the adoption of agroforestry technology in the State. Keil (2005) found out that farmers who are involved in on- farm experimentation of agroforestry technology with the researchers are more likely to adopt the practice than those who have never been exposed to it. Hence, understanding a newly introduced technology is a pre-requisite to the adoption of such technology**.** Akinnifesi *et al*. (2008) stated that trainers, farmer-to-farmer extension, and support to existing initiatives were the most effective pathways of disseminating proven technologies to smallholders' farmers in Southern Africa. However, lack of improved seedlings also constrained the adoption of agroforestry practices in the study area. Improved seed, seedlings, and trees have been a driving force behind the successes recorded for some agricultural technology. As genetically superior seedlings increase timber revenue because of their faster growth rates, greater adaptability, increased disease resistance, improved wood properties, and superior form (Whittock, 2004). Peterson (1999) and Kwesiga *et al*. (2003) also found out that lack of planting materials (seed and seedlings) is a major constraint to the establishment of fallows. Farmers also complained that bush fire is usually fueled by leave litters during the dry season. More so, the land tenure system also hinders some farmers from participating the system because of their fragmented farms land. Previous studies (Sobola *et al*., 2015; Ajayi *et al*., 2003; Kwesiga *et al*., 2003) emphasized the effect of farm size on the adoption of agroforestry practices. Ajayi *et al*. (2003) revealed that farm size is positively associated with farmers' decisions to retain or plant trees on farmland. Other factors include long gestation period, lack of incentive, labour intensive nature of the system, as well as crop damages by trees as a result of wind throw.

Table 5: Problems Influencing the Adoption of Agroforestry Practices in the Study Area

Problems	Frequency	Percentage
Long gestation period	65	54
Lack of incentive	47	36
Land tenure system	20	17
Labour intensive	36	30
Fire outbreak	66	55
Lack of improved seedlings	84	70
Lack of technical know-how	98	82
Crop damage by tree fall	55	46

Source: Field Survey 2019

CONCLUSION

The ecological, economic and environmental benefits of agroforestry for rural livelihood and sustainable development cannot be over emphasized. Agroforestry enhances biodiversity and prevent deforestation and its complications, it diversify production on farmland most especially during the crop offseason. This study assessed agroforestry practices as a land use system in Taraba state, Nigeria and the findings has shown that agroforestry practice in the study area is a long aged practice; as farmers are aware of multiple benefits accrue to retention of trees on farmland. Majority of the farmers usually retain trees, while deliberate planting is still negligible in the study area. Identified agroforestry practices in the study area are; alley cropping, improved fallow, scattered trees on farmland, live fencing, home gardening, apiculture and silvopasture. However, conscious effort towards agroforestry adoption and domestication of economical woody perennial needs to be enhanced in the study area. Hence, the government and forestry department should encourage farmers by providing genetically improved seedlings and seeds for propagation and incorporation in agricultural landscape. In addition, funds in the form of credit facilities for farmers willing to adopt agroforestry system should be allocated.

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Organic Liquid Fertilizer: Evaluation of Effect on Growth and Yield of *Abelmoschus esculentus L. Moench*

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Abstract

Evaluation of effect of organic liquid fertilizer on the growth and yield of okra was examined in this research. Liquid fertilizer (Super Gro) was applied to the treatments at 1ml of Super grow to 1litre of water which was applied once a week, twice a week, every fortnight, once a month and the control. The parameter assessed were plant height, stem girth, leaf area, number of leaf, weight of fruit and 50% day to flowering. The data collected was subjected to Analysis of Variance (ANOVA) and the mean was separated using the Duncan Multiple Range Test (DMRT). The treatments significantly ($p < 0.05$) influenced all the parameters assessed except in the number of leaves. The relationship of the leaf area was determined by Pearson's Products Moment Correlation Co-efficient (PPMC) which was positively strong ($r = 0.8$). The results show that plants treated with fertilizer application fortnightly performed best in all the parameters assessed with the highest mean values. Therefore, application of liquid fertilizer should be encouraged and used for the production of okra for better crop planting, increase in farmer's yield and income. The method can also be taught in schools for Agricultural practices.

Keywords: Liquid fertilizer, Okra, growth, and yield

INTRODUCTION

Vegetables are herbaceous plant species which are used for human consumption. Its cultivation is one of the major enterprises in horticulture which is becoming more popular due to the greater appreciation of their food values (Gardner, 2004), Vitamins and Minerals (Adeboye, 1996). The production of vegetables had developed from a small home garden to commercial farming because of its nutritive significance in diet of people (Olufolaji, 2003). The importance of vegetable in our diet therefore, cannot be over-emphasized, in that they are good supplements to animal proteins and also their leaves and fruits contain iron, phosphorus, calcium, magnesium and vitamin A – (Thiamine, Niacin, Ascorbic acid and Folic acid) which are materials essential for proper growth and development of good sight, strong teeth and bones. They render food more palatable and used as food in some tropical areas and with protein content of up to 15% has been reported (Olufolaji, 2003).

Okra is an economically important vegetable crop grown in tropical and sub-tropical part of the world. This crop is suitable for cultivation as a garden crop as well as large commercial farms. This is grown commercially in Indian, Turkey, Iran, West Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Burma, Japan, Malaysia, Brazil, Ethiopia, Cyprus and Southern United States. (Benjamin, *et al*., 2007; Qhuresh, 2007). Other spread of other species is as a result of their introduction to Africa and America (Alade, *et al*., 2008; Qhureshi, 2007). Indian ranked first in the world with 3.5million tonnes (70% of the total world production of okra produced from over 0.35hectare of land (FAOSTAT, 2018). Okra is also essentially a tropical crop and among the most commonly grown vegetable throughout Nigeria. It is cultivated for its fresh fruits in both tropical and sub-tropical countries. Okra is mostly eaten in cooked or processed form and was reported to contain protein oil, calcium, iron, magnesium and phosphorus (Omotosho, 2007). The stem yield is useful as fiber while the leaves are considered good cattle feed and are consumed sometimes. The seed however can be roasted and used as substitute for coffee (Farinde and Owolarafe, 2007). The essential and non-essential amino acid which okra contains is comparable to that soybean (Farinde and Owolarafe, 2007). Okra is cultivated for its fibrous fruits or pods containing round; white seeds. The fruits are harvested when immature and eaten as vegetable. The roots and stem of okra are used for cleaning the cane juice from which brown sugar is prepared (Chauhan and Choomsai, 2000). Matured fruits and stems containing crude fiber are used in the industry. Extracts from the seed of the okra is viewed as alternative source of edible oil (Anyanwu, 2000).

Okra production in Nigeria often recorded low yield. The low yield experience has been attributed to poor soil fertility and deficiency in important mineral nutrients (Fagwalawa and Yahaya, 2016). Fertilizer could be very useful in increasing soil nutrients based and by extension, soil fertility but improper or excessive application could be detrimental to plants, pollutes soil water bodies and deteriorate the soil structure (Brar *et al*., 1994). Surprisingly, plants take in nutrients more efficiently through stomata (plant pores) in the leaves than they do through root uptake. Crops can be given a quick boost with periodic mist or sprays of natural foliar fertilizer. Not only is it good for general fertilization but also an immediate way to revive and stimulate stressed, tired or diseased plants. Test has shown that foliar feeding can be 8-10times more effective than soil feeding (Raynor and Bay, 1993). Up to 90% of foliar-feed solution can be found in the root of the plants within 1 hour of application. Foliar fertilizer, among other things, increase chlorophyll production and photosynthesis in the leaves, (which can be measured in as little as 4 hours), which in turns increase uptake of soil applied fertilizer, in respond to increase need for water by the leaves, bringing more fertilizing elements to the plant via the vascular system (Raynor, 1997). Little or no information is available on the effect of Super Gro on the production of vegetables especially on okra performance. The contribution of okra (*Abelmoschus esculentus*) to the economy of Nigeria and other countries cannot be overemphasized. However, the potential of the growth of okra are manifesting in the contribution to economic needs of the people. Thus, the study is undertaken to investigate and analyze the effect of the application of Super Gro on the growth and yield of okra.

MATERIALS AND METHODS

Materials

The materials used were Okra seeds, Super Gro (liquid fertilizer), Measuring tape, Cutlass, Hoe, Watering Can, Veneer Caliper, Weighing balance, Biro, Hand sprayer, Recording book, Syringe, Ruler, Labels and Tags.

Methods

The land was cleared and thoroughly tilled after which the layout was done. The experimental design was Randomized Complete Block Design (RCBD). It consists of five treatments replicated three times. The size of the plot was 2m by 2m which gives 20stands per plot.

Two seeds were sown per hole at a spacing of 30cm by 50cm. They started germinating five (5) days after planting and were later thinned to one seedling per stand. Treatments commenced two weeks after planting and there were 20 plants per bed.

The fertilizers were applied to okra at the rate of 1ml of Super Gro to 1ltre of water. It was applied once a week, twice a week, every fortnight and once a month respectively while the control was not treated.

Treatment

The treatments were as follows: Control (Without adding any liquid fertilizer), once a week,
twice a week, every fortnight and once a month.

Assessment of Variables

Three plants at the middle were randomly tagged for data collection which started two weeks after treatment application. The variables assessed were plant height (cm), stem girth (mm), number of leaves, weight of fruit (g), 50% day to flowering and leaf area (cm^2).

Data Analysis

The data collected were subjected to Analysis of Variance (ANOVA) to determine the significant difference. Duncan Multiple Range Test (DMRT) was used to separate the means.

The experimental design used for the study is Randomized Completely Block Design (RCBD) because it involved the simultaneous study of two factors.

The statistical model used is $Y_{ijk} = \mu + \alpha_i + \beta_j + \varepsilon_{ijk}$

Where Y_{ijk} = K_{th} observation of level *i* of the first factor and level *j* of the second factor.

μ = overall mean

α_i = effects of level i of the first sector

β_j = effects of level j of the second factor.

ε_{ijk} = Random error (Samuel *et al.*, 2012).

Also, leaf area relationship (LAcm^2) was determined by multiplying leaf length by leaf width with the Pearson's Product Moment Correlation Co-efficient (PPMC) (r) which is 0.80

$$r = \frac{n\sum XY - \left(\sum X\right)\left(\sum Y\right)}{\sqrt{\left[n\sum X^2 - \left(\sum X\right)^2\right]\left[n\sum Y^2 - \left(\sum Y\right)^2\right]}}$$

Where n is the sampled number of leaf,
X is the leaf length and Y is the leaf width, (Yusuff, 2004).

RESULTS AND DISCUSSION

From the result of the experiment as shown in table below, there was a revelation that seedlings of okra treated with fertilizer fortnightly perform best than other treatments with mean value of 21.46cm. It could be seen that seedlings of okra treated with fertilizer fortnightly also performed best with the mean value 10.18. Results also revealed that seedlings of okra treated with fertilizer fortnightly performed best in all the treatments with the mean value of 0.94mm.

Okra treated with fertilizer application fortnightly performed best with the mean value of 628.84cm^2. Also, Okra treated with fertilizer fortnightly performs best with the mean value of 334.7g. Days to 50% flowering was least and best on fortnightly application of organic fertilizer with 30days while longest day to 50% flowering occurred at once a month with 41days.

Also, from the result of the experiment, it was evident that the application of liquid fertilizer played a crucial role in the growth and development of the plant because all the treatments favourably influenced Okra in growth parameters. The significant response of the plant to applied fertilizer could be due to low organic matter content and nitrogen, phosphorus and calcium content of the experimental plot. The liquid fertilizer apart from enriching the plant with N.P.K., it also added organic matter to the plant that improves the structure, water holding capacity and cation exchange capacity of the soil thus shall influence the growth of plant. The result obtained showed that okra in which liquid fertilizer was applied fortnight performed best in all the variables. This buttress Sanject *et al* (2010) that any organic fertilizer at a specified quantity for a specified period of time improved yield.

Table 1: Effects of organic fertilizer on various treatment of Okra

Treatments	Mean of Plant height (cm)	Mean number of leaves	Mean stem diameter (mm)	Leaf Area (cm^2)	Days to 50% flowering	Mean weight (g)
Control	12.22	6.74	0.56	397.91	38	199.0
Once a week	13.08	8.12	0.66	426.96	38	247.0
Twice a week	17.16	9.78	0.78	474.84	31	271.7
Every fortnight	21.46	10.18	0.94	625.31	30	334.7
Once a month	18.36	9.98	0.86	537.40	31	295.3

CONCLUSION AND RECOMMENDATIONS

Based on the result obtained from this experiment, it is recommended that application of liquid fertilizer (Super Gro) should be encouraged and used for the production of okra, better crop planting and increase in farm yield and income.

Government should be willing to subsidize the price of liquid fertilizer to help the farmer for optimum production because it is more expensive and may not be readily available for an average Nigerian farmer. Also, there is need to try other application rates for optimum yield of okra. The method can be taught in schools by teachers in Agricultural practices.

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Evaluation of Growing Media on Growth and Yield of Fluted Pumpkin

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Abstract
The effect of different growing media used for the growth and yield of Fluted pumpkin was investigated and evaluated in this study. Complete Randomized Design (CRD) was used to lay out the experiment with three treatments replicated three times. The treatment was compared on the basis of plant height, number of leaves, and stem girth for a period of eight weeks and fresh weight was measured and recorded prior harvesting. Data collected were subjected to Analysis of Variance (ANOVA) and mean was separated using the Least Significant Difference (LSD). The result revealed that sawdust had the highest mean value in plant height, stem girth, number of leaves and yield among the three treatments. Leafy vegetable is concerned with yield; therefore, sawdust should be used for planting fluted pumpkin.

Keywords: Fluted pumpkin, growing media, yield and sawdust

INTRODUCTION

Telfairia occidentalis (Fluted pumpkin) belong to the family of Cucurbitaceae. The plant is unisexual, a strong climber with grayish fruit and edible seeds that are smooth and also have hard seed taste (Schippers, 2000). In Nigeria, Fluted pumpkin can grow in all the agro ecological zones, with the Southeastern zone dominating the production of this plant (Ehiagbonare, 2008). The entire plant (seeds and leaves) have high nutritional values. The leaves can be used for preparation of vegetable soup and stew, the oil extracted from the seeds can be used for the manufacture of cosmetics while the juice extracted from the leaves can be used by human and it is known to increase and hemoglobin levels of the human blood (Gill, 1992). Fluted pumpkin is a tropical vine grown in West Africa as a leaf vegetable and for its edible seed. Common names for the plant include fluted ground, fluted pumpkin and ugu. The fluted gourd grows in many nation of West Africa but it's mainly cultivated in Nigeria, used primarily in soups and herbal medicines, although the fruit is inedible, the seed produced by the gourd are high in protein and fat and can therefore contribute to a well-balanced diet. The plant is a drought tolerant dioeciously perennial that is usually grown sterilized (Okoli and Mgbeogu, 1983).

Fluted pumpkin is an herbaceous, climbing annual plant of the family cucurbitaceous. Most member of the family is tendrils herbaceous annual plant often growing very rapidly. It grows fast and vines may grow up to 30.5m in length. It also produces very large; various sizes fruit and are a fairly drought resistant plant which grows best on well drained loamy soil and on poor soil (Maduewesi, 1977). The seeds of fluted pumpkin are the only known important propagation materials, since the plant cannot be easily propagated vegetative. However, the seed of this plant quickly loses their germination potential especially when the seed are poorly developed due to biochemical transformation that usually occurred in the seed at different moisture levels (Tairu and Bolounduro, 2006). The seeds of fluted pumpkin are very delicate to handle because they do not undergo maturational drying and cannot be dried without damage and also due to high moisture content of the seeds, it cannot be stored for a long period of time and still be viable (Shippers, 2000). However, (Bradbeer, 1992), recognized the use of seed sizes as a compensation for variation in environmental condition and the enhancement of the productive capacity in a plant. He also observed that large seeds were preferred by growers of fluted pumpkin, since they germinate more vigorously and gave rise to large seedlings which may mean greater herbage yield. The plant (fluted pumpkin) is drought tolerant. The young shoots and leave of the female plant are the main ingredient of the Nigeria soup (Edikangikong) and also a great nutrition importance to human body. The vegetable is rich in fat and protein; and can be eaten whole. The edible seeds of fluted pumpkin can be boiled and eaten whole or fermented and added to ‘ogili’. The fluted gourd has been traditionally utilized by indigenous tribes as a blood tonic, likely due to its high protein content. Fluted pumpkin has attained an important status as a vegetable for all in Nigeria, but it has received a limited research attention by scientist. However, most of the available research information relate to mostly on fruiting and seed production (Akoroda and Adetoro, 1990) characteristics of sexes (Ajibade, *et al*., 2006) as well as the nutritional values (Longe, *et al*., 1983). There is limited information on the relationship between germination media and seed sizes on germination and vigour of fluted pumpkin.

The main use of fluted pumpkin is a leaf and seed vegetable. The tender shoots, succulent leaves, immature leaves can be cooked and consumed as a vegetable. The leaves are used alone or together with okro, or egusi seeds. They can be mixed with iru (Gnetum africanum welvo*)* and petrocarpus soyauxitanb. They are often cooked with fish, meat and tapioca. Immature seeds are cooked or wasted; seed can also be fermented for several days and eaten as a slurp. The fruit pulp with young seed is occasionally made into marmalade. Mature seeds are not consumed directly because they have high content of anti-nutrients, but their fat and oil may be extracted. The seed cake suitable for fortifying foods and the seed oil serve as cooking oil and for making margarine. The oil can also be used as drying oil for paints and varnishes, although it is also reported to be non -drying. The raw flour shows better water and fat absorption properties than the oil. Hence, it’s useful application in baking products and ground meat products. The rind and pulp of the fluted pumpkin are used as fodder for livestock for pregnant woman and patients suffering from anemia (use leaf juice to strengthen the blood). The stems are macerated to produce fibers that are used as a sponge. (Tindal, 1986). Fluted pumpkin leaves are common in the markets of low land areas in Benin, Nigeria and Cameroon. During the dry season in Nigeria, intensive trade develops in areas along river banks for sales to urban areas where major food crop markets develop. In Nigeria, the leaves are also transported by road from the South over a long distance to the big cities in the North. The cultivation of fluted pumpkin is developing around cities as a way of reducing the high transportation costs (Longe, *et al*., 1983). No statistical data are available on the total production.

In Nigeria, demand from different parts of the country has raised the price of the leaves and fruits. The average price per fruit in Nigeria is USS 0.70 – 1.00 (Yusuff, 2017). Fluted pumpkin is typically grown vertically or trestle like structure, however, it can be allowed to spread flat on a held. A beneficial outcome of growing the gourd flat is the suppression of weeds, especially when intercropped with a tall, upright plant such as maize. The growing period begin in April or May when seeds are planted. Seeds are planted directly in the soil typically in groups of three to increase output in a case of a failed germination. Fruit is typically harvested between October and December. The seed are subsequently collected and dried. A portion of them are consumed while the remains are stored for the following planting season. Although dependent upon soil type, the fluted gourd is able to ration and subsequently produce many flushes of fruit over long periods. It is able to ration with the highest degree of success in well drained soils. It is propagated using the seeds, and its seed is housed in another greater hard shell which protects it from harm. It survives drought and can retain its life in the root even after many years, it is a creeping plant and grows well of staked with bamboo-sticks. As a result of high demand of fluted pumpkin, the problem of planting medium calls for intensive preliminary research. One of the most important criteria for successful germination is to determine the best reliable germination medium. The influence of the medium is felt even before the plant sprout, because of its water retention and aeration properties, locally and readily available materials such as wood shale, saw dust, rice hill, river sand, coconut fiber and mixture of these materials have been proven to be a good media for germination of many crops (Ekwu and Mbah, 2001). Therefore, this research is to investigate and evaluate the very best growing media on the growth and y ield of fluted pumpkin.

MATERIALS AND METHODS

Materials

The experiment was carried out in the Horticulture and Landscape Technology (HLT) garden within the premises of the Federal College of Forestry, Jericho, Ibadan. The seed of *Telfairia occidentalis* was purchased from National Horticultural Research Institute of Nigeria (NIHORT). The sawdust was collected at Forestry Research Institute of Nigeria (FRIN) and top soil was collected at the College premises. The rest of the materials were bought at Ogunpa market, Ibadan. The materials used for this experiment include: Fluted pumpkin, Sawdust, Top Soil, and Sieve, Vernier caliper, Seed germination box, wheelbarrow, hand trowel, ruler, watering can, 25litres bucket, bamboo stakes, paper tape, notebook and pen.

Methods

The soil was air dried for three (3) days after it was passed through 2mm mesh sieve to remove non soil particles. The sawdust was also soaked in water for three (3) days to remove the chemical particles in it. Both the topsoil and sawdust were taken to the laboratory for analysis to know the level of their chemical components. The seeds of fluted pumpkin were first planted in a germination tray of each treatment with thorough wetting once a day before transplanting. The seed were raised for two weeks before transplanting to the field. Watering was carried out equally. The experiments were laid out in a Completely Randomized Design (CRD). A total numbers of three (3) treatments replicated three (3) times.

Treatments

The treatments are as follows: Top soil; Saw dust and; Top soil and sawdust.

Parameter Assessed

The following growth parameters were assessed during the experiment weekly. Plant height (cm), Stem Girth (mm) and number of leaves

Data Analysis

The data collected were subjected to Analysis of Variance (ANOVA) to determine the significant difference and mean was separated using the Least Significant Difference (LSD). The experiment design used for the study is Completely Randomized Design (CRD) because it involved the study of one factor.

The Statistical Model used is $y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$

Where y_{ij} = jth observation in group i

μ = grand population mean

α_i = effects of group i

ε_{ij} = random error (Samuel *et al*., 2012)

RESULTS AND DISCUSSION

Result of the experiment as shows in the table 1 below show that sawdust had the highest mean value on the plant height, number of leaves, stem girth and yield of planted fluted pumpkin. That is, it performed best in all the parameter assessed. Therefore, Sawdust is significantly different from other treatments. This is supported by Ekwe and Uba (2001) that Sawdust performed best for quick sprout of seeds.

Table 1: Effects of media on the various parameter assessedof fluted pumpkin for 6 weeks

Treatments	Mean of Plant height (cm)	Mean number of leaves	Mean of Stem girth (mm)	Mean of Yield (kg)
Top soil	27.66b	16.06b	1.73b	5.21b
Top soil and sawdust	21.97b	14.50b	1.64b	4.53b
Saw dust	30.35a	20.78a	2.08a	5.30a

NOTE*: Means with the same letter are not significantly different from each other.*

CONCLUSION AND RECOMMENDATION

It was concluded that Sawdust performed best in all the parameters assessed, thus, sawdust is recommended as the best growing medium to propagate fluted pumpkin seeds in the nursery.

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APPENDIX I

Analysis of Variance For Plant Height at the 6th Week

Effect	SS	DF	MS	F	Prob.F
Saw dust	159.86	2	79.93	7.357778	0.024298**
Residual	65.18	6	10.86333		
Total	225.04	8	28.13		

Note: *** Significant difference at 5% level of significance*

Analysis of Variance For Number of Leaf at the 6th Week

Effect	SS	DF	MS	F	Prob.F
Saw dust	180.22222	2	90.11111	13.08065	0.06493**
Residual	41.33333	6	6.88889		
Total	221.55556	8	27.69444		

Note: *** Significant difference at 5% level of significance*

Analysis of Variance For Stem Girth at the 6th Week

Effect	SS	DF	MS	F	Prob.F
Saw dust	0.5066667	2	0.253333	11.4	0.009042**
Residual	0.1333333	6	0.22222		
Total	0.64	8	0.08		

Note: *** Significant difference at 5% level of significance*

APPENDIX II

Pre-planting Physical and Chemical Properties of the Media Used

Parameters	Properties	
	Top soil	Saw dust
pH (H_20)	6.59	7.29
pH (KCL)	6.35	
Ca (cmol/kg)	4.40	0.03
K (cmol/kg)	0.36	0.16
Na (cmol/kg)	0.19	0.06
Mg (cmol/kg)	1.74	0.19
C (%)	1.74	14.23
Total (N)	0.98	0.11
Av. P (mg/kg)	5.69	0.05
Mn (mg/kg)	19.79	24.53
Fe (mg/kg)	18.06	
Cu (mg/kg)	0.38	
Zn (mg/kg)	6.5	

Nitrogen Utilization for Improved Maize Leaf Production and Cob Yield

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Abstract

Incorporation of nitrogen fixing tree to complement inorganic fertilizer in crop production in semi-arid, Nigeria is a gap. the study assessed nitrogen utilization for improved maize leaf and cob yield . The experiments were laid out as 3 x 4 x 2 factorial in a split-split plot design with three replicates for two years (2014 and 2015) and effect of these two seasons when no biomass was incorporated termed 'residual' was determined in 2016. These factors were: control, biomass species (Albizia lebbeck and Parkia biglobosa) as main plots factor, four levels of nitrogen (0, 40, 80, 120 kg N ha^{-1}) as sub-plots factors, and two maize varieties (DMR-ESR-7 and 2009 EVAT) as sub-sub plots factors. Data were analysed using (ANOVA) at p =0.05. The soil is sandy loam and acidic with pH (4.10). Albizia lebbeck had higher concentration of nitrogen and organic carbon (32.4 g kg^{-1} and 189.4 g kg^{-1}), but lower in C: N (57.5) leading to faster decomposition and nitrogen release than P. biglobosa. A. lebbeck amended plots had significantly higher values (8.7 and 11.7) on number of leaves per plant (NL) at 4 and 10 weeks of planting (WAP) respectively, while the combined crop yield (CY) was 3041.7 kg ha^{-1}. Meanwhile, plots amended with. P. biglobosa leafy biomass had significantly higher values (7.0, 10.2 and 10.8) on NL at 4-8 WAP, while, it was significant with higher value (2784.7 kg ha^{-1}) on CY in the residual. P. biglobosa only experienced significantly lower values (6.3 kg ha^{-1}, 1731.5 kg ha^{-1} and 1620.4 kg ha^{-1}) in plots supplied with 120 kg N ha^{-1} rate on NL at 4 WAP, and at both 80 kg N ha^{-1} and 120 kg N ha^{-1} rates on CY in the residual. However, no significant difference was observed in plots supplied with nitrogen rate on NL, but, significantly lower value (1814.8 kg ha^{-1}) was recorded in plots without fertilizer application; 0 kg N ha^{-1} (control) on CY in the combined. 2009 EVAT had significantly higher values (11.9 kg ha^{-1} and 2835.7 kg ha^{-1}) at 10 WAP on NL and CY respectively in the combined. No significant difference was observed on maize varieties both on NL and CY respectively in the residual. In conclusion, A. lebbeck leafy biomass affect maize production in terms of leaves and cob yield in the conbined since it's biomass decomposed and released nitrogen faster, while, P. biglobosa leafy biomass affect maize leaf production and cob yield in the residual because of its slower rate of decomposition which also makes its nutrient effective for maize production in the subsequent season.

Abstract: Biomass transfer, Maize production, Decomposition, Soil fertility, Residual

INTRODUCTION

The term agroforestry is a land management system that accommodates both production of food crops and forest products on the same piece of land. It aims at increasing production of food and fibres. It has been noted that food crisis, declining forest resources and environmental imbalance are some of the wide spread problems in Nigeria and the world today (Oyebamiji *et al.*, 2016a). The agricultural production system in Nigeria has deteriorated due to lack of capacity to produce enough food for its population as a result of decline in soil fertility (Anon, 1991). Farming systems in Nigeria and all over the tropics are under threat due to declining soil fertility (Adjei-Nsiah, 2012). It is increasingly evident that declining soil fertility is the most widespread, dominant limitation on yields of maize (*Zea mays* L.) and the sustainability of maize-based cropping systems in Africa (Ajayi *et al.*, 2007). Lack of soil fertility, soil erosion and unequal soil fertility management contribute to soil fertility depletion in arid Africa (Vanlauwe and Giller, 2006; Bationo *et al.*, 2007). Low soil fertility has been noted to be one of the major challenges to agricultural productivity in Africa (Beedy *et al.*, 2010; Wheeler and von Braun, 2013). And this has resulted to mono-cropping and inadequate recycling of organic matter, scarce and expensive inorganic fertilizers and also deeply compounded by rainfall variability and recurrent dry spells which has led to low crop yields in most of Africa countries (Ngwira *et al.*, 2012). Due to these grave challenges, poverty, food insecurity and child malnutrition have negatively affected human livelihood in most Africa countries and Nigeria in particular.

In order to alleviate these huge challenges, particulally soil infertility through mono-cropping and lack of adequate replenishment, leguminous trees that are nitrogen fixing trees as against the sole use of inorganic fertilizer are known to play alternative role as source of organic fertilizer and have the potential to sustain soil fertility (Snapp *et al.*, 2003; Adjei-Nsiah *et al.*, 2004). Cultivation of leguminous tree crops and biomass transfer is the main possibility for soil enrichment with nutrients, especially with nitrogen. The productivity of cereals depends on soil properties, meteorological factors, fertilization, and especially humus content in soil. Incorporation of green material enriches soil with organic matter, which as a result of microbiological processes releases nutrients for plants (Ramroudi and Sharifai, 2013). The use of legume tree pruning as mulch in agroforestry system is a common and aged-old practice to maintain soil organic matter and improve soil fertility in the tropics (Duguma *et al.*, 1988). Biomass transfer which refers to mulching or green-leaf manuring using tree or shrub foliage which is cut and applied to the cropping field are employed to stimulate soil fertility replenishment (Kwesiga *et al.*, 2003). Biomass in terms of leaves are used directly as green manure or shade-dried and stored for later use, especially if the material is collected during a non-cropping period when the demand for labour is low (Cooper *et al.*, 1996). Though, traditionally, farmers are used to collecting biomass from the woodlands and incorporate it into the fields to improve soil quality (Nyathi *et al.*, 1993).

MATERIALS AND METHODS

The research was conducted at Makera, a village in Dutsinma Local Government Area of Katsina State, having an area of 527 km², altitude of 605 m and a population of 169, 671 and is found within Latitude $12^0 27'18''$ N and Longitude $07^0 29'29''$ E. Maximum day temperature reaches about 38^0 C in the month of March, April and May and minimum temperature is about 22^0 C in December and January (Tukur *et al.*, 2013). The vegetation of Dutsin-ma region combines a characteristic feature of Guinea and Sudan Savanna vegetation zones of Northern Nigeria (Tukur and Kan, 2013).

Experimental Design and Data Collection

The experiments were laid out as 3 x 4 x 2 factorial in a split-split plot design with three replicates for two years (2014 and 2015) and effect of these two seasons when no biomass was incorporated termed 'residual' was determined in 2016. These factors were: control, biomass species (*Albizia lebbeck* and *Parkia biglobosa*) as main plots factor, four levels of nitrogen (0, 40, 80, 120 kg N ha^{-1}) as sub-plots factors, and two maize varieties (DMR-ESR-7 and 2009 EVAT) as sub-sub plots factors. The gross plot had 4 m x 3 m dimension. Leafy biomass of *A. lebbeck* and *P. biglobosa* were pruned and incorporated fresh into the soil, that is, plots prepared for biomass, two weeks before maize planting at the rate of 6 kg for each (5000 kg ha^{-1}) of the *A. lebbeck* denoted by (B_1) and *P. biglobosa* denoted by (B_2) and plots without incorporation of leafy biomass denoted by (B_0). These leafy biomass were incorporated into the soil repeatedly for two cropping seasons (2014 and 2015) and effect of these two seasons when no biomass was incorporated termed 'residual' was determined in 2016. Four levels of N fertilizers in which half of it were first applied at 2 weeks after planting (WAP) include; $N_{0,}$ 0 kg N ha^{-1} (control); N_1, 40 kg N ha^{-1}; N_2, 80 kg N ha^{-1}; N_3, 120 kg N ha^{-1}, while, the remaining amount was later applied at 5 WAP. The maize varieties used include; DMR-ESR-7 (Yellow) and 2009 EVAT (White) and were obtained from Katsina State Agricultural and Rural Development Authority (KTARDA). Two maize seeds from each varieties were planted per hole at equal depth of 4 cm and later thinned to one 2 WAP in 75 cm x 25 cm conventional spacing to make the total plant population of 64 stands per gross plot and 32 stands per net plot.

Five maize plants were randomly selected within each of the net plots 4 m x 1.5 m (6 m^2) with a tag for periodic observations at 4, 6, 8 and 10 WAP during the crop growth cycle on the number of leaves per plant. And these same five tagged plants were equally used to obtain cob yield result at harvest.

Number of Leaves Per Plant: The number of leaves per plant was obtained at 4, 6, 8 and 10 WAP by counting the number of leaves from the five tagged plants in each plot. The average number of leaves was recorded per plant on combined and residual.

Cob Yield (kg ha^{-1})

Cobs of maize from each net plot (i.e. the two middle rows) were harvested, sun-dried and weighed before shelling and then weighed after shelling on combined and residual. The mean weights were recorded and cob yield per hectare were calculated using the formula: Cob yield in (kg) x 10,000 m^2/ net plot size in (m^2)

Plants (Leaves) Tissue Analysis

Leaves of *A. lebbeck* and *P. biglobosa* were analysed for initial contents of N, C, lignin and polyphenols. Total N was analysed by Macro-Kjeldahl digestion, followed by distillation and titration (Anderson and Ingram, 1993; Brandstreet, 1965). Lignin were determined by the Acid Detergent Fibre (ADF) method as outlined in Anderson and Ingram (1993). The polyphenol was extracted in hot (80^0 C) while, 50 % aqueous methanol wre calorimetrically determined with tannic acid as a standard measurement (Anderson and Ingram, 1993; Hagerman, 1988).

Data Analysis

Data were analysed using Analysis of Variance (ANOVA) with Statistical Analysis System (SAS, 2003) computer package at 5 % level of significance to determine differences in the treatment effect. The Duncan's Multiple Range Test (Duncan, 1955) was used to separate means of differences among the treatments where significant treatment effects were obtained from the analysis of variance.

RESULTS

Chemical Composition of *Albizia lebbeck* and *Parkia biglobosa* Leafy Biomass

Result of chemical composition of *A. lebbeck* and *P. biglobosa* biomass of the plant materials showed variations in their chemical compositions during 2014 and 2015 cropping seasons. The leaves of *A. lebbeck* contained more N (leading to lower C: N ratio) than *P. biglobosa*. *A. lebbeck* had the highest concentration of lignin with mean value of 110.6 g kg^{-1}, while *P. biglobosa* had highest concentration of C: N ratios with mean value of 63.0, meaning that *P. biglobosa* had low N and C contents (Table 1).

Table 1: Mean chemical composition of the leafy biomass of *Albizia lebbeck* and *Parkia biglobosa* in 2014 and 2015 (combined)

Component	N (g kg^{-1})	C (g kg^{-1})	Lignin (g kg^{-1})	Polyphenol (g kg^{-1})	C: N
Albizia lebbeck	32.4a	186.4a	110.6a	5.7b	57.5b
Parkia biglobosa	26.5b	166.7b	82.4b	7.5a	63.0a

***N:** Nitrogen; **C:** Carbon; **C:N:** Carbon to nitrogen ratio*

Means followed by the same letter(s) within the same column and treatment are not significantly different (P > 0.05).

Number of Leaves Per Plant

A. lebbeck was observed to have significantly higher values (8.7 and 11.7) at 4 and 10 WAP. Though, *A. lebbeck* amended plots had higher number of leaves per plant across the weeks of observations in combined. However, in the residual effect, *P. biglobosa* had significantly higher values (7.0, 10.2 and 10.8) at 4-8 WAP respectively. There was no significant difference observed with nitrogen application at the rate of 0-120 kg N ha^{-1} at 4-8 WAP, and between 40-120 kg N ha^{-1} at 10 WAP in the combined. Also, there was no significant difference observed in the residual at 6-10 WAP, but, there was significantly lower value (6.3) in nitrogen application with 120 kg N ha^{-1} at 4 WAP. No significant difference was noted between the two maize varieties at 4-8 WAP. Meanwhile, 2009 EVAT had significantly higher value (11.9) on leave number production at 10 WAP than DMR-ESR-7 in combined analysis. The same observation of no significance between the maize varieties was recorded in the residual across weeks of experiment on number of leaves per plant (Table 2).

Cob Yield (kg ha^{-1})

Plots amended with *A. lebbeck* had significantly higher value (3041.7 kg ha^{-1}) of cob yield than other treatments in combined. The value was comparable as *P. biglobosa* also produced significantly higher cob yield value (2784.7 kg ha^{-1}) in the residual. Plots without N rate (control) produced significantly lower value (1814.8 kg ha^{-1}) of cob yield at 0 kg N ha^{-1} among other N rates in combined, while, significantly lower values (1731.5 kg ha^{-1} and 1620.4 kg ha^{-1}) were observed on cob yield both at 80 kg N ha^{-1} and 120 kg N ha^{-1} in the residual. 2009 EVAT produced significantly higher value (2835.7 kg ha^{-1}) on cob yield in combined, while, no significant difference was observed between the maize varieties on cob yield in the residual (Table 3).

Table 2: Influence of biomass and nitrogen rate on number of leaves (cm) of two maize varieties in combined and residual

	Number of leaves per plant							
	Combined				Residual			
Treatment	4 WAP	6 WAP	8 WAP	10 WAP	4 WAP	6 WAP	8 WAP	10 WAP
Biomass (B)								
Control	8.1b	10.1	11.7b	11.2ab	6.4b	9.4b	10.2b	10.5
Albizia	8.7a	10.9	12.3a	11.7a	6.4ab	9.4b	10.6ab	10.6
Parkia	7.9b	10.1	11.6a	11.0b	7.0a	10.2a	10.8a	10.4
SE±	0.22	0.33	0.26	0.22	0.20	0.19	0.17	0.17
Nitrogen (N) Kg ha^{-1}								
0	7.9	9.9	11.7	10.6b	7.1a	9.8	10.6	10.6
40	8.4	10.6	11.9	11.4a	6.6ab	9.6	10.5	10.5
80	8.2	10.5	11.9	11.6a	6.4ab	9.5	10.6	10.4
120	8.5	10.5	11.9	11.6a	6.3b	9.6	10.5	10.6
SE±	0.26	0.38	0.31	0.25	0.23	0.23	0.21	0.20
Variety (V)								
DMR- ESR- 7	8.1	10.3	11.6	10.7b	6.6	9.8	10.5	10.5
2009 EVAT	8.4	10.5	12.1	11.9a	6.6	9.5	10.5	10.5
SE±	0.18	0.27	0.22	0.17	0.17	0.16	0.15	0.14

a, b, c, d, e: indicates means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability using Duncan Multiple Range Test (DMRT); WAP: Weeks after planting; SE±: Standard error.

Table 3: Influence of biomass and nitrogen on cob yield plant (kg ha^{-1}) of two maize varieties in combined and residual

	Cob yield (kg ha^{-1})	
Treatment	Combined	Residual
Biomass (B)		
Control	2562.5ab	1604.2b
Albizia	3041.7a	1645.8b
Parkia	2171.9b	2784.7a
SE±	200.80	162.75
Nitrogen (N) Kg ha^{-1}		
0	1814.8b	2333.3a
40	2622.7a	2361.1a
80	2796.3a	1731.5b
120	3134.3a	1620.4b
SE±	231.72	216.03
Variety (V)		
DMR- ESR-7	2348.4b	1939.8
2009 EVAT	2835.7a	2083.3
SE±	170.07	163.00

a, b: indicates means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability using DMRT. S*: Significant at 5 % level of probability.

DISCUSSION

The condition of the soil before the experiment revealed that the soil is basically sandy loam and exhibited acidic nature with pH value of 4.10. The performance in *A. lebbeck* plots were observed better because of the quality of its materials and the ability to decomposed faster to release nitrogen for crop growth (Swift *et al.*, 1997; Oyebamiji *et al.*, 2016b). Its materials contain higher average N content of 32.4 g kg^{-1} N and 186.4 g kg^{-1} C and lower average C: N ratio of 57.5 in combined than *P. biglobosa* which decomposed and released nitrogen later. (Giller and Wilson (1991); Oyebamiji *et al.* (2017) also reported that plant residues with a smaller C: N (< 30:1) is liable to decompose more rapidly with a net mineralization of N after incorporation into the soil as in the case of *A. lebbeck*. Hence, N is rapidly released and made readily available for crops.

The exciting performance in terms of production of leaves per plant and crop yield in biomass treated plots contributed to the increase in the amount of N fixed by the biomass and quantity of N derived from the decomposition of the incorporated biomass as it was observed in *A. lebbeck* in the combined and *P. biglobosa* in the residual (Push pavalli *et al.*, 1994; Oyebamiji *et al.*, 2016a). The response of maize to nitrogen application agrees with Cherr *et al.* (2006) who stated that maize growth has significant effect on biomass or litter used. The general performance of maize plants was discovered to be higher in *A. lebbeck* in combined and *P. biglobosa* in the residual both on number of leaves per plant and crop yied. Yield increases as N fertilizers are applied through the incorporation of leguminous crops (Mugendi *et al.*, 2000). The combined effects of *A. lebbeck* with application of N rates at 40 kg N ha^{-1} to 120 kg N ha^{-1} gave maximum production of 2009 EVAT maize leaves number and cropyield in the combined analysis, while, lower application of fertilizer at 40 kg N ha^{-1} in *P. biglobosa* amended plots facilitated leave and crop yield production in the residual.

CONCLUSIONS

The soil is sandy loam and acidic in nature. Leafy biomass of *A. lebbeck* and *P. biglobosa* incorporated into the soil as soil improvement remedy had significant effect on leaf production and cob yield both in combined and residual. Though, plots amended with *A. lebbeck* leafy biomass effectively improved maize production with respect to leaf production and cob yield in the first two cropping seasons (combined), while plots amended with *P. biglobosa* leafy biomass enhanced leaf production and cob yield in the residual, since its decomposition and nutrient release is slower than that of *A. lebbeck*. The combined effects of *A. lebbeck* with application of N rates at 40 kg N ha^{-1} to 120 kg N ha^{-1} gave maximum production of 2009 EVAT maize variety in terms of leaves number and crop yield, while, N rate at 40 kg N ha^{-1} in *P. biglobosa* amended plots also enhanced growth and yield components, and these are recommended for maize production in Dutsinma, Northwest, Nigeria.

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Soil Hydrothermal Properties and Yield of *Lycopersicon esculentum* Mill as Influenced by Leaf litter Mulch of Urban Agroforestry Trees

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Abstract

In urban areas, leaf litterfall from urban trees are wastes that pollute the environment. Use of litterfall from urban trees as mulching material in crop cultivation is an alternative sustainable utilization option for these wastes. This study aimed to evaluate the effect of urban tree leaf litterfall mulches on soil hydrothermal properties (soil temperature and moisture) and yield of tomato. The experiment consist of seven treatments made of organic mulches from dried leaves of six trees (*Spanthodea campanulata*, *Anacardium occidentale, Podocarpus gracilior*, *Persea Americana*, *Azadirachta indica* and Acacia Senegal) and unmulched (control). The experiment was a randomized complete block design consisting of seven (7) treatments replicated thrice. Tomato (cv Roma VF) was established in all mulched and unmulched plots Data were collected on soil moisture content, soil temperature and yield components of tomato. Degradation of each mulching material was evaluated using the above ground soil mulch degradation qualitative scale Leaf litter mulch from *Azadirachta indica* recorded the highest soil moisture content of 4.8% while *Anacardium occidentale* indicated the least value of 3.5%. Besides the control (29.8^{0}C), *Anacardium occidentale* recorded the highest temperature of 29.1^{0}C while *Azadirachta indica* recorded the least temperature of 27.6^{0}C. The highest soil coverage score was recorded in *Anacardium occidentale* (7.3), *rips, tears and holes (RTH) were highest in Azadirachta indica* (400.8). *Tomato plants mulched with leaf litter from* Acacia senegal *gave the highest number of fruits (19.9), fruit weight (30.1 g) and fruit yield (21.5kg ha^{-1}). Besides sustaining soil moisture content and temperature,* Acacia senegal mulch *contributed higher number of fruits, fruit weight and fruit yield. The study recommends the use leaf litterfall from urban trees as mulch in tomato cultivation as alternative to burning the leaves*

Keywords: Urban trees, litterfall, soil temperature, soil moisture, tomato

INTRODUCTION

Trees are cultivated within urban cities along walkways parks, in cities, towns and communities where people live and work. Urban forestry and greening provides numerous ecosystem services to society and individuals which includes improved human health and livelihood (Etim *et al*., 2012), reduced urban temperatures (Onishi *et al*., 2010), enhanced air quality (Nowak *et al*., 2013), and increased residential property values (Dimke *et al*., 2013). Urban trees also enhance interaction between urban habitats and nature. However leaf litter fall (both green and dried) is major constraint associated with urban trees. Unlike in natural forest ecosystems where leaf litterfall on the forest floor contributes to nutrient cycling, in urban areas leaf litter pollutes the environment. Governments, private entities and individuals spend lots of money to clean and dispose the leaf litter urban centres. Most common method of disposal in Nigeria and some other developing counties is burning. Burning leaves and other yard wastes pollutes the air and can lead to uncontrolled fires. Leaf smoke can make breathing difficult for people who suffer from asthma, emphysema, chronic bronchitis, or allergies. A number of States in US currently ban open leaf burning within cities,

and some communities either ban leaf burning or restrict when it can take place (Environmental Protection Agency, 1991). Alternative sustainable options for use of leaf litterfall from urban trees include agricultural practices such as mulching and composting. These agricultural practices allow these materials to be absorbed by the agroecosystem at the end of the life of the crop and used in establishment of tree nurseries and nutrient supplementation in established tree fields. The practice of covering the soil to create a conducive microenvironment for plant growth and development is termed mulching. For ages, natural (organic) mulches such as straw, dead dried leaves and crop residues have been used in crop cultivation. Mulching prevents direct evaporation of moisture from the soil and reduces the loss of water and soil erosion over the surface (Akhtar *et al.,* 2001; Tswanya *et al.,* 2017) and also helps maintain a constant soil temperature within the root crop system (Kosterna, 2014).
The yield of tomato and some other species of Solanaceae depends greatly on the weather conditions, most especially the air temperature, during the initial period of crop growth. By enhancing the hydrothermal conditions in the immediate vicinity of the plants, organic mulches influence the growth and increased the yield of vegetable crops. Mulches of *Leucaena leucocephala* and *Gliricidia. sepium* trees applied sole or in mixtures has been reported to increase yield of okra, while coconut fronds, dried leaves and crop residues enhanced yield of tomato (Kosterna, 2014; Tswanya *et al*. 2017). This study aimed to evaluate the effect of urban tree leaf litterfall mulches on soil hydrothermal properties (soil temperature and moisture) and yield of tomato in Asaba, Delta State.

MATERIALS AND METHODS

The experiment was conducted in the Teaching and Research Farm of the Faculty of Agriculture, Delta State University, Asaba Campus (Latitude 06^0 14'N and Longitude 060 49' E) during the late cropping season of 2019. Average annual temperature, relative humidity and rainfall of the study area are 26.7^0C, 75% and 1600mm respectively.
The field experiment was a randomized complete block design consisting of seven (7) treatments replicated thrice. The experiment consist of seven treatments made of organic mulches from dried leaves of six trees (*Spanthodea campanulata*, *Anacardium occidentale, Podocarpus gracilior*, *Persea Americana*, *Azadirachta indica* and *Acacia senegal*) and unmulched (control). The leaf litter from the aforementioned six trees and the control constitute the seven blocks. Leaf litter fall from trees planted within the Delta State University, Asaba Campus was collected for use as organic mulch. Three (3) weeks old tomato seedlings (Roma VF) were transplanted into plots of 3m x 3m and planted 30cm x 60cm. Dried leaves of the aforementioned six trees were applied at the rate of 10t/ha.

Table 1: Urban trees from which leaf litterfall were collected

Botanical Name	Common name	Family
Spanthodea campanulata	African tulip tree	Bignoniaceae
Anacardium occidentale	Cashew tree	Lauraceae
Podocarpus gracilior	African Fern Pine	Pinaceae
Azadirachta indica	Neem tree	Meliaceae
Acacia senegal	Gum arabic	Fabaceae
Persea americana	Avocado	Lauraceae

Measurements of soil temperature were collected biweekly at a depth of 10cm. From each experimental plot, the soil moisture was evaluated using five soil core samples collected from the top 10cm layer.
Soil moisture content (%) = [(fresh soil weight-dry soil weight)/dry soil weight] x 100
Using the methods described by Tian *et al*., (1994) duration effect of moisture / temperature of the soil were estimated from the time period within which the moisture/temperature of the soil is more than the average $LSD_{0.05}$ over the experimental period, while the prime effect is the mean decrease in the soil temperature/moisture compared to the control within the first 30 days after mulch application. In other to estimate the degradation of each mulching material, the above ground soil mulch degradation qualitative scale developed by Martín-Closas *et al*., (2016) was used as presented in (Table 2).

Table 2: Qualitative scale for the field evaluation of degradable mulch

Parameter	Criteria	Units/scores
Soil coverage by mulch	Area of soil covered by mulch material	Scores from 9 to 1: 9, 100% soil covered; 5, 50% soil covered; 1, 0% soil covered
Damages in mulch area	*No. of lesions (rips, tears and holes; RTH)*	*Number of lesions per area (RTH m^{-2})*
Strength	Resistance to tear	9, 100% full elasticity ;5, 50% full elasticity; 1, 0% extremely brittle

Data on yield and components of yield of tomato were collected at harvest. Data collected were subjected to analysis of variance (ANOVA) and significant means were separated using LSD at 5% level of probability.

RESULTS AND DISCUSSION

Soil Hydrothermal Properties

Table 3 shows the prime effects mean soil moisture content, temperature of leaf litter mulch and Table 4 shows the duration effects of soil moisture content, and temperature of leaf litter mulch during the period of growth of tomato.

Table 3: Prime effects and mean soil moisture content and temperature of leaf litter mulch during the period of growth of tomato

	Soil moisture content (%)		Soil temperature (^{0}C)	
Treatments	Means	Prime effect	Means	Prime effect
Control	2.3		29.8	
Anacardium occidentale	3.5	1.2	29.1	-0.7
Persea americana	3.7	1.4	29.0	-0.8
Spanthodea campanulata	4.1	1.8	28.4	-1.4
Podocarpus gracilior	3.2	0.9	28.7	-1.1
Azadirachta indica	4.8	2.5	27.6	-2.2
Acacia senegal	4.6	2.3	28.5	-1.3
LSD (5%)	0.6		0.9	

Table 4: Duration effects (in days) of soil moisture content and temperature of leaf litter mulch during the period of growth of tomato

	Duration effects (in days)	
Leaf litter mulch	**Soil moisture content**	**Soil temperature**
Anacardium occidentale	45	50
Persea americana	42	48
Spanthodea campanulata	40	45
Podocarpus gracilior	34	42
Azadirachta indica	32	38
Acacia senegal	28	35

Significant increase ($P< 0.05$) in soil moisture content of the leaf litter mulches over the control during the growth period of tomato was observed (Table 3). Amongst the leaf litter mulch from urban agroforestry trees, *Azadirachta indica* recorded the highest soil moisture content of 4.8% while *Anacardium occidentale* indicated the least value of 3.5%. The order of soil moisture content of leaf litter mulches was *Azadirachta indica>Acacia senegal>Spanthodea campanulata> Persea americana> Anacardium occidentale> Podocarpus gracilior.* Prime effect *of soil moisture content was at its peak in plots mulched with leaf litter of Azadirachta indica* (2.5) while the least was recorded in *Podocarpus gracilior (0.9). However a longer duration effect of 45 days was achieved by Anacardium occidentale*, while Acacia Senegal recorded the shortest duration effect of 28 days (Table 4). Soil temperature was significantly decreased ($P<0.05$) by the leaf litter mulch relative to the control (Table 3). Besides the control (29.8^{0}C), *Anacardium occidentale* recorded the highest temperature of 29.1^{0}C while *Azadirachta indica* recorded the least temperature of

27.6^0C. The order of soil temperature of leaf litter mulches was *Azadirachta indica>Spanthodea campanulata>* Acacia senegal> *Podocarpus gracilior> Anacardium occidentale*. The prime effect of soil temperature was highest in *Anacardium occidentale* (-0.7) and the least value in *Podocarpus gracilior* (-2.2). The longest duration effect of soil temperature was displayed in *Anacardium occidentale* (50 days) mulched plots while the least was observed in Acacia senegal (35 days).

The magnitude of desired effect depends on quality and durability of mulch. Application of leaf litter mulches in this study resulted in enhanced soil moisture content which would have been due to decrease in moisture evaporation from the soil. Leaf litter mulches with less degradation value showed a longer duration effect of soil moisture and temperature compared to those with high degradation value. Mulch has a great role in modification of soil hydrothermal regimes. The water holding capacity of the soil improved through mulch degradation and humus formation (Ji and Unger, 2001). This conserved moisture and balanced soil temperature is important for nutrient transporting, translocation of assimilate, cell division, and cell differentiation (Teame *et al*., 2017).

Mulch Degradation

Table 5 shows the degradation assessment scores of leaf litter mulch during the period of growth at harvest of tomato.

Table 5: Degradation assessment scores of leaf litter mulch based on soil coverage, damage and strength of mulch at harvest of tomato

Leaf litter mulch	Soil coverage	Damage (RTH m^{-2})	Strength
Anacardium occidentale	7.3	269.5	5.3
Persea Americana	6.7	275.3	4.7
Spanthodea campanulata	6.3	286.4	4.3
Podocarpus gracilior	*2.7*	*321.8*	*3.7*
Azadirachta indica	3.3	398.3	2.7
Acacia Senegal	3.3	400.8	2.7

At harvest of tomato, the highest soil coverage score for degraded leaf litter mulch was recorded in *Anacardium occidentale* (7.3), while the least soil coverage score was observed in *Podocarpus gracilior (2.7). Within a square meter, rips, tears and holes (RTH) were more pronounced in leaf litter mulch of Azadirachta indica* (400.8). Less damage was recorded in *Anacardium occidentale* with RTH value of 269.5. Except *Anacardium occidentale,* all other leaf litter mulches had less than 50% of the initial mulch still brittle. The order of weakness of the leaf litter mulches was *Anacardium occidentale< Persea americana< Spanthodea campanulata< Podocarpus gracilior Acacia senegal/Azadirachta indica*. From the results mulches with smaller leaves (*Podocarpus gracilior, Acacia senegal, Azadirachta indica*) degraded faster and showed more damages than mulches with larger leaves (*Anacardium occidentale, Persea Americana, Spanthodea campanulata*). This is because the smaller leaves provided a larger surface area for degradation. Surface area to particle size ratio controls deterioration because for a given volume of material, the smaller particle size, the larger is the surface area exposed to degradation (the presence of joints also enhances a material's surface area) (Moncmanova, 2007)

Components of yield and tomato fruit yield

Table 6: Components of yield and tomato fruit yield as influenced by leaf litter mulch

Treatments	No. of flowers	No. of fruits (plant^{-1})	Mean fruit weight (g)	Fruit yield (kgha^{-1})
Control	16.7	13.8	24.8	14.8
Anacardium occidentale	18.3	15.2	27.6	16.3
Persea americana	19.0	16.0	29.3	18.1
Spanthodea campanulata	18.7	16.3	28.0	17.7
Podocarpus gracilior	*18.0*	*17.9*	*28.8*	*17.8*
Azadirachta indica	20.7	19.5	29.7	20.8
Acacia senegal	21.3	19.9	30.1	21.5
LSD (5%)	1.2	2.3	2.1	1.8.

The tree leaf litter mulches significantly ($P<0.05$) enhanced number of flowers, number of fruits per plant, mean fruit weight and fruit yield of tomato plants when compared to the control. Maximum number of flowers (21.3) was achieved in Acacia senegal while *Podocarpus gracilior and control* recorded the least values of 18.0 and 16.7 respectively. Tomato plants mulched with leaf litter from *Acacia senegal* gave the highest number of fruits (19.9), fruit weight (30.1 g) and fruit yield (21.5kg ha^{-1}). Minimum values of number of fruits per plant (13.8), mean fruit weight (24.8g) and fruit yield (14.8 kg ha^{-1}) were observed in unmulched (control) tomato plots. Accelerated yield responses of tomato to plastic mulch have been reported in cool climates and dramatic yield response to organic mulch in warmer regions. The positive effects of plant based organic mulches on enhancing yield components and yield of tomato has been reported in other studies (Teasdale and Abdul-Baki, 1997; Kosterna, 2014; Tswanya *et al.*, 2017).

CONCLUSION

The results of the study indicated that the urban mulches from leaf litterfall have positive influence on soil moisture content and soil temperature. Smaller leaf litterfall from *Podocarpus gracilior,* Acacia senegal and *Azadirachta* indica degraded faster and showed more damages than mulches with larger leaves (*Anacardium occidentale, Persea americana, Spanthodea campanulata*). Tomato cultivated under leaf litter from *Acacia senegal* mulch gave the highest number of fruits, fruit weight and fruit yield. The tree leaf litte*r* mulches positively created a balanced soil moisture and temperature which enhanced tomato yield.

RECOMMENDATION

The study recommends the use leaf litterfall from urban trees as mulch in tomato cultivation as alternative to burning the leaves.

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The Quantification and Drivers of Mountainscape Transformation Using Remotely Sensed Data: a Case of Ado-Awaye Mountain, Southwest, Nigeria

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Abstract

Globally, the mountainscape pattern and its dynamics are currently an evolving interest in landscape ecology to ensure proper monitoring, planning, and development of a mountainous area. This study quantified the mountainscape transformation and identified its drivers over the last two decades in Ado-Awaye Mountain (the harbour of Ado-Awaye Suspended Lake), Nigeria. Field observations, remote sensing, geographic information technology and secondary data collection methods (interviews and questionnaires) employed to determine the drivers, patterns, and dynamics of the mountainscape. Landsat satellite imageries dataset (2000 and 2019) were acquired, pre-processed, and subjected to a supervised image classification using the modified United State Geological Survey land cover classification scheme. The results identified three land use and land cover (LULC) classes. It revealed that the rocky outcrop/bare-grounds/built-up area covered the highest landmass (112,140 hectares, 58.83%, and133, 920 hectares, 70.25%) in 2000 and 2019 respectively. The open secondary forest covered the least land mass (16,380 hectares, 8.59% and 17, 010 hectares, 8.92%) in 2000 and 2019 respectively. Most mountainscape transformation within the period accounted for the transition between the predominant LULC and grassy with scattered shrubs savanna. Three categories of underlying drivers (cultural, natural and technological) contributed to the transformation of the Ado-Awaye Mountain. The artificial forest restoration programs recommended improving the destination's serenity and mitigating the negative impacts of climate change. Also, ecological-friendly approaches should be encouraged to reduce the ecological impact of tourism infrastructural facilities and tourism activities.

Keywords: Mountain; Ado-Awaye; Pattern; Dynamics; LULC

INTRODUCTION

Mountainscape is a landscape associated with the mountainous regions. This landscape transformation is a gradual process that usually depends on the rate of change and varying time scales (Lofvenhaft *et al*., 2002). The landscape is dynamic with multifunctional, sequential, and continuous change which results from the interface between natural processes and human factors (Raudsepp-Hearne *et al*., 2010; Gomes *et al*., 2011; Qiu and Turner, 2015). The human factors involved different forms of human activities and had been one of the main drivers of landscape change (Haines-Young, 2010; Mooney *et al*., 2013; Bicik *et al*., 2014). The human activities could be in the form of agricultural activities, urbanization, mining with negative impacts such as biodiversity loss, habitat fragmentation, siltation, change in water quality and carbon loss (Dewi and Ekadinata, 2010; Temme and Verburg, 2011; Ishola *et al*., 2016).

Moreover, the LULC change remains the main driver of landscape transformation (Jensen *et al*., 2005; Bozkaya *et al*., 2015). It affects land composition, pattern, and structure, and contributes to landscape fragmentation through the sequence of changes in their ecosystem services and functions (Turner *et al*., 2013; Eleni *et al*., 2013; Mitchell *et al*., 2015). Also, it influences the occurrence and distribution of biodiversity that leads to the alteration of ecosystem services such as game viewing, mountain tourism, ecotourism (Wilson *et al*., 2003; Candinale *et al*., 2012). According to Turner *et al*. (2007), the advent of technologies such as geographic information systems had enhanced understanding of the drivers of LULC dynamics. Over the years, substantial efforts and breakthroughs made to generate quantitative and qualitative information from remotely-sensed and geospatial data towards LULC detection and its drivers' determination (Zhang *et al*., 2011; Ahmad, 2013). Also, evolution in these technologies allowed for LULC change detection on wide and varying temporal scales (Lu *et al*., 2004).

Ado-Awaye Mountain remains one of the unique mountainscapes in Southwest Nigeria. It harbours the only suspended Lake (SL) in Africa, and it is one of two SL in the world with intrinsic natural and cultural resources. In Nigeria, the majority of the populace is dependent on natural resources for livelihood improvement and survival (James *et al*., 2015). The mountainscape of this potential mountain tourism destination not exempted from the undue human pressure. But, there is little or no information on the transformation and drivers of Ado-Awaye Mountain. Hence, this study quantified the mountainscape transformation and identified its drivers over the last two decades in Ado-Awaye Mountain, Nigeria, using remotely-sensed data.

METHODOLOGY

The Study Area

The study was undertaken at Ado-Awaye Mountain - the habour of Ado-Awaye Suspended Lake in Southwest Nigeria (Figure 1). This mountain is also referred to as the Iyake Mountain that sprawls around the steep town of Ado-Awaye. It lies about 20km west of Iseyin, Iseyin Local Government Area of Oyo State, and falls within the basement complex of southwest Nigeria (Ibrahim, 2015). It is situated within Latitudes 07º048'00''N and 07º054'00''N and Longitudes 003º018'00''E and 003º030'00''E with an approximate land cover area of 190.62 hectares (Olaniyi and Bada, 2020). There is no major river within the catchment (Ibrahim *et al*., 2015). The destination has an elevation of 433m above sea level with a maximum annual rainfall of 1790-1850 mm (Olaniyi and Bada, 2020).

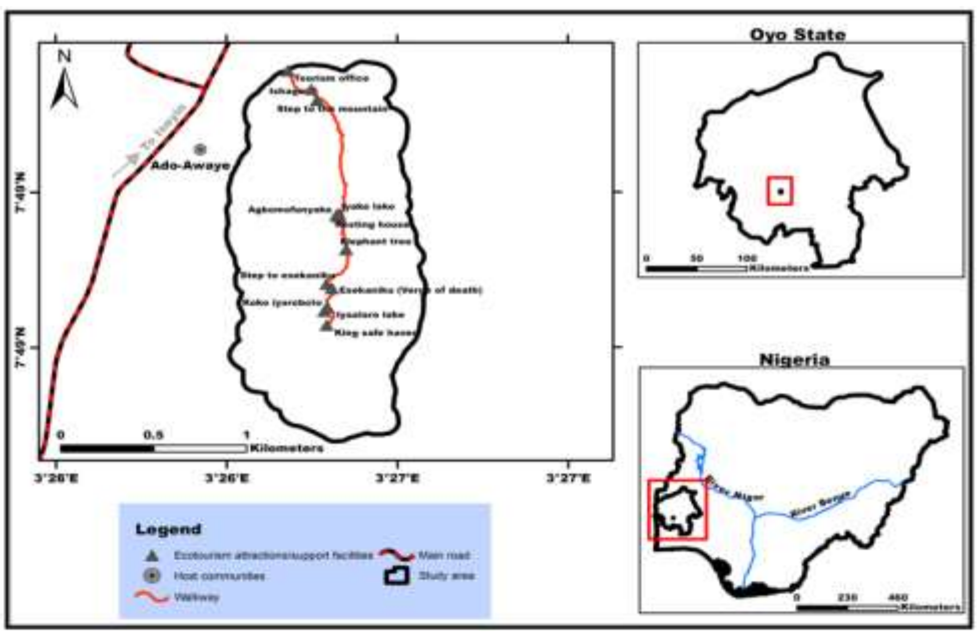

Figure 2: Ado-Awaye Suspended Lake at Oyo State, Nigeria

Source: Olaniyi and Bada, 2020

Data Collection and Analysis

The study used spatial data collected through the on-field observation with the aid of a hand-held Global Positioning System (GPSMap 72s). Landsat 7 ETM+ and Landsat 8 OLI/TIRS imageries of two-time series (2000 and 2019) respectively were acquired and pre-processed. The pre-processed images subjected to supervised image classification. Three LULC classes identified using the modified United State Geological Survey land cover classification scheme in ArcGIS 10.4 software environment to derive the land use and land cover type of Ado-Awaye Suspended Lake. On-field observation with the aid of a hand-held G.P.S (GPSMap 72s) to collect training samples for supervised image classification. The land use and land cover classes identified include rock outcrop/bare ground/built-up area, Open secondary forest, and Grassy with scattered shrub savanna.

For change detection analysis, images obtained from the two-year time-series were classified separately (2000 and 2019) and then compared to detect the LULC dynamics. On-field observation and secondary data collection method employed to identify the drivers of mountainscape transformation. The secondary data collection involved a multistage sampling technique using interview (first stage) and semi-structured questionnaires (second stage) methods. Interview method used to determine the perceived drivers of mountainscape transformation through open-ended questions. According to Farina (2000), Burgi *et al.* (2004) and Antrop (2005), the perceived drivers of mountainscape transformation categorized into cultural, natural and technological drivers. Then, semi-structured questionnaires using five-Likert scale format designed and administered to five experienced contact persons with more than twenty years experience of the study area. The contact persons' responses coded and analyzed to determine the significance of each perceived drivers through the computed means and standard errors.

RESULTS

Figure 2 and Table 1 depicted the land use/land cover of Ado-Awaye Suspended Lake and attributes in 2000 and 2019. Three categories were identified - rock outcrop/built-up/bare ground, open secondary forest and grassy with scattered shrub savanna. The rocky outcrop/bare grounds/built-up areas covered the largest landmass of 112.14 hectares (58.83%) in 2000, followed by the grassy with scattered shrub savanna with a landmass of 62.10 hectares (32.58%), while the open secondary forest has the least landmass of 16.38 hectares (8.59%). Also, the rocky outcrop/built-up/bare ground occupied the highest landmass (133.92 hectares, 70.25%) in 2019, while the open secondary forest occupied the least landmass (17.01 hectares, 8.92%). The rocky outcrop/built-up/bare ground experienced the highest increment in landmass (21.78 hectares, 11.43%) between 2000 and 2019. The grassy with scattered shrubs savanna was the only LULC with a reduction in landmass (-22.41 hectares, -11.76%) within the study period.

Figure 3 and Table 2 showed the transition matrix of the land use/land cover dynamics of the Ado-Awaye Mountain, Nigeria. The highest transition in land cover mass (48.24 hectares, 25.30%) was experienced from grassy with scattered shrubs savanna to rock outcrops/built-up areas/bare grounds, while the least transition in land cover mass (1.44 hectares, 0.76%) was experienced from open secondary forest to grassy with scattered shrubs savanna. Nevertheless, most landmass (78.03 hectares, 40.93%) occupied by the rocky outcrops/built-up areas/bare grounds experienced no changes within the study period. Figure 4 showed the significance of the underlying perceived drivers of Mountainscape transformation in Ado-Awaye Suspended Lake, Nigeria. The respondents perceived that the cultural drivers (3.47 ± 0.39) such as illegal grazing, indiscriminate logging, and bush burning significantly contributed to the mountainscape transformation of the study area. On the other hand, the technological driver, tourism infrastructural facilities/tourism activities (1.53 ± 0.20) minimally contributed to the mountainscape transformation.

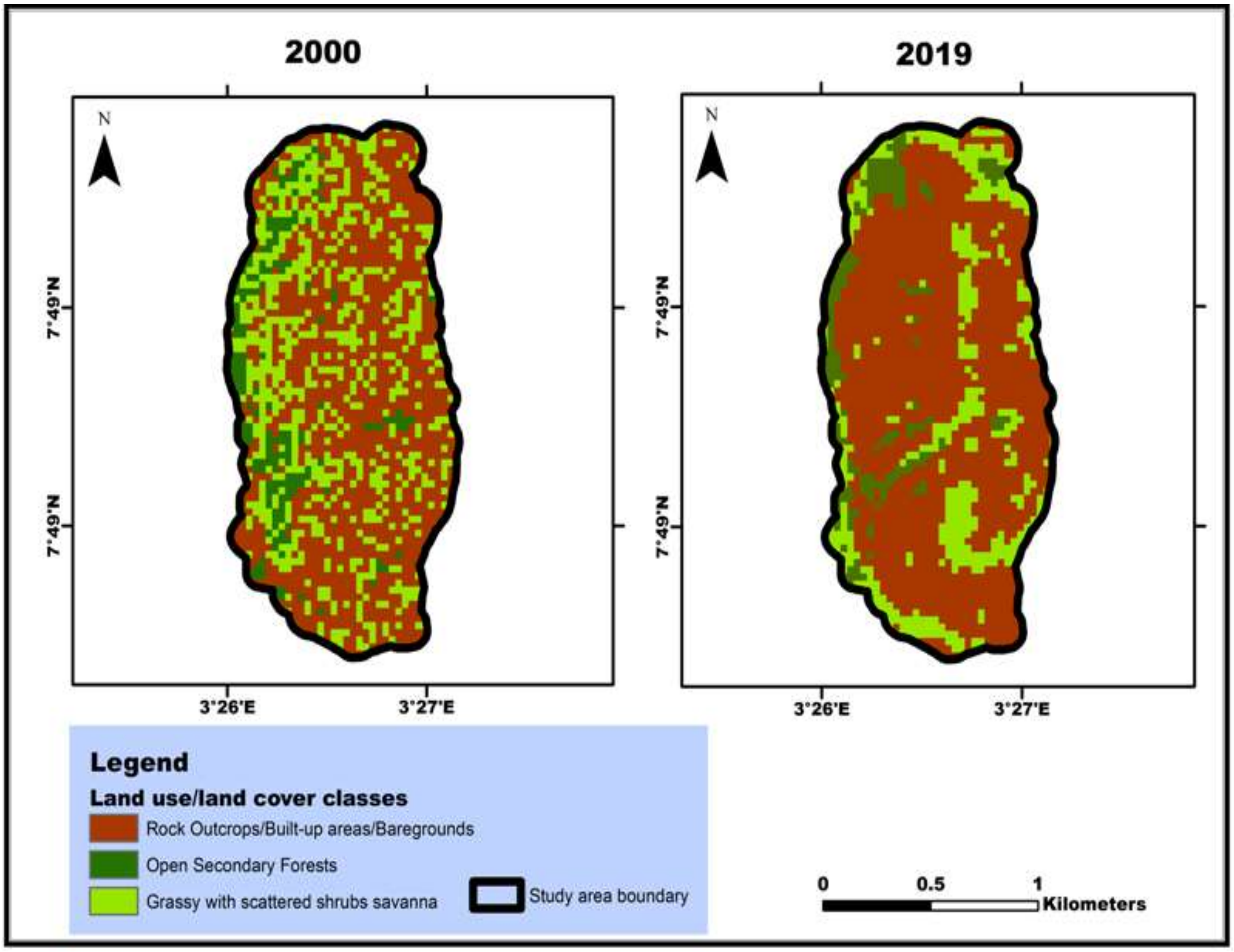

Figure 2: The land use/land cover of Ado-Awaye Suspended Lake, Nigeria in 2000 and 2019.

Table 4: The whole landscape's attributes of land use/Land cover dynamics of Ado-Awaye Suspended Lake in 2000 and 2019.

Land use/land cover classes	Area in hectares (Proportion in %)		Δ in hectares (%)
	2000	2019	
Rocky Outcrops/Built-up areas/Bare-grounds	112.14 (58.83)	133.92 (70.25)	21.78 (11.43)
Open Secondary Forests	16.38 (8.59)	17.01 (8.92)	0.63 (0.33)
Grassy with scattered shrubs savanna	62.10 (32.58)	39.69 (20.82)	-22.41(-11.76)

Total area = 190.62 hectares

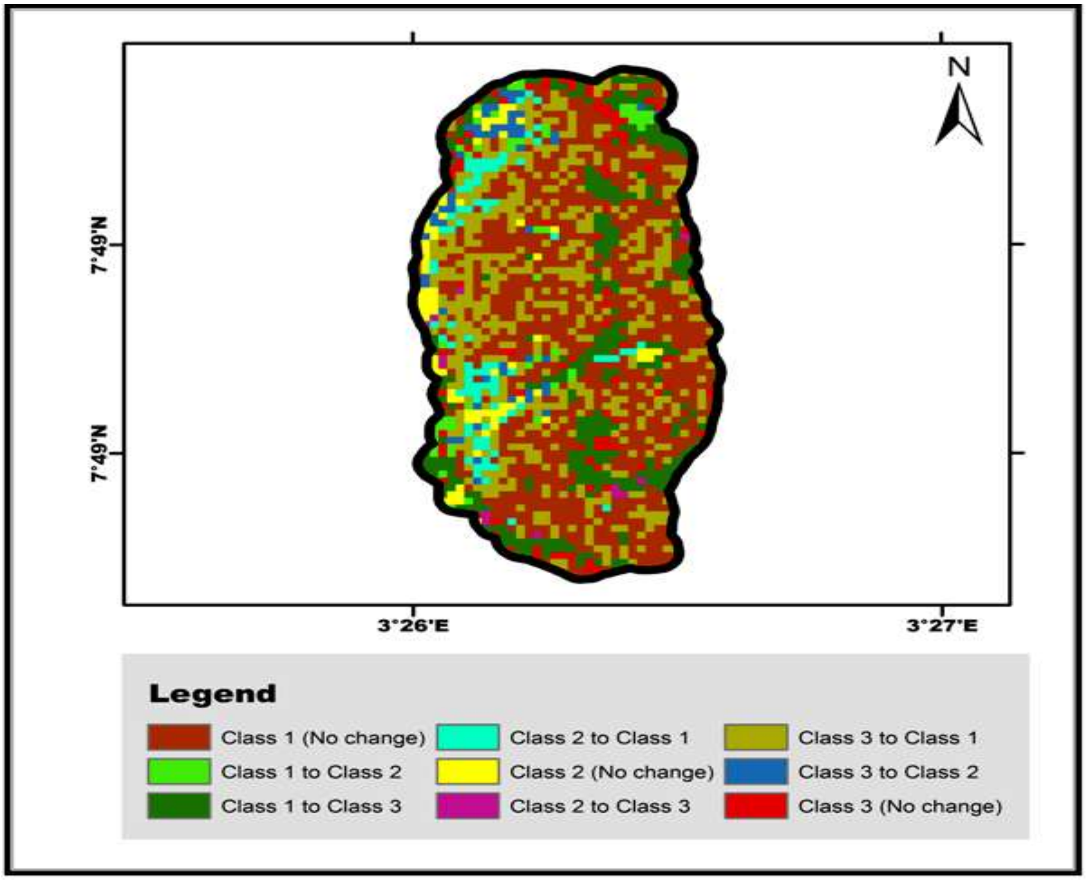

Figure 3: Transition matrix of the land use/land cover dynamics of the landscape of the Ado-Awaye Suspended Lake, Nigeria.

Table 2: Attributes of the transition matrix of the land use/ land cover dynamics of the landscape of the Ado-Awaye, Suspended Lake, Nigeria.

Land use/land cover transition classes	**Land cover transition**	
	Area cover (Ha)	**Proportion**
Class 1 (No change)	78.03	40.93
Class 1 to Class 2	4.68	2.46
Class 1 to Class 3	29.43	15.4
Class 2 to Class 1	7.65	4.01
Class 2 (No change)	7.29	3.82
Class 2 to Class 3	1.44	0.76
Class 3 to Class 1	48.24	25.30
Class 3 to Class 2	5.04	2.64
Class 3 (No change)	8.82	4.63

Total= 190.62 hectares
Rocky Outcrops/Built-up areas/Bare grounds (Class 1),
Open Secondary Forests (Class 2), Grassy with scattered shrubs savanna (Class 3)

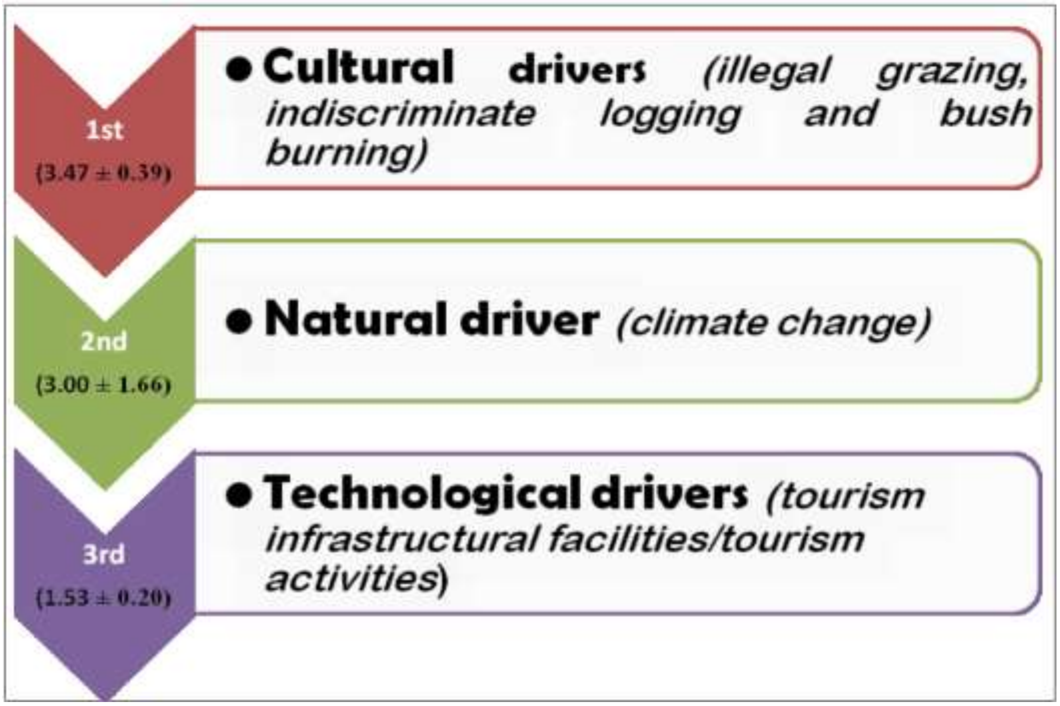

Figure 4: The significance of the underlying perceived drivers of Mountainscape transformation in Ado-Awaye Suspended Lake, Nigeria.

DISCUSSION

The study analyzed the LULC pattern and change that occurred within 2000 and 2019 in Ado-Awaye Suspended Lake, Nigeria using remotely-sensed data and GIS analysis. It revealed that the rocky outcrops/built-up areas/bare grounds are the most predominant LULC due to the mountainous nature of the studied area's landscape. Also, the grassy with scattered shrubs savanna was the dominant vegetation, and it covered the mountainous region, most especially its cliff and steep sides. This assertion supported the submissions of Aweto and Adejumobi (1991) and FORMECU (1998) that the studied area situated within the southern guinea savanna and characterized by grasses and scattered shrubs. According to Thlakma *et al*. (2018), mountainous regions usually associated with soil erosion, and its vegetation had great potential to control the erosion.

On the other, the open secondary forest had the least landmass coverage in the destination. Forest trees believed to prevent poor mental health, and to provide a serene and suitable environment for humans to rest their minds (Stigsdotter *et al*., 2011; FOREST EUROPE, 2019). It implied the non-serenity of Ado-Awaye Mountain due to its scarce and open forest trees, although this property increased over the years. Based on the LULC transition matrix, the grassy with scattered shrub savanna reduced drastically over the studied period. The reduction was majorly accounted for by its removal and conversion to rocky outcrops/built-up areas/bare grounds. However, the dynamism of the shrubby savanna attributed to a few underlying factors. They are overgrazing, indiscriminate logging, bush burning, climate change, human trampling, and tourism infrastructural development. According to Olaniyi and Bada (2020), the mountain harboured the only suspended Lake in Africa and lacked effective management to mitigate the negative impacts of tourism uses on its ecological resources. Within the last two decades, three categories of underlying drivers contributed to the transformation of the Ado-Awaye Mountain. The drivers are cultural, natural and technological. Ado-Awaye Mountainscape transformed due to the high pressure from overgrazing by the Fulani herdsmen and the inhabitants. Also, uncontrolled logging and indiscriminate bush burning posed threats to the landscape. These activities occurred during the dry season - a period with low impedance to mountainscape accessibility. Desertification due to climate change threatened and caused the disappearance of grassy with scattered shrub vegetation. The increased rate of desertification observed in different parts of Nigeria (Olagunju, 2015; Mirzabaev *et al*., 2019). Mountainous regions discovered to have less support to preserve their vegetation due to the prevailing harsher condition from climate change than other ecosystems (Tsering *et al*., 2010; Vanneste *et al*., 2017). According to Wang *et al*. (2016) and Zhu *et al*. (2017), the consequences of an increase in rock outcrops include vegetation degradation and desertification, redistribution of biodiversity, soil erosion. A few tourism infrastructural facilities such as the 245 stepped walkway, mini relaxation structure, and a wooden bridge constructed to enhance cultural and mountain tourism activities (Olaniyi and Bada, 2020). The site excavation during the construction contributed to the vegetation removal on the mountainscape. Therefore, the impacts of the above driving forces aligned with the view of Beniston (2003) that mountainous landscapes are fragile environments prone to damage when exposed to some factors.

CONCLUSION

This study had provided information on the type, pattern, rate, and drivers of land use/land cover changes in Ado Awaye Suspended Lake, Nigeria within 2000 and 2019. It revealed that the rocky outcrops/built-up areas/bare grounds and grassy with scattered shrubs savanna are the most predominant LULC and vegetation respectively. Despite the slight increase in the open secondary forest over the years, its low coverage implied the non-serenity of the mountainous landscape. However, the dynamism in the dominant vegetation (grassy with scattered shrub savanna) attributed to a few underlying factors. They are overgrazing, indiscriminate logging, bush burning, climate change, human trampling, and tourism infrastructural development. Therefore, effective management strategies such as artificial forest restoration programs recommended improving the destination's serenity and mitigating the negative impacts of climate change. Prohibition of overgrazing to reduce undue pressure on the grassy with scattered shrub savanna. Ecological Ecological-friendly approaches should be encouraged to reduce the ecological impact of tourism infrastructural facilities and tourism activities.

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Role of Sustainable Forest Management in Rural Livelihoods in Nigeria

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Abstract

Access to forest resources helps rural households diversify their livelihoods. They serve as an important coping strategy and a pathway out of poverty through household income sustainability. However, overexploitation by humans and climate change have led to huge losses in forest resources with adverse effects on their role as a key source of environmental biodiversity, hydrological regulation, climate change mitigation and habitat. The paper discussed the importance of forest ecosystem in rural livelihoods and highlighted sustainable forest management practices for the promotion of rural livelihoods in Nigeria. Forests provide inputs for rural households' subsistence use and into their agricultural systems. They act as safety nets in periods of crisis or during seasonal food shortages. This makes them prone to excessive exploitation by local communities. The situation is aggravated by the sensitivity of forests to climate. The result is the deplorable state of erstwhile flourishing forests in Nigeria. Sustainable Forest Management ensures the utilization of forest resources in a manner that the biodiversity, productivity, regeneration capacity, vitality and every of its potential are maintained for current and future purposes. Conservation, afforestation, characterization of high quality germplasm of valuable trees and disease control are essential to the maintenance of forest health, vitality and productivity in sustainable forest management. As mitigation actions such as afforestation or curbing of deforestation need to be properly planned and linked to local adaptation policies in related sectors to help local people better their livelihoods and withstand negative effects of climate change, the study suggested a holistic and multidisciplinary approach that entails collaborative effort among all stakeholders. This takes cognizance of the diverse but rational interests of all the stakeholders in the exploitation and conservation of forests. Moreover, timber harvesting methods that harmonise long term productivity, especially for co-existing NTFPs vulnerable to loss of forest cover should be integrated into silvicultural systems.

Keywords: Forests, rural livelihoods, climate change, rural poverty, sustainability

INTRODUCTION

According to Food and Agriculture Organisation (2000), a forest is a land area of more than 0.5 hectares, with a tree canopy cover of more than 10 percent and not primarily under agricultural or other specific non-forest land use. The trees should be able to reach a minimum height of 5metres. Forests include natural forests and forest plantations. Forests are determined by the presence of trees and the absence of other predominant land uses. It is defined as a tract of land covered by plant association predominantly composed of trees and other woody vegetation (Adeniyi, 2016). They are viewed as ecosystems or vegetation types supporting unique assemblages of plants and animals. Forests could also be landholdings legally designated as forests irrespective of existing vegetation cover. (Chazdon *et al*., 2016).

Forests are home to diverse animal species, about 80 percent of the world's terrestrial biodiversity. They also form the source of livelihood for many different human settlements, including 60 million indigenous people. They help keep the climate stable, absorbing carbon dioxide and releasing oxygen. They regulate water supply and improve its quality. Nigeria has a land area of 99.3 million hectares and forests make up about 10 percent of this land area. The Nigerian forest is made up of over 500 species of trees which attain a height of 12m and a girth of 60cm. The forest ecosystem contains many valuable plant species which are of considerable value in providing food, shelter, drugs and fibres. There may be over 6000 Non-Timber Forest Products (NTFPs) species in Nigeria. Like other forests, Nigerian forests provide shelter, livelihoods, water, food and fuel security. All these activities directly or indirectly involve forests (Okunlola and Akinyele, 2014).

However, despite their essentiality, forests are becoming increasingly threatened by human exploitation and climate change. This has led to huge losses in forest resources thereby hampering the pursuit of rural livelihoods, increasing their vulnerability and reducing the amount of income that can be gathered by rural livelihoods. It is against this backdrop that the study aims to discuss the importance of forest ecosystem in rural livelihoods and highlight sustainable forest management practices for the promotion of rural livelihoods in Nigeria.

Forest Ecosystem and Rural Livelihoods

Rural livelihoods refer to the diversity of capabilities, assets and activities that rural people, households and communities require to earn and secure their living (Food and Agriculture Organisation (FAO), 2003; Cambodia Human Development Report, (CHDR), 2011). Livelihood assets or resources range from natural, physical, social and financial to human assets. Forests as natural assets, play a crucial role in rural livelihoods and consequently, poverty alleviation. Forests account for about 25 percent of rural peoples' income in developing countries. They provide inputs for rural households' subsistence use and into their agricultural systems. Access to forest resources also helps rural households diversify their livelihood base and lower risk (Dil, Bhagirath and Akhter, 2016). Thus, they act as safety nets in periods of crisis or during seasonal food shortages (Langat *et al* ., 2016).

More than 70 percent of households in Nigeria depend directly on fuel wood as their main energy source and its daily consumption is estimated at 27.5 million kg/day (Ogunsawa and Ajala, 2002; Zaku *et al*., 2013). Other uses of forest resources among rural households include wood for charcoal production; pole-size wood for housing and furniture; weaving fibers for baskets, medicine extraction among others (Oriola, 2009). Harvesting and processing in many areas have contributed significantly to the welfare of rural households through subsistence exploitation and sales at local markets. While in the high forest zones of Eastern and Western Nigeria, harvesting of snails is a major income generating activity (Onuche, 2011), fuelwood, locust bean seeds, honey and gum arabic generate a lot of income for rural households in Central and Northern Nigeria.They help to cushion the effects of income shortfalls such as during illness within the household and natural disasters. Access to forest resources helps rural households diversify their livelihoods thereby complementing other sources of household income. This serves as an important coping strategy and a pathway out of poverty through household income sustainability (Kabubo-Mariara and Gachoki, 2008). In developing countries, there is the dominance of climate-sensitive sectors such as agriculture and forestry. This exposes them to a higher risk from any unusual change in climate phenomena and may perpetuate poverty. In Nigeria, poverty is largely situated in rural areas. It manifests in the form of low incomes, savings and growth; high level of inequality attributable to unequal access to income opportunities and basic infrastructure; poor education and health.

Natural resources are climate-sensitive. Thus, availability of local water supplies, fuel wood, reeds for basket- making and wild herbs among others are oftentimes, adversely affected by climate change. It increases a range of livelihood threats and vulnerabilities rather than being an isolated specific case. Its speed and intensity are threatening the ability of the poor especially, rural societies to cope. It contributes to the reduced resilience of key forest ecosystems and biodiversity that support rural livelihoods (United Nations Development Programme, 2012; Population Reference Bureau, 2013). According to World Wildlife Fund (2020), human impacts have already led to the loss of around 40 percent of the world's forests. Thousands of hectares of land are lost annually in Nigeria due to human exploitation, especially for fuel wood. This has led to worsening access to NTFPs and the reduction in their supply has been worsened. In most parts of the world, deforestation has made fuel wood to be located farther from where people live, making its gathering more physically draining, especially for women and girls who are responsible for this task.

SUSTAINABLE FOREST MANAGEMENT

Forests are carbon sinks and sources. They act as sources of greenhouse gases when they are destroyed and as sinks for carbon when they grow or expand. Forests are prime tools for climate change mitigation, especially in developing countries. Reducing emissions from deforestation and forest degradation in developing countries (REDD) are achievable through conservation and enhancement of carbon stocks through sustainable forest management. Sustainable forest management (SFM) is therefore, the stewardship and use of forests to meet specific environmental, economic, social and cultural objectives. It is the sustainable use and conservation of forests with the aim of maintaining and enhancing multiple forest values through human interventions (FAO, 2020). It is the use of forest land in a way and at a rate that maintains their biodiversity, productivity, regeneration capacity, vitality and their potentials to fulfill now and the future relevant ecological, economic and social functions at local, national and global levels which does not cause damage to other ecosystems (Oriola, 2009; Adeniyi, 2016). SFM addresses environmental services like climate change mitigation and biodiversity protection at the global level. The socioeconomic, environmental and cultural importance of forests are considered at the national level. Forests are maintained in local conditions in compatibility with ecological and social processes that sustain the forest ecosystem. This entails the long term protection of the biological diversity, soil conservation, watershed regu lation and climatic regulation. Sustainability of forest ecosystem therefore, is aimed at building resilience, increasing productivity of forests and reducing the emission of greenhouse gases. It requires an integrated approach to achieving changes in processes, systems and structures in the management of forest resources in order to address the challenges of climate change. This makes it possible for forest resources to meet the needs of the present generation without compromising the ability of future generations to meet their own needs.

The seven thematic components of SFM are the extent of forest resources; forest biological diversity; forest health and vitality; productive functions of forest resources; protective functions of forest resources; socioeconomic functions of fore st resources and the legal, policy and institutional framework (FAO, 2020). Forest resources can be sustained by first understanding the threats to the forest ecosystem; conservation and maintenance of accumulated carbon stocks in forests; increasing carbon stocks through afforestation; modification of forest species composition and tree size and age distributions; promoting planting of more resilient tree genotypes and characterizing high quality germplasm of valuable trees and planting trees to provide shade, stabilize soils and alter hydrology to reduce the expected impacts of precipitation and temperature changes. Others include fire protection of forests, improved disease control, increasing the length of time before harvest, thinning and selection harvests to reduce the fire risk and intensity, retention of existing forests, reducing the regeneration delay following harvests, and promoting tree planting outside forests, especially in urban areas (Oriola, 2009). The genetic resources of wild and semi-domesticated tree species and their varieties are essential to human wellbeing as sources of fruits, medicines, fiber, resins, oil and bioenergy. They contribute to improved income, health and food security for rural households living in and around biodiversity-rich forests. There is also need for effective long-term approaches to maintain genetic diversity and ecosystem functions of other useful tree species including wild relatives and relatives and cultivars of important tree crops such as cacao, coconut and coffee.

Polycyclic silvicultural systems (selective logging) are the predominant forest management systems in the tropics. They focus exclusively on the extraction of a few valuable timber species and usually disregard impacts on other forest resources and environmental services. Harvesting cycles for timber span many years. This limits the access to regular incomes for local communities from genetic diversity and NTFPs in such forest areas meant for timber producers, hydrological regulation and carbon sequestration. Harvesting of NTFPs within cutting cycles of timber will ensure continuous revenue for rural livelihoods. Proper timber harvesting regimes that pose no hindrance to access of NTFPs among local communities therefore constitute a key component of SFM (Centre for International Forestry Research (CIFOR), 2010). SFM is therefore, aimed at building resilience, increasing productivity of forests and reducing the emission of greenhouse gases. It requires an integrated approach to achieving changes in processes, systems and structures in the management of forest resources in order to meet the needs of the present generation without compromising the ability of future generations to meet their own needs.

CONCLUSION

In Nigeria, forests play a crucial role in rural livelihoods. Rural livelihoods are characterized by low earnings and poor asset base. This condition is worsened by overexploitation of forest resources and climate change. Sustainable forest management ensures both a healthy and productive forest ecosystem across all seasons. This will facilitate livelihood diversification for greater income generation and consequently, improved welfare conditions for rural households.

RECOMMENDATIONS

In order to ensure the availability of forest resources for the sustenance of rural livelihoo ds, there is need for a holistic and multidisciplinary approach that entails collaborative effort among all stakeholders. Such joint effort from local communities including the forest dwellers and local farmers; private sector such as the logging companies; forest and other relevant government departments and policy makers, takes cognizance of the diverse but rational interests of all the stakeholders in the exploitation and conservation of forests. Conservation must be considered as a means of improving livelihoods in the context of sustainable forest management. Moreover, timber harvesting methods that harmonise long term productivity, especially for co-existing NTFPs vulnerable to loss of forest cover should be integrated into silvicultural systems. Harve sting of NTFPs within cutting cycles of timber will ensure continuous revenue for rural livelihoods.

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Factors Influencing Spatio-Temporal Variation of Urban Green Space in Ado-Ekiti Metropolis

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Abstract
Geographic Information Systems (GIS) and Remote Sensing (RS) have proven to be an accurate means of determining Urban Green Space (UGS), extent and pattern of changes in land use land cover of a large area of land over time. However, there is dearth of information on spatial variation of UGS and its perceived factors in Ado-Ekiti. Therefore, this study adopted RS and GIS techniques to determine the factors responsible for the UGS changes in Ado-Ekiti metropolis. Map of Ado-Ekiti metropolis and Landsat imageries of 1987 (TM), 1998 (TM) and 2019 (OLI) were obtained. A set of 112 well-structured questionnaire was randomly administered to respondents in the study area. Map of Ado-Ekiti was georeferenced and digitized to obtain its shapefile. Landsat imageries were classified using the maximum likelihood algorithm of supervised classification in ArcGIS. The shapefile was superimposed on the classified imageries and clipped for determination of land use land cover sizes. The questionnaire were analyzed to determine the perceived factors responsible for the spatial variation in the UGS using logit regression model in STASTICA. Four land use land cover; Green spaces, Built-up area, water body and bare land, were identified in Ado-Ekiti metropolis. The UGS decreased from 76.1% in 1987 to 32.1% in 2019. In the same vein, water body reduced from 0.3% to 0.1% in 1987 to 2019 respectively. However, built up area and bare land increased from 20.3% and 7.5% to 54.6% and 13.2% in 1987 to 2019, respectively. Spatial and temporal variation in UGS was significantly influenced by population growth (103760.20 Odds-Ratio) and demand land for agriculture (15.53 Odds-Ratio) as represented with the equation FAUGS =-26.78+11.50(PG) - 20.20(Poverty) – 15.04(LLE) - 12.59(DT) + 2.74(AGR). However, other factors, whose contributions were not significant include lack of law enforcement, demand for timber and poverty.

Keywords: Land use cover, urban green space, geographic information system (GIS), remote sensing (RS) and perceived factors,

INTRODUCTION

Urban greenspace is the publicly managed vegetative areas within an urban environment such as forested land, wilderness, street trees, parks, gardens, backyard gardens, geological formations, coastal areas and agricultural lands (McIntyre *et al.*, 2000). There has been growing interest in green space research as it has a positive influence on human well-being and livelihood (Agbelade, *et al.*, 2017). Urbanization is rapidly evolving throughout the world. It is an inevitable process that goes along with economic development and rapid population growth. According to UN, (2007), 70 percent of the global population will live in urban areas by 2050 as cities now house slightly more than half of the world's population. According to Rimal, (2011), when the residential and commercial land uses at the peripheral of metropolitan areas are converted to green environment, this is considered to be a sign of regional economic liveliness whose benefits are increasingly unbiased against ecosystem impacts. Urbanization processes in Ado-Ekiti metropolis is envolving and have generated some geomorphological impacts in the city. The increase in infrastructural development in this city has transformed the city and the land use pattern into a more vibrant urban settlement. The expansion of the city both demographically and spatially has affected the plant biodiversity and the rapid population growths have impacted negatively on the plant conservation. The rate of these changes in green space is not well defined and documented which invariably will lead to poor urban green space management and environmental planning. Alo and Akindele (2011) reported that information in forestry sector was scares or where available, may not be up-to-date. Therefore, the status, extent and changes over time of UGS in Ado-Ekiti is not currently known. Although, previous study on land use land cover measurement in Ado-Ekiti metropolis focused on qualitative analysis, that is, changes in land use land cover changes in terms of spacing, increased pollution and waste generated (Oriye, 2013). However, there is limited information on the quantitative aspect of UGS in the study area. Therefore, this study aimed at determining the changes in the urban green space of the study area between 1987 and 2019 and the factors responsible for these changes.

METHODOLOGY

Study Area

Ado-Ekiti metropolis is located on latitudes 7° 35′ and 7° 39′ N of the Equator and Longitudes 5° 10′ and 5° 19′ E of the Greenwich Meridian. It is situated to the North of Ikere-Ekiti, West of Are-Ekiti and Afao-Ekiti, East of Iyin-Ekiti and Igede-Ekiti, and south of Iworoko-Ekiti (Figure 1). The low relief and gentle gradient characteristics of Ado-Ekiti favour agricultural and construction activities and make much of the metropolis susceptible to erosion and flood hazards during the rainy season (Awosusi and Jegede, 2013). Ado-Ekiti has a plan metric area of about $884km^2$. Geologically, the region lies entirely within the pre-Cambrian basement complex rock group, which underlies much of Ekiti State (Awosusi and Jegede 2013). The temperature of this area is almost uniform throughout the year, with very little deviation from the mean annual temperature of 27°C. February and March are the hottest 28°C and 29° C respectively, while June with a temperature of 25°C is the coolest (Adebayo, 1993; Nwatu, 2018). The mean annual total rainfall is 1367 mm with a low co-efficient variation of about 10%. Rainfall is highly seasonal with well-marked wet and dry season. The wet season is between April to October, with a break in August.

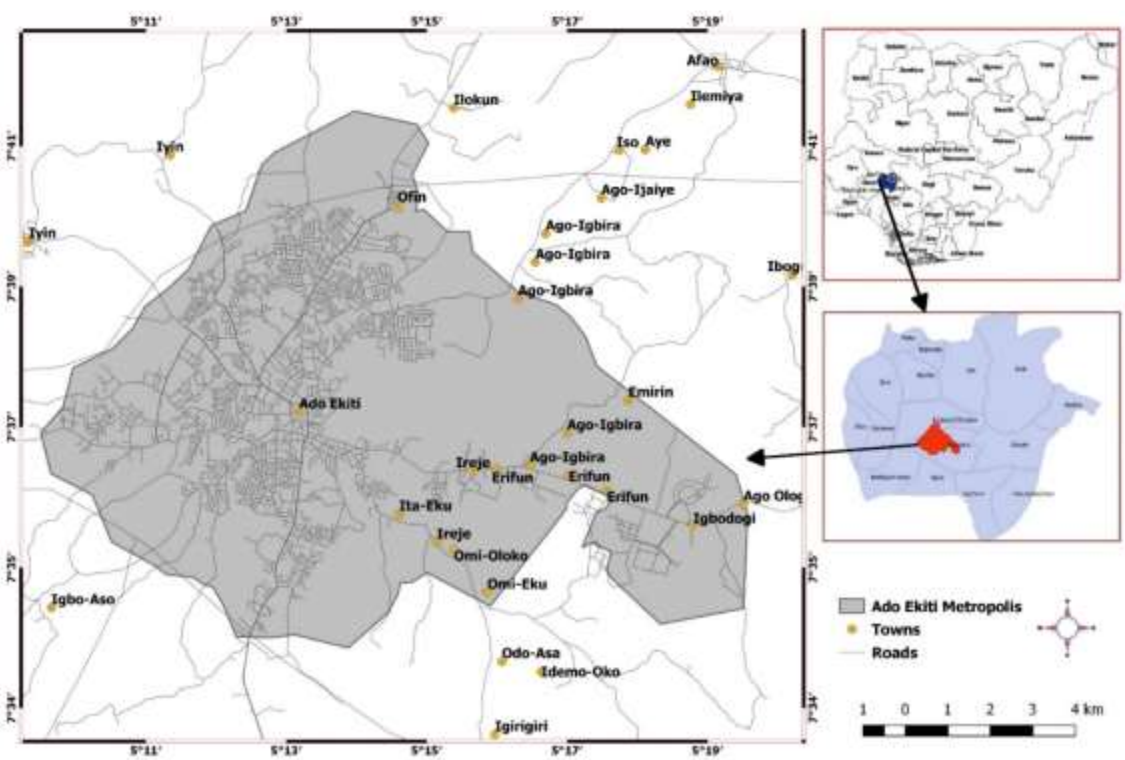

Figure 1: Ado-Ekiti metropolis

Source: Adapted from Abegunde et al., (2018)

Data Collection

Image acquisition and classification

Landsat imagery data were downloaded from USGS Earth Explorer. The Thematic Mapper (TM) imagery of 1984, 1998 and Operational Land Imager (OLI) imagery of 2019 were downloaded. The spatial resolution of landsat imageries is 30 m. They were used for image classification. Vector data used includes the shapefile of Ado-Ekiti metropolis, which was digitized. This study utilized Maximum Likelihood Classification Algorithm for the classification. The supervised classification method using the Maximum-Likelihood Classification (MLC) was used to classify the imageries into two land cover categories; Forested and Non-Forested (Built-up, Water and Bare surface) classes. Visualization and change detection maps were done using ArcGIS software.

Table 1. Satellite data

Satellite id	Year	Sensor id	Path/row	Spatial resolution
Landsat 5	1987, 1998	TM	190/55	30 m
Landsat 8	2019	OLI/TIRS	190/55	30 m

Table 2: Adopted modified version of the Anderson scheme of land use/cover classification.

LULC Categories	Description
Built-up area	Residential, commercial and services, transportation, communications, and utilities, industrial and commercial areas
Vegetation	Cropland, orchards, vineyards, nurseries, and confined feeding operations, plantation and mixed forest
Bare land	Sandy areas, barely exposed rock, transitional area and open land
Waterbody	Streams, lakes, and reservoirs

Source: Monica Cavinaw Geography, (2007)

Change Detection Analysis

It involved the comparison of independently classified images of different intervals. It aided in identifying the rate of change in percentage that has occurred within the selected years. To achieve this, the area in hectares and the percentage of each year was determined. This was calculated using the following equations:

$$\%\Delta \text{ in year} = \frac{Y_2 - Y_1}{Y_1} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(eq. 1)}$$

$$\text{Average Rate of Change} = \frac{Y_2 - Y_1}{T_2 - T_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(eq. 2)}$$

$$\%\text{Average Rate of Change} = \frac{\text{Average Rate of Change}\left(\frac{\text{ha}}{\text{yr}}\right)}{\text{Years Difference}} \times 100 \quad \ldots\ldots\ldots\ldots \text{(eq. 3)}$$

Where: $Y_2 - Y_1$ is the observed change; $T_2 - T_1$ is the difference between the final period and the initial period; Y_2 is the ending year; Y_1 is the starting year

Accuracy assessment

To determine the level of error in the classification, an accuracy assessment was carried out. This involves comparing the classified and actual reference unit, an error matrix table was formed. According to Olofsson *et al*., (2013), the matrix reveals errors of commission and omission. The User accuracy (Ua) and Producer accuracy (Pa) and overall statistics were calculated. To determine the accuracy of image classification, kappa statistics was used. It measures the agreement between the reality and the model predictions or to know if the error matrix values represent a result significantly better than random (Jensen 1996, Congalton 1991). It was computed using equation4.

$$k = \frac{N \sum_{i=I}^{r} x_{ii} \sum_{i=I}^{r} x_{ii(x_{i+} x_{+i})}}{N^2 - \sum_{i=I}^{R} (x_{i+} x_{+i})} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(eqn.4)}$$

where N = total number of sites in the matrix; R = number of rows in the matrix; x_i = number in row i and column i; x_{+i} = total for row i; x_{i+} = total for column i; x_{ii} = total number in row i column i

UGS Perceived Factors

A total of 112 structured questionnaire was administered using simple randomization within the locals in the metropolis. These comprised 56 questionnaire each for households and the government officials in Ministries of Land and Housing Planning, Environment and Forestry. This was done to capture the views of both the elites that might be well informed with data and residence that might know the history of the metropolis. The retrieved questionnaire was coded and analyzed using Logit regression model in STATISTICA to determine the perceived factors that contributed significantly to the spatio-temporal variation in UGS in Ado-Ekiti metropolis.

RESULTS AND DISCUSSION

Table 3 showed the land cover classified in the study area from 1984 to 2019. There was a significant loss in UGS in Ado-Ekiti from 76.1% in 1987 to 32.1% in 2019. This loss in UGS is gained by built-up area and bareland, which consequently increased from 20.3% and 7.5% in 1987 to 54.6% and 13.2% in 2019 respectively. The percentage change in the UGS in Ado Ekiti metropolis between 1998 (64.4%) and 2019 (32.1%) was more than changes recorded between 1987 (76.1%) and 1998 (64.4%). The high percentage change recorded between 1998 and 2019 could be as a result of the creation of Ekiti State in 1996 from the old Ondo State. As a result, there was rural-urban drift to Ado-Ekiti as the capital of Ekiti State, thereby increasing the social infrastructures and amenities in Ado-Ekiti. Therefore, increase in population growth within the metropolis led to increase in demand for land, for infrastructural developments and other human related activities which had effect on the green spaces in the study area. This is in line with the findings of Agboola (2019), that a considerable change in the pattern and process of land use in Ado-Ekiti metropolis had effect on it land cover. This is also corroborated by Kong and Nakagoshi (2005) and Anqi and Edwin (2019) that UGS reduction was influenced by urban sprawl, which also increase the population and consequently increased the built up area. In a similar finding, Alo and Aturamu (2014) argued that increase in infrastructure and population significantly reduces forestland. Our result indicated drastic reduction in UGS which is a threat to biodiversity conservation, increase in land surface temperature of the city and harsh climatic conditions.

Table 3: Land Cover Classification (1987, 1998 and 2019)

	1987		1998		2019	
Classes	Area (km²)	Area (%)	Area (km²)	Area (%)	Area (km²)	Area (%)
Green Spaces	89.7	76.1	75.8	64.4	37.8	32.1
Built-Up	20.3	17.2	34.8	29.5	64.3	54.6
Bare Soil	7.5	6.4	7.1	6.0	15.6	13.2
Water Body	0.3	0.3	0.1	0.1	0.1	0.1
Total	117.8	100	117.8	100	117.8	100

Land Use Land Cover Trend

Figure 2 showed the trend in the changes in the land use land cover of Ado-Ekiti metropolis between 1987 and 2019. It showed the rate at which each land cover changes over the years and the changes in the land cover for each year considered (Figure 3-5). Area covered by built up area increased from 1984 through 1998 to 2019. The changes in the land use is related to the discovery of Agboola (2019) that both in population size and spatial coverage, Ado-Ekiti has experienced continuous and unprecedented growth. And this can be attributed to factors such as rural-urban migration, residential development, economic growth and pattern of transportation routes.

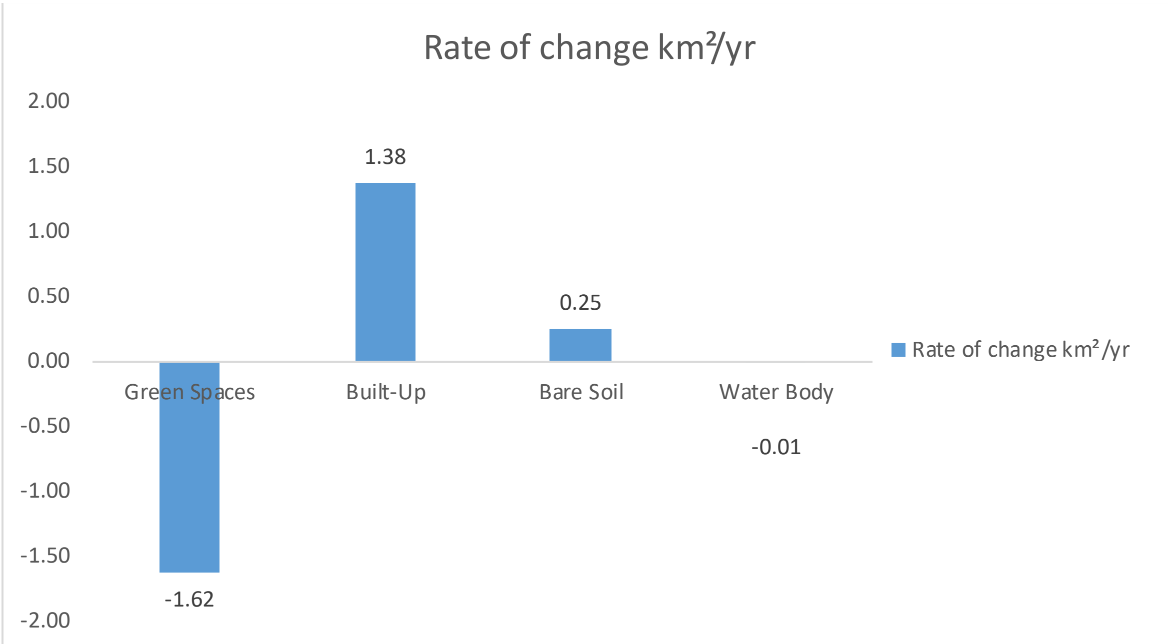

Figure 2. Land Cover trend between 1987 and 2019

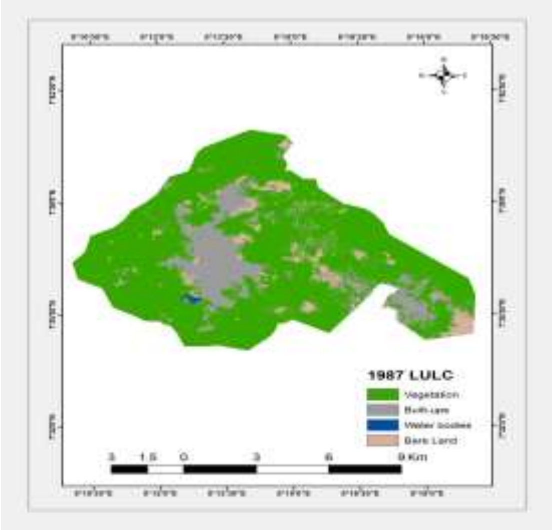

Figure 3: 2019 Land cover changes for year 1987

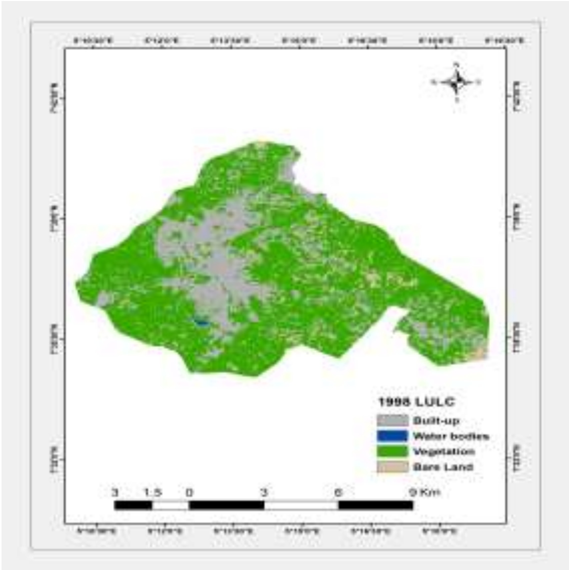

Figure 4: 2019 Land cover changes for year 1998

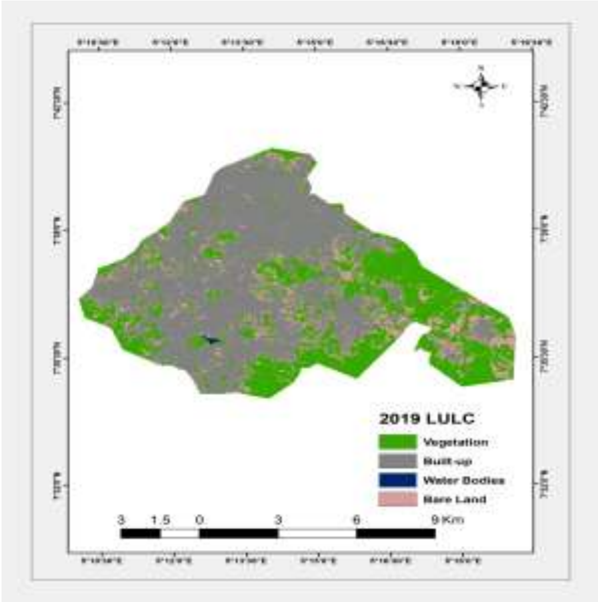

Figure 5: 2019 Land cover changes for year 2019

Image Accuracy Assessment

The accuracy assessment gives user's accuracy (Ua), producer's accuracy (Pa), Kappa statistics (k) and overall accuracy for the years considered for the land use land cover trend analysis. Table 4 indicates classification accuracy for user's accuracy (Ua), and that producer's accuracy (Pa) was greater than 50%. The kappa statistics that show the level of accuracy for 1987, 1998 and 2019 were 0.87, 0.79 and 0.85 respectively. The overall accuracy for 1987, 1998 and 2019 were 78.1%, 88.75% and 91.3% respectively.

Table 4: 1987, 1998 and 2019 Error matrix

LULC	**1987**	**1998**	**2019**
	Pa Ua	***Pa, Ua***	***Pa, Ua***
Green spaces	85, 77.3	81.8, 85	90.9, 100
Built-up	75, 88.2	100, 85	83.3, 100
Bare Surface	68.2, 75	88.9, 80	93.3, 70
Water body	85, 73.9	87, 100	100, 95
Kappa statistics	0.87	0.79	0.85
Overall accuracy	78.1%	88.75%	91.3%

Factors Influencing Urban Green Space Dynamics

Table 6 shows the logit regression determine the most significant factor affecting urban green space dynamics. Population Growth had the highest (103760.20) odds-ratio. This was followed by agriculture (15.53), while Poverty, Lack of law enforcement and Demand for Timber had 0.00 odds-ratio. The model indicated that, Population growth contributed significantly to change in the UGS in the study area. This was followed by quest for agricultural for food production. However, the contributions of other factors were not significant to the saptio-temporal variation of UGS in Ado-Ekiti. The model is represented with equation (1).

FAUGS =-26.78+11.50(PG) - 20.20(Poverty) – 15.04(LLE) - 12.59(DT) + 2.74(AD)............ (equation 1)

n = 112, Final loss=1.90

Odds ratio (unit change): Constant (-26.7658); PG (103760.2); POVERTY (0.00); LLE (0.00); DT (0.00); AD (15.53).

Where FAUGS = Factors Affecting UGS

LLE = Lack of Law enforcement

PG = Population Growth;

DT = Demand for Timber;

AD: = Agricultural Demand

UGS: Urban Green Space

Table 5. Increase in Population

	Frequency	Percentage (%)
Increase in Population		
Yes	95	84.8
No	17	15.2
Total	**112**	**100.0**
Change in LULC		
Yes	98	87.5
No	14	12.5
Total	**112**	**100.0**

Table 6. Logistic binary nature of perceived factors that influenced urban green space dynamics

Dependent Variable (LULC): Perceived factors that influence UGS (Presence = 1; Absence = 0		
Independent Variables	**Coefficient**	**Odds-ratio**
Whether the presence of PG influence the change in UGS	11.50	103760.20*
Whether the presence of Poverty influence the change in UGS	-20.20	0.00
Whether the presence of LLE influence the change in UGS	-15.04	0.00
Whether the presence of DT influence the change in UGS	-12.59	0.00
Whether the presence of AD influence the change in UGS	2.74	15.53*
Model χ^2 (df = 6) = 2.68		

* = significant ns = Not significant

PG: Population Growth; LLE: Lack of Law enforcement; DT: Demand for Timber; AD: Agricultural Demand; UGS: Urban Green Space **χ^2 = Chi-sqaure**

Based on the model fitted to discover the most significant factors affecting the change in urban green space, out of the factors: poverty, population growth, lack of law enforcement and demand for timber and agriculture, increase in population due to rural-to-urban migration and increase in birth rate was the factor with highest level of significance followed by agricultural demand for food security. This implies that increase in a unit level of significance of these factors will have effect on the land use land cover of the study area.

CONCLUSION

There were variation in urban green space in Ado-Ekiti between 1984 and 2019 with a significant decrease over the years. However, the built up area and bareland have taken over the loss by urban green space. Two factors that contributed significantly to the spatio-temporal variation in urban green space in the study area were population as a result of urban sprawl, and agricultural demand for food security.

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Influence of Plant and Animal Based Fertilizer on Growth and Yield of *Abelmoschus esculentus L.*

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Abstract

This study was carried out to investigate the effects of plant and animal based fertilizer on the growth and yield of two different varieties of Okra. The experiment was designed using the Completely Randomized Design (CRD). The study was carried out using different treatments such as; *Chromolaena odora*, *Tithonia diversifolia*, cow dung and poultry manure. Ninety (90) Polythene pots were filled with top soil and they were replicated thrice. Thirty (30) pots on each of the three replicates and each treatment were replicated three times. The *Abelmoschus esculentus* seeds were sown directly into the polythene pots and the germination of seed was first noticed seven days after planting. The parameters were assessed for growth were number of leaves, fruit length, leaf area, average fruit weight, plant height, stem diameter, number of fruits and fruit yields. Data obtained from parameters assessed were subjected to Analysis of Variance (ANOVA). The result obtained revealed that poultry manure had the best performance in all parameters assessed. This indicated that poultry manure had impact in development of *Abelmoschus esculentus.* Data obtained from parameters assessed were subjected to Analysis of Variance (ANOVA). Poultry manure performed best in all parameters assessed while the control had the least performance. It can therefore be concluded based on the result obtained from this experiment that poultry manure had the best influence on the growth and yield of *Abelmoschus esculentus.*

Keyword: Manure, okra, yield, growth and fertilizer.

INTRODUCTION

Okra (*Abelmoschus esculentus* L.) is one of the most important vegetable grown in Nigeria. It is an annual crop grown mainly as fruit and leafy vegetable in both green and dried state in the tropic (Wiesmeier *et al.,* 2015 and Gibbon, 1983). The crop is used as soup thickener which may also serve with rice and other food types; the fruit is a good source of vitamin, mineral and plant protein. Okra contains about 20% edible oil and protein, which its mucilage is utilized for medicinal purposes (Eke *et al.*, 2008). Also, Okra is one of the most important warm season fruit vegetable grown throughout the tropical countries. It is also recognized as one of the world oldest cultivated crops. It shows a wide adaptability and is cultivated in various regions of the country either as a home garden crop or on a commercial scale. The main stem contains crude fiber which is used in paper industries and for making rope. Okra flower can be very attractive and sometimes used in decorating rooms (Schippers, 2000). Okra plays an important role in vegetable market during summer season when the supply of vegetable is acute (Schippers, 2000). But unfortunately, the production of this population vegetable is very low according to demand. So, the production of this vegetable should be increased to meet the increasing demand.

In Nigeria, Okra is widely grown, distributed and consumed either fresh or dried form (Fatokun and Cheddar, 1983).Its fruits are used as vegetable; boiled, sliced and dried. It is mainly grown by many farmers because of its tender texture which is highly mucilaginous and useful in soup thickening. The seed can be very used as a source of edible oil as well as in the soup industry (Oyolu, 2017). It is cultivated in irrigated area on a wide range of soil. It is much appreciated because it continues fruiting even during the dry season when only few other vegetables can be found. The plants also remain green during period of drought, thus allowing people to eat its young leaf needed, but production is seriously affected by the use of different varieties and inappropriate manure doses. Organic manure, if properly used, is essential for the growth and yield of Okra (Wiesmeier *et al.*, 2015). Vegetable cultivated in one of the greater enterprises in horticulture which is becoming more popular due to the greater appreciation of their food value (Gardner, 2004), vitamins and minerals (Adeboye, 1996). Vegetable contribute an important part of the diet to many people, in the tropics more essential the most commonly grown vegetable throughout Nigeria. It is cultivated for its fresh fruit in both tropical and sub-tropical countries (Philips, 1997). The stem yield is useful as fiber and the leaves are considered good cattle feed and are consumed sometimes. The seeds however can be roasted and are used as substitute for coffee. The essential amino acid which okra contains is comparable to that of Soybean (Farinde and Owolarafe, 2007).

In addition, Okra requires a lot of nutrient to perform well; therefore prior to sowing, it is recommended that organic material reduce the introduction of acid and chemical to the soil. Organic manure improves soil fertility by activating soil microbial biomass (Ayuso, *et al*., 1996). Application of manure sustains cropping system through better nutrient cycling (El-Shakweer, *et al*., 1996). Manure provides a source of all necessary macro and micro nutrient in available forms, thereby improving the physical properties of the soil (Abou-El-Magd, 2006). The organic matter of the soil which can be replenished and maintained by the application of animal manure has been considered as the life of soil as well as store house of plants nutrients especially nitrogen, phosphorus, potassium and macro nutrients as well prevent leaching of nutrient. Poultry manure and cow dung manure are very good source of organic matter and play a vital role in soil fertility improvement as well as supplying primary, secondary and macro nutrient for crop production. Although, the organic manure contains nutrient in small quantity as compared to the organic or chemical fertility, its application promotes constituents like enzymes and hormones and them useful for improvement of soil fertility and productivity based on the important of *Abelmoschus esculentus* being used for many purpose, and it is socio economic importance of the life of the people together with its various importance for example as source of food in many part of Africa including okra seed as non-caffeinated substitute for coffee. It serves as source of iron and calcium, all these importance necessitated the need to determine the best medium of raising species. The best treatment requires growing *Abelmoschus esculentus* seedling so as to have healthy stock for field establishment, to meet its population demand and also to serve as a basic necessity for improving the farmers' economy. This study is, therefore, conducted to determine the effect of both plant and animal based fertilizer on the growth and yield of Okro.

METHODOLOGY

Location of the Experiment

The experiment was conducted at the National Horticultural Research Institute (NIHORT) Ibadan, Oyo State. The location lies on $7^0 23^1$ N, $2^0 50^1$E and 158m above sea level. The area has a humid tropical climate characterized an annual rain. The area experienced two distinct season which are dry season usually from November to March and rainy season from April – October. The Materials used for the experiment are seeds of okra (*Abelmoschus esculents*), polythene pot (medium size),hoe, loamy sand, poultry manure, cowdung, *Tithonia diverrsifolia* (Mexican sun flower), *Chromolaena odorata* (siam weed), watering can, transparent measuring ruler (30cm), venier caliper and tape rule.

Method

Ninety (90) polythene pots were filed with soil, in which three (3) replicate were made. Thirty (30) pots on the first replicate, thirty (30) pots on the second replicate, and thirty (30) pots on the third replicate .The *Abelmoschus esculentus* were sown directly into the pot and the germination of seed was first noticed seven days after planting. Watering of *Abelmoschus esculentus* was carried out twice a day, morning and evening, while weeding is done anytime weed are noticed in each perforated polythene pots before fillings with soil so as to prevent the plant from being water-logged. The parameters that were assessed at the end of the germinations were the number of leaves; leaf length; plant height; stem diameter ; number of fruits; fruit length; fruit weight (kg) and fruit yield/plant (kg).

Data Analysis

The data collected were subjected to Analysis of Variance (ANOVA) to determine the differences. Duncan Multiple Range Test (DMRT) was used to separate the mean.

RESULTS AND DISCUSSIONS

The result in Table 1below revealed that there was significant difference in the treatment for plant height of okra plant. At 8 weeks, Poultry on NHAe47-4 had the highest plant height with a mean of 34.75cm.It is in accordance with Jaja and Odomena (2004) who stated that poultry manure perform best in vegetable crop production and the least by 47-4NHAe with no manure while poultry on NHAE47-4(10) had the highest and the least by *Tithonia diversifolia* on

LD88 (8). It supported by Aliyu (2000) who reported that poultry manure brought about improvement in soil chemical property as well as physical property of the soil as shown in table 1 below.

TABLE 1: Effect of plant and animal based fertilizer on the growth and yield of okra on plant height and number of leaves

TREATMENT	Plant Height(Cm)			Number Of Leaves		
	4WAS	6WAS	8WAS	4WAS	6WAS	8WAS
Chromolaena odorata on LD88	15.10de	18.82cde	24.67cd	4.51ab	6.22a	8.89de
Tithonia diversifolia on LD88	16.15de	19.68cd	30.33b	3.78cde	5.22c	8.76e
Poultry on LD-88	15.23de	19.59cd	24.74cd	3.70cde	6.22a	9.43bcde
Cowdung on LD-88	20.01b	24.99b	29.44b	4.96a	6.20a	9.87abcd
LD-88 with no manure	13.87e	16.14e	23.92d	3.62cde	5.33bc	9.70abcde
Chromolaena odorata NHAe474	17.03cd	20.80c	27.61bc	3.89cd	5.22c	10.11abc
Tithonia diversifolia NHAe474	17.27a	20.68cd	23.22d	3.56de	4.78c	8.81e
Poultry on NHAe47-4	27.35a	29.73cd	34.75a	4.56ab	6.05ab	10.56a
Cow dung on NHAe47-4	19.18bc	21.37cd	23.50a	4.22bc	6.15ab	10.25ab
47-4 NHAe474 with no manure	13.61e	18.43de	23.32d	3.25e	5.53abc	9.13cde

Same alphabets along the column are not significantly different.
WAS - Indicates Weeks After Sowing

Table 2 below shows that there was significant difference in the treatments used in monitoring the growth of Okra plant. For stem diameter (cm), poultry on LD88 (2.29cm) had the highest stem and the least by LD88 with no manure (1.82cm) had the least stem diameter at 8 weeks after sowing while the result of leaf area (cm^2), *Tithonia diversifolia* on LD88 had the highest (587.98cm^2) and the least by cow dung on LD88 (218.23cm^2) at 8 weeks. This result of this study is similar to work of Wiesmeier *et al.*, (2015) who reported that green manure application to the soil significantly increase nutrients in the soil as shown in table 2 below.

Table 2: Effect of plant and animal based fertilizer on growth and yield of Okra on stem diameter (cm) and leave area (cm^2) of okra

	Stem diameter(cm)			Leaf area (cm^2)		
TREATMENT	**4WAS**	**6WAS**	**8WAS**	**4WAS**	**6WAS**	**8WAS**
Chromolaena odorata on LD-88	1.35cd	1.66cd	2.11ab	153.67de	248.33d	363.38d
Tithonia diversifolia on LD-88	1.62cd	1.79bc	2.26a	353.00a	484.08a	587.98a
Poultry on LD-88	1.43cd	1.83bc	2.29a	148.00de	370.06c	426.73c
Cowdung on LD-88	1.46bc	1.65cd	2.10a	126.00ef	173.57g	218.23f
LD-88 with no manure	1.13e	1.40e	1.82d	334.33a	425.72b	443.18c
Chromolaena odozxrata NHAe47-4	1.76a	2.12a	2.24a	238.00b	441.61b	476.18b
Tithonia. Diversifolia on NHAe47-4	1.32cd	1.64cd	2.02bc	178.67cd	215.67ef	265.87e
Poultry on NHAe47-4	1.71a	1.95ab	2.11ab	164.33cd	223.44efd	245.46ef
Cow dung on NHAe47-4	1.27de	1.50de	1.86cd	193.00c	205.53f	256.50e
NHAe47-4 with no manure	1.72a	1.89b	2.12ab	113.45f	234.67ed	273.02e

NOTE: Same alphabets along the column are not significantly different from one another.

Table 3 below discussed as regards average fruit, *Chromolaena odorata* on NHAe47-4 had the highest (10.86) and the least by NHAe47-4 with no manure (8.13). On number of fruits, *chromolaena odorata* on LD88 had the highest and the least by NHAe 47-4 with no manure (10.33). As regard fruit yield per plant (kg), *Chromolaena odorata* on LD88 had the highest fruit yield and the least by NHAe47-4 with no manure (84.09). This is in line with Ojeniyi, (2007) who stated that *Tithonia diversifolia* and *Chromolaena odurata* improves soil nutrient for crop productivity as shown in table 3 below.

Table 3: **Effect of plant and animal based fertilizer on fruit yield and yield components.**

TREATMENT	Fruit length	Average fruit Weight	Number of fruit	Fruit yield/ plant (kg)
Chromolaena odorata on LD-88	5.53c	10.32ab	16.00a	164.97a
Tithonia.diversifolia on LD-88	5.43c	9.57bc	13.67b	130.75cd
Poultry on LD-88	6.53b	10.56a	12.33bcd	130.87d
Cowdung on LD-88	6.47b	8.31de	11.33cde	93.94fg
LD-88 with no manure	6.67b	8.41de	11.33cde	95.22efg
Chromolaen odorata on NHAe47-4	7.53a	10.86a	14.00b	151.71ab
Tithonia diversifolia on NHAe47-4	6.60b	10.43a	13.00bc	135.33bc
Poultry on NHAe47-4	7.47	10.10ab	11.00de	111.06ef
Cow dung on NHAe47-4	7.47	8.96cd	12.67bcd	113.21de
NHAe47-4 with no manure	7.63a	8.13	10.33e	84.09g

CONCLUSION

Due to the fact that *Abelmoschus esculentus* is highly nutritious vegetable crop which is widely consumed, efforts had been made on how to improve the production of Okra crops. It is however, necessary to determine the best manure in improving the production of Okra crops. From data assessed which included plant height, number of leaves, stem diameter, leaf area, fruit length, average fruit weight and number of fruit shown that okra (*Abelmoschus esculentus*) responded well to the application of animal manure. Hence, the best growth performance exhibited by okra with animal and plant manure was statistically different. This could be used to minimize the cost of production; the use of poultry manure will improve soil organic matter and nutrient availability and the high yield because it contains 0.8% potassium, 0.48% phosphorous, and 1.49% nitrogen.

The following recommendations are made from the result obtained from this research. Poultry manure should therefore be used in the cultivation of Okra because of its economic importance and nutritional values to human. Further research should be attempted to optimize and derived advantages on different animal manure to be used as agricultural manure.

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Assessment of Stakeholders Participation in the Management of Odoba Forest Reserve, Ogbadibo Local Government Area, Benue State, Nigeria

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Abstract

The study was conducted to provide information on stakeholders' participation in the management of Odoba forest reserve due to paucity of information that could be used for decision making on its management. Semi-structured questionnaire was used to obtain data from 376 stakeholders sampled using the Taro-Yamane formula. Descriptive statistics and Participatory Index was used to analyze field data. The results of the study showed that the stakeholders participated more in the monitoring process with PI=0.64. The planning, implementation and benefit sharing process of the reserve all had low stakeholders participation of PI 0.40, 0.34and 0.20 respectively. The study concluded that the participation of the adjoining villages in the management of the forest reserve was generally Low across all four villages studied. Involving local people in the management of the reserve should be promoted by developing participatory management plan, such measures can improve rural livelihood and conserve forest resources and biodiversity.

Keywords: Stakeholders, participation, management, Odoba, forest reserve

INTRODUCTION

Globally, the forestry sector has been experiencing a paradigm shift from conventional-led forestry approach to Participatory Forest Management (PFM), in response to demands for greater equity in the allocation of forest resources and the failure of conventional-led forestry approaches to achieve objectives of sustainable development (Geoghegan, 2002). Participatory forest management is based on the hypothesis that if local people whose daily lives are affected by forest management activities are involved in decision-making, efforts can be made to maintain the integrity of the ecosystems and improve livelihood of the local people (Ferraro, 2000; Lise, 2000; Sekher, 2001; Sreedharan, 2002 cited by Glover, 2005). This approach enables marginal members of local community to voice preferences, make decisions and engage in local politics by which resources are allocated and distributed (Agrawal *et al*., 2006).

The PFM approach envisages improved forest resources management through people's participation, and this has advocated a major shift from the earlier timber-oriented, state-controlled management system (Westoby, 1987; Gilmour and Fisher, 1991; FAO, 2001; ADB/EC/FAO, 2003 cited by Glover 2005). Dalton (2008) defined participation as the ability of people to share, influence, control, design, partake in decision-making and authority in development projects and programs that affect their lives and resources. The integration of people's preferences and expectations in the decision making process is an important aspect of sustainable natural resources management (De Meo *et al*., 2015), thus increasing the social acceptance of the decisions and reducing conflict among users (Beierle 1998, Kangas *et al*., 2006). According to FAO (2015), participation of rural communities in forest resources management is necessary to ensure the sustainable maintenance of the resources. Indigenous people and their communities have a vital role in environmental management and development because of their traditional knowledge and practices (UNCED, 1992). The involvement of rural residents who are closer to the natural resources enclaves is important as Forestry Departments, have limited financial and human resources to ensure sustainable use of several hectares of land under their sole jurisdiction (Enuameh-Agbolosoo *et al*., 2015). Osumba (2011) adds that community participation could enhance sustainable use of forest resources, support the establishment of community forestry associations and protect the traditional interests of local communities customarily resident in and around forests. Forest management initiatives in Nigeria vary from one State to another (Ogar, 2001). Community based forest management practices exist in Benue State (Dagba *et al*., 2017). however, study on participation of people in the management of Odoba forest reserve has not been investigated. This study therefore assessed the involvement of adjourning villages in the management of Odoba forest reserve in Benue State for decision making and policy implementation.

METHODOLOGY

Study Area

The study area was conducted at Odoba Forest Reserve in Otukpa district of Ogbadibo Local Government Area (LGA) of Benue State. It is located between latitude 7° 08’ 34’’ - 7° 10’45’’ N and longitude 7° 49’ 16” -7° 51’29’’E. Bennett (1979) reported that the reserve has an area of 2.77 km^2 and was established for pole production with Teak (*Tectona grandis*) as the dominant tree species. Other species planted were *Gmelina arborea, Eucalyptus deglupta, E. torreliana and E. citriodora*. The forest reserve is adjoined by four communities; Ogonukwu, Epaiegbo, Eloga, and Odoba (Figure 1). According to Ofomata (1978), the land uses of Ogbadibo were Agriculture (farm land, 70%), commercial (markets, 10%), and institutions (Schools and religious buildings, 20%). The vegetation is made up of broad leafed species and herbaceous graminoids. The reserve is overseen by a Divisional Forest officer (DFO) who reports to the Director of Forestry in the State Ministry of Water Resources and Environment. The DFO is assisted in the reserve by field workers.

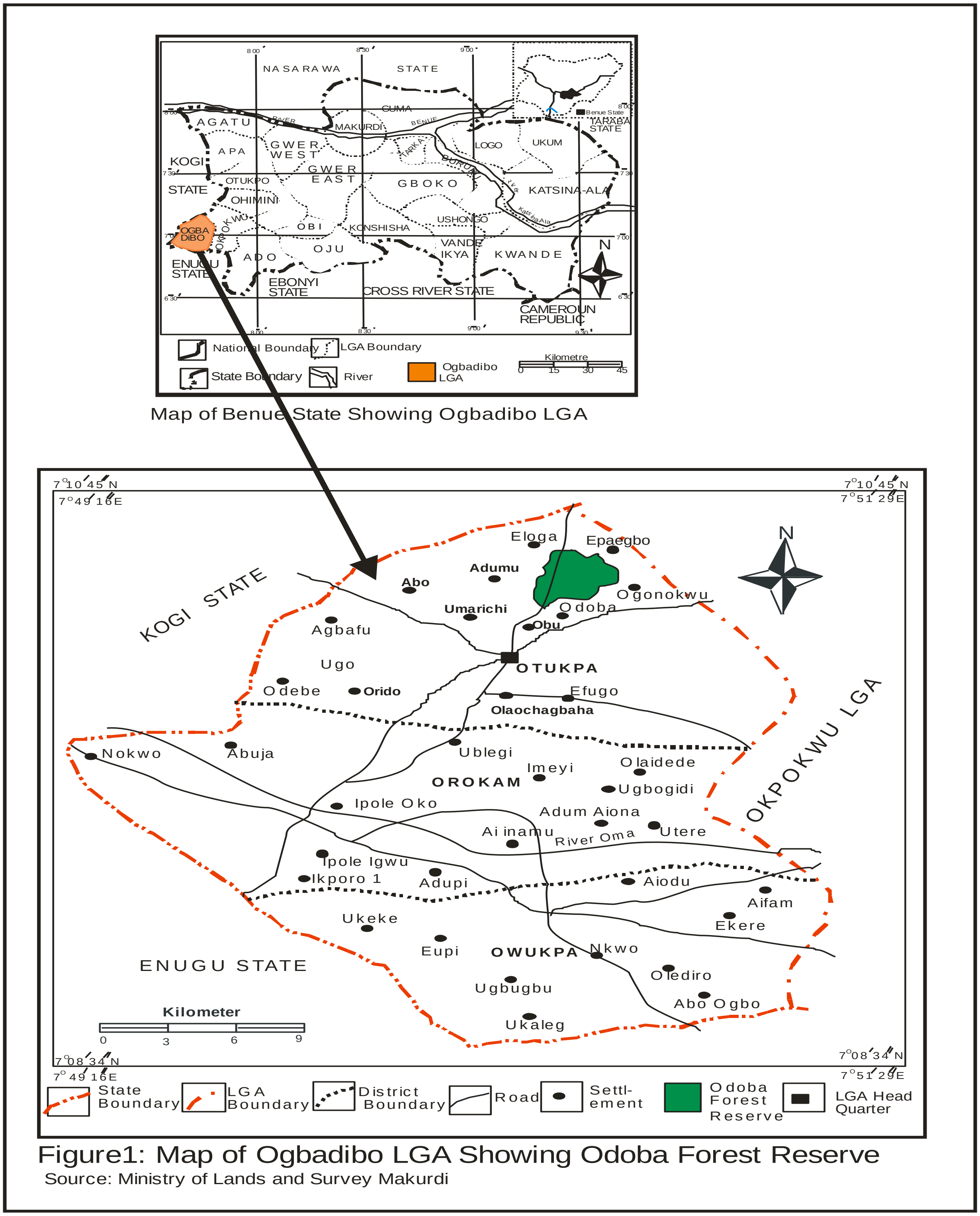

Figure1: Map of Ogbadibo LGA Showing Odoba Forest Reserve

Source: Ministry of Lands and Survey Makurdi

Population, Sampling Procedure and Sampling Size

The 2006 population figures of the adjoining communities were projected to 2016 (year study was conducted) using 2.8% growth rate as expressed by George et al., 2004).

$$P_t = P_o(1+r)^t$$

Where:
P_t = Population Projection figure for 2016 for any community
P_o = Existing population as at 2006
1 = Constant
r = Population Growth Rate (2.8%)
t = Number of years population was projected (10 Years)

Taro-Yamene (1967) formula was then used for determination of the projected population sample size as shown in (Table 1). Taro-Yamene formula is expressed as:

$$n = \frac{N}{1 + N(e)^2}$$

Where:
n = Projected population sample size
N = Total size of projected population
1 = Constant
e = Error degree of tolerance 0.05
The sample size of each community was determined using the formula:

$$nh = \frac{n \times Nh}{N}$$

Where
nh = Community sample size
n = Projected population sample size
Nh = Community Population (Projected)
N = Total size of projected population

The communities were purposely selected due to their proximity to the forest reserve. Systematic random technique was used to select households in each of the communities. The first household in each community was identified and selected for interview and thereafter every fourth household was selected. Two matured persons in each household were purposively selected for interview as they could provide useful information for the study. This procedure was maintained until the sample size for the community was obtained. Therefore, 376 Stakeholders were sampled for the study.

Table 1 Determination of Sample Size for the Study

		2006 Population	**2016 Projected**	**Community**
S/No	**Communities**	**Figures**	**Figures**	**Sample Size**
1	Odoba	1734	2285	136
2	Ogonukwu	954	1257	75
3	Epaeigbo	1409	1857	111
4	Eloga	689	908	54
Total	-	4786	6307	376

Source: National Population Commission, 2006 projected to 2016 using 2.8 % growth rate.
Sample size (n) = 376

Pre-tested semi-structured questionnaire was used to obtain primary data from the stakeholders. Data collected included socio-economic characteristics of stakeholders in the study area, and responses on level of participation in the management of resources in the forest reserve. Direct administration of the questionnaire at the stakeholders' homes was done with the support of research assistants.

Data Analysis

Descriptive statistics was used to analyze the socio-economic characteristics of the people as reported in (Ancha *et al*., 2019). The participation index (PI) was used to measure stakeholders involvement in forest resources management stages based on a five-point scale (always= 1.0, often= 0.8, occasionally=0.6, rarely= 0.4 and never= 0.2).The participation index for the various stages in forest management was obtained by using the method adopted by (Allahasan, 2010):

$$PI = \frac{[(fa*1)+(fo*0.8)+(fc*0.6)+(fr*0.4)+(fn*0.2)]}{N}$$

Where, PI = Participatory index for forest management stage

fa = frequency of respondent always participating in a particular management stage,

fo = frequency of respondent often participating in a particular management stage,

fc = frequency of respondent occasionally participating in a particular management stage,

fr = frequency of respondent rarely participating in a particular management stage,

fn = frequency of respondent never participating in a particular management stage,

N = Total number of stakeholders for each stakeholder category.

The value of PI can be interpreted on a scale of 0 – 1, where zero means primary stakeholder has no chance of participating and 1 means always participating. Increase in values from 0 – 1 implies increase in participation level of the stakeholder group with respect to the specific forest resources management stage.

RESULTS

The participatory indexof stakeholders' participation in the management of Odoba forest reserve is presented in Table 2. The stakeholders participated more in the monitoring process with PI=0.64. The planning, implementation and benefit sharing process all had low stakeholders participation of PI 0.40, 0.34and 0.20 respectively.

Table 2: Participatory Index of Stakeholders in the Management Odoba Forest Reserve

Management Stage	Participation Index (PI)
Planning	0.40
Implementation	0.34
Monitoring	0.64
Benefit sharing	0.20

Roles in Played Stakeholders in the Planning Process

Table 3 indicates that 4.1% of stakeholders' role in the planning process in the management of forest resources in the forest reserve was listening. 13.5% of stakeholders provided information, 5.6% of stakeholders disseminated information. While 3.0%, 63.8% of stakeholders provided suggestions and did nothing respectively as their roles in the planning process of the forest resources management in the study area.

Table 3: Stakeholders Roles in Planning Process of Odoba Forest Reserve, Benue State

Role in planning process	(F)	(%)
Dissemination of information	17	5.6
Listening	43	14.1
Providing information	41	13.5
Providing suggestion	9	3.0
None	194	63.8
Total	304	100

Roles Played by Stakeholders in the Implementation Process

Table 4 shows various roles of stakeholders in implementation of forest resources decision and activities. The result show that 15.1% of stakeholders were involved in tree planting, 10.9%respondent's s role was reporting illegal activities. Other roles by stakeholders are boundary clearing/tree planting 4.35% of stakeholders, 5.3% of stakeholders, refraining from illegal activities and 64.5% of stakeholders did nothing.

Table 4. Stakeholders Roles in Implementation Process at Odoba Forest Reserve, Benue State

Role	(F)	(%)
Boundary clearing	13	4.3
Reporting illegal activities	33	10.9
Refraining from illegal activities	16	5.3
None	196	64.5
Total	304	100

Roles in Played Stakeholders in the Monitoring Process

The result in table 5 indicates roles performed by stakeholders in forest monitoring process. The result showed that 3.6% stakeholders took part in enforcement of local laws monitoring aspect of the management of the forest resources of the reserve in the study area. Other roles performed by stakeholders in the study area are; implementing forest projects which covers about 29.6% of stakeholders, those that took part in decision making are 12.5% of stakeholders, and those that took part in reinforcement and surveillance team were 24.3% stakeholders

Table 5: Stakeholders Roles in monitoring and evaluation Process of Odoba Forest Reserve, Benue State

Role	(F)	(%)
Take part in decision making	38	12.5
Enforcement of local laws	102	33.6
Implementing forest projects	90	29.6
Part of reinforcement and surveillance team	74	24.3
Total	304	100

DISCUSSION

The results on participation index show that participation is generally low across all four key areas of participation in the studied. However, participation in benefit sharing had the least (PI= 0.2).This implies that the attendance of majority of stakeholders" in forest resources management activities remain low, particularly in sharing of benefit accrued from forests. These results contradicts study done by Patwary (undated, cited by Quazi *et al*.,2008) in Bangladesh who reported that local people were mostly involved in sharing of benefits derived from the forest in co-management with wildlife sanctuary, and considerably less involved in planning and evaluation processes. The participation index is high in monitoring, planning and implementation compared to benefit sharing because the collaborative system approach is gradually engendering forest dependent community's participation in those areas as compared to benefit - sharing. According to studies carried out by Amanor (2004), Marfo (2001) and Wily (2001), participation in forest resources management and decisions (especially in benefit-sharing) revolves around the chiefs and elites who still remain most powerful actors in the forest sector, and are not fully accountable to their community members. These findings also corroborated with recent literature on natural resources decentralization and devolution, which argues that local elites at the community level do capture benefits intended for poorer groups (Platteau and Gaspart, 2003; Shackleton *et al* ., 2002; Kumar 2002 cited by Behera and Engel, 2005). Another possible explanation for the low involvement of stakeholders in forest management may be due to the poor partnership that exists between the forestry agencies and local communities. Under the collaborative system approach, Kotey *et al*. (1998) and Marfo (2007) have reported that the relationship between the Forest Services Division (FSD) and local people has historically been one of mistrust and plagued with conflicts, and this has affected local people's involvement in forest resources management.

This result is consistent with many studies including Kotey *et al*. (1998); Amanor (1999); Ganz *et al*. (2003) Borrini - Feryerabend *et al*. (2004) and Eshun (2008) they all reported that forest resources management is hitherto characterized by extensive state forest agencies involvement with little recognition of the potential of forest - dependent communities for achieving positive long - term sustainable forest management. The implications are that resource managers continue to view forest - dependent communities as a threat to the reserve and inimical to its sustainability. This has reflected in the pre-determined ways and roles designated for stakeholders management of the reserve. The results therefore re-enforced the need to re-examine policies relating to stakeholders participation in forest resources management. Major roles of stakeholders in planning process of the forest reserve management were; dissemination of information, listening, providing information and providing suggestions. The major roles of stakeholders in implementation stage were tree planting /establishment of fire breaks. Other roles were boundary cleaning, reporting illegal activities and refraining from illegal activities. The major roles of the stakeholders in monitoring process were enforcement of local laws, implementing forest projects and part of reinforcement and surveillance team. On benefit sharing of the forest resources management of the forest reserve, the result shows that less than one quarter of all the stakeholders were involved in benefit sharing. This corroborates with Behera and Engel (2005), their study suggests modified taungya system in the reserve to engage households in forest regeneration efforts as well as the sharing of benefits from such efforts. The major roles of stakeholders were tree planting and reporting illegal activities. This corroborates work done by Wily (2002) and Amanor (2003) who reported that under the collaborative system approach, state forestry agencies have involved local people in management functions such as boundary cleaning, tree planting and establishment of firebreaks among others. The mechanism for promotion of forest - dependent communities' involvement has been the establishment of Community Forest Committees (CFCs) in communities around the edge of forest reserves Amanor, (2003).

CONCLUSION

The participation of the adjoining villages in the management of the forest reserve is generally Low across all four key areas of participation studied, participation index in benefit sharing had the least PI=0.02. The forest adjoining villages should be carried along in the management of the reserve (i.e. participatory forest management). Involving local people in participation in management of the reserve should be promoted by developing participatory management plan, such measures can improve rural livelihood and conserve forest resources and biodiversity. Summarily, to enhance optimum cooperation from local people and achieve sustainable conservation and utilization of the forest resources, greater stakeholder participation is recommended in the design of any management plan.

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Mapping and Assessment of Some Settlements in Oluwa Forest Reserve Using Geographical Information System

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Abstract

Ever since Oluwa forest reserve was created, some people make the reserve their abode and also depending solely on resources from the forest reserve and also they cultivate and also earn their living through the forest resources. There is need for the creation of a map of a map, identification and assessment of how these communities had been with the evaluation of the basic amenities present and also to create a map of the forest reserve with respect to the various communities identified. A geo-referenced map of Oluwa forest reserve showing all the settlements located within the reserve was prepared using the Geographic Information System (GIS) technique. A list of communities was obtained from the forestry officials and also with aid of Google earth imagery, locations of the communities were obtained for easy access. The coordinates were saved in text (tab delimited) file format in Microsoft Excel spread sheet, this was loaded into QGIS 2.18.3 for further analysis using the Coordinate Reference System of WGS84 for the final map production showing all the identified communities with the roads linking them up. A semi-structured questionnaire was administered to key individuals (mostly community heads or experienced individuals who knows the history of the communities identified) in each community stating and assessing all the community needs as well as to know the relationship between the communities and the forestry officials to produce the attribute data for the data to each community identified. A total of 49 settlements were identified within the forest reserve, the geographic coordinate of the communities were taken at various strategic places in each community using the Global Positioning System (GPS). In getting the appropriate quantitative data for analysis, the questionnaire was coded showing the various responses. The data were subjected to descriptive statistical analysis using Statistical Package for Social Sci entists (SPSS) software. It was shown that 46.86% of the communities have a relationship that is not too cordial with the forest officials, 30.61% have cordial relationship with the forest officials, 14.29% have no relationship the forest officials and 12.24% have a very cordial relationship with the forest officials The results also showed the various demographic characteristics and others attributes of the communities represented and the map of the forest reserve showing all the communities identified and the roads linking them.

Keyword: Geographical Information System, forest reserve, mapping, assessment, attribute data

INTRODUCTION

Every year the global forest records serious damage which varies in location. As a result of the various importance the forest has for man and the environment, this has increased the pressure on the global forest. The need for assessment is important so that the various forces contending for various the resources from the forest would be known.

The contribution of forest resources to the livelihood strategies of the rural poor had long been appreciated and seen as significant for a very long time Salafsky and Wollenberg, (2000). According to Belcher (2003), prior to the establishment of forest reserves, the various communities believe the land belong to the communities due to the fact that they have occupied the land for a long period of time and this has really caused so many problems as the famers who are occupants of the land have established on the land perennial crops, like cocoa, kolanuts and some go as far as having their buildings on the forest reserves, and these people spread themselves into every part of the reserves as they grow into large communities.
According to Anon, 1955, the communities that have established themselves in the forest reserves have some specific rights in relation to their livelihood. These include:

i. The rights to collect edible fruits, thatching leaves and other NTFPs
ii. Right to hunt and fish
iii. Right to tap rubber under permit, and
iv. Right of way along certain specified paths

According to Aruwajoye and Ajibefun (2013), some people make the reserve their abode and also depending solely on resources from the forest reserve and also they cultivate and also earn their living through the forest resources. The need to create an up-to-date map of the forest reserve showing the various communities present, apart from the satellite imagery of the area which when to be acquired is sometimes expensive to procure is part of the reasons for this study. There is need for the identification and assessment of how these communities had been with the evaluation of the basic amenities present and also to create a map of the forest reserve showing the various communities present.

Geographic information system (GIS) has been seen as a tool in forestry that is important in the evaluation and the proper assessment of the various available forest resources. Geographical Information Systems (GIS) is an information technology that has been used in public policy-making for environmental and forest planning and decision-making over a long time. For effective forest management system, it is important to obtain relevant information about the forest communities dwelling in the forest reserve. Such information will include their location, population, and some other attributes, these information will be obtain through the use of Geographic Information System. The general objective is to produce an up-to-date map showing the various settlements located in Oluwa forest reserve, Ondo State, Nigeria.

The specific objectives are to:
i. determine the number and the location of some human settlements within Oluwa forest reserve as well as to get some major attribute data for each settlement and lastly to show the status of relationship between forestry officials and the identified communities.

METHODOLOGY

Study Area

This research was carried out in Oluwa forest reserve in Odigbo local government and Ondo West Local government areas of Ondo State, Nigeria. The reserve covers and occupies an area of about 827km^2, consisting both natural forest and plantation establishment of different species. It is part of Omo-Shasha-Oluwa forest reserves Ikemeh, R. (2013). The study area is Oluwa Forest Reserve in the South-western part of Nigeria. Oluwa forests in Oluwa forest reserve is between (latitudes 6°40'0"N and 7°00'0"N and longitudes 4°30'0"E and 4°50'0"E), it falls within the tropical rainforest (Adekunle and Bakare, 2004) the area is part of the western plains and ranges of Nigeria with much of it lying approximately between 300 and 600 metres above the sea level (Ogunjemite et al., 2006; Iloeje, 1981). The Benin-Lagos expressway cuts through the southern part of the forest, with Shasha forest reserve at the northern part of the forest reserve. The soils of Oluwa are classified as Alfisols (SSS 2003). The soil parent materials were formed from crystalline rocks of undifferentiated basement complex of pre-cambrian series. The soils are well-drained, mature, red, stony and gravely in the upper parts of the sequence according to (Smyth *et al*., 1962; Onyekwelu *et al*., 2006).

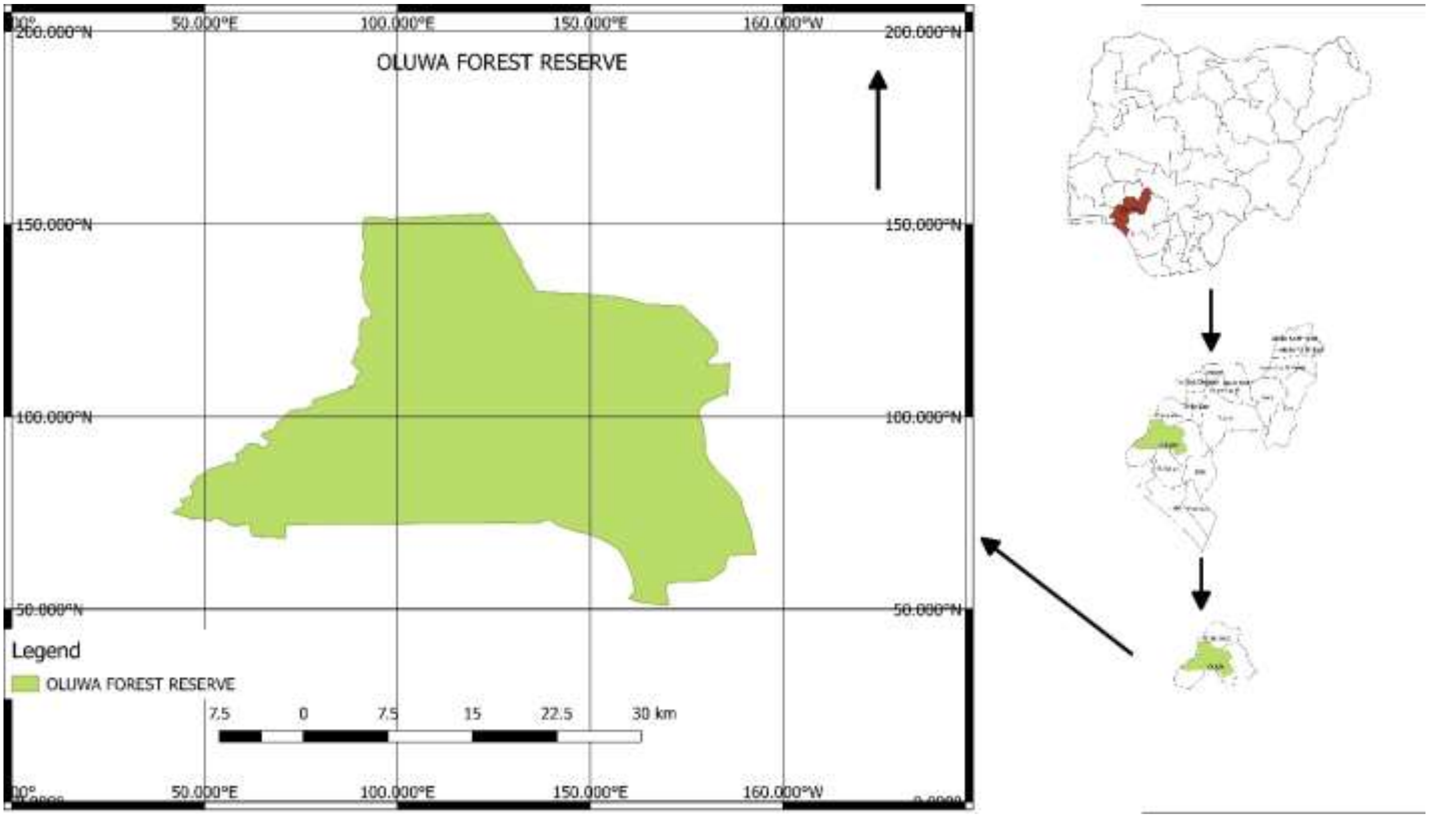

Figure 1: Map of Oluwa Forest Reserve, Located in Ondo State Nigeria

Data Collection

Sampling technique

100% enumeration was used and the various communities in the forest reserve were covered A set of questionnaire was administered to each community and used to get the quantitative data containing the coordinates and other responses from each of the settlement visited, the head of each settlements or someone with high knowledge about the settlement was the focal respondent who answered the questions administered.

Data Analysis and Map Production

Data analysis was carried after the collection and gathering of the necessary data on the questionnaire. After the coding on the Microsoft Excel Spread Sheet, various descriptive statistical analyses such as Frequency Distribution, Pie Chart, Percentages were carried out after using SPSS (Statistical Package for Social Sciences). Likert scale was used to show the level of relationship between the forestry officials and the communities present the relationship is ranked very cordial, cordial, not too cordial and no relationship and the result was presented in table and percentage level shown in pie chart. The coordinates was saved in text (tab delimited) file format in Microsoft Excel spread sheet this was loaded into QGIS 2.18.3 for further analysis using the Coordinate Reference System of WGS84 and the final map production of the forest reserve showing the communities identified.

Digitizing

In map production, it is important that the map is digitized, the map must be converted from a spatial data on the map to a digital format. In digitizing tracing out of the various features are required and this would be done on the base map. Oluwa topographic map showing the boundary of Oluwa forest reserve was acquired, digitized and the boundary was traced out, the other features were clearly digitized and aligned were necessary.

Image Processing and Map Representation

The download of satellite imagery of Oluwa forest reserve was done using an a software called universal map downloader, the imagery used for this research was downloaded from Google Earth, the coordinates of the area was imputed to the software, then to get a high resolution imagery, adjustment was made depending on the quality or high resolution imagery we want. That image downloaded is geo-referenced automatically. Various points on the map were adjusted and verified. In map representation, way points in the forest reserve tracked using the GPS (Global Positioning System), and the other minor road areas were digitized and linked. The points and location of communities and other features were overlaid on the map.

RESULTS

The communities are located in Odigbo and Ondo West local government areas of the State. At the end of the research in the forest reserve, a total of 49 communities were identified. The communities came to existence between the year 1910 and 2013, these shows that communities had been existing in the forest reserve even before the forest reserve was gazette in the year 1953, and the resulting implication is that, most of the communities and dwellers have become established and evacuation now has become a problem. All the efforts of the government to evacuate those that are not in the free areas have been so difficult as a result of the returns the people in power wants from them.

Relationship with Forestry Staff

The table below shows the relationship between the forest guards and the communities, the relationship is ranked very cordial, cordial, not too cordial and no relationship. The various communities have been categorized under the various ranks.

Table 1: Attributes of the Communities Mapped

S/N	COMMUNITY	L.G.A	LATITUDE(DD)	LONGITUDE (DD)	YEAR	FOUNDER
1	Aba Paanu (Oniparaga)	Odigbo	6.728690	4.445710	NA	Pa. Ogunbiyi
2	Abeku Camp	Ondo West	6.893308	4.707560	2013	NA
3	Adejori Camp	Odigbo	6.889600	4.636440	1910	Mr. Adesanlu
4	Ago Alaafia	Okitipupa	6.725390	4.521000	1974	High Chief Omope Nathaniel
5	Ajebambo (Tokunbo)	Ondo West	6.872410	4.750400	1999	Chief (Oloja) Festus Ayodeji
6	Ajebamibo	Odigbo	6.752710	4.434870	1913	Mr. Ayodeji
7	Akinfosile	Okitipupa	6.725310	4.617860	1937	Chief Ejelu, Manugba, Isema,Akide
8	Ayeferere Makinde	Odigbo	6.757590	4.554280	1940	Pa Akadiri Epemakinde
9	Ayetimbo	Odigbo	6.829410	4.558600	1940	Mr. Alo
10	Ayetoro	Odigbo	6.724750	4.532640	1952	Chief Fapetu
11	Bakare	Odigbo	6.826490	4.594510	1830	Mr. Sadiku
12	Bolorunduro	Odigbo	6.829290	4.552300	1940	Chief Babawode
13	Bolorunduro (Orita Ajebamibo)	Odigbo	6.730660	4.438710	1930	NA
14	Danje	Ondo West	6.942700	4.595400	1990	NA
15	Gbekelu Camp	Ondo West	6.928241	4.652848	2009	NA
16	Gbojulogun Camp	Odigbo	6.844180	4.797230	2000	Chief (Baale) Oje Ayodele
17	Gmelina Camp	Odigbo	6.778450	4.557180	NA	FGN/ODSG
18	Ilugba Camp	Ondo West	6.914181	4.647105	2009	Oba Adesanoye Festus
19	Ilu-Titun (Imorun)	Odigbo	6.812340	4.582000	1977	Mr. Babayemi Oladokun
20	Ilutoro Akinto	Odigbo	6.865760	4.819650	1988	Pa Jeremiah Akinto
21	Imorun	Odigbo	6.819950	4.584750	1530	Mr. Ogboloyo
22	Jagiodo	Odigbo	6.781350	4.480250	1960	Gabriel Ikuesan
23	Kajola (Oja) Lagos Express	Odigbo	6.725690	4.508800	1930	Chief Gbose Fawehinmi
24	Keseomi1	Ondo West	6.940200	4.634300	2005	NA
25	Keseomi2	Ondo West	6.941600	4.620100	2009	NA
26	Labon	Odigbo	6.767750	4.437060	1912	Mr. Falekulo

27	Laoso Camp	Ondo West	6.965168	4.645790	1932	Chief Kuteyi and Chief Akinyilade
28	Legee	Odigbo	6.824550	4.595820	1912	Pa Joshua Akinrinmola
29	Lisagbede	Odigbo	6.848340	4.556760	1910	Mr. Ogunnikasi
30	Masole	Odigbo	6.816900	4.582260	1950	Pa Akinyemi Akintomide
31	Miliki Camp	Ondo West	6.939100	4.570000	2007	Mr. Miliki
32	Modebiayo(Kabiyesi) Camp	Ondo West	6.911885	4.690370	1997	prince Adebisi
33	Nirowi (Odigbo)	Odigbo	6.852830	4.764540	2000	Chief Arugbo Aderotoye
34	Nirowi (Ondo West)	Ondo West	6.884941	4.717035	1998	Nirowi_Company
35	Obadore	Odigbo	6.812010	4.516820	1982	Mr Oguntusi
36	Ogunlepa	Odigbo	6.846300	4.621000	1920	Pa Famakinwa
37	Olorunsogo	Ondo West	6.892860	4.788760	1987	Mr. Jerome Akinkuowo
38	Oloruntedo	Okitipupa	6.725050	4.525010	1918	Mr Obasemo
39	Omotosho	Okitipupa	6.725650	4.648390	1914	Chief Omotosho
40	Onipako	Ondo West	6.891480	4.768210	1994	Iya Onipako
41	Oniparaga	Odigbo	6.723040	4.453940	1923	Baale Gbose
42	Onipetesi	Odigbo	6.725180	4.548110	1905	Chief Taiwo Akinwande / Chief Saba Ogunmakinwa
43	Orimoogunje Camp	Ondo West	6.932900	4.641403	1990	NA
44	Orisumbare	Odigbo	6.824150	4.592420	NA	Pa Joshua Akinrinmola
45	Saare Camp	Odigbo	6.854160	4.819710	1983	Mr. Yusuf Alarape
46	Sakoto 1	Odigbo	6.774360	4.496590	1943	Pa Akinsanmi Akintomide
47	Sakoto 2	Odigbo	6.783110	4.515140	1914	Mr Muhammed
48	Tale	Ondo West	6.884680	4.760460	1989	Mr. Tale
49	Temidire	Odigbo	6.769770	4.456220	1963	Chief Ogundeji, Chief Olayanju,Chief Adeyemi

NA = Not Available; FGN = Federal Government of Nigeria; ODSG = Ondo State Government

Table 6: Relationship between Forest guards and the Communities

VERY CORDIAL	CORDIAL	NOT TOO CORDIAL	NO RELATIONSHIP
Ajebambo(Tokunbo)	Akinfosile	Bolorunduro	Bolorunduro (Orita Ajebamibo)
Ayeferere Makinde	Ayetimbo	Gbojulogun Camp	Ilutoro Akinto
Ayetoro	Bakare	Kajola (Oja) Lagos Express	Labon
Gmelina Camp	Jagiodo	Ilu-Titun (Imorun)	Orisumbare
Imorun	Legee	Masole	Ajebamibo
Oniparaga	NIROWI 1	Olorunsogo	Saare Camp
	Obadore	Omotosho	Abeku Camp
	Ogunlepa	sakoto2	
	Oloruntedo	Tale	
	Onipako	Laoso Camp	
	Onipetesi	Orimoogunje Camp	
	Sakoto 1	Gbekelu Camp	
	Temidire	Ilugba Camp	
	Ago Alaafia	Modebiayo(Kabiyesi) Camp	
	Aba Paanu (Oniparaga)	Lisagbede	
		NIROWI 2	
		Keseomi 1	
		Keseomi 2	
		Danje	
		Miliki Camp	

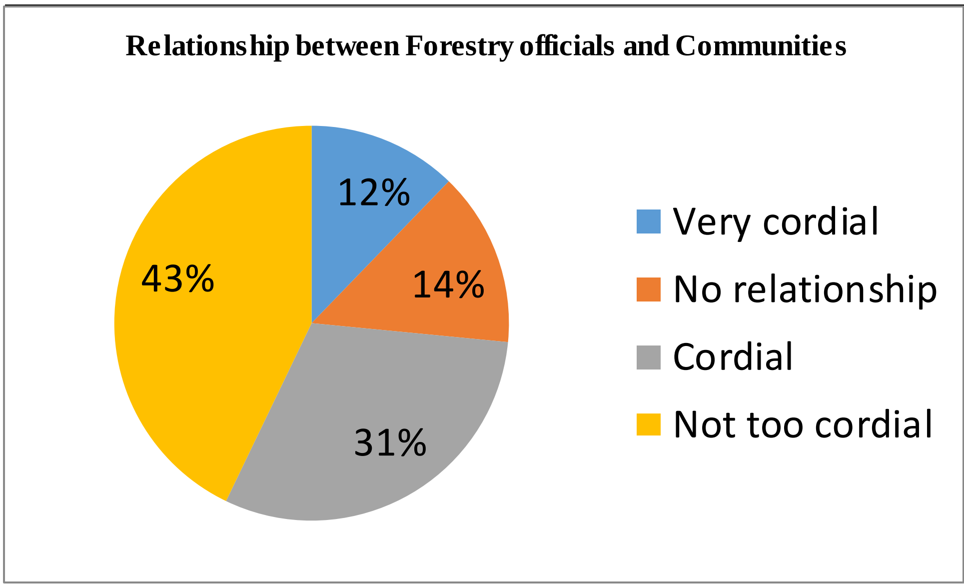

Figure 3:Pie chart showing the percentage distribution of the relationship between forest guards and communities within the Oluwa forest reserve.

GIS Map

Figure 4 shows the map of Oluwa forest reserve showing various features, the map shows the roads linking one community to another, it is represented in red colour lines, and the various communities are linked with a road network. The communities are also represented with points on the map, the various points, represents each location of the communities and also with the names of the community. The major rivers in the forest reserve are also represented with blue colour, these rivers are river Oluwa, river Oni, river Ominla. The major road along the forest reserve is the Lagos Benin express way and it is represented on the map. Another representation on the Map is the pipeline way that passes through the forest reserve. The boundary of the forest reserve is represented on the map, this shows the extent and size of the forest reserve. Through this map, better knowledge about the forest reserve could be obtained, in the access to the communities, number of communities, location of the communities and other major components of the forest reserve. This will help in major decision making on the forest reserve.

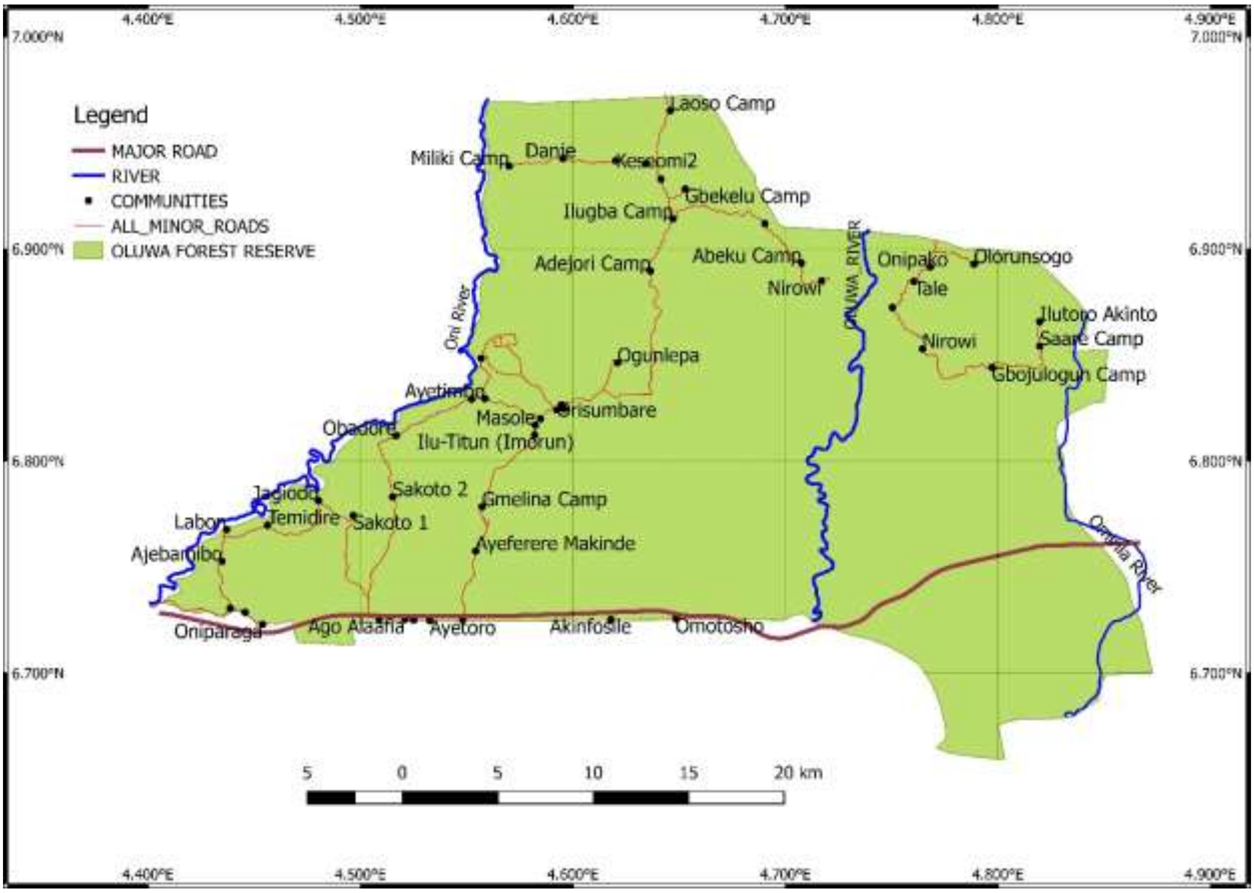

Figure 5: Map of Oluwa Forest reserve showing the communities, Minor Road networks, Major Road Network, and River networks.

DISCUSSION

Some of the communities in the forest reserve are illegal and most of these communities have existed long time ago even before the creation and the gazette of the forest reserve, as times goes by there are new communities emerging in the forest reserve. This implies that the management of the forest reserve in many years back have participated in the management of the forest reserve. The female have a larger portion of the population, this shows that women are so much important in the management of forest, this shows the importance of women in community based forest management. The percentage of women forms a larger portion of the Nigerian population that is according to (Agbogidi and Okonta, 2003), as much as women are important part of a nation, it is also good to know that they partake actively in food production. They are involved in conservation, production and utilization of the values of the forest, such as food, medicines, and also in trading some of the forest products.

Relationship with Forestry Staff

Result shows that 46.86% of the communities have a relationship that is not too cordial with the forest officials, 30.61% have cordial relationship with the forest officials, 14.29% have no relationship the forest officials and 12.24% have a very cordial relationship with the forest officials. From all indications, the forest officials have no good relationship with the communities, the communities are always afraid of them, while some communities sort themselves out and those who cannot do such live in fear and wrought of the forest officials. Most of the communities that have good relationships with forest official are those on the enclaves and others who know how to find their ways each time the forest official visits. The major cause of the fallout in the relationship between the forestry officials and the communities is because of the land issues, communities want to expand and encroach forest areas while the forestry officials give them no chance of further expansion this claim is supported by Barrett *et., al* (2001) who opined that Hunger for land, demand for land for farming among other factors are responsible for conflict and poor relationship. Agbeja and Otesile (2001) also highlighted that one of the major cause of conflicts between agricultural and forestry land uses in a because of the hunger for land.

Maps

Every information provided can be represented on the map, and this shows how flexible the map could be. This is important such that every decision making body can find it easier to make the necessary decisions and also in location of any community where necessary. Implementation would be easy and also strategic planning for the communities. This is an indication of how effective a GIS tool could be used in forest management practices.

CONCLUSION AND RECOMMENDATION

This study and research has shown how GIS is an effective tool for map production and also for the effective creation and management of database in forest management. This research has also proved beyond doubt that GIS has power in analyses, storage of the various kind of information present. The database created can be effective for policy making and implementation, motoring and also how poverty and sustainable forest manage practices could be carried in map production and spatial data analyses. The importance and the effectiveness of GIS as a forest management tool cannot be overemphasized as it has been shown beyond all indications how this tool is important. Government should explore GIS technology by using it as a major tool for management. It is important that the government should get GIS expert for the training and retraining of forestry staffs so as to ensure their functionality. In order to help the people of these communities, government should provide more enclaves that will facilitate farming activities in the forest reserve. For effective management of the forest reserve, the forest guards should work more on the security of the forest reserve and making illegal fellers should be apprehended. Government should not neglect the fact that, research activities that will ensure proper data collection should be embarked upon, not neglecting the data storage, management and updating the data at a given Interval.

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Volume Equations in Selected Privately- Grown Teak Stand in Ekiti State, Nigeria

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Abstract

Lack of adequate data and baseline information are some of the problems facing sustainable forest management in Nigeria. This study was carried out to develop volume equations for sustainable management of privately grown stands of Tectona grandis Linn.f stands in Ekiti State, Nigeria. Data for the study were collected from three (3) age series (10, 13 and 15 years) in each of the locations. Five (5) temporary sample plots (25 x 25 m) were randomly located p er age series. Seventy percent (70%) of the data were used for calibration, while the remaining thirty (30%) were used for validation purposes. Models (Simple linear regression, binomial, polynomial and Logarithm transformed) were generated through regression analysis for this study. The resulting equations were validated using a paired t-test and percentage bias. A total of 1085 trees were enumerated in the study area, though the density of trees was higher in Aisegba (1011/ ha) than Ikere (795/ ha). The mean DBH of trees ranged from 15.58 cm to 19.06 cm in both sites while mean tree height varied from 6.83 m to 10.49 m. The stand volume varied from 72.81 m^3/ha to 192.45 m^3/ha. The R^2 for the linear models ranged from 59% to 87%. The recommended models for Ikere was logarithm transformed model ($LNV=-9.691+0.961LND^2H$), the binomial model ($V=0.008+(0.003D)+0.001D^2$) for Aisegba and logarithm model ($LNV=-9.610+0.948LND^2H$) for the pooled data. The developed volume equations derived in this study cannot be used for other species. Therefore, similar studies should be conducted for other species.

Keyword: Volume equations, Sustainable Forest Management, *Tectona grandis*.

INTRODUCTION

Forests are important part of our environment and economy, continuous depletion of forest resources in Nigeria is on the increase rate due to the demand for wood and its products. Managing forests sustainably increases their benefits including timber and food, to meet society's needs in a way that conserves and maintains forest ecosystems for the benefit of present and future generations. Forest plantations have this ability to grow faster than natural forests, so, they are seen as an increasingly important source of timber supply (Zhang and Stanturf, 2008). Onyekwelu (2001) reported that a total of 224,524 ha of forest plantations were established in different parts of Nigeria by 1996. By 2005, the area of land under forest plantation was reported to have grown to about 700,000 ha (Onyekwelu and Fuwape, 2008). According to Adekunle (2006), Poor forest management, negligence of recommendations through previous study (progress in growth and yield research technique), weak and non-implementation of forest policies by stakeholders have resulted into inefficient management of the forest resources.

Teak is a hardwood species of high quality timber. It is highly durable with good dimensional stability and a valuable timber species for industrial plantations. It's a fast growing tree species (good site quality) and they are very profitable option for both public and private forestry schemes because it can be used for building and furniture production (Tewari, 1992). For timber production, an estimate of growing stock is often expressed in terms of timber volume. The most common method is to use volume equations based on relationships between volume and other tree growth variables such as diameter and height (Akindele and LeMay, 2005).

Sustainable management of timber resources depends on accurate volume assessments of forest stands. According to Tonolli *et al*., (2011), data needed to estimate timber volume can only be obtained through field inventory that is time consuming and expensive. There are many challenges involved in the development of tree volume equation, some of the challenges are high tree species diversity and forest structure (Akindele and LeMay, 2006).However, these challenges can be overcome by; developing equations for each tree species using data obtained for individual tree species; pooling data obtained for all the tree species and developing a single set of equations for all species combined; and/or categorizing species into groups and combining data for all species within each group to develop equations for the group(Akindele and LeMay, 2006).

METHODOLOGY

Study Area

The study was carried out at selected privately-grown Tectona *grandis* stands in Ekiti State, Nigeria. Ekiti state was carved from the old Ondo state in 1996, is made up of 16 Local Government Areas and covers an area of 6353 km. The plantations are located in Ikere in Ikere LGA and Aisegba in Gboyin LGA of the state. Ikere plantation is located between latitude and longitude 7.441°N 5.235°E and 7.444°N 5.234°E. The plantations in Aisegba lies between latitude and longitude 7.621°N 5.494°E and 7.629 5.493. The state is mainly on upland zone, rising above 250 meters above the sea level. Ekiti state has a rhythmically undulating surface. It lies within area underlain by metamorphic rock of the basement complex. Map of Local Government of the study area is presented in figure 1

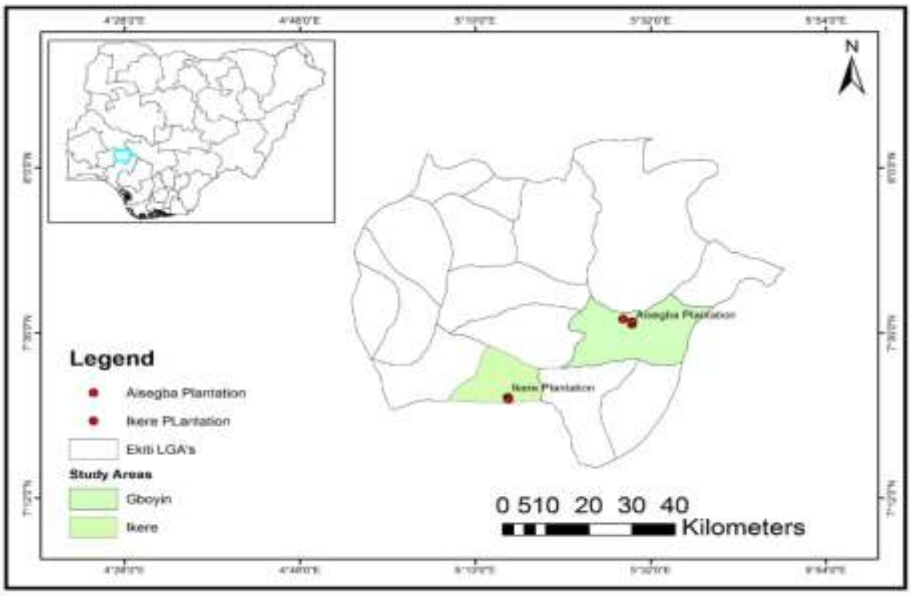

Figure 1: Map of Ekiti State Showing the Selected Local Government Area

Data Collection

Plot Layout

Three age series (10, 13 and 15years) were used for this study. In each of the age series, five temporary sample plots of 25 × 25 m were randomly laid for data collection.

Tree growth variables

In each plot, all trees were tagged for tree growth variable (DBH, diameters at the base, middle and top and the total height) measurement. Diameter at breast height (DBH) and height of all the trees within each plot were measured. The number of trees were also obtained per hectare.

Data Analysis

Basal Area Computation

The basal area of all trees encountered in the sample plots were calculated using the formula:

BA = $$BA = \frac{\pi D^2}{4}$$

Where: BA= Basal area (m²), D = Diameter at breast height (cm), π = Pie (3.142).

Basal area per hectare was computed by multiplying the mean basal area per plot by the number of 25 m x 25 m sample plots per hectare which is 16.

Volume Computation

The volumes of all trees per plot were also calculated using the Newton's formula:

$$V = V = \frac{\pi h}{24}\left(D_b^{\ 2} + 4D_m^{\ 2} + D_t^{\ 2}\right)$$

Where V = Volume (m^3), Db = Diameter (m) at the base of the tree, Dm = Diameter (m) at the middle of the tree, Dt = Diameter (m) at the top of the tree, H = Total height of the tree (m). Volume per hectare was obtained by multiplying the mean volume per plot by the number of 25 m x 25 m sample plots per hectare which is 16

Volume Equations

Tree Volume Models

Data were divided into two sets. The first set (calibrating set), which comprises 70% of the tree data were used to generate the models while the second set (validating set) which comprises 30% of the tree data were used to validate the models and the individual tree growth variables across all the sample plots. The generalized allometric equation for mathematics and science, and the linear regression models that followed the general Schumacher (1939) yield models were used. The Schumacher model is of the form:

Y= f (A, SQ, SD).

Where: Y = function of yield e.g. volume, A = age, SQ = function of site quality e.g. site index, height, SD = function of stand density e.g. diameter at breast height, basal area.

The regression models that were adopted in this study followed the Schumacher function are presented as Equations 1 to 2.

Simple Linear model: $Y = b_O + b_1X$ ………………………………………………….......(Eqn 1)

Polynomial Models: $Y = Bo + B_1X_1 + B_2X^2 + B_3X^3$ ……………………………….. (Eqn 2)

Logarithmic transformed Model: $LnY = b_o + b_1 lnX$…………………………………..(Eqn 3)

In this study, volume is the dependent variable and DBH and height are the independent variables.

Model Assessment

The models were assessed with the view of recommending those with good fit for further use. The following statistical criteria used include: Correlation coefficient (R), Coefficient of Determination, R^2, Significance of Regression equation (F-ratio) and Standard Error of Estimate (SEE).

Correlation Coefficient (R)

Correlation coefficient was used to show the strength of relationship between tree variables. It measures the direction and strength of the relationship between two quantitative variables i.e., Y- dependent variable and X- independent variable (Mead *et al*., 1994). Correlation coefficient (r) ranges from -1 to +1. The R-value must be high (>0.5) for models to have good fit. This revealed a strong relationship between the variables. The closer the r value to 1, the better the equation.

Coefficient of Determination (R^2)

This is the measure of the proportion of variation in the dependent variable that is explained by the behavior of the independent variable. It is usually expressed in percentage. For model to be accepted the R^2 value must be high, that is, most of the variability in the dependent variables is accounted for by the independent variables.

Significance of Regression (F-ratio)

This was used to test the overall significance of the regression equations. The critical value of F (i.e., F-tabulated) at p<0.05 level of significance was compared with the F-ratio (F-calculated). Where the variance ratio (F-calculated) is greater than the critical values (F-tabulated) such equation is therefore significant and can be accepted for prediction.

Standard Error of Estimate (SEE)

This is the measure of the accuracy of predictions made with the regression line. The smaller the Standard Error of Estimated, the better the equation.

Model Validation

This was achieved by comparing the models output with values that were observed on the field using simple linear regression equation. The validation process was used to examine the usefulness or validity of the models (Marshall and Northway, 1993). The observed output is the dependent variable while the models output is the independent variable. The model must be significant, highly correlated, the coefficient of determination value must be very high and the standard of error of estimate must be small.

The Student's t-test

The Student t-test was employed to test for significant difference ($p \leq 0.05$) between the model output (i. e. Predicted and Observed values). For the model to have good fit there must be no significant difference.

Bias and % Bias Estimation

This was used to determine the deviations of the predicted values (Vp) from the observed values (Vo). For models outputs to be valid, the % bias must be less than 30%

$$\text{Bias (\%)} = \frac{Vo - Vp}{Vo} \times 100$$

RESULTS

The summary of the tree growth variables for teak stands in the study sites is presented in Table 1. A total of 795ha^{-1} trees was enumerated in Ikere teak stands. The table shows that fifteen (15) years old stand had the highest number of trees per hectare (313/ha), followed by the ten-year-old stand (244/ha) while the lowest was obtained from the thirteen-year-old stand (238/ha). This density trend was as a result of poor management of the plantation both at planting and growing stages. Meanwhile, the dominant DBH (23.77 - 25.36 cm) was lowest and highest at 15- and 13-years plantations respectively. The results of the tree height revealed that the 10-year-old stand had the lowest value (6.83 m) and the highest value was of 10.49 m was obtained from the 15-year-old stand. This revealed that the teak stand followed an increasing order from 10 to 15 years. The results further revealed the values of the basal area per hectare ranged from 19.87 m^2/ha to 25.10 m^2/ha. More so, the results of the volume per ha follow the same trend and ranged from 72.81 m^3/ha to 154.30 m^3/ha. Aisegba teak stands had a total of 1,011ha^{-1} trees. The thirteen-year-old stand had the highest number of trees per hectare (357/ha), followed by age ten with 338 trees per hectare and the lowest was obtained in the age fifteen stand with 316 trees per hectare. Meanwhile, the dominant DBH (range: 20.99 to 26.50 cm) was lowest and highest at 10- and 13-years stands respectively. The 10-year-old stand had the lowest height of 8.53m while the highest (10.49m) was recorded for 13-year-old stand. The basal area ranged from 22.34 m^2/ha to 36.70 m^2/ha.

Table 1: Summary of Tree Growth Variables for *Tectona grandis* Stands in Ikere and Aisegba Location

Locations	Age (years)	No of trees/ha	DBH (cm)	Height (m)	Dominant DBH (cm)	Dominant height(m)	BA (m^2/ha)	Vol (m^3/ha)
Ikere	10	244	17.06 ± 0.31	6.83 ± 0.12	20.60 ± 0.59	9.49 ± 017	19.87	72.81
	13	238	19.06 ± 0.33	8.55 ± 0.15	23.29 ± 0.73	11.72 ± 0.19	22.89	108.46
	15	313	17.10 ± 0.25	10.49 ± 0.13	20.19 ± 0.71	13.75 ± 0.15	25.1	154.3
	Total	795					67.86	335.7
Aisegba	10	338	15.58 ± 0.18	8.53 ± 0.09	20.99 ± 0.30	10.81 ± 0.13	22.34	123.32
	13	357	17.96 ± 0.27	10.49 ± 0.12	26.50 ± 0.45	13.68 ± 0.13	36.7	192.45
	15	316	17.55 ± 0.26	9.03 ±0.12	25.52 ± 0.42	12.48 ± 0.21	25.48	123.55
	Total	1011					85.52	439.32

**Each value is the mean ± standard error*

The results of volume equations using Dbh and height are presented in Table 2. The models generated are the simple linear, binomial, polynomial and logarithm transformed model functions. The R-squared ranged from 59% to 87%. The lowest R-squared was obtained for the Ikere plantations while the highest was obtained in the 10 years old stand. All the models had high F values ranging from 280.63 to 7176.34 indicating significant equations, with relatively small standard error ranging from 0.03 to 0.31. High R^2 of 85% was obtained when data from the two locations were pooled together. All the models were highly significant and with a relatively small standard error of estimate.

Table 2: Volume equations using Dbh and height.

Location	Equation	R	R^2(%)	Radj	SEE	F ratio
Ikere	$V=0.0003+0.00004D^2H$	0.91	82	82	0.04	2565.59
	$V=-0.057+0.006D+0.0003D^2$	0.77	59	59	0.07	396.88
	$V=0.185 -(0.040D)+0.003D^2-(0.00005D^3)$	0.78	60	60	0.07	280.63
	$LNV=-9.691+0.961LND^2H$	0.93	87	87	0.31	3949.07
Aisegba	$V=0.004+0.00004D^2H$	0.93	86	86	0.03	4241.80
	$V=0.008-(0.003D)+0.001D^2$	0.84	71	71	0.05	873.95
	$V=0.141-(0.029D)+0.002D^2-(0.00003D^3)$	0.85	72	72	0.05	593.69
	$LNV=-9.215+0.897LND^2H$	0.93	86	86	0.28	4279.70
Pooled	$LNV=-9.610+0.948LND^2H$	0.92	85	85	0.32	7176.34

D=diameter at breast height, H=height, V=volume

Results of paired t-test and %bias of selected equations are presented in table 3. The validation results revealed that the models are of good fit because there was no significant difference in the observed and the predicted volumes. The percentage bias for each age series was below 30 % for all the study sites.

Table 3: Results of paired t-test and % bias for selected equations

Location	Equation	Observed Mean Volume	Predicted Mean Volume	T-stat	T-crit	Bias	Bias%
Ikere	$LNV=-9.691+0.961LND^2H$	0.16	0.14	1.56	1.96	0.15	15.23
Aisegba	$V=0.008+(0.003D)+0.001D^2$	0.21	0.27	-0.78	1.96	0.28	28.48
Pooled	$LNV=-9.610+0.948LND^2H$	0.15	0.14	1.55	1.96	0.08	8.35

DISCUSSION

Plantation development began in Nigeria to augment wood supply from the natural forest when it was discovered that the supply from the natural forest alone could no more meet the ever increasing demand for wood and wood products. This was initiated by the government with the involvement of few private individuals were involved later. Prominent among the exotic species in plantation today are *Tectona grandis, Gmelina arborea, Eucalyptus spp,* while the few indigenous species are *Nauclea dederrichii*, *Terminalia superba* and *Triplochiton scleroxylon*. Therefore, this work was carried out to develop volume equations for selected privately-grown teak stands in Ekiti State, Nigeria. The mean diameter at breast height ranged from 17.06 cm to 19.06 cm which was considered low for the stands. This is an indication that most of the trees encountered in the study sites are below the minimum merchantable size of 48cm stipulated by logging policy of southwestern Nigeria (Adekunle, 2006). This size at their ages could be as a result of poor management of the plantation both at planting stage and during growing after planting. Among the important consideration when determining forest management strategies is the modelling objectives. Development of volume equations for teak stands is very useful to forest managers. Due to important roles of models in decision making, models credibility is becoming increasingly important in forest management. In inventory exercise, models give fast results, it is cost efficient and requires less labour because few parameters such as height and DBH which can be measured accurately from the field are required (Segura and Kennien, 2005). Volume equations developed for this study were significant with high correlation coefficient, coefficient of determination and low standard error of estimate.

Generally, the percentage biases when the output of each model was compared with the observed volume were very small (less than 30%) for all the models (Adekunle, 2007). The paired-mean t-test was also used in several studies to test the adequacy of models for stand volume estimation. Marshal and Northway, (1993) reported that for models with good fit, there should be no significant difference between the observed and predicted values with the result of the student t-test. All the assessment criteria revealed that the models have a good fit. However, the combined and the double-entry volume models that made use of DBH and total height as input variables were easily measurable, highly correlated with volume, more precise, less biased than single-entry ones and more consistent in predicting the volumes of different stems (Shuaibu and Akindele, 2016). The logarithmic transformation of the models was also very efficient. This is in line with Louis (2005) who reported that the logarithmic transformed model provides an excellent fit to the sample data using linear regression and that of Akindele and LeMay, (2006) who stated that the generalized logarithmic volume function (also termed Schumacher's volume function) performed better than other forms of volume functions for tropical rainforest area of Nigeria.

CONCLUSION AND RECOMMENDATIONS

Tree volume equations were developed in this study to estimate the stand volume of tree species. Growth and yields models development may be affected by spacing, species, soil type (ecological zones), or the cultural treatment carried out in the plantations such as thinning and pruning which affect stem form. Hence the appropriate timing of silvicultural operation could be enhanced through obtaining suitable models. The volume equations developed for this study area are appropriate and can be recommended for further use for the same species in the study area. However, before applying the models beyond the study area there is a need for model validation. More so, the developed equations should not be used for other species within or outside the study area.

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Evaluation of Leaf Litter Decomposition as Process of Nutrient Return in Forest Plantations

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Abstract
Analysis of litter characteristics are important in understanding energy flow, primary productivity and nutrient cycling in forest ecosystems. This study evaluated leaf litter decomposition for providing nutrients and maintaining soil fertility in forest ecosystems. Four forest land-use types of Leucaena leucocephala, Gmelina arborea, Tectona grandis and Secondary forest plantations were adopted in completely randomised design considering seasons, days and species as variables and studied for six months (dry and wet seasons) using litterbag technique. Fifty grammes dry leaf litter of Tectona grandis, Gmelina arborea, Leucaena leucocephala and secondary forest were each weighed into 2mm mesh litter bags of 35x25 cm^2 to make up 72 bags (18 litter bags of each litter types) and distributed on the forest floor. The bags were retrieved at 0, 7, 14, 28, 49 and 98 days and litter remaining were cleansed, oven dried, weighed and analysed for Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Phosphorous (P), Organic Carbon (OC), Nitrogen (N) and Lignin content for the two seasons. Data were analysed using Generalized Linear Model for 2-factorial experiment and two-way ANOVA to test for significant effects. Results revealed significant differences among N (1.05±0.19 %), OC (33.54±0.77 %), Lignin (20.99±1.29 %), Na (6129.2±1089.48 mg/kg), K (1447.9±341.72 mg/kg), Mg (3597.4±407.39 mg/kg), and Ca (62982±9167.65 mg/kg) concentrations with varying days of decomposition at ($p<0.05$). The N (1.60±0.04 %), Lignin (21.92±0.40 %), K (4712.5±441.49 mg/kg), Mg (6442.2±421.44 mg/kg), andCa (70883±3931.29 mg/kg) were significant ($p < 0.05$) in the dry season while P (2.70±0.22 %), C (31.52±0.64 %), Na (7283.3±502.57 mg/kg) were significant ($p < 0.05$) in the wet season. The percentage mass loss was highest ($p<0.05$) in Leucaena in the dry and wet seasons (60.24% and 75.94%) when compared to other leaf litters. We conclude that significant seasonal variation existed in litter decomposition, nutrient composition and release among the examined trees species.

Keywords: Leaf litter, Nutrient, Forest Plantations, Abeokuta

INTRODUCTION

Litter decomposition is an important ecological process that provides the main source of nutrients for microorganisms and plays a crucial role in the maintenance of soil fertility in forest ecosystems (Fuqiang *et al*., 2010; Salah and Scholes 2011; Li *et al.*, 2011). The rate and variability of decomposition depend on several factors, including temperature, moisture, litter quality as well as the nature and abundance of decomposing organisms (Melillo *et al*., 1982).

Plant litter decomposition is the process of biological disintegration of litter during which mineralization of complex organic compounds into simple in-organic forms occurs. It includes leaching, break up by soil fauna, transformation of organic matter by micro-organisms and transfer of organic and mineral compounds to the soil (Loranger *et al.*, 2002). Decomposition of litter which produces organic matter is an important factor for soil formation as well as nutrient cycling processes (Onyekwelu *et al*., 2006; Pandey *et al*., 2007). This is primarily influenced by the environmental conditions in which decay takes place, the chemical quality of leaf litter, and the nature and abundance of decomposing organisms present (Polyakova and Billor, 2007). Many studies have shown that there exist considerable variations in leaf litter decomposition rates among species (Koukoura *et al*., 2003). Knowledge of litter quality from various trees species and how this varies seasonally is necessary for a proper judgement of the effect of these changes in ecosystem function (Tolsma *et al*., 1987). Quantification of the nutrient flux associated with litter is important to the understanding of ecosystems dynamics. The maintenance of natural systems or soil fertility in tropical forest ecosystems is achieved by high and rapid circulation of nutrients through the fall and decomposition of litter. The release of nutrients during litter decomposition is a key process governing the availability of nutrients in ecosystems (Moore *et al*., 2006) and an important ecosystem function, playing a crucial role in nutrient release in forest and tree-plantation ecosystems. It is a complex process regulated by a number of abiotic and biotic factors (Lavelle *et al*., 1993, Reddy 1995a). Decomposition and nutrient release are two key processes in tropical forests, where the vegetation is generally sustained on soils with low fertility (Lavelle *et al*., 1993). Therefore, forest productivity depends on efficient nutrient cycling mechanisms that ensure rapid turnover of litter nutrients (Vendrami *et al*., 2012). The decomposed litter is also the basis of many food chains in tropical forest and is a principal source of energy for the saprobiota of the forest floor and soil where the trophic chain of detritus predominates (Ola-Adams and Egunjobi, 1992; Oliveira and Lacerola, 1993; Regina *et al*., 1999). Litter decomposition is a major pathway for providing organic and inorganic elements for the nutrient cycling processes and controls nutrient return to the forest ecosystem. In the recent years, studies have quantified the rate of litter fall and decomposition as an important pathway for the transfer of litter mass and minerals to the soil in forest ecosystems. Large scale forest plantations have been established in tropical countries under a wide range of climatic conditions. Most studies of nutrient cycling in tropical forest have been concluded in areas where the rainfall exceeds 2000mm and also most of the studies involve comparison of litter fall and decomposition between single species at different sites or between single species of different spacing within the same site as in the studies of (Vogt *et al*., 1986; Melillo *et al*., 1982; Eklabya and Ambasht 1987; Ola-Adams and Egunjobi, 1992; Terrell *et al*., 2001,) or it could be between different species within sites. Leaf litter of different plant species has diverse nutrient release patterns, which are related to quality, season, and environmental factors (Arunachalam *et al*., 2003, Abiven *et al*., 2005). Different litter parameters like initial litter N concentration and C/N ratio (Perez-Harguindeguy *et al*., 2000) on the one hand and the lignin concentration or lignin : N ratio (Loranger *et al*., 2002) on the other, have been found to be correlated with, and useful as predictors of the decay rate. The soil organisms contribute to litter decomposition by playing the role of decomposers. The soil fauna through commuting mechanisms fragment the substrates, thereby increasing the surface area leading to the acceleration of microbial activity (Wise & Matthias 1994, Reddy 1995b, Seastedt 1995, Coleman & Crossley 1996, Knoepp *et al*., 2000, Ekschmitt *et al*., 2005, Janzen, 2006).

Mathur *et al*., (1982) observed that the thick layer of humus beneath the forest floor improves the infiltration rates of the forest soils. Verma *et al*., (1982) reported a great heterogeneity in the chemical contents of forest soil under heterogeneous forest composition. Dwyer and Merriam (1981) observed that greater litter weight and depth reduced moisture loss and supported a larger bacterial population. Thus litter on the forest floor plays a significant role in determining the moisture status, runoff pattern and liberation of mineral elements accumulated in the aerial parts of the vegetation. Litter represents an essential link in organic production-decomposition cycle and is thus a fundamental ecosystem process (Meentemeyer *et al*., 1982). Proctor (1983) has argued that litter fall is relatively easy to measure and has been investigated at least for one of the following reasons: to provide an index of production; to give information (when combined with measurements of floor litter standing-crop) on decomposition rates; to give information on tree phenology, and to quantify an important pathway in mineral nutrient cycles. Decomposition process play important role in soil fertility, in terms of nutrient regeneration and maintenance of organic matter level. Lisane *et al*., (1994) had stated that the analysis of litter quality, its quantity and rate of decomposition are important processes in understanding the energy flow, primary productivity and nutrient cycling in forest ecosystem. Following these assertions, reports by Moughalu *et al*., (1993); Odiwe and Moughalu, (2003), and Oladoye *et al*., (2006) of studies on litterfall and nutrient content, its rate of decomposition in temperate, rainforest zone and plantation are available. This study was conducted to provide information data base on the decomposition under four forest types (*Tectona grandis* plantation, *Gmelina arborea* plantation, *Leucaena leucocephala* plantation and a secondary forest) in a forest savannah transiting zone. This is thus to evaluate their litter quality and how seasons affect the rate and pattern of their decomposition.

METHODOLOGY

Study areas

The study areas are four forest lands within the Federal University of Agriculture Abeokuta campus located on latitude 7^0 and 7^0 58^1N and on the longitude 3^0 2^1E and 20^0 37^1 600m above sea level (figure 1).

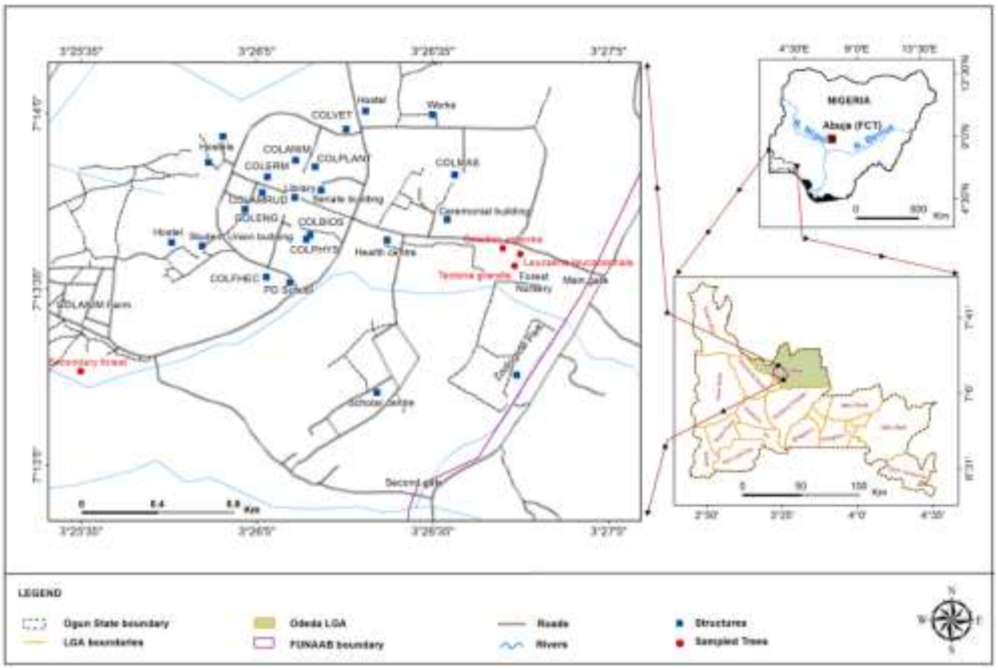

Figure 1: Areas showing the different study locations

The general topography of the land terrain are undulating. The four forest land are *Tectona grandis* (Teak), *Leucaena leucocephala*, *Gmelina arborea* and Secondary forest site

Documentation of Climate and Climatic data

The area has a tropical climate with a bimodal distribution of rainfall. It lies within the humid lowland region with two distinct seasons. The wet season extend from April to October while the dry season extends from November to March. The mean annual rainfall is 1113.1mm. The bimodal distribution of rainfall has its peaks in July and September and break in August. Generally, the rainfall could be heavy and erosive and sometimes accompanied by lightning and thunderstorms at the beginning and the end of the rainy season (Aiboni, 2001). Climatic data were collected from the University of Agriculture, Metrological station, Abeokuta.

Leaf litter Collection and Decomposition Studies

Fresh leaves of *Tectona grandis, Gmelina arborea, Leucaena leucocephala* plantation and secondary forest ecosystem were collected and air dried for 5 days. Fifty grams (50g) of the air dried leaf litter were weighed into a 2mm mesh bag chosen to prevent the inflow of excess material. The litter bags were closed at both ends. A total of 72 litter bags were used per season; which implies 18 litter bags/per study site per season. Leaf litter decomposition and mass loss were evaluated using the standard litter bag techniques described by Oladoye (2006). The litter decomposition evaluated was carried out in two seasons i.e. the dry and wet season for 180 days (6 months). Seventy two (72) litter bags of eighteen (18) litter bags each from *Tectona grandis*, *Gmelina arborea*, *Leucaena leucocephala* plantation and secondary forest were filled with leaf litter and placed at the respective sites. A total of one hundred and forty-four (144) litter bags were used for the study in the two seasons. A total of twelve (three litter bags per study site) litter bags were retrieved randomly, from the forest floor of *Tectona grandis*, *Gmelina arborea*, *Leucaena leucocephala* and from a secondary forest at day zero, day 7, day 14, day 28, day 49 and day 98 for the two season of dry and wet season and assessed. The remaining samples were oven dried at 100ºC to a constant weight, to determine the final weight. The samples were sorted based on their retrieval date respectively, and analysed for phosphorus (P), Magnesium (Mg), Sodium (Na), Calcium (Ca), Potassium (K), Nitrogen (N), Carbon and lignin. The final weights which represent the mass remaining after decay from the initial mass remaining were calculated. The study utilised a 4x6 CRD factorial experimental design as shown in table 1

Plant Nutrient Content Analysis

A 1.0 g of finely ground plant material were weighed for each of the plants components into porcelain crucible and placed in cold muffle furnace with temperature set to 500ºC. Care was taken not to let the temperature exceed 500ºC to prevent the loss of phosphorus and the formation of soluble silicate. The samples were allowed to remain in the furnace for 2 hours after the set temperature reached. The appearance of grey colour indicated complete dry ashes of the sample. Crucibles were removed and allowed to cool and 5ml of HCL added to the ignited samples and allowed to stay for 20 minutes and moistened with distilled water. Each of the samples was filtered through whatman.no.40 filter paper into 100ml volumetric flask. The residues were removed and the precipitate diluted with distilled water making it up to 50ml. The samples were labelled for easy identification. The solution was thoroughly mixed.

From the solution;

i. Sodium (Na) and Potassium (K) were determined by flame photometry.
ii. Calcium (Ca) and Magnesium (Mg) were determined by atomic absorption spectrophotometry.
iii. Phosphorus (P) by colorimetry,
iv. Organic carbon content was determined by the Walkley and Black procedure (Okalebo *et al.*, 1993).

v. Nitrogen was determined by the Kjeldahl distillation method and 0.20grams was measured for Nitrogen (Isaac and Kerber, 1972)
vi. Lignin was determined using procedure by Van Soest and Robertson (1985). Lignin determination involved analysing neutral detergent fiber (NDF) and acid detergent fiber (ADF) using the Van Soest detergent procedure (Van Soest and Wine 1967). Lignin was determined gravimetrically after the ADF was extracted with 72 % H_2SO_4 and ashed.

Data Analysis
Two way ANOVA was used to determine the differences in leaf litter from each plantation treatment means in the proportion of original mass and Nitrogen remaining at various intervals. Data obtained was analysed using Generalised Linear Model for 2-factorial experiment in SAS version 9. Mean were separated using DMRT.

RESULTS
The nitrogen content in the leaf litter during the wet season was significantly different only at day zero (0.29%). At day 7 (0.21%), 14 (0.19%), 28 (0.21%), 49 (0.15%) and 98 (0.18%) were not significantly different (Table 2). Phosphorous, Lignin, Mg and Ca were not significantly different with varying days in litter collections in wet season. Carbon, Na, and K varied significantly with days. For carbon content, there was significant difference between day 49 (30.20%) and 98 (26.30%). For Na and K content, there were no significant differences between day zero and 7 and between day 49 and 98, however, there was significant difference between the values obtained for day 14 and 28 in wet season. In the dry season, the nitrogen content between day zero (1.43%) and 98 (1.5%) were not significantly different. Also, between day 14 (1.83%) and day 28 (1.89%) there was no significant difference. However, day 28 (1.89%) was significantly different from day 98 (1.50%). Phosphorous, carbon, lignin, Na, K, Mg and Calcium content also varied significantly with days of collection (Table 3). Results of the variations in nutrient content of decomposing litter with varying days irrespective of season are presented in Table 4: There was a slight variation in the concentration of elements and lignin after seven days of decomposition with the initial nutrient concentration. There was initial increase in nutrients concentration after seven days in P, C, Na, K, Mg, Ca and lignin except in nitrogen where there was a decrease at day seven from the initial nutrient concentration. Nitrogen content decreased at day seven and began to increase at day 14. Further increase was noticed at day 28 before it began to decrease gradually at day 49 and day 98. Phosphorus increased at day seven and decreased at day 14 and further increase was noticed at day 28 before decreasing at day 49 and 98. Organic Carbon increased at day seven higher than the initial concentration at day zero and thereafter a gradual decrease was noticed from day 14 to 28, 49 and 98. There was an increase in day seven higher than the initial lignin concentration at day zero.
Nitrogen (N) content varied significantly with days of litter decomposition. N content at day 28 (1.05%±0.19) was significantly different from other days of decomposition. N content at day 49 (0.90%±16), N content at day 0(0.87%±0.13) and N content at day 98 (0.84%±0.15) were not significantly different. There was no significant difference between N content at day 0 (0.87% ± 0.13) and 98 (0.84% ± 0.15). N content at day 14 (1.02% ± 0.18ab) and N content at day 28 (1.5% ± 0.19) were not also significantly different from each other. Phosphorus (P) content was higher at day 7 (0.16% ± 0.05) and day 28 (0.16% ± 0.05) with least values at day 98 (0.11%±0.03). However, P was not significantly different with days of decomposition.

Carbon content varied significantly with days of decomposition. C content at day 7 (33.54% ± 0.77) was significantly different from other days of decomposition. However, there was no significant difference between C content at day 49 (20.01% ± 2.40) and C content at day 98 (18.44% ± 2.17). Similar trend between C content at day 0 (28.95% ± 1.91) and C content at day 14 (32.24% ± 0.89). Lignin content varied significantly with days of decomposition. Lignin content at day 7 (20.99% ± 1.29) was significantly different from Lignin content of other days of decomposition. Lignin content at day 14 (19.87% ± 1.08) and day 28 (19.28 ± 0.78) were not significantly different. Lignin content at day 0 (16.97% ± 0.52), day 49 (17.37% ± 0.62) and day 98 (17.56% ± 0.46) were not significantly different. There was no significant difference in Sodium (Na) content at day 0 (5815.14m/kg ± 1055.32), day 7 (6129.2m/kg ± 1089.48) and day 14 (5700m/kg ± 939.93). There was a noticeable decrease in Na content with days of decomposition. Na content at day 49 (2462.5m/kg ± 544.0) and Na content at day 98 (1877.1m/kg ± 351.32) were not significantly different. Potassium (K) and Magnesium (Mg) followed similar trend, there was no significant difference in K and Mg content from day 0 to day 49. There was a noticeable increase in the K and Mg content between day 7 (3806.3m/kg ± 781.98, 5367.7m/kg ± 710.71) and day 14 (4064.6m/kg ± 757.66, 5793.2m/kg ± 649.41) respectively, followed by a decrease in K and Mg content from day 28 to day 98. Calcium (Ca) content was significantly different at day 14 (62982m/kg ± 9167.67). There was no significant difference between Ca content at day 0 (49,426m/kg ± 6,606.89) and Ca content at day 7 (50,231m/kg ± 7,035.29). Similarly, no significant difference among Ca content at day 28 (39,765m/kg ± 8349.99), day 49 (35,185m/kg ± 4452.51) and day 98 (36,006m/kg ± 4610.54). Seasonal variations in nutrient content between the two seasons are presented in Table 4. The result shows that the nutrient content of Nitrogen (1.60% ± 0.04), lignin (21.92% ± 0.40), K (4712.5m/kg ± 441.49), Mg (6442.2m/kg ± 421.44) and Ca (70883m/kg ± 3931.29) were significantly different during the dry season. However, P (2.67% ± 0.22), C (31.52 ± 0.64) and Na (7283.3 ± 502.57) were significantly different during the wet season. In the wet season (Table 5), Nitrogen content among species was not significantly different between Leucaena (0.29%) and Gmelina (0.23%) and also, between Teak (0.14%) and Secondary forest (0.15%). Phosphorus content was higher in Leucaena (4.83%) and least in Teak (1.70%). Carbon is significantly low in secondary forest (28.87%). However, there is no significant difference in Carbon content among Leucaena (32.44%), Gmelina (32.31%), and Teak (32.44%). Lignin content was highest in the secondary and significantly different while it was least in Leucaena (13.48%). Sodium, Potassium and Magnesium content were higher and significantly different in Leucaena. Calcium was significantly different in secondary forest (2411m/kg) than in the other forest types. In dry season (Table 6), there was no significant difference in nitrogen content among the various land uses. However, nitrogen content was higher in Leucaena (1.62%) and least in Gmelina. Phosphorus content was significantly higher in Leucaena (4.83%) in the dry season. Carbon content ranged from (20.11%) in Gmelina to (21.70%) in Teak. However, there was no significant difference among the land uses. Lignin content was not significantly different among the species. However, the Lignin content was least in Leucaena (21.37%) and highest in secondary forest (21.52%). Sodium content was significantly different between Leucaena (2936.1m/kg) and Gmelina (1513.9m/kg). However, there was no significant difference in sodium content between Teak (3311.1m/kg) and secondary forest (938.9m/kg). There was no significant difference in Magnesium content between Gmelina (5954.2m/kg), Teak (4531.9m/kg) and Secondary forest (6011.1m/kg). However, magnesium content was significantly higher in *Leucaena* (9271.5m/kg). There was no significant difference in Calcium content among the various land uses as the variation in the content was statistically insignificant. The percentage (%) mass loss during the study period in the tree plantations and secondary forest is shown in (Table 7), reveals that decomposition reduces as the day increases. There were variations in the rate of % mass loss among the different litters. The highest percentage (%) mass loss of 75.94% was observed for the wet season and 60.21% for the dry season at Day 98. The least % mass loss for wet season and dry season (35.13% and 21.11%) was observed for Tectona grandis respectively. At day 98, during the wet and dry season, % mass loss among species was in this order: *Leucaen*a (75.94%)>Secondary forest (55.66%), *Gmelina* (48.87%)>Tectona (35.13%), and *Leucaena* (60.21%)>Gmelina (30.02%) >Secondary forest (29.25%) >Tectona (21.11%) respectively. At day 7, *Tectona* had more rapid mass loss (23.54%) followed by Secondary forest (23.48%) in wet season than other species and least mass loss at day 98

In day seven, percentage mass loss in *Gmelina arborea* was 8.20% and 12.88% in dry and wet season respectively. *Tectona grandis* had 8.05% in dry season and 23.54% in wet season; *Leucaena* had 12.84% in dry season and 17.12% in the wet season. In the Secondary Forest, percentage mass loss was 12.65% in dry season and 23.48% in wet season. At day14, percentage mass loss was 15.20% in dry season and 22% in wet season in *Gmelina arborea*. *Tectona grandis* had 12.94% in dry season and 25.06% in wet season. Percentage mass loss was 22.36% in dry season and 43.64% for wet season in *Leucaena*. Secondary forest had 19.20% mass loss in dry season and 23.86% in wet season (Table 9). At day 28, percentage mass loss had increased to 15.75% in dry season, 24.42% in wet season for *Gmelina arborea*, 14.68% in dry season and 27.20% in wet season for *Tectona grandis.* For *Leucaena,* the percentage mass loss for dry and wet season was 30.33% and 60.34% respectively. The secondary forest had 22.74% in dry season and 28.80% in wet season.

In day 49, 26.80% of leaf litter had decomposed in dry season and 62.26% in wet season for *Gmelina arborea*. 19.27% and 29.94% of leaf had decomposed in *Tectona grandis* during (dry and wet season) respectively. For *Leucaena*, percentage mass loss was 48.73 % for dry season and 73.20% at wet season. Secondary forest released 26.73% in dry season and 47.20% during the wet season. In day 98, percentage mass loss for *Gmelina* was 30.02% for dry season and 66.86% for wet season. *Tectona grandis* percentage mass loss was 21.11% for dry season and 35.13% for wet season. *Leucaena* in the dry season have percentage mass loss of 60.21% and 75.94% in the wet season. The Secondary forest had percentage mass loss of 29.25% in dry season while in the wet season valued recorded was 55.66%

DISCUSSION

The nutrient content of the leaf litter with respect to days of litter decomposition in both wet and dry seasons was comparable in that, nitrogen, lignin, potassium, magnesium and calcium were higher in dry season, and phosphorous, carbon and sodium were also higher in wet season. This could be possible as a result of microbial activities which were inactive state during the wet season, as supported by Fioretto *et al.* (2003) who said that microbial activities can be limited by available moisture content in the soil during the rainy or wet season. Also, there was higher concentration of aerobic organisms which were active during the rainy or wet season causing high rate of aeration and thereby influenced the increased nutrient release pattern of the leaf litter (Oladoye *et al.*, 2006). The variation in nutrient concentration among the leaf litter of the species studied suggested that the species are from different families with varying rate of nutrient uptake, chemical and biochemical properties (Mahmood & Saber; 2007, Mahmood et al., 2009, Hasanuzzaman &, Mahmood, 2015). Comparatively, higher concentration of Nitrogen, Phosphorous, Potassium in *Leucaena* & *Gmelina* may imply that the capabilities of the species to translocate these nutrients maybe slow (Berg & Laskowsk; 2006, Hagen-thorn et al., 2006).

Higher decomposition rate of leaf litter during the wet season is accelerated and this may be attributed to physical determinant, particularly soil moisture content, temperature and evapotranspiration and the activities of decomposers, leaching (Facelli and Picket,1991). This is similar to the findings of Krishna and Mahesh,(2017) who reported that climate variations could be a major reason as this is known to be a leading factor influencing leaf litter decomposition in a large geographical scale (Austin & Vitousek, 2000). Studies have shown that the rate of decomposition is usually high in species that are low in lignin content and C/N ratios. Relatively slower decomposition rate of leaf litter at the later stages maybe due to accumulation of more recalcitrant constituents such as N-containing humus compounds in the residual litter mass (Sundarapandian & Swamy; 1991). This trend has been observed in the studies of Devi (2002), Kumar and Deepu (1992), Anderson (1983), Okeke and Omaliko (1992), Kanal, (1995), Jama and Nair (1996). Leaf litter decomposition rates of the species used for this studies varied which might be attributed to the leaf anatomy and varying chemical composition like internal nutrient and lignin content as reported by Chanda *et al.,* (2015). Nutrient content in leaf litter decomposition between wet and dry seasons irrespective of days revealed that lignin and mineral nutrients of nitrogen, potassium, magnesium, calcium in dry season could only be released after microbial activities had been completed on the leaf litter, and thereby release the nutrients for use as against the wet season result. The effect of nutrients was clearly observed in wet season where lignin was seen to be low in *Leucaena*, calcium in *Gmelina*, magnesium in *Teak* and sodium in secondary forest. Therefore, decomposition was observed to be higher in Leucaena than Gmelina and Teak. Nitrogen nutrients were also high in *Leucaena* and *Gmelina* respectively, while, phosphorus, calcium, sodium, potassium, magnesium was high in *Leucaena*; while carbon was high in *Leucaena*, *Gmelina* and Teak respectively. Meanwhile, in dry season, *Leucaena* experienced high nutrient content in all the treatments observed or measured. Nitrogen, carbon and calcium had higher effect of nutrient with Leucaena, Gmelina and Teak respectively among other nutrients parameter measured. Leaf litter decomposition was observed to be reduced as the days increased. Loss in weight during decomposition of leaf litter in Gmelina, Tectona (Teak), Leucaena and secondary forest with days was rapid. Mass loss was higher at 98 days as the decomposition was controlled by the quality of the litter, decomposer organisms and the environment (both biotic and abiotic factors) ((Vanlauwe *et al.,* 1996; Mungai and Motavalli, 2006; Teklay *et al.*, 2007).

The percentage mass remaining was high at 0 and 7 days of incorporation at both dry and wet seasons. This was because decomposition has not taken place at this time yet. There was no significant effect on the annual decomposition constant of the original dry weight of leaf litter in comparison with species of trees evaluated or examined. In this study, the four different trees species showed from 19.27% - 48.73% disappearance after 49 days in the dry season and in the rainy season the percentage (%) mass loss by the same species at day 49 was from 29.93% − 73.20%. At day 98 the decomposition that occurred compared to decomposition at day 49 was not as rapid as observed between seven to 49 days. Across the season higher % mass loss occurred in the rainy season compared to the dry season. Greater decomposition during the rainy season is perhaps due to microbial activity under favourable temperature and moisture conditions and leaching due to rainfall as reported by Pandey & Singh (1982). The rate of decomposition was found the highest for *L. leucocephala* in dry and wet season and the lowest was observed for *T. grandis* in dry and wet season. The mass loss pattern and rate of decomposition showed differences among the studied tree species. This may be due to the litter quality, the presence of varying amounts of water soluble phenolic compounds, flavonoids, tannin, physical and chemical properties of leaf litter and the presence of thick waxy cuticles (Simlai and Roy 2012; Mahmood *et al.* 2013). Mass loss of leaf litter decreased gradually during the experiment in dry and wet season due to decomposition as reported by Mahmood et al. (2013). Higher mass loss of leaf litter was found during the first 49 days, followed by a gradual mass loss for the subsequent 49 days which indicates two stages i.e. initial stage and advanced stage (Semwal *et al.* 2003). Among the considered tree species *L. leucocephala* was the best in terms of nutrient return through leaf litter decomposition followed by *G. arborea*, Secondary forest and *T. grandis.* Initial litter quality plays a central role in determining microbial community composition and decomposition rate K- Value is primarily controlled by climate and litter quality. Higher k-values correspond to faster rates of decomposition, while lower values are a function of temperature and moisture.

A considerable amount of organic matter and nutrients added to the soil through the process of leaf litter decomposition and a portion of these organic matter and nutrients would be reused by the plants. More organic matter and nutrients can be added to the soil through the process of leaf litter decomposition during wet season because of higher rate of decomposition in wet season than dry season. The added nutrients may contribute to the sustainability of soil fertility, which is becoming an important phenomenon for agroforestry practices. Among the considered tree species *L. leucocephala* was the best in terms of nutrient return through leaf litter decomposition followed by *G. arborea*, Secondary forest and *T.grandis*. It is recommended that leaf litter should be applied to the soil surface as mulch to control run-off and soil erosion.

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Table 5: Experimental Design (4x6 CRD Factorial)

Days	G1	T1	L1	SF
0	$G_1 0_1$	$T_1 0_1$	$L_1 0_1$	$SF_1 0_1$
7	$G_1 7_1$	$T_1 7_1$	$L_1 7_1$	$SF_1 7_1$
14	$G_1 14_1$	$T_1 14_1$	$L_1 14_1$	$SF_1 14_1$
28	$G_1 28_1$	$T_1 28_1$	$L_1 28_1$	$SF_1 28_1$
49	$G_1 49_1$	$T_1 49_1$	$L_1 49_1$	$SF_1 49_1$
98	$G_1 98_1$	$T_1 98_1$	$L_1 98_1$	$SF_1 98_1$

Legend: G- *Gmelina arborea*
T- *Tectona grandis*
L- *Leucaena leucocephala*
SF- Secondary Forest

MODEL

$$Y_{ijk} = \mu + A_1 + B_j + (AB)_{ij} + E_{ijk}$$

Where,

Yijk = individual observation
μ = general means
A1 =effect of factor A
Bj = effect of factor B
(AB)ij = effect of interaction AB
Eijk = experiment error

Table 2: Nutrient content with varying days of leaf litter decomposition in Wet Season

Days	N (%)	P (%)	C (%)	Lignin (%)	Na (m/kg)	K m/kg)	Mg (m/kg)	Ca (m/kg)
0	0.29a	2.67a	33.21a	15.20a	10133.3a	1266.7a	3675.0a	19625a
7	0.21b	3.25a	34.29a	15.20a	10350.0a	1781.7a	3683.3a	19108a
14	0.19b	2.81a	33.26a	15.22a	9600.0a	1850.0a	3741.7a	21767a
28	0.21b	3.22a	31.82a	16.12a	6650.0b	1575.0ab	3600.0a	20300a
49	0.15b	2.13a	30.20a	14.73a	3625.0c	1300.0b	3533.3a	21058a
98	0.18b	2.13a	26.30b	16.07a	3341.7c	1275.0b	3708.3a	20033a

Legend: Means with the same superscript along the same column are not significant.

Table 3: Nutrient content with varying days of litter decomposition in Dry season

Days	N (%)	P (%)	C (%)	Lignin (%)	Na(m/kg)	K(m/kg)	Mg(m/kg)	Ca9m/kg)
0	1.43bc	1.14ab	24.68b	18.74d	1497.5ab	5404.2a	6739a	79226b
7	1.29c	1.17ab	32.78a	26.79a	1908.3a	5820.8a	7052a	81354ab
14	1.83a	1.26a	31.20a	24.51b	1800.0ab	6279.2a	7845a	104198a
28	1.89a	1.35a	16.17c	22.42c	2058.3a	5495.8a	7502a	59229bc
49	1.64ab	1.22a	9.80c	20.00d	1300.0b	3654.2b	6029a	49313c
98	1.50bc	0.97b	10.57c	19.04d	412.5c	1620.8c	3486b	51979c

Legend: Means with the same superscript along the same column are not significant.

Table 4: Nutrient content with varying days of litter decomposition.

Days	N%	P (%)	C %	Lignin %	Na (m/kg)	K (m/kg)	Mg (m/kg)	Ca (m/kg)
0	0.87±0.13dc	0.13±0.03a	28.95±1.91b	16.97±0.52c	5815.4±1055.32a	3335.4±666.88a	5206.8±544.03a	49426±6606.89b
7	0.75±0.12d	0.16±0.05a	33.54±0.77a	20.99±1.29a	6129.2±1089.48a	3806.3±781.98a	5367.7±710.71a	50231±7035.29b
14	1.02±0.18ab	0.14±0.04a	32.24±0.89ab	19.87±1.08b	5700.0±939.93a	4064.6±757.66a	5793.2±649.41a	62982±9167.67a
28	1.05±0.19a	0.16±0.05a	23.99±2.23c	19.28±0.78b	4354.2±616.31b	3535.4±592.56a	5551±590.73a	39765±8349.99c
49	0.90±0.16bc	0.11±0.03a	20.01±2.40d	17.37±0.62c	2462.5±544.00c	2477.1±479.53a	4781.3±558.80a	35185±4452.51c
98	0.84±0.15dc	0.11±0.03a	18.44±2.17d	17.56±0.46c	1877.1±351.32c	1447.9±341.72b	3597.4±407.39b	36006±4610.54c

Legend: Means with the same superscript along the same column are not significant.

Table 5: Nutrients content in leaf litter decomposition with varying season irrespective of days.

Parameter measured	Season	
	Dry	Wet
Nitrogen	1.60±0.04a	0.21±0.01b
Phosphorus	1.19±0.05b	2.70±0.22a
Carbon	20.87±1.39b	31.52±0.64a
Lignin	21.92±0.40a	15.43±0.26b
Sodium	1496.1±143.45b	7283.3±502.57a
Potassium	4712.5±441.49a	1509.7±82.01b
Magnesium	6442.2±421.44a	3656.9±61.06b
Calcium	70883±3931.29a	20315±569.66b

Legend: Means with the same superscript on the same column are not significantly different

Table 6: Effect of Leaf litter Species on nutrient in Wet season

Measured parameter	Leucaena	Gmelina	Teak	Secondary forest
Nitrogen (%)	0.29a	0.23a	0.14b	0.15b
Phosphorous (%)	4.83a	2.14b	1.70b	2.09b
Carbon (%)	32.44a	32.31a	32.44a	28.87b
Lignin (%))	13.48c	15.17b	16.29ab	16.76a
Sodium (m/kg)	10827.8a	7200.0b	6038.9bc	5066.7c
Potassium (m/kg)	2261.1a	1472.2b	1172.2b	1133.3b
Magnesium(m/kg)	4250.0a	3661.1b	3177.8c	3538.9b
Calcium (m/kg)	19944b	15617c	21089b	24611a

Legend: Means with the same superscript along the same column are not significant.

Table 7: Effect of Leaf Litter Species on Nutrient Content in dry season

Measured parameter	Leucaena	Gmelina	Teak	Secondary forest
Nitrogen (%)	1.62a	1.58a	1.60a	1.59a
Phosphorous (%)	1.88a	1.07b	0.86c	0.94bc
Carbon (%)	21.44a	20.11a	21.70a	20.22a
Lignin (%)	21.37a	22.43a	22.34a	21.52a
Sodium (m/kg)	2936.1a	1513.9b	595.6c	938.9c
Potassium (m/kg)	9275.0a	4438.9b	1825.0c	3311.1b
Magnesium(m/kg)	9271.5a	5954.2b	4531.9b	6011.1b
Calcium (m/kg)	72472a	78340a	63644a	69075a

Legend: Means with the same superscript along the same column are not significant.

Table 8: Percentage Mass Loss of the Species for the Study site

% Mass Loss for the Study Site								
Day	Gmelina		Tectona		Leucaena		Secondary Forest	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
0	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
7	8.20 (4.10)	12.88 (6.44)	8.05 (4.03)	23.54 (11.77)	12.84 (6.42)	17.12 (8.56)	12.65 (6.32)	23.48 (11.74)
14	15.20 (7.60)	22.00 (11.00)	12.94 (6.47)	25.06 (12.53)	22.36 (11.18)	43.64 (21.73)	19.20 (9.60)	23.86 (11.93)
28	15.75 (7.88)	24.42 (12.21)	14.68 (7.34)	27.2 (13.6)	30.33 (15.17)	60.34 (30.17)	22.74 (11.37)	28.80 (14.40)
49	26.80 (13.40)	62.26 (31.13)	19.27 (9.63)	29.94 (14.97)	48.73 (24.37)	73.20 (36.60)	26.73 (13.37)	47.20 (23.60)
98	30.02 (15.01)	48.87 (24.43)	21.11 (10.56)	35.13 (17.57)	60.21 (30.10)	75.94 37.97)	29.25 (14.63)	55.66 (27.83)

- ***Mass loss in parenthesis.***

SUB-THEME 3

Forest Ecosystem and Climate Change Adaptation and Mitigation

Emerging Potentials of Hydroponic Farming in Nigeria: An Alternative Farming Practice in the Face of Climate Change-A Review

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Abstract

The review accessed the emerging potentials of hydroponic farming in Nigeria as an alternative farming practice in coping with the effects of climate change. Specifically, it explained the concept of hydroponic farming, identified the types, discussed the benefits and compared the yield between hydroponic farming practice and conventional farming practices and identified the possible challenges of practicing hydroponic farming in Nigeria. Hydroponic farming is the method of growing plants in different types of substrates (chemically inert), sand, gravel, or liquid (water), in which nutrients are added, but no soil is used. Types of hydroponic farming practice includes Deep Water Culture (DWC), Float Hydroponics (FH), Nutrient Film Technique (NFT), Deep Flow Technique (DFT) and Aeroponics. Benefits of Hydroponic farming practices includes higher productivity, reduced labour requirement, not season-bound, low management cost, no weed competing, no soil-borne pest and disease, no big expensive machinery required and precision in terms of nutrient supply. It was also revealed that the yield of hydroponic farming practice were higher than the conventional farming practice. Possible challenges of hydroponic agriculture include power failure, high initial cost of investment, technical know-how, government policy and low awareness. It was concluded that hydroponic farming practice could be an antidote to solve farmers' problems if adopted by Nigerian farmers especially in the face of climate change. The review recommended that grants and loans should be provided in conjunction with private public partnership to encourage youths and entrepreneurs to invest money and resources into this emerging concept of farming

Keywords: Hydroponic farming, Climate Change, Crop Production, Nigeria.

INTRODUCTION

Over the years, due to continuous increase in human population among other reasons, there has been a drastic rise in the demand for food production which has depended almost entirely on soil as a growing medium for crops. Soils as defined by Richard *et al*. (2015)is a complex mixture of minerals obtained from the breakdown of underlying rocks or sub-soils, organic matter obtained from the decay of plant and animal material, water, air and other gases, plus biological life in the form of worms, insects and microbes. It provides basic medium for plant growth, supporting the production of crops and fodder and assisting a range of ecosystem activities (Theresa, 2013). United Nation (2009) estimated that by 2050 the world population is expected to rise from its present 7 billion to 9 billion. This will require another production of about 1 billion tons of cereals per year (Bruinsma, 2009). However, soil degradation has been identified as a major global challenge facing land use for food production which has been further worsened by the effect of climate change (Montanarella, 2007).

In addition to this, the use of soil for crop production in order to feed the ever growing human population is been competed with by the need for shelter, transport, urbanization and industrialization and other socio-economic needs (Tajudeen and Taiwo 2018). According to FAO (2011), land and water resources and the way they are used play a principal role in food security and these resources are at risk due to demographic pressure, climate change and increased competition and so to ensure food security and nutrition improvement, agricultural production will have to rise faster than population growth to about 70% globally which will depend majorly on existing Agricultural land. The problem of soil degradation is a global challenge with Nigeria while her population and consequently the need for food production increases. All these and many more challenges possess a great deal of opposition to the actualization of the “zero hunger” SDG (Sustainable Development Goals) and raises a question of whether or not soil farming can be relied upon solely for food production and food security in order to consistently feed her estimated population.

The objectives of this review are to:

i. discuss the concept of hydroponic farming;
ii. identify types of hydroponic farming practice;
iii. compare the yield between hydroponic farming practice and conventional farming practices; and
iv. identify the possible challenges of hydroponic farming in Nigeria.

Concept of Hydroponic Farming

Hydroponics can be briefly defined as cultivation of plants without soil (Savvas, 2017). hydroponics, a Greek word meaning “hydro” (water) and “ponos” (labor), is the method of growing plants in different types of substrates (chemically inert), sand, gravel, or liquid (water), in which nutrients are added, but no soil is used (Savvas, 2017). Europe is considered the biggest market for hydroponics in which France, the Netherlands, and Spain are the three top producers, followed by the United States of America and Asia-Pacific region. These systems are becoming increasingly widespread over the world, and according to the most recent report (Jensen and Collins, 1985) it is expected to reach a world growth of 18.8% from 2017 to 2023, corresponding to a global hydroponic market USD 490.50 Million by 2023.

According to growers, hydroponic systems help them in expanding their ability for a continuous production in a short growing period, require less space, and plants can be produced anywhere, *i.e*., in a small space with a controlled growth environment (Hughes, 2017). Growers often said that hydroponics always allows them to have higher productivities and yields without any constrains of climate and weather conditions (Sarah, 2017). In addition, growers often claimed that quality of hydroponic produce is superior because it uses a highly controlled environment and enables a more homogeneous production without any loss of water and nutrients. Moreover, hydroponics is not dependent on seasonality, and therefore, their productivities are higher and homogenous throughout the year (Okemwa, 2015). Growers also often report that hydroponic productions are easier, and since they do not require cultural operations such as plowing, weeding, soil fertilization, and crop rotation, they are light and clean (Nguyen *et. al*., 2016).

Types of Hydroponic Farming

There are different types of hydroponic farming. The type of system chosen depends primarily on the type of plant as well as any limitations of the grower and or growing space (Jensen 1997). The most popular are deep water culture, float hydroponics, nutrient film technique and aeroponics (Resh 2015). Hydroponics systems can generally be delineated into open and closed systems (Abd-Elmoniem *et al*., 2006; Nederhoff and Stanghellini 2010). Open systems, also known as “run to waste systems,” do not employ water reuse measures and the nutrient solution flows through the system only once and is discarded (Jensen 1997; Nederhoff and Stanghellini 2010). Open systems provide two primary advantages: they eliminate the need for nutrient solution maintenance and reduce the risk of plant pathogens and infection (Jones Jr. 2005). On the other hand, closed systems reuse the nutrient solution via recirculation for an unspecified length of time (Lykas *et al* 2006). More water and nutrients are added instead of replacing the entire solution. The nutrient solution is regularly monitored and adjusted to maintain proper nutrient ratios. As a result, closed hydroponic systems use 20-40 percent less water and nutrients than open hydroponic systems, but are more difficult to monitor and maintain.

1. Deep Water Culture (DWC)
This technique allows plant to be grown in bucket containing nutrient solution covered with a lid, and the plants, contained in net pots, suspended from the centre of the cover. This system is aerated using an air pump as the covering of the bucket limits air-water exchange.

2. Float Hydroponics (FH): In this technique, floating materials such as polystyrene or Styrofoam are placed on a trough containing nutrient solution. These floating materials are used to support each plant in net pot which are placed in holes made on the material. Most float systems are long, rectangular reservoirs built out of cement or wood and lined with a durable polyliner (Saaid *et al*., 2015).

3. Nutrient Film Technique (NFT) in this technique, thin layer of nutrient solution is made to flow through an elevated channel (trough) within which the root of the plant. Thin layer of the nutrient solution allows the upper part of the plant root to be adequately oxygenated while the elevation of the channel is to allow nutrient solution to reach plants at the lower end. The nutrient solution may be delivered continuously in a 24-hour cycle, intermittent (alternating watering and dry periods to increase root system oxygenation), or continuous recirculation during daylight hours and automated switching off at night (Saaid *et al*., 2013).

4. **Deep Flow Technique (DFT):** similar to some other aforementioned techniques, the root of plants are continuously exposed to moving nutrient solution by supporting them with floating materials but the channel here usually contains solution of a depth of 50–150 mm and width of about 1m. Control of the nutrient solution is simplified by the large water volume and this buffers the temperature, making it suitable for regions where fluctuation in temperature of nutrient solution can be an issue (Saaid *et al*., 2013).

5. **Aeroponics:** this has to do with growing plants with their roots suspended while fine mist of nutrient solution is continuously or intermittently applied. In some parts of Bangladesh most affected by flood and waterlogging, farmers are using methods similar to hydroponic know as floating agriculture (Mithunesh *et al*., 2015). In this method, plants are grown on the water in a bio-land or floating bed made of water hyacinth, or other plant residues (Nguyen *et al*., 2016). This method of farming is not only practiced in Bangladesh but in some other part of the world faced with similar challenge (Saha, 2010) and it is recommended able for regions in Nigeria having such issue of flooding or waterlogging or little land but much water resources.

Importance of Hydroponic Farming Practice

Soilless farming has been discovered to proffer solution to the problems being faced by tradition soil farming. The major advantage with such a system is the absence of weeds and other soil borne pests, absence of toxic pesticide residue, better use of water, better control over nutrient and oxygen, increased crop quality and yields (FAO, 2016). Importance of Hydroponic farming practice includes:

i. **Higher Productivity**: in line with the need for food production to rise faster than population growth to ensure food security and nutrition improvement, crops grown under soilless farming techniques have been studied and observed to be better and faster than soil farming.
ii. **Reduced Labour Requirement**: Labour requirement in soilless farming is lesser as there are no soil to till, no plough or ridge to make, no weeding to be done, no watering and requires less for pest control especially in greenhouses.
iii. **They are not Season-Bound**: plants grown in soilless farming are not affected by the season as they are constantly fed with the required nutrient and water to grow.
iv. **Low Management Cost**: cost of running this system is usually low especially for the NFT system because these are kept running almost entirely automated and each input is expected to last for years.
v. **Absence of Weed Competition:** since soil is not used, with all seeds carefully selected, soilless farming has no weed or weeding problem. This saves cost on herbicide and spraying.
vi. **Absence of Soil-Borne Pest and Disease:** plants under soilless planting system can be attacked by pest and diseases too but not usually as much as that of soil farming as most soil and diseases are known to be soil-borne. Soilless farming has been observed to have little pest and disease issue.
vii. **Big and Expensive Machinery not required**: since the system doesn't involve land ploughing, ridging, tilling, clearing, windrowing, no big or expensive machineries like tractors, bulldozers, combine harvester are needed.
viii. **Precision in Terms of Nutrient Supply**: excessive use of fertilizer know with geoponics is not the case in soilless farming as nutrients are either released based on plant requirement or are recycled or reused in most cases.

Possible Challenges of Hydroponic Agriculture

i. **Power (Electricity)**: power has been a major challenge in Nigeria for several decades with each successive government promising to provide stable and affordable electricity but without success. Soilless farming though uses far less energy than traditional farming (Joel, 2007), requires stable power to run certain equipment especially air pump and water pump. The epileptic nature of the Nigerian electricity supply without exception of any state and its high cost poses a great limitation to the implementation of a full scale commercial soilless farming.
ii. **High Initial Cost of Investment**: according to Olympios, and Choukr-Allah (1999), the initial stage of establishment of soilless farming system involves high cost of inputs for construction and maintenance.
iii. **Technical knowhow**: soilless farming can be technical as the knowledge of plant physiology, chemistry, instrumentation and the likes might. be required from time to time.
iv. **Government Policy**: Government is needed to put in place structures, framework and policies to aid the success and development of soilless farming.
v. **Low Awareness of Hydroponic Agriculture:** due to the fact that it is a somewhat new (emerging) innovation just gradually gaining publicity compared to soil farming and also acceptability due to the sceptical nature of people in accepting new innovations. Application on commercial scale requires technical knowledge and high initial investment, though returns are high (Treftz and Omaye, 2015).
vi. **Hydroponic is Limited to High Value Crops**
Considering the high cost, the soil-less culture is limited to high value crops. Great care is required with respect to plant health control. Finally energy inputs are necessary to run the system (Ajlouni *et. al*., 2001).

Crops Grown Using Hydroponic Farming

Table 1 shows the list of crop that thrives well on commercial level using hydroponic farming

Table 1. List of Crops that can be grown on commercial Level Using Hydroponic Farming.

Types of Crops	Name of Crops
Cereals	*Oryza sativa* (Rice), *Zea mays* (Maize)
Fruit	*Fragaria ananassa* (Strawberry)
Vegetables	*Lycopersicon esculentum* (Tomato), *Capsicum frutescens* (Chilli), *Solanum melongena* (Brinjal), *Phaseolus vulgaris* (Green bean), *Beta vulgaris* (Beet), *Psophocarpus tetragonolobus*(Winged bean), *Capsicum annum* (Bell pepper), *Brassica oleracea var. capitata* (Cabbage), *Brassica oleracea var. botrytis* (Cauliflower), *Cucumissativus* (Cucumbers), *Cucumis melo* (Melons), *Raphanus sativus* (Radish), *Allium cepa* (Onion)
Leafy Vegetables	*Lactuca sativa* (Lettuce), *Ipomoea aquatica* (Kang Kong)
Condiments	*Petroselinum crispum* (Parsley), *Menthas picata*(Mint), *Ocimum basilicum* (Sweet basil), *Origanum vulgare* (Oregano)
Flowers/Ornamental Crops	*Tagetes patula* (Marigold), *Rosa berberifolia* (Roses), *Dianthus caryophyllus* (Carnations), *Chrysanthemum indicum* (Chrysanthemum)
Medicinal crops	*Aloe vera* (Indian Aloe), *Solenostemon scutellarioides* (Coleus)

Source: Singh and Singh. (2012).

Comparative Analysis between Hydroponic and Ordinary Soil Yields

Table 2 shows the comparative analysis between hydroponic and ordinary soil yields according to Singh and Singh (2012)

Table -2: Hydroponic Averages Compared with Ordinary soil yields.

Name of Crop	Hydroponic Equivalent Per Acre	Agricultural Average Per acre
Wheat	5,000 lb.	600 lb.
Oats	3,000 lb.	850 lb.
Rice	12,000 lb.	750-900 lb.
Maize	8,000 lb.	1,500 lb.
Soybean	1,500 lb.	600 lb.
Potato	70 tons	8 tons lb.
Beet root	20,000 lb.	9,000 lb.
Cabbage	18,000 lb.	13,000 lb.
Peas	14,000 lb.	2,000 lb.
Tomato	180 tons	5-10 tons
Cauliflower	30,000 lb.	10-15,000 lb.
French bean	42,000 lb. of pods for eating	-
Lettuce	21,000 lb.	9,000 lb.
Lady’s finger	19,000 lb.	5-8,000 lb.
Cucumber	28,000 lb.	7,000 lb.

Source: Singh and Singh (2012).

CONCLUSION

Hydroponic farming has the potential to transform the face of farming in Nigeria if embraced especially with the advent of climate change. This development if adopted will lead to all year round food production for the teeming populace and improve the livelihood of farmers. It is therefore concluded that hydroponic farming practice could be an antidote to solve farmers’ problems if adopted by Nigerian farmers especially in the face of climate change effect.

RECOMMENDATIONS
Based on the data reviewed in this paper, the following are recommended:

i. The problem of power should be speedily addressed as it not only affects agriculture but all other sectors of the economy;
ii. Government, private investors, companies, manufacturing equipment for soilless farming and all stakeholders should not only encourage hydroponic farming but assist research and training of all interested on the technicalities involved; and
iii. Grants and loans should be provided in conjunction with private public partnership to encourage youths and entrepreneurs to invest money and resourcefulness into this emerging concept of farming practice.

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Faidherbia albida (Del.) A. Chev: An Ideal Agroforestry Tree Species for Small Holder Farmers in the Midst of Climate Change Impacts in Nigeria

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Abstract

Despite the fact that agriculture provides mankind with a lot of benefits, it has also been singled out as the major cause of deforestation in Nigeria and this has aggravated the trends and forms of climate change impacts in the country. The unequivocal impacts of climate in Nigerian agroecosystems include increasing rainfall, deforestation, flooding, heat stress, drought, depletion of soil organic carbon, and soil and wind erosion. In order to check this antagonistic problem, agroforestry have been highly advocated for. However, successful execution of agroforestry projects will to a large extent depend on the identification and use of agroforestry tree species with sound ecological benefits. This paper therefore discussed the various ways in which F. albidabased agroforestry system can be employed in tackling the menace of climate change in Nigeria. Successful integration ofF.albida in different Nigerian farmlands will engender enhancedcarbon sequestration,erosion control, soil improvement, drought and desertification reduction and heat stress mitigation. Therefore it was recommended that the tree species should be accepted, grown and integrated into Nigerian agroecosystems to enjoy the ecological benefits thereof.

Keywords: Climate change, agroforestry, *F. albidia*, farmland, agroecosystem

INTRODUCTION

Agroforestry over the decades has been defined in so many ways by different authors and bodies although the definitions of Lundagreen and Raintree (1982) and that of Leekey (1996) are most times the most commonly used among all. In their works, they defined Agroforestry as a collective name for land- use systems and technologies where woody perennials (trees, shrubs, palms, bamboos etc) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. However, an alternative definition by FAO (2015) describes agroforestry as a dynamic, ecologically based, natural resource management system that, through the integration of trees on farms and in agricultural landscapes, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels. From the latter it is glaring that socioeconomic and environmental benefits can be accrued from agroforestry when properly developed and managed. Literatures (Thorpe and Muriuki, 2001; FAO, 2012; Swai*et al*., 2014; Herrero and Thornton, 2014) have described smallholder farmers as small-scale farmers, pastoralists, forest keepers, fishers who manage areas varying from less than one hectare to 10hectares. Irrespective of the relatively small area of land been managed by these farmers, they contribute significantly to the food production sector of many continents and/or sub-regions of the world. Most especially that in Asia and sub-saharan Africa they account for 80% food production outputs and this evidenced in Nigeria where 80% of its total farmers are smallholder farmers (Akinsuyi, as cited in Adetoye, 2019)

Despite the fact that agriculture provides mankind with a lot of benefits, it has also been singled out by several authors (Allen and Barnes, 1985; Ogunleye*et al*., 2004; Benhin, 2006) as the major cause of deforestation especially in developing countries of the world. In order to check this antagonistic problem, agroforestry practices in recent times have been highly advocated for. However one of the major threats to successful execution of agroforestry projects in contemporary times here in Nigeria is climate change and its impacts. Therefore, developing a sound agroforestry practice that will engender food security and climate change mitigation and adaptation in Nigeria will to a large extent greatly depend on the identification and utilization of agroforestry tree species with good ecological and socioeconomic features hence the place of *Faidherbia albida* in Nigerian agroforestry system. This paper discuss the various ways in which the integration of *Faidherbia albidida* in Nigerian agroforestry systems can help the small holder farmers contribute more to climate change mitigation in their quest for increased food security in the country.

BREIF BOTANICAL DESCRIPTIONS OF *F. albida*

F. albida belongs to a large and economically significant family of flowering plants, Fabaceae. It features among of the largest thorn and could reach 30m in height with round crown formed from spreading branches and the stem can reach 1.5m in diameter upon maturity (Kariba, 2013;Ereso, 2018). The bark is dark brownish or grayish in colour though young seedlings are light grey and smooth (Oluwakanyinsola*et al*., 2010). Upon maturity the barks becomes fissured, flaky and more corklike. *F. albida* possesses compound leaves which are bipinnate with leaflets borne along the pinnae, typical for Mimosoidae(CTFT, 1989). At the base of the leaves, there are the presences of pairs of thorns modified to tiny stipules. Thorns occur in pairs at the base of the leaves and are modified spiny stipules (Ereso, 2018). They are straight and robust, thickened at the base and often orange or brown at the tip and are 0.2-3.2 cm long and they can be differentiated from other members of Acacia by their basal thickening (Vandenbeldt, 1992). Born in axillary panicles, the flowers transform themselves from white, cream and yellow colouration before maturity with a pleasant scent (Centre technique forestier tropical, 1989). The flowers give rise to indehiscent fruits in form of pods which are orange to reddish brown which bears dark brown shiny ovoid seeds with lathery and waterproof structures which provide protection and viability to the seed.

SOME ECOLOGICAL FEATURES OF *F. albida*

Phenology

Deciduous trees physiologically adapt to excessive evapotranspiration especially during the dry season by shedding their leaves and this is conventional for almost all deciduous trees with the exception *F. albida*.The behavior of *F. albida* is unusual because at the start of raining season, it goes dormant by shedding its leaves while it becomes fully evergreen during dry season (Barnes and Fagg, 2003). However, seedlings are exempted of this phenology until well developed taproots are established into the water table (Fagg, 1995). This unusual trait of reverse phenology may have arisen as adaptation to competition from other tree species (Haskett*et al*, 2019)

F. albida and Nutrient Enrichment

Legumes play important role in agriculture owing to their ability to form symbiosis with rhizobia to obtain nitrogen from the air (Giller as cited in Dabessa, *et al*., 2018). *F. albida*, a typical leguminous tree species, fixes atmospheric nitrogen by taking advantage of its nitrogen fixing bacteria laden roots which it then reincorporate to the soil through its massive shedding of its protein-rich foliage and pods during the rainy season (Esore, 2008; Haskett*et al*., 2019). Due to high level of moisture during the rainy season, mineralization processes for the litters becomes faster thus increasing the mineral content of the soil within the canopy range when compared to soil samples outside the canopy range. Umar *et al* (2012) have reported similar nutrient gradient in parkland with *F. albida* in Ethiopia. In their study, they observed that the Nitrogen, Organic Carbon and Potassium levels were 42, 31 and 25% respectively higher under the canopies than outside devoid of the tree's canopy.

Flood and Drought Tolerance

The ability of *F. albida* to thrive both in savanna and forest zone makes it ideal for good agroforestry projects in both regions. Another advantage of the phenology of the tree species is that it enables it to remain dormant during the periods of flooding when found around the coastal areas (Haskett*et al*., 2019). This accounts for its affinity for alluvial soils. On the other hand it has also been reported to be thriving in on rocky, heavy and cracking clays (Saka and Bunderson 1989) and as well as areas. In South-Western Africa, Fagg and Barnes (1995) have reported that the tree species also thrive under desert and arid conditions. Its ability to develop a long taproot system that can penetrate up to 80m depth into the soil could have been one of the major traits enabling it to survive arid conditions where there is relatively low supply of moisture.

A REVIEW OF THE IMPACTS OF CLIMATE CHANGE ON NIGERIAS' AGROECOSYSTEM

Climate change is global, as well as its impacts; but the most detrimental effects will be felt mainly by developing countries, especially those in Africa, as a result of their low level of contending capabilities and Nigeria is among these developing countries (Nwafor 2007; Jagtap 2007; Odjugo, 2010). Glaring evidences have confirmed the vulnerability of Nigeria to climate change impacts including its agroecosystems (Chima *et al*., 2019). Such evidences include rising temperature and sea levels, stormy and devastating rainfall, flooding among other impacts on Nigerian agroecosystems (Chima *et al*., 2019)

Temperature and rainfall are good indicators of climate change (Nwagbara, 2008 and Uguru*et al*., 2011). The southern area of Nigeria (blessed with rainforest and mangroves) largely known for high rainfall is currently experiencing irregularity in the rainfall and temperature is increasing gradually towards the guinea savannah zone of the country while the northern zone faces the threat of desert encroachment (Federal Ministry of Environment as cited in Bello, *et* *al*., 2012). Apart from flooding affecting the southern agroecosystems (Rainforest), rising sea levels has left arable lands in coastal agrarian communities within the zone less productive due to salinity issues resulting from salt water intrusion (Chima *et al*., 2019). On the other hand, the issue of soil salinity has also emerged as a serious environmental problem in arid and semi-arid regions (Allbed and Kumar, 2013). Consequently this is the case in Sudan and Sahel savanna agroecosystems due to high irrigation agriculture resulting from inadequate rainfall.

Rainfall is by far the most important water resources potential and source in Nigeria (Adejumo, 2004) but its occurrence recently has been irregular, unpredictable and unreliable as rainfed agriculture is no longer sustainable in the country. Consistent reduction in rainfall according to Fasona and Omojola (2005) leads to reduction in the natural regeneration rate of land resources and this has become the fate of the Nigerian savanna agroecosystems as droughts and forest fires are regular events in the region thus leading to poor and unpredictable agricultural yields. In the Nigerian Sahelian region, there has been a 25% decrease in precipitation on average in the last 30 years (Amanchukwu*et al*., 2015; Olapido, 2010). These have overtime increased the vulnerability of farmers in the zone to further climate change impacts, (UNFCCC, 2007; Zoellick, 2009). One of the major disadvantages of climate change is the depletion of soil organic carbon pool (SOCP) due to increasing earth temperature. At such condition mineralization rate are aggravated which result in decrease of soil organic carbon pool (SOCP). Lal (2004) stated that an increase in temperature would deplete the SOCP in the upper layers by 28% in the humid zone, 20% in the sub-humid zone and 15% in the arid zone such depletions have detrimental effects on soil properties. Under such condition soil loses its multipurpose activities like biodegradation of contaminants, buffering of greenhouse gas emission from the soil to the atmosphere, moderation of soil pH and temperature, aggregate stability, ion exchange, storage and supply of macro and micronutrients (Lal, 2004). Cases of low soil fertility have been reported in Nigeria as inorganic fertilizer application has come to stay in its agricultural sector. The savanna belts are becoming drier, its soils have follow suit and must be enriched with fertilizers for good productivity.

The water and land degradation nexus cannot be overemphasized in forest ecology. Water is the main factor directly or indirectly responsible for soil and land degradation processes (Pla, 2008). Generally, there is high runoff at Rainforests zones especially in South-Eastern Nigeria (Uguru *et al*., 2011) due to increasing trends of the region's rainfall resulting from climate change. As a consequence, the area is under rapid transformations from forest to derived savanna ecosystem. Rainfall erosivity indices (R) of South Eastern Nigeria as reported by Ezemonye and Emeribe (2012) ranges from very low which coincided with dry season months to very high. The high R value in their study (Ezemonye and Ezeribe, 2012) was recorded during the peak months of rainfall i.e. June to September respectively. As a result of climate change impacts, the mean monthly rainfall volumes between June to September for the region are very high as compared to the initial trends under little or no influence of climate change. As NEST (1991) explained, a rainy night can just trigger the development of gullies capable of growing into a huge gash of over 30,000m^2 in volume, this is the situation in southeastern states as the measured rates of gully growth in one rainy season for South-Eastern Nigeria as reported by Abegunde*et al* (2006) may be up to 157 metres in length, 50 metres in width, and 5 metres in depth.

CLIMATE CHANGE IMPACTS MITIGATION POTENTIALS OF *F.albida*

If properly chosen managed and integrated into Nigerian agroforestry systems, *F. albida* has the potentials to mitigate some climate change impacts affecting Nigerian agricultural systems thus creating a pleasant environment and conserving the soil's productive capacity in Nigeria's agroecosystems in the following ways:

Erosion Control and Soil Improvement

The conversion of forestlandsto croplands and grasslands devoid of trees on vulnerable soils has resulted into run-offs and increased erosion in many regions. However, through its leaves shed during the rainy season, water erosion is greatly reduced. The natural litter fall protects the soil from the heavy impact of raindrops. *F. albida* has strong and fast growing tap roots that can reach aquifers of up to 80m below the surface to secure permanent water availability (Le Houérou *et al*., 1988). These roots, together with the litter fall, not only enhance infiltration of water, but also increase structural stability of soil, and improve water storage capacity by increasing the number of soil pores. The macropores of the soil increasingly allow excess surface water flow and allow air and moisture to move into the soil freely. Thus, the risk of erosion is reduced.*F. albida* has also been seen to serve efficiently in control of wind erosion in agricultural lands (Leenders, 2006). This can be attributed to its ability to attain very large sizes.

Drought

In semi-arid regions, tree canopies help to conserve water content of soil much more than bare lands, which is due to reduced evapotranspiration in soils under tree shades. Thus, *F. albidia*, which is known to shed its leaves during the rainy season at the time of higher microbial activity in the soil, improves the soil structure, while retaining leaves in the dry season provides shade and mulch reducing evaporation thus conserving the available soil moisture (Dangasuk *et al*., 2006).

Carbon Sequestration and Shelter Belt

The incorporation of trees or shrubs in agroforestry systems can increase the amount of carbon sequestered compared to a monoculture field of crop plants or pasture (Sharrow and Ismail 2004; Kirby and Potvin 2007). In addition to the significant amount of carbon stored in aboveground biomass, agroforestry systems can also store carbon belowground.

Like every other agroforestry species, F. albida has the ability to sequester carbon from the atmosphere. This agrees with the findings of Beedy *et al.* (2016), which opined that *F. Albida* is effective in storage of carbon in Malawi. Upon maturity *F.albida* is highly resilient to wind throws and its rooting system gives it strong anchorage to the soil while the highly lignified and stout branches pushing against stormy winds.

Fertilizer Substitution

In agroforestry systems, *F. albida* through shedding of leaves increases soil organic matter content and adds nutrient to the soil. Through this, nitrogen and other important elements needed for the growth of the agricultural components are added to the soil. The provision of nitrogen ensures the avoidance of manufactured urea. This is a substitution of solar energy that the trees use to obtain nitrogen from the atmosphere, for the fossil fuels used in the manufacture and transport of urea fertilizer, thus, greenhouse gas emissions are completely avoided.This is different from carbon sequestration, as carbon sequestered in soil is released if the tree is cut or burned or the soil is subjected to intensive tillage (Haskett *et al.*, 2019). In addition, the deep rooting system of *F. albida* ensures that nitrogen is captured before it leaches out of the rooting zone. This will reduce NO_2 emissions as a result of denitrification in surface water resources. This potential of F. albida to significantly increase soil fertility was recorded in Burkina Faso (Reij *et al.*, 2009b), Niger (Kho *et al.*, 2001), Ethiopia (Haskett *et al.*, 2019) and Zambia (Yengwe *et al.*, 2018).

CONCLUSION AND RECOMMENDATION

Climate change has impacted negatively on Nigerias' agroecosystems as glaring evidences abound. Such impacts have led to low agricultural yields among the smallholder farmers in Nigeria. In other to contain such impacts, farmers are been forced to use fertilizers and other inputs to increase their productivity thus resulting in high cost of production. On the other hand agriculture itself contributes to deforestation and global warming which in turn trigger climate change impacts. In order to balance these, agroforestry is the way forward. The success, of good agroforestry projects without no doubt depend on the identification and utilization of tree species with good ecological features hence the place of *F. albida*.The potential role of *F. albida* in ensuring food security in the face of climate change makes it unique. Its unique phenology makes it suitable in both seasons for agricultural activities. If integrated into Nigeria's agroforestry systems, it will address the climate change issues facing Nigerian agroecosystems, hence its recommendation to agroforestry practices in Nigeria.

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Assessment of the Impact of Climate Change on Agricultural Production in Edo State, Nigeria

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Abstract
The study examined the impact of climate change on agricultural production in Edo State using climatic parameters (rainfall and temperature) and crop yield (cassava, rice, melon, groundnut, maize and yam). Secondary time series data obtained from Nigeria Bureau of Statistics (NBS) and Nigerian Meteorological Agency (NIMET) were used for the study. The climatic data and crop yield data obtained was from 1951 to 2012 and 1995 to 2010 respectively. The data were analyzed using linear regression. The result revealed an R-squared value of 0.322, 0.527 and 0.64 for yam, rice and melon respectively. This suggests that the impact of climate variables (temperature and rainfall) accounts for only 32%, 52% and 64% of the crop yield changes, while 67.8%, 48% and 36% of the variation in the three crop yield is explained by other factors, while only 0.26%, 1.4% and 2.2% of the variations in cassava, maize and groundnut yield are controlled by the climatic variables. The result of the analysis of data collected showed that climatic parameters had significant impact on three crop yield in the study area. It was therefore, recommended that measures should be put in place by the government for improved rain-fed agriculture, adoption of modern agricultural techniques and provision of agro-chemicals to farmers.

Keyword: climate change, crop yield, food crop, Edo state.

INTRODUCTION

Climate change has generated a global issue and more threatening to the sustainable development of agriculture in Nigeria and Edo State is not an exception. Agricultural production depends on a number of factors which include human, technological and natural elements such as temperature, rainfall, evaporation, sunlight, etc. (Idumal *et al*., 2016). Odjugo (2008) and Rahman (2014) predicted that changes in the world's climate will bring major shift in agricultural production, increase in temperature and rainfall in some places and decrease in some region. However, the global demand for agricultural crops is expected to roughly double by 2050, driven by increases in population, meat and dairy consumption and biofuel use (Tilman *et al*., 2011). This situation is not favourable to Agricultural production and may lead to food insecurity, especially in Nigeria which mostly depends on climate for rain-fed agricultural production. Adejuwon (2004) asserted that Agriculture depends highly on climate variables of temperature, sunlight, water, relative humidity which are the main drivers of crop growth and yield. Furthermore, Climate change, which is attributable to natural climate cycle and human activities, has adversely affected agricultural productivity in Africa (Ziervogel *et al*., 2006). This is particularly because African agriculture is predominantly rain-fed and hence fundamentally dependent on the vagaries of weather. Zoellick (2009) stated that, as the planet warms, rain fall patterns shift, and extreme events such as droughts, floods and forest fires become more frequent. However, climate variability is one of the most significant factors influencing year to year crop production, even in high-yield and high technology agricultural area. Recently attention has been paid to the risk associated with climate change resulting to poor and unpredictable yields which will increase uncertainty with respect to food production (Reddy and Pachepsky, 2000). The anticipated impact of climate change on agriculture underscore the need to examine climatic trends in the state to ascertain whether there is an upward or downward trend for better planning and management.

MATERIALS AND METHODS

Study Area and Data Collection

The study was carried out in Edo State in southern Nigeria. It lies between longitudes 05° 35'E - 05° 44'E and latitudes 05°44'N - 07°34'N. It is bounded in the north and east by Kogi State, in the south by Delta State and in the west by

Ondo State. Secondary data on mean annual climatic variables such as temperature (°C), and rainfall amount (mm) from 1951 to 2012 for Edo State, Nigeria were obtained from the archives of the Nigeria Meteorological Agency (NIMET), Benin City. The selected climatic parameters and crop-yield/output data were based on consistent and continuous availability of data for the period of study. The crop-yield/output for some common staple food crops (cassava, yam, maize, melon and groundnut) in the state were obtained from 1995 to 2010 in National Bureau of Statistics, Abuja, Nigeria. All expressed in metric tons per hectare (mt/ha).

Data Analysis

Trend analysis

Annual temperature and rainfall were computed from the monthly climatic data of Edo State. The annual trends of the climatic parameters were determined using the simple linear regression analysis specified as follows:

Y= a + bt, Where, Y=temperature or rainfall (dependent variable)

t=time (year) i.e. independent variable

a andb = are regression parameters to be estimated.

Second order polynomial = ax^2 +bx+c

Trend of estimated crop yield/ output for a period of ten years was depicted using line graph.

Changes in the climatic parameter

The monthly climatic data was divided into two time slices (1951-1981 and 1982-2012) and their respective mean computed. The variation in the two climatic periods was used to determine if there is evidence of climate change.

RESULT AND DISCUSSION

The trend analysis of the annual rainfall in Edo State between 1951 and 2012 is presented in Figure 1. The result of the second order polynomial showed that the annual rainfall in Edo State experienced a declining trend since 1951 up to 1981 and upward trend thereafter till 2012. The simple linear regression used to ascertain the significance of the overall trend (1951-2012) as well as the two-time slice suggested by the second order polynomial shows that the overall upward trend is not statistically significant at 99% level of confidence (α=0.01). It reveals that the trend of the rainfall over the state shows that the more recent years recorded higher annual rainfall compared with the earlier years indicating that the region is becoming wetter.

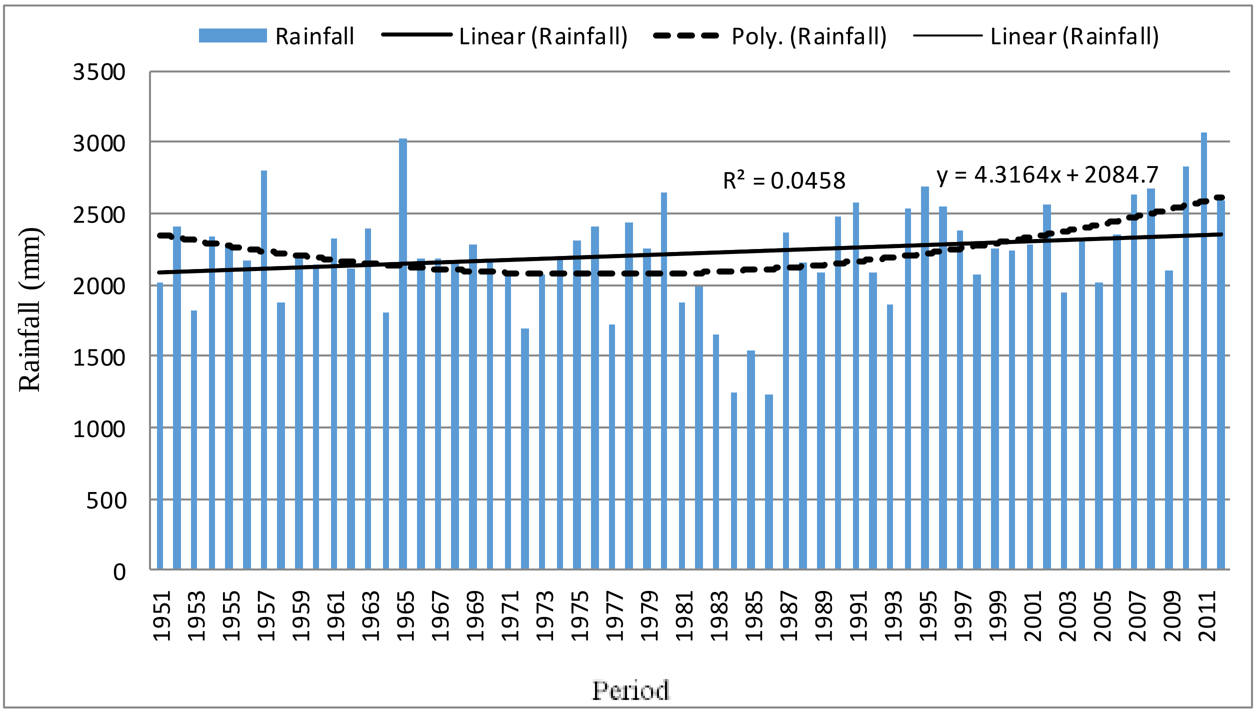

Figure 1: Annual mean rainfall in Edo State (1951-2012)

The result of the second order polynomial showed that the annual mean temperature experienced an upward trend between 1951 and 2012 (Figure 2). It revealed that the gradient of the trend is slightly upward within the first climatic period but thereafter a downward trend towards the last year. The simple linear regression analyses were performed to ascertain the significance of the overall trend (1951-2012) as well as the two time slice suggested by the second order polynomial, the result showed that there is a statistically significant upward trend in the mean temperature at 99% level of confidence. In the 1951 – 1981 climatic periods, the mean temperature was 26.7°C the mean temperature slightly increased to 27.4°C in the second climatic period (1982 - 2012). This implies that mean temperature increase between the two periods was of 0.7°C. This can be attributed to the growth of the city and increasing human activities.

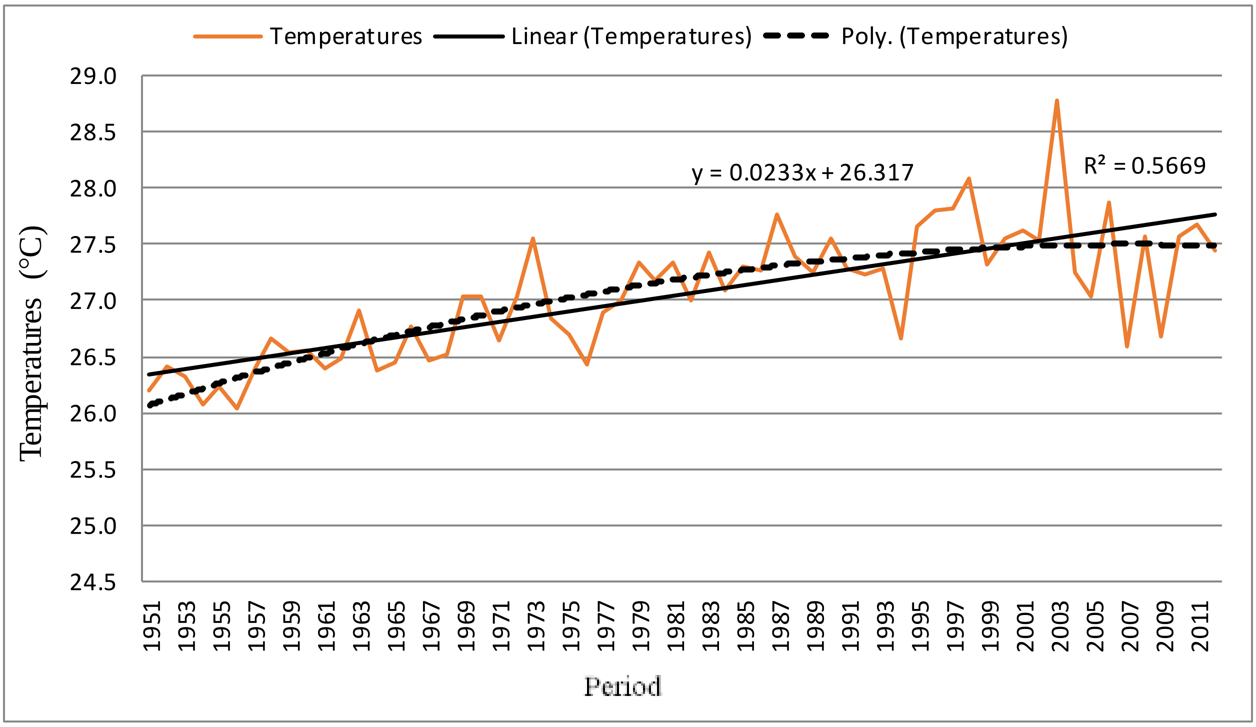

Figure 2: Annual mean temperature in Edo State (1951-2012)

Figure 3 showed the trend of crop yield in the study area. The region under this study produced predominantly tuber (yam and cassava) than other crops. The production trend for cassava and yam were very similar, implying that similar factors affected their production. The yields for the grains (maize and rice) do not follow the same trend in some years, but they have peaks occurring in the same year. The lowest yield for groundnut, maize, cassava and yam was recorded in 2009 while melon and rice was recorded in 2004 and 1995 respectively.

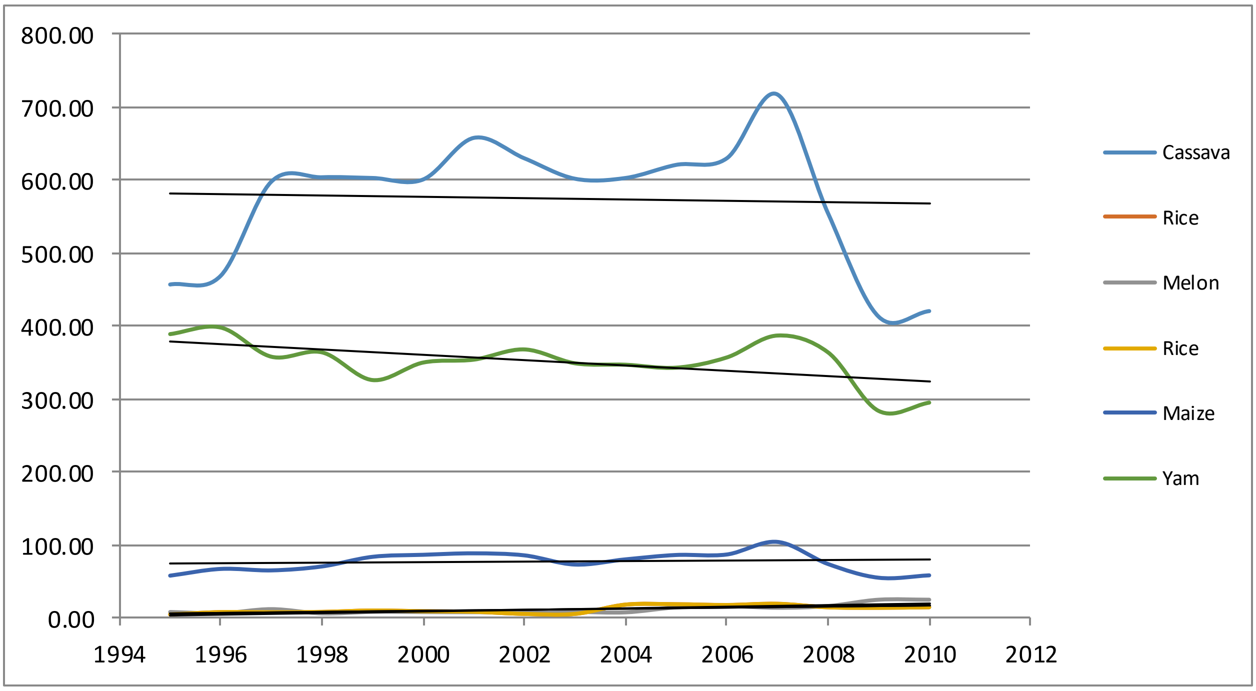

Figure 3: Trend of crop yield/output in Edo State (1994 -2012)

The relationship between crops yields and the temperature variables is presented in Figure 4. The graph showed that the lowest temperature was recorded in 2009 which coincided with a period of low crop yield for groundnut, maize, cassava and yam but favoured high yield of melon. Similarly, the regression analysis indicates an R-squared value of 0.322, 0.527 and 0.64 for yam, rice and melon, respectively. This suggests that the impact of climate variables accounts for only 32%, 52% and 64% of the crop yield changes, while 67.8%, 48% and 36% of the variation in the three crop yield is explained by other factors, such as the use of fertilizers, better seed, better crop management practice, introduction of new agro-technology etc. Additionally, only 0.26%, 1.4% and 2.2% of the variations in cassava, maize and groundnut yield are controlled by the climatic variables.

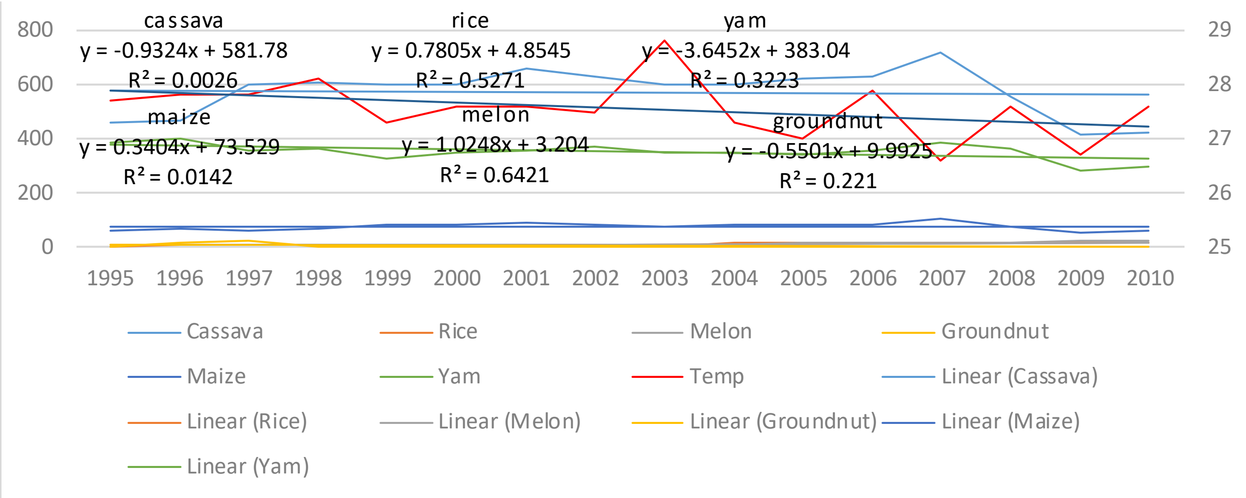

Figure 5: Trend of crop yield and temperature in Edo State (1995-2010)

The relationships between crops yields and rainfall variables are depicted in Figure 5.The results of this study showed that crop yields and amount of rainfall varied from year to year. The trend of rainfall in the study area shows that the recent years recorded lower annual rainfall compared with the earlier years indicating that the region is becoming drier. The crops yield is dependent on the amount of rainfall. The result of the study showed that high yields of cassava, rice and maize were recorded in 2007 that coincided with a period of gradual increase in rainfall amount that may have favoured the growth and yield of the crops.

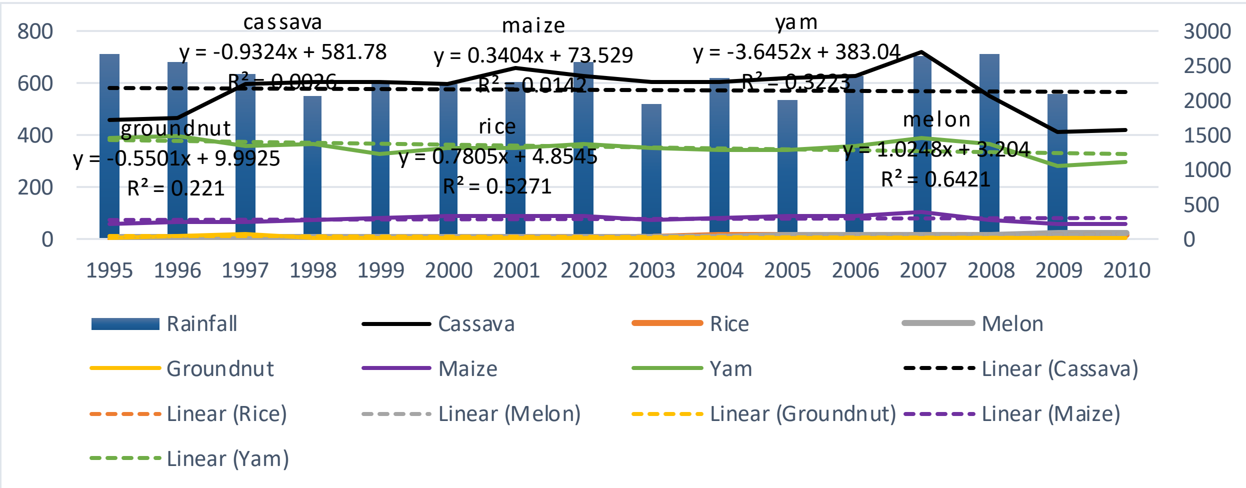

Figure 5: Trend of crop yield and rainfall in Edo State (1995-2010)

CONCLUSION

The study has been able to establish that climate variables are related to melon and rice yield. The result implies that, though there are variations in climatic parameters within the years, such variation has little impact on the other selected crops. This suggests that crop yields or crop production in Edo state may largely depend on combinations of number of interacting factors which are of both climatic and non-climatic components. To proper tackle this challenge there is the need for timely policy intervention by the government to improved rain-fed agriculture, adoption of modern agricultural techniques and provision of agro-chemicals to farmers. In addition, other climatic parameters such as sea surface temperature, soil temperature, wind, relative humidity and sunshine should be investigated in other to find out their influence on crop yield in the area.

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Application of Heat Shock Protein Genes: An Innovative Approach to Mitigating Abiotic Stresses to Plant Development

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Abstract

Agricultural productivity in developing countries is limited by diverse abiotic and biotic constraints. One of these stresses and a major constraint is high temperature. It is a constant changing component of the environment and a threat to food security. Fluctuations in the environmental temperature occur more speedily than changes in other stress factors thereby aggravating the effects of other stresses on plants. Global warming characterized by rise in temperature alters plant normal metabolism thus putting plants under risks for survival and sustainability. Plants in order to survive in their environment, have employed various adaptive mechanisms and appropriate responses to avoid harm and maintain basic metabolic processes under heat stress and other stress factors. Thermo-tolerance in plant responses involves biochemical and physiological signals which are governed by expression of heat shock proteins (HSPs). Heat stress proteins are molecular chaperones that offer protection to cells against the damaging effects of heat stress. Under heat stress condition, HSP70 and small HSP respond to adaptations by producing specific proteins that deal with environmental stresses. A comprehensive insight into the cell metabolism regulated by ATP and ADP helps to better enrich our understanding of the mechanisms by which HSP70 enhance thermo-tolerance in plant. There is need for research to unveil the molecular pathways that enable plants adapt to high temperatures in their environment.

Keywords: Agricultural productivity, global warming, heat stress, food security, thermo-tolerance

INTRODUCTION

The vulnerability of the ecosystems caused by the changing climate is of great importance to all biological processes and defines the level of pressure put on the biodiversity. In the face of the growing world population, agriculture and food security is undergoing through serious challenges due to climate change and loss of biodiversity. It is projected that an increase of above 60% in annual crop production must be met by 2050 if the need of the world's population must be met (FAO, 2012). Compant *et al*. (2010), due to climatic changes, plants are more prone to abiotic stresses of increasing carbon dioxide, elevated temperature, drought, salinity and nutrient deficiencies due to environmental degradation and it is predicted that these stresses would affect plant production and food security. High temperature has become a global concern as it stands as one of the influential factors of the climate that seriously affects plant growth and reproduction. Exposure of plant cells to high temperature results in cellular damage and can be lethal to plant. Modern research focusing on advanced physiology, molecular biology and genetics have unravelled more understanding on plant responses to stresses and the basis of varietal differences in tolerance. Plants are rooted in the environment and are constantly interacting with both biotic and abiotic factors in their environment; one of the major challenges of agriculture and forestry is how to manage abiotic stresses which defines not only the choice of crops to grow but agricultural production and livelihoods of the entire populace. Developing adaptation strategies to cope with these production constraints through modern and molecular understanding of plant interactions in their environment, will be a positive approach towards food security and ending hunger for the teeming population.

Heat Stress in Plants

Heat stress (HS) can be defined as a rise in temperature beyond a threshold level for a period of time, sufficient to cause irreversible damage to plant growth and development (Wahid *et al*., 2007). It is one of the abiotic factors that constrain agricultural production and yield, food security and species distribution (Hemantaranjan *et al*., 2014). It is accepted generally that the increase in reactive oxygen species during heat stress causes both cellular damage and downstream signaling, leading to heat tolerance (Mesihovic *et al*., 2016). Crassulacean Acid Metabolism (CAM) plants, are well furnished to manage heat by conserving water in their fleshy leaves; though majority of plants do not have this luxury and therefore suffer heat extremes. Plant's response to heat stress always show as wilting symptoms which is as a result of the deficit due to the rapid loss of water, as the temperature of the leaves increases and the lag in the absorption of water in the roots (DaMatta *et al*., 2006). The effect of heat stress on crop plants are devastating as it affects essential physiological functions including protein denaturation, increase in membrane fluidity, higher than optimal con centration of reactive oxygen species, decrease in electron transport through photosystem II (PSII)-mediated and inactivation of chloroplast and mitochondrial enzymes (Sehgal *et al*., 2018). With the rising temperature due to climate change, heat stress has become one of the limiting factors to crop productivity and adversely affecting the plant growth (Kul *et al*., 2019).

Extreme Temperature on Plant Growth and Development

Plants employ a number of chemical reactions during their growth stages and all thes e cell processes have optimal temperature range that can easily be affected by heat stress (Fahad *et al*., 2017). The effect of extreme temperature on the development of plant, especially at flowering, grain filling, grain weight and chemical composition is most critical and have severe effect on plant yield (Farooq *et al*., 2017). Considering the importance of seed in plant propagation and food availability, there is a need to make concerted efforts in understanding plant interaction and environmental factors that could limit yield. Mostly, temperature is an important external factor for seed germination and its range is crop specific (Wani *et al*., 2016). Generally, an optimum temperature range during germination increases the germination potential but above the limit results in decreased germination percentage. Chandra and Bhattacharya (2019) noted that heat stress (45°C) during wheat seeds germination hindered seed germination and also an interference in development of root and shoot systems with a reduction percentage in shoot length was noted by Kaushal *et al*., (2016). Other reports, apart from the negative effect of HS, suggest that heat stress is required to release energy from stored food for germination despite the fact that it reduces plant emergence. However, it is crop specific and seasonal (Martinez *et al*., 2018).

Heat stress interfere with developmental processes and results in reduction of cell division and elongation which ultimately decrease plant size and weight including root growth and number of roots (Akter *et al*., 2017). Other morphological symptoms include scorching and sunburn on twigs, leaves stem and branches along with leaf abscission. Internal morphological characters like cell size and density and xylem vessels in shoot and root are also disturbed (Bishnoi *et al*., 2017). These morphological changes under heat stress can damage the regulation of endogenous enzymes and accumulation of osmolytes (Hossain *et al*., 2018).

Plant Responses to Heat Stress

A series of changes in cell metabolism and gene expression under extreme temperature have been observed (A huja *et al*., 2010). Plants use a combination of physiological, morphological and anatomical responses to cope with the stress condition and thereby to mitigate the harmful effect of heat (Vurukonda *et al*., 2016). At physiological level, plants are equipped to adjust the rate of photosynthesis with the changing environmental condition. It clearly indicates that under optimal conditions, plants are not growing well. Moreover, stomata are specific factor of cells with an important role in the exchange of water and gasses transpiration. Under heat stress, plants close their stomata to conserve water under limited water supply but this can cause imbalance in gasses exchange (Endo and Torii, 2019). When stomata are closed, the CO_2 concentration decreases in leaf tissue thereby interfering with photosynthetic machinery and ultimately reduced the speed of photosynthesis (Siddique *et al*., 2016). Some electrically neutral and small molecules also play dual role in the cell. They are source of energy and raw material for the synthesis of macromolecules on their normal concentration and play a protective role against the harmful effects of heat stress.

Thermotolerance in Plant growth and Development

A capability of an organism to tolerate excessively high temperatures is called "thermotolerance". For plants, the ability to survive under high temperatures is an inherent trait known as basal thermotolerance while acquired thermotolerance is response that exists in plants against heat stress (Song *et al*., 2012). Jiang *et al*. (2017) observed that responses against abrupt temperature changes can be assessed under greenhouse conditions by growing plants to optimal temperature and then immediately changing the temperature up to the limit that is considered as heat stress. Plant cell mostly accumulates transcripts that encode HSPs and ROS detoxifying enzymes. Both type of tolerance mechanisms result in accumulation of different chemical products (Schoepf *et al*., 2015). For example, transcriptional regulator MBF1c and the ROS detoxifying enzyme "catalase" develops under basal thermotolerance but not under acquired thermotolerance; whereas, many chaperons like HSP70 gene family required for both responses (Carmody *et al*., 2016).

Extreme Temperature and Reactive Oxygen Species (ROS)

Under normal environmental conditions, roots emergence from seeds are controlled by Reactive Oxygen Species (ROS) especially H_2O_2 and an adequate supply of energy which comes from storage reserve mobilization and synthesis of new compounds. In normal conditions, ROS is continuously generated by plants (González, 2018). One of the most important effects of climatic stresses at the molecular level is the increase of ROS within the cells which destroy proteins, lipids and DNA that influence cell integrity, morphology, physiology, and therefore plant growth (Cassia *et al*., 2018). Heat stress, affects the metabolic activity necessary for normal root growth is partly reduced because of the balance between ROS scavenging enzyme and ROS production. The production of ROS in plants are majorly responses to stress factors which are aggravated by nutrient deficiency, salinity, other abiotic factors of the environment and majorly increased photorespiration, β-oxidation of fatty acids and disorders in the mitochondrial, chloroplastic electron transport chains and NADPH oxidase (NOX) activity (Wang *et al*., 2015). Higher plants have therefore evolved in the presence of ROS and acquired ways of protecting themselves against its toxicity. Antioxidant process for plant (AS) contains ROS detoxifying enzymes (Choudhury *et al*., 2017).

Extreme Temperature and HSP70s Gene Family

Environmental conditions that is different from optimal cause denaturation of proteins and results in their malfunctioning. Function of heat shock proteins is to maintain normal cellular homeostasis under different type of stress. HSPs are also considered as buffers to maintain protein functioning (Sanfelice and Temussi, 2016). They were mainly studied under heat stress because high temperature mostly results in protein miss-folding. Qazi *et al*., (2019) reported that HSPs play their role under many stresses like salt, drought, cold, UV, osmotic and high light. A number of HSPs have been identified from many organisms and they have a heat shock domain at C-terminal that is considered as identification mark. HSPs range from 10 to 200kDa in five different classes on molecular weight bases (Haslbeck and Vierling, 2015). Several reports have shown that HSPs play an important role in folding and aggregation of proteins together with their position and degradation within the cell. As chaperone, HSPs do not allow the protein to accumulate inside the cell and they also actively participate in protein folding under stress conditions (Lang *et al*., 2019; Park and Seo, 2015). HSPs are categorized into several families according to their homology and molecular mass, including HSP70, HSP40, small HSPs, HSP100, HSP90 and HSP60. It has also been inferred from genomic studies that such expression of HSPs may be correlated with temperature sensitivity (Zahid *et al*., 2016) which up-regulated when cells are exposed to high temperatures or other stresses (Costa-Martins *et al*., 2018). As intracellular chaperones, they contribute to cellular homeostasis in prokaryotic and eukaryotic cells under optimal and detrimental growth conditions (Roy *et al*., 2019). Park and Seo (2015) reported that during cellular growth and development of plants, heat shock protein gene family are responsible in preventing protein degradation. They perform critical functions such as 3D folding of newly formed proteins and/or proteins that are damaged by stress in cells. Because of its existence, most chaperones are known to be HSPs when denatured by heat stress. Their expression levels are increased transcriptionally under high temperature conditions by heat shock transcription factor (HSTFs), which are activated by trimerizing their monomeric forms. To facilitate HSP expression, trimeric HSTFs bind to DNA at the HSPs promoter (Trivedi *et al*., 2016). This HSP gene regulation is one of the most established response mechanisms for organisms subjected to extreme temperature conditions identified at molecular level. The cDNA coding HSP70 has been identified in various species of plants. The HSP70 superfamily's genomic analysis revealed an evolutionary history in the form of a phylogenetic tree of all HSP70 members that suggested the similarity of HSP70s in subgroups, including those expressed previously to the mammalian HSP110 and GRP170 in the same sub-cell portion (Wen *et al*., 2017). Study of HSP70 in Rice, Tomato and Arabidopsis genomes revealed that about 37 genes of HSP70 were identified, 30 and 13 for tomato and Arabidopsis respectively (Liu *et al*., 2018). HSP70 has been documented to be present in every cellular compartment of plants.

Mechanism of HSP70 in Plants

The ability of plants to tolerate harmful effects of extreme temperatures without irreversible damage is heat stress resistance (Levitt, 2015). Effect of temperature contributes to a number of negative changes in plants' life: extreme dehydration and dryness, chlorophyll burning and other physiological disorders, the cessation of protein synthesis improves the degradation and accumulation of ammonia toxic substances especially (Uprety and Reddy 2016). However, the heat tolerance mechanisms in plants were partially understood that HSP70 gene protects plants from oxidative damage (Ohama *et al*., 2017). Additional mechanisms potentially contributing to heat tolerance involve phytohormones, second messenger molecules such as Ca++, and a variety of transcription factors (Wani *et al*., 2016). Among the downstream processes, protection against oxidative damage and protein aggregation during heat stress are crucial for maintaining cellular membrane integrity and photosynthesis (Qazi *et al*., 2019). Therefore, over-expression of HSP70 initially appeared to be a promising approach for engineering acquired heat tolerance in plants; however, only limited success has been reported in past decades (Khanna-Chopra and Semwal, 2015), and no field-tested, heat-tolerant, transgenic line has been reported to date. These observations suggest that a single heat tolerance mechanism might not be sufficient and additional mechanisms will be needed to generate durable heat-tolerant cultivars. Highly conserved protein, HSP70s are omnipresent proteins best known for their susceptibility to numerous stresses such as heat stress (Jacob *et al*., 2017). HSP70 help to place each protein in the organelles of the cell and interplay the mitochondrion and chloroplast proteins (Usman *et al*., 2017). They have a link to proteasomal degradation pathway mediated by ubiquitin. Further unfolded outer membrane proteins in the intercellular spaces sends a signal to the inner membrane proteins under extreme temperature within the cytosol. This causes the heat shock transcription factors to be activated (Quirós *et al*., 2016). The heat shock transcription factors (HSFs) associated with Heat shock protein (HSP70) are one of the most reported protein families. HSFs usually hold together heat-induced elements (HSEs) in the promoter areas to activate their expression, which transcribes the HSP70 (Bäurle, 2016).

CONCLUSION

Establishing new plant cultivars with high yielding and tolerance to unfavourable environmental challenges can be tackled by identifying the potential gene regulatory networks which may come through gene wide data for high temperature stress. This will be a crucial improvement in the era of green biotechnology in relation to genomic selection. Advance regulatory components inside these networks could be sorted as key candidate gene via system biology to exploit their functional relevance.

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Assessment of Awareness Level of the Effects of Climate Change on Forest Dependents in Onigambari and Olokemeji Forest Reserves in Oyo State, Nigeria

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Abstract
The level of awareness of the effects of climate change was investigated on forest dependents in Onigambari and Olokemeji Forest Reserves in Oyo State. This was aimed at identifying constraints faced by the people and possible coping strategies. A simple random sampling technique was used to select 223 respondents from selected communities in the two forest reserves. The communities were purposely selected for the study and the instrument used for data collection was structured questionnaire. Data collected were analysed using descriptive statistical tools. Farmers in the study areas were mostly males (68.3%) and married(85.6%). Majority (93.3%) had farm size less than 5ha while 45.7% earned less than or equal to ₦20,000 monthly . Majority of respondents (81.3%) were fully aware that rainfall pattern was changing and 88.5% alluded to the fact that atmosphere was getting hotter. Respondents (24.5%) agreed that flood was now a very common occurrence while 28.4% respondents were aware about persistent occurrence of flooding in recent years which caused low reduction of yield. It is recommended that deforestation should be banned and afforrestation should be adopted by forest dependents as coping strategies against climate change effects in the study areas.

Keywords: Climate change, awareness, coping strategies, forests and afforestation

INTRODUCTION

Climate change has become a global concern for which several international summits and conferences are being held to find solution to stem down the occurrence. Climate change is one of the greatest environmental, social and economic threats facing our world today (Chomitz *et al*., 2006). It is caused by two basic factors which include natural processes (biogeographical) and human activities(anthropogenic). The anthropogenic factor in climate change is caused by human activities (industrialization, burning of fossil fuel, gas flaring, urbanization and agriculture) that either emit large amount of greenhouse gases into the atmosphere which depletes the ozone layer or activities that reduce the amount of carbon absorbed (deforestation) from the atmosphere(Odjugo, 2010). The human factors have been proven to be responsible for the ongoing unequivocal global warming (IPCC, 2007). It is widely recognized that climate change has caused substantial impacts on forested ecosystems (Parmesan *et al*.,2007). The forest dwellers and adjacent farmers identified by Byron and Arnold (1999) are particularly at risk due to climate change. Forest dependents tend to suffer more than others when extreme events like floods, erosion, tropical storms and landslides occur. This happens for three reasons: first, they live in areas and shelters that are more susceptible to these extreme events; second, they do not have the resources to cope with this extreme events; and third, the poor in developing countries cannot depend on social opportunities like safety nets to cushion the impacts of extreme events (Sen, 1999).

The forest is vital to man's existence because of the many ecological and economic functions it performs. It assists in the global cycling of water, oxygen, carbon and Nitrogen and lend stability to hydrological system. It ensures a regular supply of fresh water, prevents flood, soil erosion and situation of river beds downstream. It also assists in improving air quality, stabilizing global climate conditions and soil protection (Sharma *et al*.,1992). Forests support the livelihoods of 87% of the rural poor (Miledge *et al*., (2007). The implication of a rapidly warming climate for long-lived organisms (such as trees) and for human management systems with long planning horizons (such as forestry) are significant (Dale *et al*., 2000). The vulnerability of many communities in developing countries like Nigeria is immense and their capacity to adapt to future climate change impact is assumed to be very low (Huq *et al*., *2004*). In view of the above, the level of awareness of the effects of climate change on forest dependents was investigated on forest dependents in Onigambari and Olokemeji Forest Reserves in Oyo State in order to profer some recommendations to stem down the effects of climate change on dependents within and around the two forest reserves.

METHODOLOGY

Study Area

The study was carried out in Onigambari and Olokemeji Forest Reserves of Oyo-state, Nigeria. The state is an inland State located in south-western part, with its capital at Ibadan. It lies within latitude 8°00'N and longitude 4.000°E. The state was created on 3rd February 1976 as one of the states from the former Western Region. It covers an area of 28,454 square kilometers. The climate of the state is equatorial with two distinct seasons .The raining season commences in April and ends in October with a peak in July/August while the dry season occurs between November and ends in March. Average daily temperature ranges between 25°C (77.0°F) and 35°C (95.0°F), almost throughout the year .The study was carried out in two Local Government Areas in Oyo state. They are Oluyole Local Government area where Onigambari forest reserve situates and Ibarapa East Local Government Area where Olokemeji forest reserve situates.

Sampling Procedure and sample Size

The two forest reserves (Onigambari and Olokemeji) were purposively selected in which communities in and around the forest plantations within 2km radius were identified . Among the identified communities, three communities were randomly selected per reserve, totalling six communities sampled for the study.

RESULTS AND DISCUSSION

Socio-economic Characteristics of Respondents

The result of the socioeconomic characteristics of all selected respondents in the study area revealed that majority (68.3%) of respondents were males while 31.8% were females (Table 1). This implies that there were more male farmers in the study area. The result is similar to the findings of Acharya(2011) that in mid hills of Nepal, 58.0% were males and 42.0% were females. The table also revealed that 6.3% were under 30 years of age. This implies that low percentage of youths were engaged in agriculture. Also 32.7% falls in the age category of 41-50years. This implies that older people engaged in agriculture more than younger people in the study area. This is not differ from Adekunle *et al.(*2011) findings from a study in Southwest Nigeria, which reported the mean age of the farmers to be 43 years . Age does not relate to their vulnerability to climate change. Meanwhile, 85.6% were married, while 3.8% were single. This suggests that married people engaged in farming more than singles. Majority(63.0%) had primary education, 24.0% had secondary education and 0.5% had tertiary education. This means that majority of the respondents were able to read and write. This would assist the farmers to be aware of climate change and adapt to its effects as they could gain access to information. Majority (68.3%) were Christians, 25.5% were Muslims and 6.2% were Traditionalists. This implies that more Christian respondents engaged in agriculture as compared to Muslims and Traditionalists in the study areas. This is similar to Adekunle *et al*., (2011) who found that in Southwest Nigeria, 65.9% were Christians, 33.5% were Muslims while Traditionalists accounted for 0.6%.. Religion does not determine the vulnerability of the respondents to climate change. All the respondents were vulnerable to climate change. Adekunle *et al*. (2011). Generally, majority (64.9%) had household size of 5-8 members, while 6.3% had household size of 13-16 members. This shows that the groups that formed the largest family size were relatively few in number compared to those up to 13-16 members. Majority (98.6%) had farming as major occupation and 5.3% engaged in fishing. Majority (93.3%) had less than 5ha of land and 1.9% had 8-10ha. Those that earned less than or equal to ₦20,000 monthly were 45.7%, 13.9% earned ₦40,000 - ₦60,000 monthly and 1.9% earn greater than ₦80,000 monthly. The farmers supplement their income with income from the sale of forest products, such as wood, medicinal herbs, gums, latex, resins and spices that provide financial capital that can be used as working capital for trading activities or to educate children (Byron and Arnold, 1999).

Table 1: Socioeconomic characteristics of respondents in the study area

Variables	Category	Frequency (n = 208)	Percentage
Sex	Male	142	68.3
	Female	66	31.8
Age (years)	≤ 30	13	6.3
	31 – 40	51	24.5
	41 – 50	68	32.7
	51–60	47	22.6
	>60	29	13.9
Maritalstatus	Single	8	3.8
	Married	178	85.6
	Widowed	13	6.3
	Divorced	9	4.3
HighestlevelofEducation	No formal	26	12.5
	Primary	131	63.0

	Secondary	50	24.0
	Tertiary	1	0.5
Religion	Christianity	142	68.3
	Islam	53	25.5
	Traditional	13	6.2
Householdsize	<5	25	12.0
	5 – 8	135	64.9
	9 – 12	35	16.8
	13 – 16	13	6.3
Occupation	Farming	205	98.6
	Fishing	11	5.3
	Games/Hunting	104	50.0
	Wood selling	74	35.6
	Charcoal production	47	22.6
	Artisan	62	29.8
	Gathering of NTFPs	200	96.2
Farmsize (ha)	<5	194	93.3
	5 – 7	10	4.8
	8 – 10	4	1.9
Monthly income (#:k)	≤20,000	95	45.7
	20,500 – 40,000	67	32.2
	40,500 – 60,000	29	13.9
	60,500 – 80,000	13	6.3
	>80,000	4	1.9

Source: Field survey 2016

Respondents' Awareness about Climate Change

Table 2 revealed that majority (81.3%) were fully aware that rainfall pattern was changing, atmosphere was getting hotter (88.5%), 24.5% were averagely aware that flood was a very common occurrence and 28.4% affirmed that there was persistent occurrence of flooding in recent years. This implies that persistent occurrence of rainfall causes flooding and eventually leads to reduction in yield. The reduction in yield can be due to flooding which according to Armah *et al*. (2010) during the month of August and early September 2007, heavy rainfall led to severe flooding in Northern Ghana resulting in the loss of lives, displacement of vulnerable persons, food stocks and livestock throughout the region. While, soil nutrients are fast depleting so fast due to frequent erosion (58.6%).

Table 2 : Distribution of respondents by awareness about climate change

Awareness	Fully aware (%)	Averagely aware (%)	Not aware (%)	mean
Rainfall pattern is changing	81.3	17.3	1.4	1.8
There is persistent occurrence of flooding in recent years	27.4	28.4	44.2	0.8
There is an increased heating of the earth surface	82.2	16.3	1.4	1.8
The atmosphere is getting hotter	88.5	10.6	1.0	1.9
There is prolonged duration of drought in recent years	80.8	16.8	2.4	1.8
Annual rainfall pattern is unpredictable	63.5	29.8	6.7	1.6
Temperature is rising fast every year	76.0	20.2	3.8	1.7
Over the years, sun intensity has risen	82.7	14.4	2.9	1.8
Erosion of the soil surface is more prevalent recently	22.1	27.4	50.5	0.7
Flood is now a very common occurrence	17.3	24.5	58.2	0.6
Carbon in the atmosphere keeps increasing	12.5	43.3	44.2	0.7
Soil nutrients are fast depleting so fast due to frequent erosion	28.8	29.8	41.3	0.9
There is unstable cropping calendar year in year out	83.7	13.0	3.4	1.8
Bi-modal rainfall is gradually disappearing	33.7	51.0	15.4	1.2

Sources: Field survey 2016

Effects of Climate Change on Rural Farmers

Table 3 revealed the result of analysis on perceived effects of climate change by respondents on their livelihoods. The result revealed that 17.3% of respondents indicated that flooding had mild effect on their livelihood, this made them perceived it as unfavourable. In the study area, 100% of the respondents experienced hunger during climate change due to the reduction in forest resources and also in agricultural production. This is in agreement with Armal *et al.*, (2010) who reported that the reduction in food production resulting from floods also means loss of income for many in these communities which further reduce their ability to purchase food and thereby contributes to increasing the problems of food shortages and starvation within households. All of the respondents fed from the sale of firewood, vegetable, fruits, seeds, herbs and mushroom during climate change. Respondents reported that these forest resources have been reduced due to climate change and over exploitation, 41.3% indicated that drought had mild effect on their livelihood, this made them perceived it as unfavourable, 50.5% indicated that increased temperature had mild effect which made them perceived it as unfavourable, while 15.4% indicated that erosion had mild effect on their livelihood activities this made them perceived erosion as unfavourable. This led to washing away soil nutrients which led to decrease in land productivity. This is in agreement with Paudel *et al*., (2011) findings that decrease in productivity of land was becoming dominant due to impact of changes in climate events. The reduction in yield can be due to flooding which according to Armah *et al*., (2010) during the months of August and early September 2007, heavy rain lead to severe flooding in Northern Ghana resulting in loss of lives, displacement of vulnerable persons, food stocks and livestock throughout the region.

Table 3: Distribution effect of climate change on rural farmers

S/N	Effects	Serious effect (%)	Mild effect (%)	Not an effect (%)	Mean
1	Flooding	48.1	17.3	34.6	1.13
2	Drought	44.7	41.3	13.9	1.31
3	Landslide	45.7	33.2	21.2	1.25
4	Storm	49.0	29.3	21.6	1.27
5	Increased temperature	38.5	50.5	11.1	1.27
6	Change in rainfall pattern	61.1	11.5	27.4	1.34
7	Increase eating of earth surface	43.3	49.5	7.2	1.36
8	Erosion	30.8	15.4	53.8	0.81

Sources: Field survey 2016

Adaptation strategies utilized by respondents to climate change

Table 4 shows the result of adaptation strategies utilized to climate change, majority (88.5%) utilized soil protection through tree planting. This establishes Ofuoku's (2011) report that rural farmers in Delta state, Nigeria utilized planting of trees as adaptation measure against climate change. Majority (62.0%) utilized different planting dates. This is similar to Adekunle *et al*., (2011) findings that in their study area choosing of different planting dates were utilized by their respondents. This further confirms Agwu *et al*., (2011) findings that 38.0% of farmers in West Africa changed their planting dates in response to changes in rainfall patterns due to climate change. Majority (87.0%) adopted planting of different varieties of NTFPs and TFPs as adaptation strategy to climate change. This is in agreement with Onyekuru *et al*., (2014) findings that among the adaptation option identified in their study area, planting of NTFPs and NFPs stood out as the adaptation option of choice for most farmers. While 26.9% utilised increase water conservation as adaptation strategy utilized by the respondents

Table 4: Distribution of adaptation strategies utilised by respondents to climate change

S/N	Coping strategies	Yes (%)	No (%)
1	Planting of different varieties of NTFPs and TFPs	87.0	13.0
2	Different planting dates	62.0	38.0
3	Practicing shifting cultivation	81.8	18.8
4	Increase irrigation	63.0	37.0
5	Use of organic fertilizer	81.7	18.3
6	Increase water conservation	26.9	73.1
7	Soil conservation	58.7	41.3
8	Use of weather insurance	34.6	65.4
9	Soil protection through tree planting	88.5	11.5
10	Desalination	38.9	61.1

Source: Field survey (2016)

Constraints to forest dependent livelihood

The result of analysis on Table 5 reveals possible constraints caused by climate change that could be faced by forest dependent livelihoods. Majority (31.7%) of the respondents indicated that disease attack on forest products was not a serious constraint to their livelihood. This showed that climate change is one of the greatest environmental, social and economic threats facing our world today (Chomitz *et al*., 2006), inadequate knowledge about climate change (35.5%), lack of adequate information about climate change (37.0%), no market for forest products (34.1%), government policies about climate change (41.3%), while majority (45.7%) also considered low quantity and quality of produce was not a serious constraints.

Table 5: Distribution of constraints to forest- dependent livelihood

S/N Table	Possible constraints	Serious constraints	Not a serious constraints	Not a constraints	Mean
1	Inadequate knowledge about clime change	38.5	35.5	26.0	1.1
2	No market for forest products	17.8	34.1	48.1	0.7
3	Lack of adequate information about climate change	37.0	37.0	26.0	1.1
4	Government policies about climate change	27.4	41.3	31.3	1.0
5	Pest infestation	30.8	37.0	32.2	1.0
6	Disease attack on forest product	46.2	31.7	22.1	1.2
7	Rottening of forest product	40.4	47.6	12.0	1.3
8	Leaching of soil nutrients	43.8	26.4	29.8	1.1
9	Erosion	21.2	33.2	45.7	0.8
10	Low quantity and quality of produce	38.5	45.7	15.9	1.2

Source: Field survey (2016)

Source of information about climate change

The result of analysis on table 6 showed the source of information about climate change. Majority (96.2%) of the respondents were informed about climate change through radio, 80.8% through extension agents, bill boards (2.9%) and through news 9.7%. This implies that most of the respondents got to know about climate change through radio and extension agents. Adekunle *et al*., (2011) reported that the use of radio was the first external sources of awareness about climate change by his respondents. This revealed that most of the respondents were aware about climate change.

Table 6: Distribution of source of information of respondents about climate change

S/N	Source of information	Yes (%)	No (%)
1	Radio	96.2	3.8
2	Pamphlets	11.5	88.5
3	Farmers' association	83.2	16.8
4	Bill boards	2.9	97.1
5	Television	25.5	74.5
6	News paper	9.7	90.3
7	Extension agents	80.8	19.2

Source: Field survey 2016

CONCLUSIONAND RECOMMENDATIONS

The findings revealed the level of awareness of forest dependents about the effects of climate change. It is concluded that majority of the households were headed by men who are adults, they were married, had formal education, engaged in farming as primary occupation. Constraints faced by the respondents were inadequate knowledge about clima te change, lack of adequate information about climate change and pest infestation disease attack on forest products, etc. Coping strategies used by most of the respondents were soil protection through tree planting, practicing shifting cultivation, planting of different varieties of NTFPs and TFPs and increase irrigation. Almost all the respondents were fully aware about climate change and got informed mostly through radio and farmers' association.

It is recommended that forestry offices both Federal and State should educate forest dependents in both forest reserves to halt deforestation and embark on afforrestion on a large scale for effective mitigation measures against the negative effects of climate change which in turn would increase their productivity.

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Potentials of Species Distribution Modelling in Response to Climate Change Impacts on Biodiversity in Nigeria

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Abstract

Biodiversity conservation planning under the current threats posed by climate change depend on modern techniques such as ecological modelling for predicting future species distribution over time and space. Species distribution models have been further recommended for developing management intervention strategies for biodiversity conservation. In this review, we identify required inputs for successful species distribution modelling in Nigeria. The article focused on the type of data required, suitable algorithms, model evaluation and validation criteria and expected model outputs for species distribution. Species coordinates and environmental data are the major inputs for species distribution modelling. There is scarcity of coordinates of indigenous species whereas the environmental data are easily accessible. Several algorithms were identified for species distribution modelling. However, Maximum Entropy (MAXENT) was proposed as a suitable model that could be used for species distribution modelling in Nigeria based on the strength of its predictive accuracy from statistically evaluated and validated results. Maps generated with Geographic Information System are the outputs of the modelling process. It can be used in species conservation planning in Nigeria.

Keywords: MAXENT, modelling, evaluation, distribution, conservation.

INTRODUCTION

Species distribution modelling (SDMs) is modern day approach to management in species conservation, ecology and biogeography (Hao *et al.,* 2019). These are models which relate species occurrence at spatial and temporal levels to environmental variables using statistical algorithms and response surfaces (Philip *et al.,* 2006; Hijmans *et al.,* 2005). The models can be applied when evaluating invasive species management, and climate change impacts on ecosystems (Idohou *et al*., 2016). They are further used to support conservation planning, protected area selection, and developing of ecological and evolutionary assumption (Idohou *et al*., 2016; Chang *et al*., 2012). Species distribution models are helping to evolve strategies aimed at reversing biodiversity loss occasioned by population growth, environmental degradation and climate change (Koshaka *et al*., 2013; Rahman *et al*., 2019). In Nigeria, there is limited information on the conservation status of most indigenous plant species (Borokini, 2014). The situation is exacerbated by the predicted negative impacts of climate change on plant species distribution in the nearest future. (Cayuela, 2009). In addition, spatial and temporal information on most plant species are scanty partly due to low investment in biodiversity conservation in the country. Species distribution modelling provide enormous information on the dynamics of species distribution, spatial and temporal occurrence in different landscape. It is veritable tool that could be useful in biodiversity management in Nigeria.

Climate change has been implicated in the shifting of natural distribution ranges of many flora and fauna species. Therefore, there is a need to implement conservation schemes that would ensure species sustainability in the face of changing climate. Species spatial distribution models and their relationship with environmental variables would assist the efforts aimed at understanding the climate change response of many plant and animal species. Hence, conservation priority areas could be identified, and management strategies put in place to forestall the negative consequences, where possible (Rahman *et al*., 2019). This article highlights, the potential use of species distribution modelling in conservation management of plant species in Nigeria.

Species Distribution Modelling Algorithms.

Algorithms are sets of instructions designed to perform specific tasks. These are sets of finite sequences of definite, computer-implementable commands, used for typically performing different computations. They can be expressed within a finite amount of space and time, with their operations, data processing and outputs being automated. The ability of algorithms to perform tasks based on time and space allow them to be suitable for the prediction of the geographic spread of species over a spatio-temporal scale. Machine learning algorithms are computer programs that modify themselves for better performance on exposure to different datasets. These modifications lead to the simulation of species distribution models governed by the data output on machine learning algorithms (Gobeyn *et al.,* 2019). A numbers of algorithms have been developed for predicting the impact of climate change on species distribution (Qiao *et al.,* 2015). The algorithms are statistical e. g. generalised additive models and generalised linear models. Approaches are also based on machine learning algorithms such as Maximum Enthropy and Artificial Neutral Networks (Pearson, 2010). However, majority of the algorithms are not widely used in species distribution modelling (Qiao *et al.,* 2015). Some of the algorithms used in SDMs are shown in Table 1:

Table 1. Species distribution modelling approaches and algorithms used for their development

Method	Algorithms	Species data type
Climatic envelope	BIOCLIME	Presence only
Gower Metric	DOMAIN	Presence only
Ecological Niche Factor Analysis (ENFA)	BIOMAPPER	Presence/background
Maximum Entropy	MAXENT	Presence /pseudo absence
Genetic algorithm	GARP	Presence /pseudo absence
Regression: Generalized linear model	GRASP	Presence/absence
(GLM) and Generalized additive model		
(GAM)	SPECIES	Presence /absence
Artificial Neural Network (ANN)	BIOMED	Presence /absence
Classification and regression trees		
(CART), GLM, GAM and ANN		
Boosted regression trees	BRT (implemented in R)	Presence /absence
Multivariate adaptive regression splines	MARS (implemented in R)	Presence /absence

Source: Pearson, 2010

MAXENT, GLM and GAM has the highest application in conservation management among the species distribution modelling algorithms (Qiao *et al.,* 2015). This is because of its strength in producing predictive accuracy when compared with other algorithms (Merow *et al.,* 2013). It has been used to predict plant invasiveness, the impact of climate change on species distribution, as well as, future and potential suitable areas for growing plant species (Li *et al.,* 2014). However, it has been asserted that no algorithms can be single out for better performances for the development of correlative ecological niche models (Qiao *et al.,* 2015).

Data Required for Species Distribution Modelling

The type of data required for species distribution modelling depends on the algorithms being used in the modelling process. Two very important data required are species occurrence/absence records and environmental/climatic variables (Philip *et al.,* 2006). BIOMOD algorithms rely on species occurrence and /or absence data, while BIOCLIME and MAXENT use only species occurrence data (Pearson *et al.,* 2004). Access to species presence and absence data enable general purpose statistical modelling. However, species absence data are very scarce in tropical countries (Cayuela *et al.,* 2009). Hence, species distribution modelling in Nigeria would heavily rely on presence or pseudo absence data algorithms such as Maximum Entropy (MAXENT). This is because records on species occurrence and their coordinates can be sourced from museums, herbaria and online facilities. An example of such facility is the Global Biodiversity Information Facility (GBIF). However, a major drawback is the fact that species occurrence records do not always have corresponding information on the geographical coordinates or most times are outdated. Hence, the most reliable source of species occurrence data are recent field surveys. Researchers may see this as an obstacle, however, statistically significant species distribution modelling had been achieved with occurrence records of less than 10 (Pearson, 2007). A major caution is that when smaller species occurrence records are available sampling must be done from wider spatial area. Climatic data applied in species distribution modelling are precipitation and temperature derivatives; usually referred to as bioclimatic variables (Li *et al.,* 2014). They are 19 in all; converted to raster format; and deduced from the average daily measurement of precipitation and temperature. The data which can be freely accessed from 'WORLDCLIM' database are available in 3 spatial resolutions: 30 seconds, 2.5 minutes and 5 minutes (Hijmans *et al.,* 2005). This database contains global data on the bioclimatic variables such that data for specific study areas can be extracted for species distribution modelling using geographic information system software's such as ArcGIS, DIVA *etc*.

The bioclimatic data are segregated into current and future conditions. The current dataset ranges from 1950-2000 while the future database is based on prediction from 2000 to various years as determined by the predicting organisation. Future species distribution modelling is done from data derived from outputs of General Circulation Models (GCMs). These models are set to atmospheric conditions anticipated under a set of representative concentration pathways developed by the Intergovernmental Panel on Climate Change (IPPC, 2013). They are comprised of scenarios of emission intensities with consideration for global development trajectory (Riahi *et al*., 2011). Presently, there are various GCM outputs, while the Representative Concentration Pathways (RCPs) scenarios has four concentration pathways, which were set at specific projected atmospheric carbon-dioxide concentrations (Hounkpèvi *et al*., 2016; IPPC, 2013). There are other variables like elevation and edaphic factors that could be included in species distribution models (Xu *et al*., 2018). However, the contribution of these additional variables is dependent on the particular species being investigated (Zuquim *et al*., 2019; Xu *et al*., 2018; Hageer *et al*., 2017; Ashraf *et al*., 2016; Idohou *et al*., 2016).
In spite of the statistical compliance of climate generated species distribution models (Xu *et al*., 2018; Hounkpevi, *et al*., 2016; Idohou *et al*., 2016; Pearson, 2007). The use of climatic data alone for species distribution models has generated a lot of criticisms. This was due to the exclusion of soil factors, Co_2, dispersal indicators, biotic interactions, species traits and phylogenies (Humphreys *et al*., 2019; Hageer *et al*., 2017). Results from few studies has call to question the general assumption of the reliability on the exclusion of other factors of species distributions in predicting species distribution. This was as a result of the observation the highest contribution of edaphic variables to species distribution models in some species of plants (Lyam *et al*., 2018; Zuquim *et al*., 2018). Therefore, it is imperative to look beyond climate variables in predicting potential species distribution under climate change to avoid over estimation of species range. However, species distribution modelling in Nigeria will have to rely on climatic data. This is because of inadequate funding's for research to accumulate information on species biotic interaction, species traits and phylogenies (FAO, 2014).

Species Distribution Models Evaluation/Validation
Some of the methods used for evaluating model accuracy include the application of Area under the Curve operation receiving characteristics (AUC), Kappa Statistics, and True Skill Statistics (TSS). Alternatively, model accuracy could be evaluated based on the known occurrence knowledge of the species. Nevertheless, AUC is the most used model evaluation criteria, because the accuracy of AUC is based on the closeness of the result to 1 (Mi *et al*., 2018). Values greater than 0.90 is assumed to be excellent (Araújo *et al*., 2005). Values greater than 0.5 are said to be better predictions (Li *et al*., 2014). However, when the AUC values are below this range better than the random values, the model maps produced cannot be accepted to be of good quality. In some cases, better than random AUC values are obtained and yet the maps failed to correspond to the known range of the species. This may be attributed to species range shift which are often as a result of climate change (Xu *et al*., 2018).

Outputs Of Species Distribution Modelling: Maps
Species distribution maps are usually produced using Geographic Information System (GIS) tools. These maps are categorised based on predicted percentage survival represented in colours as displayed on the map. Areas with 75%-100% are categorised as highly suitable, 50%-75% as suitable, 25%-50% as marginally suitable and 0%-25% as unsuitable (Li *et al*., 2014). This categorisation is based on the inputted classified command of the GIS tool. However, in some situations lower suitability categorisation can be used and model maps may sometimes project species occurrence records for the model as unsuitable. In such circumstances, the survival of the species in such unsuitable areas shown in the model may be due to microclimatic conditions (Sanchez, 2010). Estimate of retracted with assumed potential for extinction, or expansion with potential for sustainability distribution can be determined from species distribution models (Kakpo *et al*., 2019; Xu *et al*., 2018; Hounkpevi *et al*., 2016: Idohou *et al*., 2016). This is based on suitability and unsuitability of habitats. However, this estimate for suitability or unsuitability does not take into account microclimatic variables that had been validated to enhance species distribution (Sanchez, 2010). This pattern of species distribution modelling is therefore too conservative. Therefore, relying on visual viewing of maps that allowed more classification will be more beneficial to species conservation. This had been applied in identifying species distribution in current and predicted climate change scenarios (Zuiqium *et al*., 2019; Idohou *et al*., 2016; Li *et al*., 2014; Chen *et al*., 2011; Sanchez, 2010).

Species Distribution Modelling for Conservation Management in Nigeria
Nigeria has high level of biodiversity, which supports human livelihoods and promotes ecosystem sustenance. Therefore, there is the need to incorporate biodiversity management in the country's economic plan (Lameed, 2019). Species distribution modelling is a potentially useful tool that could be employed in conservation management planning in Nigeria. This could be explored in the evaluation of agroforestry systems and underutilised plant species that could be introduced to different ecological regions of the country. In addition, the impact of climate change on many threatened species can be studied particularly with the confounding effects of deforestation.

Modelled Indigenous Species Distribution in Nigeria

There is limited information on the application of species distribution modelling in conservation management in the tropics (Cayuela *et al*., 2009). This is evidence by the limited research on the species distribution modelling. Some studies that have used this approach in Nigeria are presented in Table 2.

Table 2: Species distribution models for some plants and animals in the Nigerian ecosystems

Species	Life form	Application	Algorithm used	References
Adansonia digitata	Plant/tree	Identify impacts of climate change on distribution	MAXENT	Sanchez *et al*., 2010
Chrysophyllum albidum	Plant/tree	Identify potential distribution	MAXENT	Lyam *et al*., 2012
Cyclosorus afer	Plant/fern	Identify potential invasiveness	MAXENT	Zakaria *et al*., 2019
Gorilla gorilla	Animal/mammal	Impact of deforestation on habitat suitability	MAXENT	Onojeghuo *et al*., 2015
Pan troglodytes	Animal/mammal	Identify impacts of climate change on distribution	MAXENT	Clee *et al*., 2015
Sclerophrys perreti	Animal/reptile	Identify potential distribution	MAXENT	Nneji *et al*., 2019

CONCLUSION AND RECOMMENDATIONS.

Species distribution models provides useful information that would assist biodiversity conservation. Unfortunately, this tool is currently underutilised in Nigeria. The potential threat to local species extinction calls for the prediction of futu re species distribution under climate change and the models could provide the information required for planning conservation strategies. A major limitation to the development of species distribution models is the limited data on occurrence and absence data for many species in the various ecosystem in Nigeria. Therefore, environmental managers and researchers must intensify efforts in correcting the lack of available data to maximise the use of species distribution modelling for sustainability. The relevant government agencies also need to conduct a national forest inventory to ascertain the current status of species in the country. The data repositories requires updating and integration into species distribution models. This could aid the implementation of sustainable management. For instance, certain computer applications can be used to monitor forest logging with the aid of satellite imagery. The relevant government agencies also need to partner with all stakeholders in biodiversity conservation in order to develop a robust repository on species occurrence, their geographical coordinates and remotely sensed data. There is therefore a need for concerted efforts geared towards integrating species distribution models into biodiversity conservation plans in the country.

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SUB-THEME 4

Impact of Insurgency and Human/ Wildlife Conflicts on Forest Ecosystem in Nigeria

Characterisation of Feral Helmeted Guineafowl in Captivity by Smallholder Farmers in Precinct of National Parks

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Abstract

Fertility and hatchability of all eggs laid are serious problems in guineafowl domestication and production. These problems coupled with habitat disturbance, poaching/hunting, predation by co-habitants and climate changes are determinant factors in the occupancy and availability of feral and captive birds. Therefore, studies that will provide answers to sustainable management of guineafowl within human habitation to forestall the aforementioned problem are well desired. One hundred (100) structured questionnaires were administered to smallholder guineafowl farmers in precincts of Old Oyo and Kainji Lake National Parks to gather information on characteristic approach of guineafowl husbandry, egg laying and hatchability in captivity. We examined the questionnaires at different five communities in each of the National Parks but forty-nine (49) and forty-eight (48) questionnaires were returned from the respondents around Old Oyo (OO) and Kainji Lake (KL) National Parks respectively. The guineafowl farmers were mostly males (OO61.2%, KL68.8%) in the communities at precincts of both National Parks with highest qualification being primary school (OO46.9%, KL41.7%) and most of the respondents were within the age group of 31-40 years (OO69.4%, KL56.2%). The farmers were polygamous (OO91.8%, KL81.2%) and kept the guineafowls as subsistence farming (OO63.2%, KL89.6%). Purchase of matured guineafowls (OO71.4%, KL68.7) was preferred than home hatching (OO24.5%, KL18.8%) or purchase of juvenile (OO18.4%, KL33.3%). Most farmers said that guineafowl laid about 80 eggs (OO69.4%, KL81.2%) in every season and average of 100-150 eggs (OO65.3%, KL62.5%) were usually stored at ambient temperature and incubated at a time after laying. More so, the farmers mostly preferred use of adult chicken hens (OO87.8%, KL87.5%) to hatch the eggs than using guineafowls (OO12.2%, KL12.5%). The study shows specific husbandry, guineafowl egg laying and hatchability as well as the chicken hens that are more adaptable to hatch guineafowls eggs more than guineafowls themselves. Therefore, guineafowls cannot hatch as more eggs as chicken hens.

Keywords: Guineafowl, egg laying, incubation, hatchability and national parks precinct

INTRODUCTION

Guineafowl can be kept both for meat and egg production (Smith, 2001). There are hardly any cultural barriers against the consumption of guineafowl products (Saina *et al*., 2005). The meat of guineafowl is in very high demand in both rural and urban areas (Ayeni and Ayanda, 1982). The meat of guineafowl is served extensively in hotels and restaurants because of its wild game flavour (Feltwell, 1992). Its attractive plumage and value as a table bird with game-type flavour and high meat to bone ratio has led to its worldwide acceptance (Embury, 2001). Moreover, guineafowl has a unique ability to free-range and is tolerant of most common diseases of chicken (Bonds, 1997; Mandal *et al*., 1999).

Guineafowls in the wild are essentially territorial, monogamous and seasonal in their reproductive habits. Both traits are low at the beginning of the breeding season but reach their peak about three months later. Thereafter, they decrease as the gonads undergo regression towards the end of the breeding season (Ayorinde and Okaeme, 1984, Ayorinde and Ayeni, 1986, Ayorinde *et al*., 1989). Low fertility, poor hatchability and occurrence of dead in-shell embryos were affected by nutrition especially manganese level of the diet, season, sex ratio, period after insemination, age, variety and method of insemination (Ayorinde and Ayeni, 1986, Ayorinde *et al*., 1987, Ayorinde *et al*.,1989, Ayorinde, 1987a & b, 1989a, 1990a, 1995b). Although a mating ratio of one male to four or five females gave the satisfactory result, much higher fertility was obtained when there were only two females to a male.

The fertility of guineafowl egg is usually low at the beginning of the rain in April, reaches a peak in June to August and then declines (Ayorinde and Ayeni, 1986). As a rule, fertility and hatchability are lowest during the October to March period, which corresponds to seasons of adverse climatic spermatogenic activity in the guineafowl. It is advisable therefore that those eggs for incubation be collected between June and August which correspond with peak of rainfall as well as highest spermatogenic activity and fertility in the guineacock. Fertility of eggs from free-ranging guineafowls varied from 10 to 45 percent (Ayorinde and Okaeme, 1984, Ayorinde, 1988, 1990a). However, eggs collected from the wild or those purchased from the open market had fertility values in the range of 5 to 20 percent (Ayorinde and Ayeni, 1986). The poor fertility and hatchability could be attributed to the time lag between egg-laying, collection and incubation, poor handling or holding conditions, poor nutrition and failure of the males to mate with some females. Fertility was slightly higher in semi intensively raised stocks and varied from 28 to 51 percent (Ayorinde, 1999). On the deep litter with a mating ratio of one male to four or five females, the fertility of 34 to 74 percent was obtained (Ayorinde *et al*., 1989). However, management of guineafowl economically to contribute substantially to protein consumption through sustained yield and improvement of captive stocks is highly paramount.

MATERIALS AND METHODS

Study Area

The study was conducted within the precincts of Old Oyo and Kainji Lake National Parks, Nigeria. Old Oyo National Park (OONP) lies between longitudes $8^{0}15^{l}$ and 9^{0}E and latitudes $3^{0}45^{1}$ and $4^{0}20^{l}$N, while Kainji Lake National Park (KLNP) lies between longitudes $3^{0}30^{1}$ and $5^{0}50^{l}$E and latitudes $9^{0}40^{l}$ and $10^{0}30^{l}$N (Jayeola, 2009). One hundred (100) structured questionnaires were examined on smallholder guineafowl farmers in different five local communities around each of the National Parks.

Sampling

Equal numbers of fifty (50) questionnaires were distributed using the purposive and snowballing technique but forty-nine (49) and forty-eight (48) questionnaires were returned from respondents in Old Oyo (OO) and Kainji Lake (KL) National Parks respectively. The farmers were selected based on their commitment to guineafowl rearing and they were also asked of others having experience as theirs. The data were analysed using descriptive statistics of measures of frequency.

RESULTS

Socio-economic characteristics of the guineafowl farmers around the National Parks

The guineafowl farmers were mostly male (61.2%, 68.8%) with the highest qualification being primary school (46.9%, 41.7%). Most of the respondents were within the age group 31-40 years (69.4%, 56.2%). The farmers were polygamous (91.8%, 81.2%) and kept the guinea fowl as subsistence farming (63.2%, 89.6%) (Table 1).

Table 1: Socio-economic characteristics of the guineafowl farmers around the National Parks

National Park	OONP		KLNP	
Variable	Frequency	Percentage %	Frequency	Percentage %
Sex				
Male	30	61.2	33	68.8
Female	19	38.8	15	31.2
Total	49	100.0	48	100.0
Education				
Post-Secondary	4	8.2	3	6.2
Secondary	9	18.4	9	18.8
Primary	23	46.9	20	41.7
No formal educatio	13	26.5	16	33.3
Total	49	100.0	48	100.0
Age distribution (years)				
21-30	4	8.2	4	8.3
31-40	34	69.4	27	56.2
41-50	11	22.4	17	35.4
Total	49	100.0	48	100.0
Family Status				

Monogamous	4	8.2	9	18.8
Polygamous	45	91.8	39	81.2
Total	49	100.0	48	100.0
Purpose of rearing guineafowls				
Commercial	10	20.4	3	6.2
Interest	8	16.3	2	4.2
Subsistence	31	63.2	43	89.6
Total	49	100.0	48	100.0

The farmers had 21-40(61.2%, 52.1%) guinea fowls per family and 1-20 (71.4%, 68.7%) each for guineacock and guineahen per family. It signified that the guineacocks and guineahens were reared by the farmers in ratio 1:1 and there was a strong indication that the guinea fowls are monogamous (Table 2). The farmers preferred to purchase matured guineafowls (71.4%, 68.7%) than home hatching (24.5%, 18.8%) or purchase of juvenile (18.4%, 33.3%) and all the guineafowls have been domesticated as they lived well in the surrounding provided for them (Table 2). Most of the farmers said that about 80 eggs (69.4%, 81.2%) were laid by guineafowl in every season and that average of 100-150 eggs (65.3%, 62.5%) were stored at ambient temperature and incubated at a time after laying (Table 2). Guineafowl starts laying of eggs around 8 months and stopped laying the eggs at the end of raining season.The farmers mostly preferred using adult chickens (87.8%, 87.5%) to hatch the eggs than using guinea fowls themselves (12.2%, 12.5%).
Some activities during the raising/husbandry were gender-sensitive. It shows that main operations such as feed and maintenance of the housing are being carried out by the women while assurance of good health condition and care for the birds is ensured by man (Table 3).

Table 2: Guinea fowls farming of the respondents around the National Parks

National Park	OONP		KLNP	
Variable	Frequency	Percentage %	Frequency	Percentage %
Number of guinea fowl/family				
1-20	5	10.2	4	8.3
21-40	30	61.2	25	52.1
41-60	14	28.6	19	39.6
Number of guineacock/family				
1-20	35	71.4	33	68.7
21-40	14	28.6	15	31.3
Number of guineahen/family				
1-20	35	71.4	33	68.7
21-40	14	28.6	15	31.7
Source of guineafowl				
Home hatching	12	24.5	9	18.8
Purchase juvenile	9	18.4	16	33.3
Purchase matured	28	57.1	23	47.9
Number of egg lay/season				
About 80	34	69.4	39	81.2
About 100	15	30.6	9	18.8
Egg incubated at a time				
51-99	17	34.7	18	37.5
100-150	32	65.3	30	62.5
Mode of incubation				
Guineafowl	6	12.2	6	12.5
Adult chicken	43	87.8	42	87.5

Table 3: Guineafowl husbandry mechanism of the respondents around the National Parks

National Park	OONP		KLNP	
Variable	Frequency	Percentage %	Frequency	Percentage %
Feeding				
Husband	8	16.3	6	12.5
Mother	18	36.7	17	35.4
Son	14	28.6	16	33.3
Daughter	9	18.4	9	18.8
Drinking				
Husband	5	10.2	4	8.4
Mother	20	40.8	22	45.8
Son	19	38.8	17	35.4

Daughter	5	10.2	5	10.4
Cleaning				
Husband	11	22.5	8	16.7
Mother	29	59.2	28	58.3
Son	6	12.2	6	12.5
Daughter	3	6.1	6	12.5
Drug administration				
Husband	34	69.4	26	54.2
Mother	15	30.6	22	45.8
Health				
Husband	32	65.3	28	58.3
Mother	17	34.7	20	41.7
Brooding				
Husband	32	65.3	32	66.7
Mother	17	34.7	16	33.3
Weaning				
Husband	15	30.6	21	43.8
Mother	34	69.4	27	56.2

The result also shows that the roosting habit of the bird is a semblance of what it is to be in the wild. They prefer to roost on a tree (40.8%, 47.9%) and on top of the wall (36.8%, 39.6%). This is an indication that height is one of the habitat components to ensure healthy living by the birds (Table 4). The respondents also indicated that during the day an elevated platform is preferred (73.5%, 79.2%) to the kitchen (26.5%, 20.8%) as a place to keep the guineafowl at all stages of development. The reasons for this were not detested by the farmers but it was suspected to be a learned action resulting from experience (Table 4). The farmers kept guineafowls and other birds in the same place. Guineafowls cohabit with other birds successfully (Table 5). This could be shown in the table above with fowl having the highest percentage (75.5%, 70.8%) and the turkey (10.2%, 8.3%) could not be housed with guineafowl because of the huge size and showing of dominance. The farmers could recognise the sex of the birds by both head and reproductive organs (46.9%, 45.8%) (Table 6). In table 7, some of the farmers said that 51-100 eggs (59.2%, 62.5%) hatched from incubation and sometimes 101-150 eggs hatched (28.6%, 27.1%). Keets were allowed to feed by themselves after 5-6weeks of hatching. The farmers said that 11-20% of the birds survived well (63.3%, 66.7%) and guineafowls laid at 31-40 weeks after hatching.

Table 4: Habitat of keets and guineafowls of the respondents during the day and night around the National Parks

National Park	OONP		**KLNP**	
Variable	Frequency	Percentage%	Frequency	Percentage%
Roosting				
Tree	20	40.8	23	47.9
Platform	11	22.4	6	12.5
Wall	18	36.8	19	39.6
Habitat (Adult): Day				
Elevated house	36	73.5	38	79.2
Kitchen	13	26.5	10	20.8
Habitat (Adult): Night				
Elevated house	12	24.5	17	35.4
Kitchen	37	75.5	31	64.6
Habitat (Keet): Day				
Elevated house	27	55.1	34	70.8
Kitchen	22	44.9	14	29.2
Habitat (keet): Night				
Elevated house	16	32.7	13	27.1
Kitchen	33	67.3	35	72.9

Table 5: Cohabitation of guineafowls with other birds around the National Parks

National Parks	OONP			KLNP		
Type of Birds	Fowl	Turkey	Mix of birds	Fowl	Turkey	Mix of birds
Frequency	37	5	7	34	4	10
Percentage%	75.5	10.2	14.3	70.8	8.3	20.8

Table 6: Identification of sex of guineafowls around the National Parksational Park

	OONP		KLNP	
Method of sex identification	Frequency	Percentage%	Frequency	Percentage%
Head	11	22.4	5	10.4
Reproductive organ	15	30.6	21	43.8
Head and reproductive organ	23	46.9	22	45.8

Table 7: Hatchability and survival of captive guinea fowls

National Park	OONP		KLNP	
Variable	Frequency	Percentage %	Frequency	Percentage %
Average of eggs hatched (season)				
10-50	6	12.2	5	10.4
51-100	29	59.2	30	62.5
101-150	14	28.6	13	27.1
Keets survival (%)				
5-10	18	36.7	16	33.3
11-20	31	63.3	32	66.7

DISCUSSION

The guineafowl management was dominated by male gender in both communities surrounding the National Parks. In Old Oyo National Park (OONP) and Kainji Lake National Park (KLNP) 61.2% and 68.8% respectively of male guineafowl farmers were recorded while lower 38.8% and 31.2% of female guineafowl farmers had interest and reared guineafowl in OONP and KLNP respectively. This was in agreement with Ayorinde research in 1990 which stipulated that men were the owners of guineafowl farming in Nigeria. According to Oke et al., in 2004 their studies suggested that women were not able to manage the guineafowl particularly in a situation when the guineafowl did not respon d to calls from feral fowl within the vicinity. But Sonaiya in 1990a and 1990b disagreed with the aforementioned assertions and opined that women were the primary management players in guinea fowl rearing with the duty to ensure their wellbeing, while the children helped in nest search and egg collection. Active involvement of women in guineafowl husbandry might be a prudent strategy to curb poverty and boast food protein consumption among the communities. The level of formal education of the farmers is low and it is a major factor influencing farmers' disposition and acceptance of innovation for ecological justification of guineafowl husbandry and rearing within the communities. Also, age distribution of 31-40 years having highest record shows that the farmers are rearing the guineafowl for subsistence since they are married and polygamous. The farmers can make use of returns from sales of guineafowl flesh and eggs as well as keeping the fowl for period of festival to cater for the family needs.

Habitat of the captive guineafowls shows similar features as they are in the feral. That is why trees, walls and platform are sensitively reoccurred with desirable percentage. The birds need trees or platforms as the components of their habitats. Most farmers do not stress themselves that is why they used to purchase guineafowls that had reached maturity stage as well as juvenile than collection of eggs in the wild or buying eggs. These methods would in short period yield returns than hatching eggs themselves. The use of adult hens to hatch guineafowl eggs is mostly used by the farmers for desirable hatchability as guineafowls lay in large quantities but few eggs hatch. Guineafowls are good layer but waste eggs during incubation. This is because guineafowls would not incubate their eggs until the end of rainy season. This debarment causes most of the eggs losing their fertility and become unproductive. The eggs incubated by the farmers are proportional to actual population of the guineafowls that the farmers keep for a season. This is a factor of population of guineafowls that have reached stage of laying eggs. The active fertile eggs enhance desirable good number of eggs collection over a particular period in ecozones. Increase in number of matured guineafowls that can lay fertile eggs is a determining condition which results into number of eggs that would be incubated. The guineafowl husbandry mechanisms of the farmers around the National Parks indicate that the family labours are utilized by the farmers to assist in keeping of the guineafowls. The farmers, their wives and children engage in maintenance of the guineafowls husbandry and production. In other words, they played vital roles in successful subsistence of the guineafowls in the communities.

Guineafowls can cohabit successfully with some other species of birds especially when the other species cooperate within their ecological niche. Turkey could not live well with the guineafowls as they threaten and fight them during feeding. Few farmers keep guineafowl with turkey while some do not keep the turkey at all to safeguard fighting of dominance between the two birds. Both head and reproductive organ can be used to identify the sexof guinea fowl. The farmer used to adopt both methods altogether for appropriate identification of sex of guineafowls. Average number of eggs hatched by the farmers is still at level of subsistence while the keets survival proportion was much prefer to keets survival of eggs collection from the National Parks (Yusuf *et al*., 2019). This can be affected by number of factors including handling of eggs after collection, mode of incubation of eggs, system of husbandry, ecological factors, internal and external features of eggs (Yusuf *et al*., 2019).

CONCLUSION

Basic status of guineafowl farmers in the surrounding of National Park creates some strategic plans for poverty alleviation and empowerment of guineafowl farmers towards improved studies for abundance of guineafowls and food security. The study reveals that hatchability through the mother hens proves to be more effective compare to use of guinea fowls and improve management for hatchability.

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Human - Wildlife Conflict in Communities Surrounding Falgore Game Reserve, Kano State, Nigeria.

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Abstract

This study focused on the human-wildlife conflict between the protected area of Falgore Game Reserve and the surrounding communities. The study was undertaken to derive information on the human-wildlife conflict in the study area and examine the problems faced by humans in relation to wildlife conservation in the Reserve. The methodology employed in the study includes the use of structured questionnaire and oral interviews to acquire information from sampled members of the communities around Falgore game reserve. The data collected were analyzed using descriptive analysis- tables, charts and percentages. The result shows that the communities harvest forest resources in the reserve having 70% response. Also, majority of the respondents (90%) reported that wild animals usually attack their farm crops and their livestock (35%) while 61.6% of the respondents reported wild animals such as baboon is the major cause of conflict in the area, attacking and destroying their farmlands, followed by hyena (41.7%). These therefore result to conflict between the protected area of Falgore Game Reserve and the surrounding communities trying to protect their farmlands and livestock's. The finding also indicates that 38.20% respondents stated that lack of employment is the major force that makes them to depend on the game reserve resources surrounding for their daily livelihood support thereby causing disagreement with the staff, while 33.33% respondents said that lack of other sources of livelihood is the cause of their much attention to the Game Reserve resources. ***It is therefore recommended that the Game Reserve Authority should intensify its awareness programme on wildlife-human conflict to the communities in the area, as this will help the public to know the types of animal causing destruction, the period and time the animals usually come out and also suggest the simple methods the communities can use to drive away the problem animals from their farms.. This will go a long way in resolving conflicts in the area.***

Keywords: Human-wildlife conflict, protected area, surrounding communities and Falgore Game Reserve.

INTRODUCTION

Human–wildlife conflicts are escalating and have become a significant issue in conservation and land management of a protected area (Hudson and Cattadori, 2006). In wildlife conservation conflicts are those negative experiences that humans receive from wildlife. Wildlife could be classified into plants and animals and their natural environment. Hence the conflicts that could exist because of wildlife conservation can be categorized into human –wildlife conflicts, human – human conflicts and wildlife –wildlife conflicts. Frequently, communities are forbidden from extracting natural resources that are important for their livelihoods, and in many instances, traditional communities are removed from their lands with little consultation or adequate compensation (Jim and Xu 2002, Brown 2003). Inevitably, this has often triggered adverse social impacts on local communities, disrupting their traditional ways of living (Garcia-Frapolli *et al*. 2009). This approach can result in hostile attitudes toward conservation strategies (Hamilton *et al*., 2000; Jim and Xu 2002, Fu *et al*., 2004), jeopardizing protection policies through conflicts between park managers and local communities, reducing the effectiveness of protected areas (PAs) for biodiversity conservation (Lane 2001). For example, in Bwindi Impenetrable Forest, Uganda, after the national park was gazetted, several fires were deliberately set, burning 5% of the forest (Hamilton *et al*. 2000). Also in Tsitsikamma National Park, South Africa, local communities practice illegal activities as a form of retaliation to command-and-control conservation policies (Watts and Faasen 2009).

According to Andrade and Rhodes (2012) restricting local access to natural resources, which can play a crucial role in their livelihoods, health, and culture, might favor biodiversity conservation in the short term. However, in the long term, such strategies may fail to preserve biodiversity if Protected Areas authorities disregard the importance of simultaneously promoting active local community participation in Protected Areas management, capacity building, implementing adequate outreach programs and also efficient governance, guaranteeing that penalties will be applied and consistently enforced (Andrade and Rhodes, 2012). For instance, in the East Africa, the Mau forest complex has lost about 107,000 hectares, or 25 percent of its forest covers through: irregular and unplanned settlements, illegal logging and charcoal burning, change of land use from forest to unsustainable agriculture and change in ownership from public to private. This scenario threatens potentials of energy generation; tourism, agriculture and water supplies into Kenyan cities and industry and therefore deteriorate East Africa's biggest economy (Siringi, 2010). In Nigeria, many rural people living close to a protected areas depends directly on natural resources including wildlife for their livelihoods and food security, while this wildlife causes losses as well as pose threat to man and his livestock. This therefore leads to non-co-operation of the rural people and consequently constant disagreement between the people and the protected area authority of which Falgore game reserve is not an exemption. There is need for study on human –wildlife conflicts in the study area. This will provide information on measures for empowering communities to address conflict in partnership with protected area management authority. Also, knowledge of conflict between people and protected areas is required for the design of sustainable conservation strategies for the management of the protected area (Hudson and Cattadori, 2006). The study is aimed at assessing the human-wildlife conflict in the study area and to examine the problems faced by humans in relation to wildlife conservation in the study area.

MATERIALS AND METHODS

Study area

Falgore game reserve covers a total area of the forest about 1000sqkm geographically. Falgore game reserve lies between latitude 80º 30′ and 80 º 50′ East and latitudes 100 46′ and 110 20′ North, 150 km South of Kano City. It has an estimated land area of 92,000 ha. The game reserve is contiguous to Tiga artificial Lake to the north, and Lame Burra Game Reserve in Bauchi State to the Southeast (Yelwa 2008; BirdLife International, 2007). Falgore Game Reserve is one of the numerous protected ecosystems in Africa South of Sahara. It was established in 1949 by the British colonial government and it was then called "Kogin - Kano" forest reserve. The government upgraded it into game reserve in the year 1969-1970. Falgore Game reserve is designated mainly for protection of fauna and flora resources in southern Kano state of Nigeria (Yelwa, 2008).

Data Collection and Sampling Techniques and Analysis

Data were collected using structured questionnaire and oral interviews to acquire information from sampled members of the communities around Falgore game reserve. Out of 9 proximity (between 1-12km away) communities to the reserve, 6 communities were selected. Sixty (60) structured questionnaires were administered randomly to respondents in the area, 10 questionnaires were administered to the most senior of a clan in each community and this was used to elicit information on the human-wildlife conflict in the study area, examine the problems faced by humans in relation to wildlife conflict in the study area. Also 10 questionnaires were administered to the Falgore Game reserve staff. The data obtained were analyzed using descriptive analysis - tables, charts and percentages.

RESULTS

The result on the human –wildlife conflicts is presented below. Figure 1 shows the occupation of the respondents (%). It shows that 56.7% respondents across the communities are farmers while hunting 3.3% and builder 1.7% are the lowest.

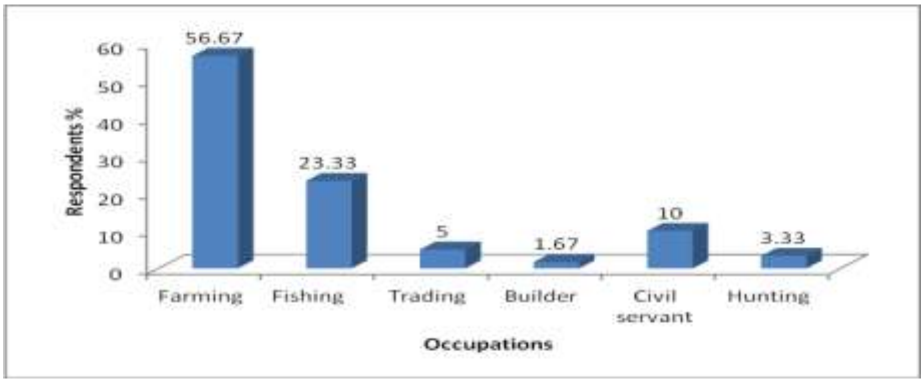

Figure 1: Occupations of the respondents (%)

Figure 2 shows the employment status of the respondents (%), it shows that 80% of the respondents are unemployed while 15% are employed.The table 1 shows the sources and effect of wild animals on the respondent's sources of livelihood (%), the result shows that 70% of the respondents harvest forest resources in the reserve, 78.3% stated that they are not allowed to carry out activities in the reserve, 20% respondents admitted being arrested by the reserve authority once or twice. Majority of the respondents (90%) reported that wild animals usually attack their farm crops and their livestock (35%).

Table 1: Sources and effect of wild animals on the respondents' sources of livelihood (%)

Sources and Effect	Yes	No	Undecided
Harvest in the reserve	30	70	
Allows to carryout activities in the reserve	8.33	78.33	13.33
Arrested	20	80	
Wild animal attack farm crops	90	10	
Wild animal attack or eat your livestock	35	65	

Figure 3 shows the factors causing conflict in the study area (%), The figure shows that 38.2% respondents stated that lack of employment is the major cause that makes them to depend on the game reserve resources for survival thereby causing disagreement with the staff while 33.33% respondents said that lack of other sources of livelihood is the cause of their much attention to the GR resources.

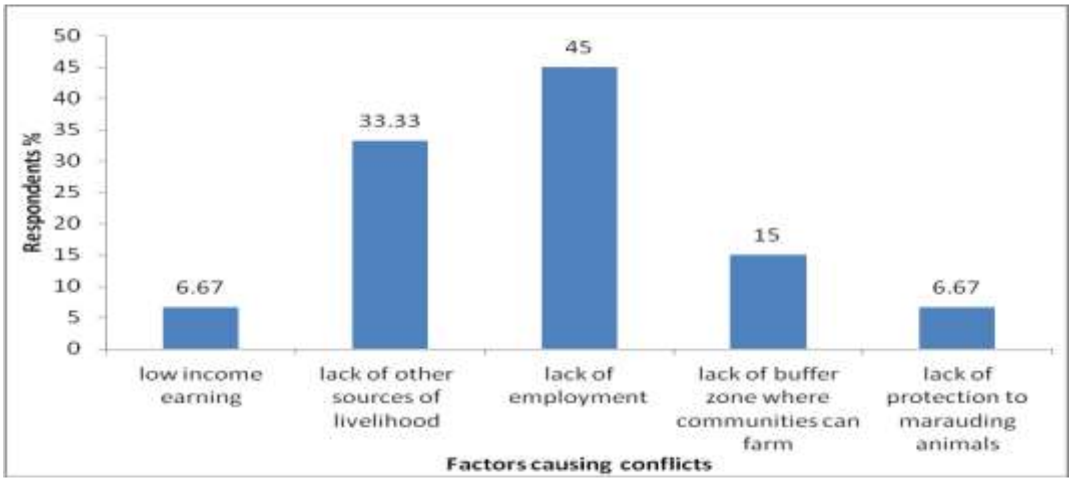

Figure 3: Factors causing conflict in the study area (%)

Table 2 shows the kinds of wild animals that cause conflict in the study area. The result shows that 61.7% of the respondents reported baboon as the major cause of conflict in the study area, followed by Hyena 41.7%.

Table 2: Types of destructive animals (%)

Types of wild animals	Frequency	Percentage %
Jackal	18	30
Hyena	25	41.67
Monkey	14	23.33
Baboon	37	61.67

Figure 4 shows the methods of controlling wildlife effect in the study area. The result shows that majority of the people applied the use of scarecrow (38.3%) to deter the animals from entering their farmland, while the use of trapping (5%) is the least method applied.

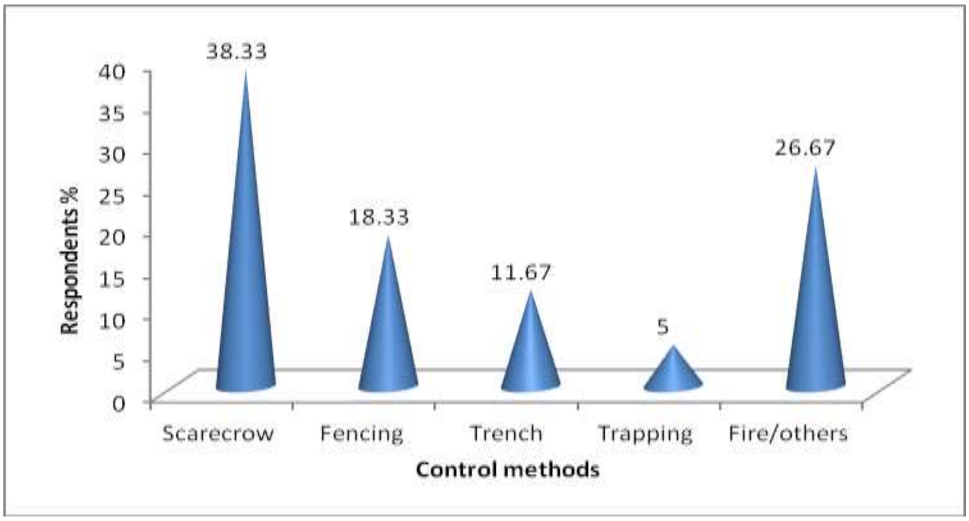

Figure 4: Methods of controlling wildlife effect in the study area (%)

Figure 5 shows the other actions and attitudes of the respondents on wildlife problems, majority of the respondents (45%) stated that they kill the animal when seen in their farms or surroundings, while 15% respondents scare the animals away.

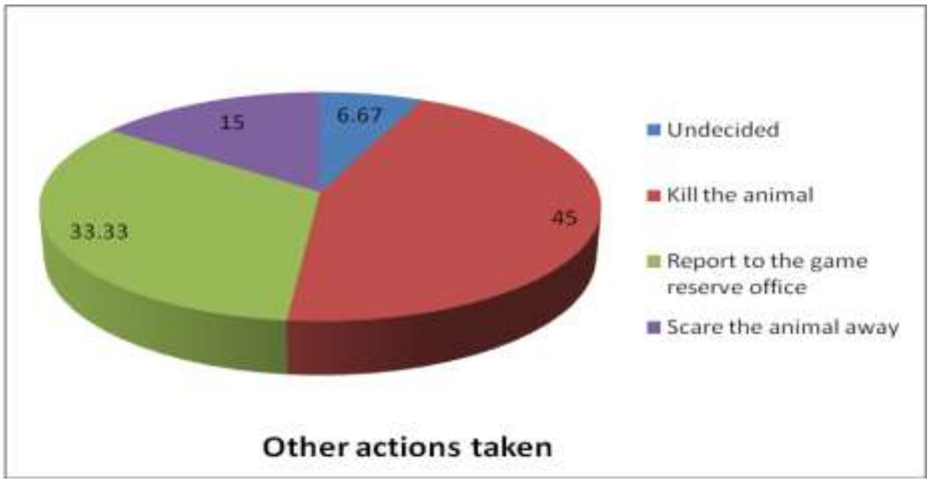

Figure 5: Other actions and attitudes of the respondents on wildlife problems (%)

Figure 6 shows that the Gsme Reserve staff response on the causes of conflict between the park and the communities. The Figure shows that 40% of respondents stated that grazing is the major cause of conflict in the park while 8.33% said that the fruit gathering is responsible.

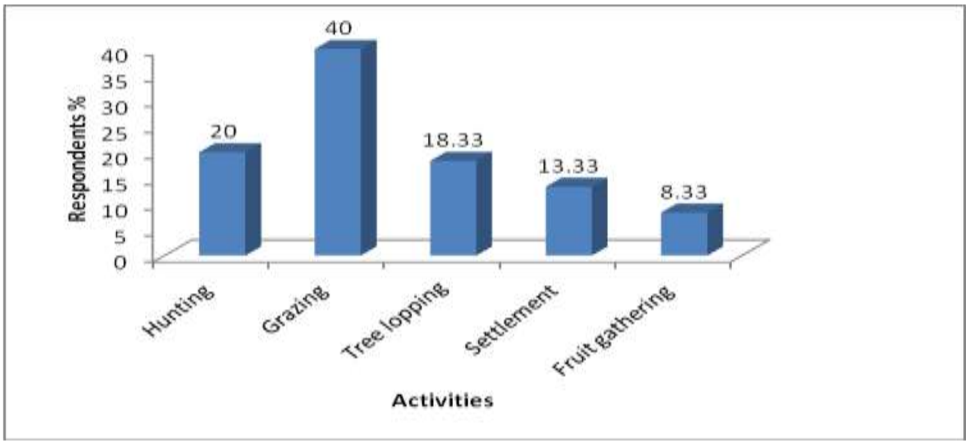

Figure 6: Game Reserve staff response on the causes of conflict between the Game Reserve and the communities (%)

Figure 7 shows the Game Reserve Staff reactions on the causes of conflict between the GR and the surrounding communities. The result shows that 93% of the communities are not compensated for their loss.

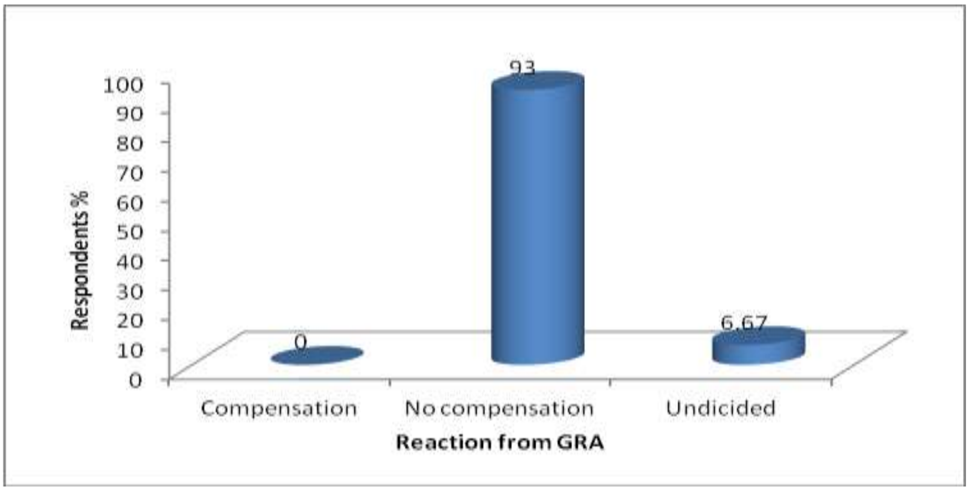

Figure 7 Game Reserve Staff reactions on the causes of conflict between the Game Reserve wild animals and the surrounding communities (%)

The table 3 shows the suggestions by communities and Game Reserve staff response on how to address the issue of conflicts in the study area. The figure shows that the respondents suggested that the Game Reserve should give compensation to affected people, and that government should create more jobs for the communities and their families.

Table 3. Game Reserve staff response on the Impact of conflict on wildlife and suggestions proffered by the communities.

Causes of conflict	Impact on wildlife	Reaction from the Game Reserve authority	Solution
Trespassing into the park area	Create unnecessary paths in the park	Chasing by game guards	Game Reserve Authority should give compensation to affected people.
Grazing in the Game Reserve by livestock	Degrading the soil causing soil erosion	Chasing by rangers	Government should create more jobs for the communities and their families.
Tree lopping, fruit harvesting in the Game Reserve	Leads to constant migration of wildlife	Chasing by rangers and arrest	Game Reserve should adequately protect their boundary.
Poaching in the Game Reserve	Leads to reduction in animal	Chasing by rangers and arrest and persecution	More patrol guards should be deployed all over the Game Reserve
communities attack on wild animals	Causes injury to wild animals and reduction in animal number	Chasing by rangers and arrest	Government should provide loans to communities to help them engage in other trades.

DISCUSSION

The findings from the survey work revealed that all the 6 communities randomly chosen for the study were located very close to the Game Reserve. The occupations of the respondents indicate that majority of the people across the communities are farmers while hunting and builder are few. This agrees with Ayeni *et al*., (1982) assertion that farming is one of the major activities of the rural people living very close to a protected area. The findings indicate that the effect of wild animals on the respondent's sources of livelihood shows that as high as 70% respondents harvest forest resources from the reserve. This means that there is little or no protection from the game reserve authority against encroachment close to the reserve. While only 20% respondents admit being arrested by the reserve authority once or twice. The arrest does not have much effect on them, since they are being fined a little and release. Majority of the respondents 90% reported that wild animals usually attack their farm crops and 35% stated that wild animal use to attack or their livestock and poultry. According to Weladji and Martin (2006) the relative frequency of reported conflict with wildlife was significantly and inversely related to human density on lands adjacent to a protected area. The findings on the factors causing conflict in the study area as shown in figure 3 indicate that the lack of employment with 38.20% response is the major force that makes them to depend on the game reserve resources for survival thereby causing disagreement with the staff and the humans. Hence the feeling of marginalization, loss of source of livelihood and lack of concern from the protected area authorities triggered the incidence of conflict (Andrew and Francis, 2009).

Livestock attack by wild animals such as carnivores dated as far back as ancient time, livestock being easier to capture by wild animals has been a source of food for the carnivores. Also human lives are also attacked by wild animal when human either live closer to the wild or enters the forest, carnivore attack humans in homes as well as tourists. Destruction of forest by man and damage of soil structure through construction work result to conflict between human and wildlife over the environmental resources (Conover and Decker, 1991).The findings on the major wild animals that cause conflict in the surrounding community indicate that the Baboon having 61.67% response is the major cause of conflict in the study followed by Hyena 41.67%. This finding agrees with Weladji and Martin (2006) report that wild animals that causes conflict includes, patas monkeys, elephants, baboon, warthog, green parrots and carnivores. The findings on the methods of controlling wildlife effect in the study area %. The result shows that majority of the people applies the use of scarecrow38.33% to deter the animals from entering their farmland, while the use of trapping 5% is the least method applied.

The findings on Game Reserve staff response on the causes of conflict between the Game Reserve, wild animals and the communities are shown in fig 6. The fig shows that 40% respondents stated that grazing is the major cause of conflict in the Game Reserve having the highest, while 8.33% said that the fruit gathering is responsible being the least. This causes conflicts between the people and the Game Reserve authorities. This finding agrees with Andrew and Francis, (2009) observation that over exploitation or utilization of conservation areas as a result of poverty among the people causes conflicts between the people and the protected area authorities. The Game Reserve staff admits that they use to encounter some problem with the surrounding communities in the area of hunting, grazing, firewood collection, fishing and farming encroachment, this result to the degradation of the land, soil erosion, and death of most animals. The Game Reserve Authority supports the communities by giving them the fruits of *Borassious ethiopicus* during the dry season. The findings on the suggestions by respondents on how to address the issue of conflicts in the study area shows that the communities wants the Game Reserve Authority to give compensation to affected people, many wants the government and Game Reserve Authority to help them by giving them loans in form of grants either as individual or communities to engage in other trades to sustain their livelihood, while some few people wants the Game Reserve Authority to adequately protect their boundary.

CONCLUSION

The Falgore game reserve has a lot of wildlife species and this includes species that causes damage to people's farm and lives stock. Primates generally therefore is the most destructive wild animal in the study area, this could be as a result of their wider home range which makes them to move from the Game Reserve interior to the boundary area were they cause destruction on communities farmland. The Game Reserve also contains a lot of economic trees that could lure communities around to enter the reserve. There is therefore a very high impact of wild animals on the livelihood of the Game Reserve surrounding communities. Hence it can be concluded that human- wildlife conflicts between the people and the Game Reserve authorities is very high and this need to be checked. The following recommendations are deduced from the study. The game reserve authority should intensify its awareness programme on wildlife-human conflict to the surrounding communities in the area, this will help the public to know the types of animal causing destruction, the period and time the animals usually come out and suggest the simple methods (such as hitting bells to scar the animal) the communities can use to drive away the problem animals from their farms. Government should employ more staff to help secure the reserve properly. Also aadequate compensation should always be paid to the communities that their farms are destroyed by wild animals, so as not to trigger adverse social impacts on local communities, and thus reducing the effectiveness of the protected area for biodiversity conservation in the area.

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Birds and Tree Species Diversity of Osun-Osogbo Sacred Grove World Heritage Site Osun State Southwestern, Nigeria

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Abstract

Birds and tree species diversity was studied in Osun- Oshogbo Sacred Groove World Heritage site in South West Nigeria. A total of 20 transect lines of 500m were randomly laid out and the minimum distance between two transect lines was 200m. The number of transect lines was determined by the site size. Data were collected for six months (Dry and Wet seasons) in 20019. The ecological survey for the floristic study was conducted in March 2019. In all, a total of 125 bird species belonging to 49 families and 18 orders were recorded in the three study sites, The Order Passeriformes had the highest frequency (51 %) of the entire number of birds recorded, while the dominant families were Estrildidaeand Pycnonotidae, comprising (74 %) of the total species One endemic and one rare weaver bird species were recorded. A total of 741 individual tree species in 174 tree species and 49 families were enumerated. The highest occurring tree species are Brachystegia eurycoma and Bracchystegia nigerica with 36 and 19 tree species respectively. DBH of 466cm was recorded in Brachystegia eurycoma, followed Bracchystegia nigerica 456 cm in the study area. Also the highest mean height of 41m was recorded in Millicia excelsa and the highest occurrence of tree species was recorded in Brachystegia eurycoma 39.Shannon diversity was 4.849 in the study area.

Key words: Birds, tree species, ecological survey, habitat fragmentation, conservation

INTRODUCTION

Birds are among the best monitors of environmental changes and have been used to evaluate the environment throughout history as bio-monitors and the changes in their population, behavior patterns, and reproductive ability have most often been used to examine the long term effects of habitat fragmentation. Hence they are the good indicators of the ecological status of any given ecosystem (Castelletta *et al*., 2000). Forests attract much avifauna because of the habitat suitability for most of them. This especially includes the birds that are associated with the vegetation, and for most, the existence of trees is vital to their life cycle. Birds show different levels of interest to various stands depending on the age of the stands Deforestation in the tropics is one of the major threats to global biodiversity (Dobson *et al*., 1997). In Nigeria at present, the destruction of natural habitats continues rapidly, resulting in the depletion of the country's biodiversity). However, South Western Nigeria is the region of high population densities and intense agricultural land-use area (Agbelusi, 1994). For this reason, perhaps biodiversity depletion may be occurring at much higher rate than elsewhere in Nigeria. NEA,(2002) reported that increased export demands for primates and birds for research and trade in timber and non-timber species are indirect causes of biodiversity loss in various parts of the country. Agricultural intensification, logging, and poaching within and around most forest reserve in south west Nigeria have resulted insharp decline of bird species in recent times, avian species are becoming intolerant of pressures on their habitats (Manu, 2000). An assessment of the abundance and diversity of bird species in Oshogbo Groove therefore, serve as a good indication of the health of the environment.

MATERIALS AND METHODS

Study Area

Osun-Osogbo Sacred Grove is located along the bank of Osun River in Osogbo Local Government Area of Osun State, Southwestern Nigeria (Oseghale, *et al*, 2014)Its geographical coordinatesare 7 02 and

08 E. The sacred grove is situated on the margin of the southern forests of Nigeria on a raised parcel which is about 350 meters above sea level. The grove is bounded in the North by Laro and Timehin Grammar Schools, the South by entrance of Ladoke Akintola University of Technology (LAUTECH) which runs parallel to form a western boundary. In the east, it is bounded by Osun State Agricultural Farm Settlements (NEA, 2010) Annual rainfall varies between 1600 and 2000 ml, mean annual temperature is 30 °C and the relative humidity is not below 40 % during dry season and 100 % during the wet season (Mengistu, and Salami, 2007). The study site experiences a bimodal annual rainfall pattern, between April and July and from September to October, separated by dry season (Isichei, 1995). Vegetation is predominantly rainforest, including wetlands along the rivers and P*anicum maximum* dominated open land. Among the common trees are *Celtis zenkerii, Triplochiton scleroxylon, Antiaris africana, Pycnanthus angolensis and Antiaris africana, Pycnanthus angolensis and Alstonia boonei* (Keay 1989)

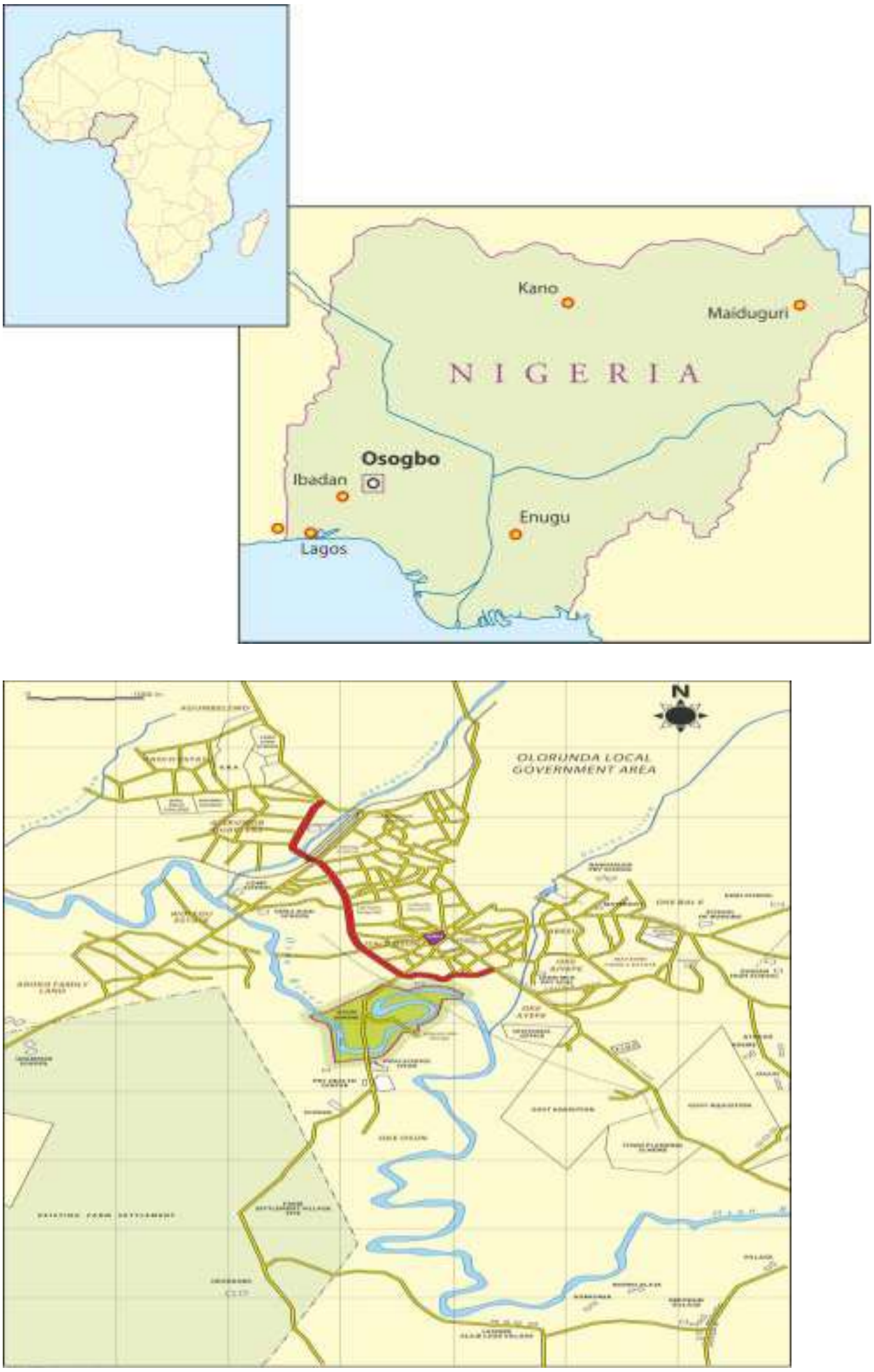

Figure 1 Map of the Study Area Source: (African World Heritage Sites)

Data Collection

Line transects method according to (Sutherland, 2009)was used to collect data on bird species diversity, and abundance in the study area. In all of 20 transect lines were randomly placed measuring 500 m each transect was divided into 200 m sections randomly placed. The programme GPS 2011 Utility (GPSU, 2012) was used to locate the starting and ending points of transects. Transect lines were walked three times a week for three months in both seasons (May, July and September for wet season and November, January, and March for dry season) of the year.Survey was conducted between 0.600hours and 10.00hours and 1600 hours to 1800 hours, the survey was not conducted beyond 10.00hours in the morning in other to reduce day light effect. Transects were walked at an average speed of 1.5 kilometer per hour, depending on the terrain and the number of bird species recorded. All birds viewed on the ground or in the vegetation, as well as birds that are flying ahead, were identified and the number in the group recorded. Birds of the same species within 10m of each other were counted in the same group. A pair of binoculars with a magnification 7x 50 was used in the identification of bird species.

Distance estimates were obtained by using a digital range finder. Physical features of birds sighted but could not be identified immediately were taken and field guide book of West African birds (Burrow and Demey, 2011) was used to identify the bird species and bird calls were used to confirmed the presence of nocturnal bird species within the study sites

From the data collected, avian species diversity was calculated using;

Shannon diversity index, (Usher, 1991) which is given as:

$H^i = - \Sigma$ Pi In Pi
Where: $H^i = {}^{\text{diversity}}$ index
Pi = is the proportion of the ith species in the sample
InPi = is the natural logarithm of the species proportion.

Species Relative Population Density
The relative population density of bird species at various sites and seasons were determined as outlined by Bibby (*et al*, 1992) as follows:

$$D = \frac{n_1 + n_2}{\pi r^2 m} Log_e \frac{[n_1 + n_2]}{n_2}$$

where: D = density
r = radius of the first zone
n1 = number of birds counted within zone
n2 = number of birds counted beyond zone and m = number of replicatecount in such area.

Habitat Survey
The ecological survey for the floristic study was conducted in March 2019 (Ogunjemite, *et al* 2005). . In this study, a total of 20 study plots of about 25 m × 25m Quadrats (500 sq m) size were established. All woody plants with stems rooted independently within a plot and with a DBH (measured at 1.3 m above ground for all lifeforms) equal to or greater than 2.5 cm were measured, inventoried and identified to species level. Multiple stems were measured separately, but all stems rooting in the same place were counted as one individual. Specimens were collected in April and May 2019. All specimens were sorted to species level and identified by matching them with vouchers identified by specialists or professional botanists. DBH measurement was taken with the simple tape measure while the height of trees was taken using Haga Altimetre.

Data Analysis
Species diversity, floristic composition and similarity were measured with quantitative and qualitative indices. The frequency of a species for each habitat type is defined as the number of (25x25m) plots in which it is present, and the sum of all frequencies as the total number of plots per site. Species diversity values were expressed in terms of species richness for each habitat type. To quantify and compare floristic composition between habitats, the Past Model version 3 was used analyzed the diversity.

RESULTS
From the result obtained from the research study it indicates that the study area supports the diversity of bird life and plant species. A total of 125 bird species belonging to 49 families and 18 orders enumerated in the study areas. The result of the family composition indicates that *Estrildidae and Pycnonotidae* had the highest number of bird species of 12 each. One endemic bird species *Malimbus ibadanesis* and one species of weaver *Ploceus tricolor* were encountered during the survey. The understory statum has the highest number of bird species in the study area, these bird species that belong to these families are *Sylvviidae, Cisticolidae, Cuculidae, Estriltidae, and Pycnonodidae*. The results of the Shannon_H diversity shown that it was highest during the dry season (4.659) than the wet season (4.297). A total of 741 individual tree species in 174 tree species and 49 families were enumerated. The highest occurring tree species are Brachystegia eurycoma and Bracchystegia nigerica with 36 and 19 tree species respectively. DBH of 466cm was recorded in Brachystegia eurycoma, followed by Bracchystegia nigerica 456 cm in the study area. .Also the highest mean height of 41m was recorded in Millicia excelsa and the highest occurrence of tree species was recorded in Brachystegia eurycoma 39. Shannon_H diversity was 4.849 in the study area. The result of the family composition indicates that *Sterculiaceae* has the highest tree species 14 followed by *Euphorbaceae* 13 tree species.

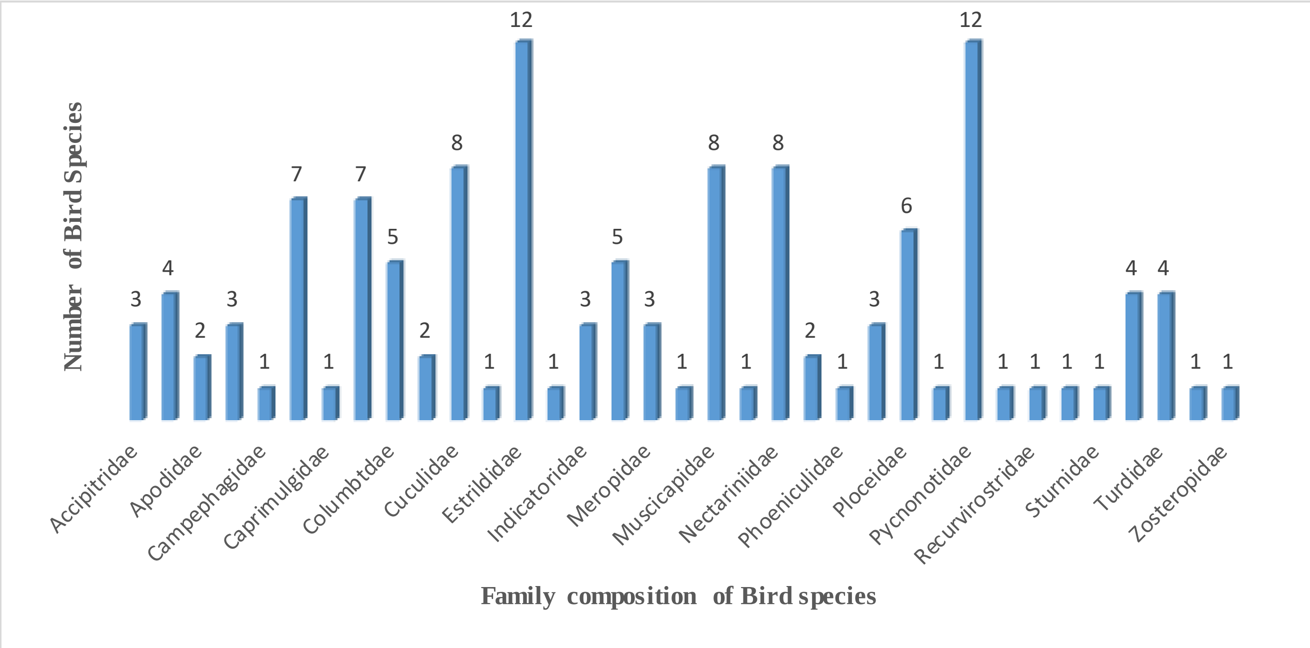

Figure 2:Bird species family composition in the study area

Table 1, Bird species diversity index in the study sites

Diversity Index	Dry season	Wet season
Taxa_S	125	100
Individuals	210	175
Dominance_D	0.01229	0.02315
Shannon_H	4.659	4.297
Evenness_e^H/S	0.8439	0.735
Margalef	23.19	19.17
Equitability_J	0.9649	0.9331

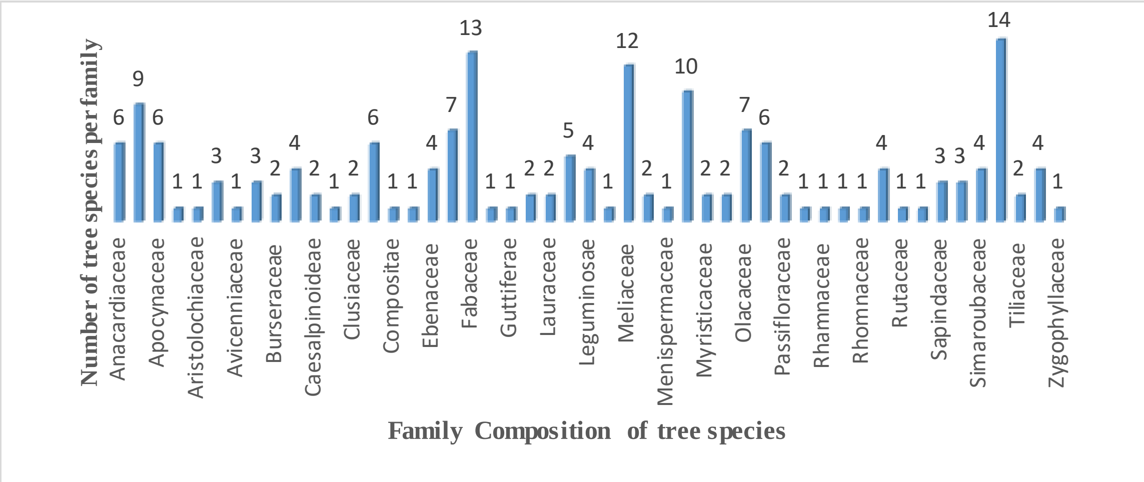

Figure 3: Tree species family composition in the study area

Table 2: Pyto-sociological parameters of tree species in the study area

Habitat Type	Number of Tree Species	Number of Individual Tree Species	Highest DBH (cm)	Highest MH (m)	Highest Occurrence	Shannon-Wiener H'
Rain Forest	174	1047	466 *Brachystegia nigerica*	41 *Milicia excelsa*	39 *Brachystegia nigerica*	4.849

DISCUSSION

The majority of bird species encountered during this study were resident bird species and few migratory bird species. The 98% of the bird species encountered in the study area were forest species which in agreement with (Elgood et al, 1977) who carried out s bird species survey in Southwestern Nigeria. The study area is located in the low land rain forest which offered even distribution pattern of birds showed highest species richness and Shannon diversity in in both seasons of the year which comprises mixed moist deciduous canopy, that could be due to the presence of the majority of evergreen trees, which provided the sufficient food in the form of flowers and insects (Thiollay, 1998). The result showed that 125 bird species utilized the study area throughout the period of the research study. This result is consistent with the work of Matlock Jr, *et al*, (2003) who reported that forest patches and protected area in Sao Tome have high a retention of bird species than agricultural landscapes. This is also supported by previous research studies that suggested multi-strata agroforestry systems are being able to accommodate high levels of species richness and abundance for several tropical groups, especially when compared with alternative land use. The comparison of species diversity between dry and the wet season, the result indicates diversity was higher in the dry season than wet season in the study area. This is consistent with MacArthur and MacArthur (2001) who reported that diversity increases with the number of layers in the vegetation. Pearson (2001) reported that tropical wet evergreen forest support more rare bird species than other habitats. Manu (2007) reported that birds select vegetation variables according to the manner by which an individual habitat affects access to food, mates or its vulnerability to predators.

This study shows that lowland forest in the study areas are best habitats for the birds as far as the numbers and diversity is concerned. This is in agreement with (Pramod *et al., (*1997) who reported that serious loss of the biodiversity value occurs in the transformation of original landscapes to croplands due to human interference. Karr and Roth, (1971) reported that the more complex the structure or composition of the vegetation, the more likely that habitat will contain more bird species. In this study, tree density, high DBH, presence of tall emergent tree, trees occurrence and understory density were important vegetation characteristics responsible for the high bird species richness recorded in the study area. Bird species behavioral pattern was found to play a big role in bird diversity in the conserved area, for example, (Pied Flycatcher, Black shouldered Puffback, Lagden's Bush-Shrike and Blue Shouldered Robin Chat, Ibadan malimbe, Yellow Mantled weaver Pipping hornbill and Black cuckoo were more or less resident in the study area throughout the period of this study and forest edges despite the availability of food resources in the surrounding farmlands (Cody, 1985).

CONCLUSION AND RECONMENDATION

The presence of some endangered and threatened bird species in the study area is a sign of hope. However, their conservation must be guaranteed and that will only be achieved by the conservation of extensive areas of natural vegetation. Houses are springing up in the buffer zone in the study area it means high population and faming intensification is ongoing in the area, the study host high population of rare bird species of ecotourism value such as Malinbus ibadanesis,Coracias cyanogaster Spizaetus africanus Ceratogymna fistulator Cuculus clamosus and Yellow Mantled Weaver. The management of these areas should design programmes to discourage bush burning, deforestation and poaching by the local people.The conservation strategy must integrate the physical, economic, social and cultural condition of the farmers and Local people so as to come up with innovations and technologies that conserve and sustain biodiversity.

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Appendix 1: Checklist of bird species in the study area

Family	Scientific Name	Common Name
Accipitridae	*Spizaetus africanus*	Cassin's hawk Eagle
	Kaupifalcomono grammicus	Lizard Buzzard
	Polyboroidestypus	African Harrier Hawk
Alcedinidae	*Ispidinalecontei*	African Dwarf Kingfisher
	Halcyon badia	Chocolate Backed Kingfisher
	Halcyon malimbica	Blue Bresated Kingfisher
	Halcyon senegalensis	Woodland Kingfishr
Apodidae	*Cypsiurusparvus*	African Palm Swift
	Apus affinis	Little Swift
Bucerotidae	*Tockusfaciatus*	African Pied Hornbill
	Tockusnasutus	African Grey Hornbill
	Ceratogymnafistulator	Pipping Hornbill
Campephagidae	*Coracinaazurea*	Blue Cuckoo Shrike
Capitonidae	*Tricholaemahirsuta*	Hairy Barbet
	Pogoniulus atroflavus	Red RumpedTinkeredbird
	Gymnobuccocalvus	Naked Faced Barbet
	Pogoniulusscolopaceus	Speckled Tinkerbird
	Pogoniuluschrysoconus	Yellow Fronted Tinkerbird
	Gymnobuccopeli	Bristled Nosed Barbet
	Pogoniulussubsulphureus	Yellow Throated Tinkerbird
Caprimulgidae	*Macrodipteryxlongipennis*	Standard Nightjar
	Caprimulgusnigriscapularis	Black-Shouldered Nightjar
Cisticolidae	*Bathmoercuscerviniventis*	Black Head Rufous Wabbler
	Cisticolaerythrops	Red Faced Cisticola
	Camaropterachloronota	Olive Green Camaroptera
	Priniabairdii	Banded Prinnia
	Camaropterabrachyura	Grey Backed Camaroptera
	Priniasubflawa	Tawny- Flanked Prinia
	Apalisjacksoni	Black Throated Apalis
Columbtdae	*Treron calva*	African Green Pigeon
	Turturbrehmeri	Blue Headed Wood Dove
	Streptopeliasenegalensis	Laughtng Dove
	Streptopeliasemitorquata	Red Eyed Dove
	Tuerturtympanistria	Tambourine Dove
Coraciidae	*Eurystomusglaucurus*	Broad Billed Roller
	Coraciascyanogaster	Blue Billed Roller

Cuculidae	*Chrysococcyxcupreus*	African Emerald Cuckoo
	Centropusgrillii	Black Coucal
	Cuculusclamosus	Black Cuckoo
	Chrysococcyxcaprius	Dideric Cuckoo
	Cercococcyxmechowi	Dusky Long Tailed Cuckoo
	Chrysococcyxklaas	Klaas Cuckoo
	Centropussenegalensis	Senegal Coucal
	Ceuthmocharesaereus	Yellowwbill
Dicruridae	*Dicrcurusadsimillis*	Fork Tailed Drongo
Estrildidae	*Spermestes bicolor*	Black And White Mannikin
	Nigrita bicolor	Chestnut Breasted Negrofinchh
	Nigritacanicapilla	Grey Headed Negrofinch
	Nigritaluteifrons	Pale Fronted Negrofinch
	Lagonostictasenegala	Red BilliedFirefinch
	Cryptospizareichenovii	Red Faced Crimsonwing
	Spermophagaruficapilla	Red Headed Bluebill
	Spermophagahaematina	Western Bluebill
	Nigritafusconota	White Breasted Negrofinch
	Parmoptilarubrifrons	Red Fronted Antpecker
	Parmoptilawoodhousei	Woodhouse's Red Headed Antpecker
	Spermestes cucullatus	*Bronze Mannikin*
Hirundinidae	*Cecropis semirufa*	Rufous Chested Swallow
Indicatoridae	*Prodotiscus insignis*	Cassin's Honeyguide
	Dryoscopus senegalensis	Black Shouldered Puffback
	Malaconotuslegdeni	Lagden's Bush Shrike
Malaconotidae	*Dryoscopussabini*	Large Billed Puffback
	Dryoscopus angolensis	Sabine's Puffback
Meropidae	*Meropsgularis*	Black Bee Eater
	Meropspusillus	Little Bee Eater
	Meropsalbicollis	White Throated Bee Eater
Monarchidae	*Elminianigromittrata*	Chestnut -Capped Flycatcher
Muscicapidae	*Fraseriaocreata*	African Forest Flycatcher
	Trochocercusnitens	Blue Headed Crested Flycatcher
	Cossyphacyanocampter	Blue Shouldered Robin Chat
	Stiphrorniserythrothorax	Forest Robin
	Cercotrichasleucosticta	Forest Scrub Robin
	Sheppardiacyornithopsis	Lowland Akalat
	Ficedulahypoleuca	Pied Flycatcher
	Muscicapainfuscata	Sooty Flycatcher
Musophagidae	*Tauracopersa*	Green Crested Turaco
Nectariniidae	*Fraseriaocreata*	Green Crested Turaco
	Trochocercusnitens	Buff Throated Sunbird
	Cossyphacyanocampter	Collard Sunbird
	Stiphrorniserythrothorax	Green Sunbird
	Cercotrichasleucosticta	Reichenbach1's Sunbird

	Sheppardiacyornithopsis	Splendid Sunbird
	Ficedulahypoleuca	Supberb Sunbird
	Muscicapainfuscata	Variable Sunbird
Oriolidae	*Oriolusbrachyrhynchus*	Western Black Headed Oriole
	oriolushosii	Black Winged Oriole
Phoeniculidae	*Phoeniculuscastaneiceps*	Forest Wood Hoopoe
Platysteiridae	*Platysteiracastanea*	Chestnut Wattle Eye
	Megabyasflammulatus	African Shrike Flycatcher
	Platysteiracyanea	Common Wattle Eye
Ploceidae	*Malimbuserythrogaster*	Red Headed Malimbe
	Ploceusnigerrimus	Velliot's Weaver
	Malinbus scutatus	Red-Vented Malimbe
	Ploceus tricolor	Yellow Mantted Weaver
	Ploceus cuculators	Village Weaver
	Malimbus ibadanensis	Ibadan Malimbe
Prionopidae	*Prionopscaniceps*	Red Billled Helmet-Strike
Pycnonotidae	*Andropadusansorgei*	AnssorgesGreenbull
	Bledasyndactyla	Common Bristlebill
	Pycnonotus barbatus	Common Bulbul
	Bledaeximius	Green Tailed Bristlebill
	Baeopogon indicator	Honeyguide Greenbull
	Phyllastrephusicterinus	IcterineGreenbull
	Andropadusvirens	Little Greenbull
	Andropaduscurvirostris	Plain Greenbull
	Chlorocichla simplex	Simple Greenbull
	Chlorocichla simplex	Simple Leave Love
	Nicatorchloris	Western Nicator
	Andropaduslatirostris	Yellow Whiskered Greenbull
Rallidae	*Sarothrurapulchra*	White Spotted Flutail
Recurvirostridae	*Himantopushimantopus*	Black Winged Stilt
Strigidae	*Strixwoodfordii*	African Wood Owl
Sturnidae	*Poeopteralugubris*	Narrow Tailed Starling
	Lamprotornispurpureiceps	Purple Headed Starling
Sylviidae	*Sylviettavirens*	Green Combec
	Hyliaprasina	Green Hylia
	Macrosphenusconcolor	Grey Longbill
	Eremomelabadiceps	Rufous Crowned Eremomela
Turdidae	*Alethecastanea*	Fire Tailed Alethe
	Zootheraprincei	Grey Ground Thrush
	Alethediademata	White Tailed Alethe
	Neocossyphuspoensis	White Tailed Ant Thrush
Viduidae	*Viduamacroura*	Pin Tail Whaydah
Zosteropidae	*Platysteiraconcreta*	Yellow White Eye

Appendix 2: Checklist of tree species in the study area

Name of Tree Species	DBH	MH	Frequency
Adenostemmaperrotteii	35	13	7
Adenia lobate	43	17	6
Adenostemmaperrotteii	40	19	2
Afzelia Africana	233	34	9
Albiza coriaria	188	31	1
Albiza gummifera	199	29	8
Albizia ferruginea	212	32	13
Albizia zygia	246	32	6
Allanblackia floribunda	178	35	4
Alstonia boonei	280	31	4
Alstonia congensis	145	30	6
Altrocarpus heterophylla	47	17	9
Amphimas pterocarpoides	190	29	2
Anarcadium occidentalis	57	17	6
Angylocalyx zenkeri	133	28	8
Anona muricata	34	14	6
Anonidium manni	48	18	4
Anopyxiskli aneana	67	21	5
Anthoceleista nobilis	76	24	3
Anthonotha macrophylla	59	21	4
Antiaris africana	233	35	3
Antiaris welwitschii	222	36	2
Antrocaryon micraster	97	28	5
Aristolochina ningens	111	27	4
Artocarpus attilis	79	27	7
Aviceniagermirans	87	30	5
Azadirachtaindica	99	24	9
Balaniteswilsonana	43	13	5
Baphianitida	110	28	7
Bateria fistulosa	57	21	4
Berlinia grandiflora	77	25	8
Berlinia SPP	65	25	3
Bidenspilosa	14	8	3
Blighia sapida	122	27	2
Blighia welwithil	34	12	6
Bombax brevicuspe	133	28	6
Bosqueia angolensis	112	22	6
Brachystegia eurycoma	456	35	36
Brachystegia nigerica	466	39	19
Bridelia ferruginea	375	21	4
Bridelia micrantha	57	24	6
Bryophyllum pinnantum	89	21	9
Canarium schweinfurthii	76	21	7
Carpolobi alutea	64	23	4

Cassia alata	10	8	5
Cassia hrusta	87	24	7
Cathium hispicum	66	21	9
Ceiba pentandra	398	35	8
Celtisaldolfi- friderici	98	23	4
Celtis mildibraedii	56	21	5
Celtis mildibraedii	87	23	6
Celtis zenkeri	111	21	5
Chrysophyllum abidun	231	31	4
Chrysophyllum delevoyi	234	30	4
Chrysopyllum africana	67	21	5
Cissampelos mucronata	41	20	2
Cleistopholis patens	65	21	8
Cola acuminate	110	25	8
Cola ginganta	221	31	8
Cola lateritia	245	31	8
Cola melleni	64	21	5
Combretodendron macrocarpum	131	24	8
Cordia millenii	132	25	5
Crescentia cujete	46	20	12
Cylicodiscus gabunensis	76	26	6
Cymbopogon citratus	99	27	12
Spathodeacom panulata	132	21	8
Daniella ogea	341	34	4
Deinbollia piñata	88	24	5
Desplatsia subericarpa	42	21	3
Dialium guineense	131	24	9
DIopros nigerica	121	23	6
Diospyrosalbo flavescens	67	21	7
Diospyros dendo	55	20	9
Diospyros mesipiliformis	62	25	6
Distemonanthusbenthamianus	87	26	6
Elaesis guineesis	110	27	6
Entada Africana	122	28	9
Entandrophragm aangolense	351	34	7
Entandrophragma utile	366	38	9
Erythrophleum suaveolens	174	25	6
Fagara macrophylla	95	21	4
Ficus sur	133	27	5
Ficus capensis	121	23	5
Ficus esasperata	326	34	8
Ficus glumosa	98	25	0
Ficus glumosa	57	21	0
Ficus sur	43	20	3
Ficus thoniigii	54	21	3
Funtumia Africana	136	28	17
Funtumia elastic	90	23	3
Garcinia kola	122	21	3

Gossweilorodendron balsaminiferum	34	14	1
Grewiavenusta	43	20	2
Guareacedrata	79	27	1
Guibourtia sp.	89	23	1
Halleacilata	38	12	1
Hannoaklaineana	76	23	1
Heveabrasiliensis	85	25	1
Homaliumaylmeri	39	11	1
Hunteria umbellate	63	23	2
Hymenostegiaafzelii	42	21	2
Icacinatrichantha	56	23	1
Irvingiagabonensis	172	28	2
Irvingiagrandifolia	129	30	1
Khayagrandifoliola	166	31	3
Khayaivorensis	34	12	1
Kigelia Africana	199	32	3
Lanneawelwitschi	73	23	2
Lonchocarpusgriffonianus	72	21	5
Lophiraalata	155	29	1
Lovoatrichilioides	111	21	1
Maesobotryabateri	122	24	2
Maesopsiseminii	26	8	7
MagniferalIndical	67	26	1
Memocylonblakeoides	210	34	8
Milicia excelsa	239	39	3
Milleticecerriceus	56	24	2
monodoramyristica	45	21	1
Moringalucida	56	20	5
Musangacecropioides	131	21	1
Myrianthusarboreus	133	23	3
Napoleoneavogelii	98	20	2
Naucleadiderrichii	67	22	3
Nesogordoniapapaverifera	79	20	5
Newbouldialaevis	73	21	5
Ntrocaryonmicraster	84	22	1
Okoubakaaubrevillei	54	21	1
Olaxsubscorpioidea	59	20	1
Oxytenantheraabyssinica	78	21	2
Pachyelasmatessmannii	53	20	2
Panda oleasa	45	21	3
Pausinystaliamacroceras	87	24	2
Pentaclethramacrophylla	99	23	3
Pentaclethramacrophylla	87	26	3
Pentaclethramacrophylla	84	27	1
Pentadesmabutyracea	55	21	3
Piptadeniastrumafricanum	145	29	1
Polyalthiasuaveolens	34	8	2

Polyceratocarpusparviflorus	122	23	1
Psidiumguajava	13	5	1
Pterocarpussoyauxii	28	7	3
Pterocarpusosun	117	26	2
Pycanthusangolensis	231	39	1
Rauvolfiavomitoria	98	24	1
Ravolfiatraphylla	23	7	2
Ricinodendronheudelotii	32	9	3
Rothmanniahispida	67	24	1
Saacharumofficinarum	14	7	1
Scottelliacoriacea	54	20	3
Snysepalumdulcificum	13	9	1
Sopondiamombin	63	21	3
Spathodeacampanulatu	46	22	1
Staudtiastipitata	76	20	2
Sterculiaoblonga	49	21	3
Sterculiatragacantha	54	22	2
Sterculliacoriata	34	23	1
Stombosiagrandifolia	53	28	1
Strombosia postulate	63	27	3
Tabernaemontanapachysiphen	122	29	1
Terminalia ivorensis	143	29	4
Terminalia superba	167	30	2
Tetracarpidiumconophorom	112	21	1
Tetrapleuratetaptera	143	25	2
Tetrorchidiumdidymostemon	54	23	1
Theobroma cacao	13	7	1
Tramaorientalis	25	10	2
Treculia Africana	175	30	2
Trichilialanata	54	21	1
Trichiliaprieuriana	54	21	1
Triplochiton scleroxylon	257	37	4
Triumfettapentandra	38	21	2
Uvariopsisdioica	11	5	4
Xylopiaaethiopica	29	17	1

Assessment of Indigenous knowledge in Protected Area Management: Case of Old Oyo National Park.

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Abstract

Indigenous knowledge of protected area is important to the success of any protected area and conservation of biodiversity. This study assessed and indigenous ways through which Old Oyo National Park was managed prior to its establishment with the possibility of blending the indigenous knowledge with the recent ideas for better park management in Old Oyo National Park.Data collection was through structured questionnaire and interview methods to elicit information on the indigenous knowledge in protecting the protected area. Twenty five communities were selected from the five ranges of the park with five respondents in each community making a total of one hundred and twenty five (125). Interview was held with the same group of people for further information. Data collected were descriptively analyzed. Results showed that communal efforts were used to manage and protect certain areas of interest such as Ibuya river and burial grounds for kings which were of cultural, religious/spiritual significance to people of support zone communities. Traditional land usage showed farming as being predominant in the area, this is followed by hunting expeditions, collections of herbs, leaves and roots, logging as well as medicinal plants usage with 39.6%, 23.2%, 14.4%, 14.4% and 8.8% respectively. Some of these traditional land use systems are believed to have adverse impact on protected area; and this impact not only involve changes in forest ecosystem, species composition, genetic structures but also potential extinction of plants and animal. Recommendation was made on the need to intensify community support programs and conservation awareness in order to educate the people on the need to conserve/preserve the natural heritage of the Park. Alternative means of livelihood should also be provided for the people in the area by training of the teeming youths in the support zones in entrepreneurial skills and acquisition programmes.

***Key words**:* Protected area, Indigenous knowledge, Park management, Support zone communities

INTRODUCTION

There are 238,563 designated protected areas all over the globe covering about 14.9% of the earth's surface. (Protected Planet, 2018) with more being added daily. These areas have been established and managed through special rules for conservation goals. Protected area management and protection requires more than the manager's effort as the input of indigenous and traditional owners of the areas is needed if conservation objectives for which they have been established would be achieved. Indigenous knowledge of protected area is vital to the success of any protected area and conservation of biodiversity in general. The culture or way of life, occupation and the various activities of the indigenous people around a conservation site determines to a great extent the sustainability and continuity of the area.

Respect for cultural values as essential connections of biodiversity and the need to involve indigenous and local communities in management decisions affecting them is now given attention if conservation objectives must be met. (Oviedo *et al*, 2000). Beltran 2000 observed that indigenous people have always had relationships with nature and understand it in so much that they often made significant contributions to the maintenance of many of the earth's delicate ecosystems through their traditional sustainable resource use practices and culture-based respect for nature. Hence, there should be no inherent conflict between the objectives of protected areas and the existence, within and around their borders, of indigenous and other traditional peoples.

In years past, prior to Federal Government taking over the management of the protected area, indigenous and local knowledge have managed the areas through various ways. It is sometimes assumed that protected areas must be in conflict with the rights and traditions of indigenous and other traditional peoples on their terrestrial, coastal/marine, or freshwater domains. In reality, where indigenous people are interested in the conservation and traditional use of their lands, territories, waters, coastal seas and other resources, and their fundamental human rights are accorded, conflicts need not arise between those peoples' rights and interests, and protected area objectives. In accordance with recent understanding of the concept of sustainable development and several international treaties, the world conservation bodies including International Union for Conservation of Nature (IUCN) and the World Wildlife Fund for Nature (WWF) have recognized that protected areas will survive only if they are seen to be of significance, in the widest sense, to the nation as a whole and local people in particular. The privileges of indigenous and other traditional peoples residing in an around protected areas must be valued and not withheld from themby encouraging and permitting their full participation in co-management of resources in a way that would not affect or undermine the objectives for the protected areas as set out in its management plan. It had been severally recognized that awareness, improvement, innovation and practices of indigenous and other traditional people have much to contribute to the management of protected areas. It is therefore important that government and protected area users should include customary, indigenous tenure, knowledge and resource use as a means of enhancing biodiversity conservation (Beltrán, 2000).

MATERIALS AND METHODS

Study Area

Old Oyo National Park is among the seven national parks in Nigeria created by Act No. 36 of 1991 and was later repealed and replaced with Act No. 46 of 1999. It derives its name from Oyo-Ile, the ancient political capital of Oyo Empire of the Yoruba people, and contains the ruins of this city. Situated in Oyo State in the South West of Nigeria, it lies between latitude $08^o\ 15^1 – 09^o\ 00^1$ N and longitude $03^o\ 35^1 – 04^o\ 42^1$ E (Fig 1) and has a total land mass of 2,512km^2 with the administrative office located along Iseyin - Isokun road, Oyo. The location placed the park at a vantage position of abundance land area as well as diverse wildlife and cultural/historical setting. The entire park is in the southern guinea savanna with the vegetation classified into four- types as follows:

- Dense woodland and forest outlier in the south- eastern part and the north west corner, dominated by *Burkea africana, Afzelia africana, Detarium microcapum, Danielia oliveri, Pterocarpus erinaceous,Piliostigma thonningil, Vitex doniana, Nauclea latifolia, Terminalia glaucescens, Kigelia africana, Anogeissus leiocarpus,Diospyros soubreana, Parkia biglobosa and Vitellaria paradoxum.*
- Mixed open savanna woodland in the middle and northeast portions dominated by *Terminalia aviceniodes, Prosopis africana, Terminalia laxiflora, and Khaya senegalensis*. Outcrop vegetation in the hilly and rocky area throughout, dominated by *Adansonia digitata, Anogeissus leiocarpus, Parkia biglobosa*, and *Acacia species.*
- Riparian grassland and fringing woodland occupying the forest plains and valleys along the Ogun river dominated by *Burkea africana,Piliostigma thonningil, Danielia oliveri, Khaya senegalensis, Anogeissus leiocarpus, Terminalia species, Borassus aethiopium, Andropogan species, and Panicum species*.

  In a broader sense, the vegetation of the park maybe divided into two – Dry savanna and moist Riverine forest /woodland. Old Oyo National Park is responsible for the conservation, preservation and protection of fauna and flora (biodiversity) as well as its unique attraction historical, archaeological and cultural site in Oyo-Ile area of the park.

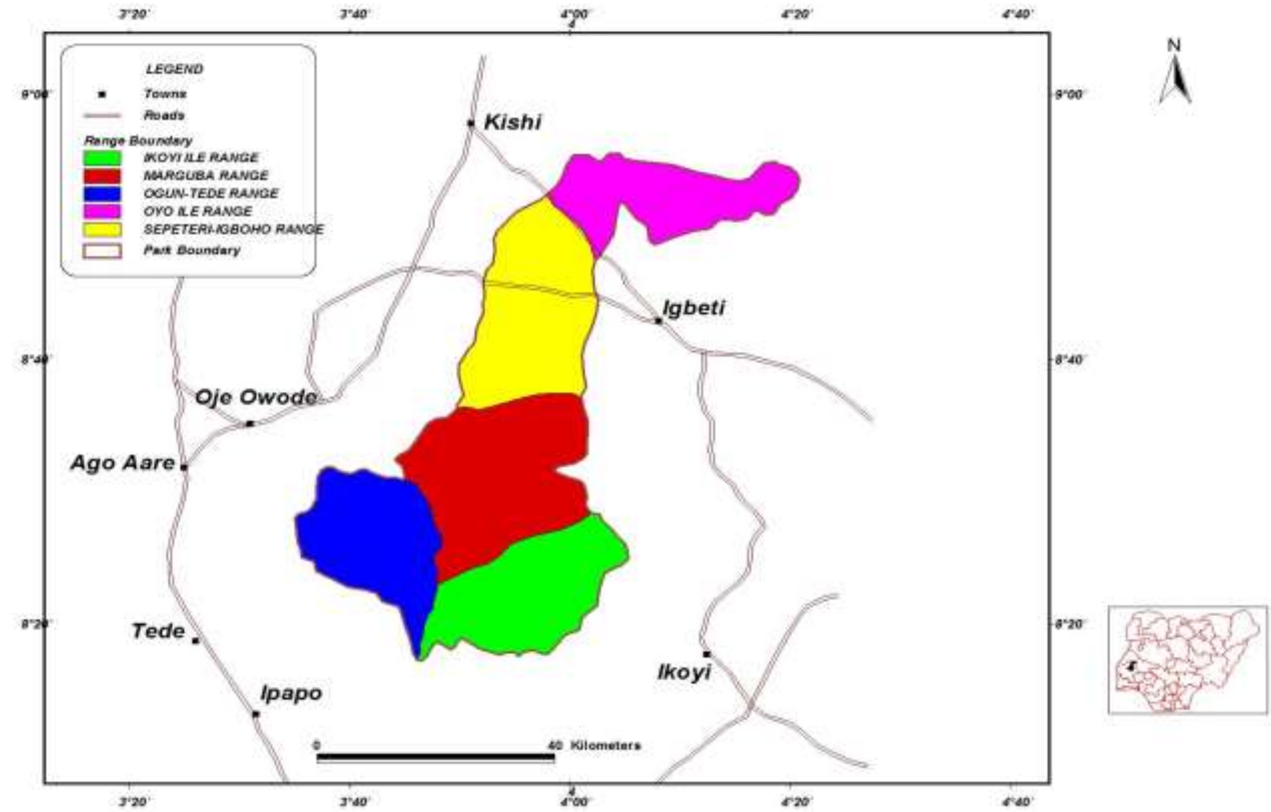

Figure 1: Map of Old Oyo National Park. **Source**: Ogunjinmi, 2010.

The park is about 300km from Lagos, 60km from Ibadan, 160km from Ilorin, 660km from Abuja and 910km from Kano. It is surrounded by twelve (12) local government areas out of which eleven (11) falls within Oyo State these are: Atiba, Atisbo, Irepo, Iseyin, Itesiwaju, Iyamopo/Olorunsogo, Oorelope, Orire, Oyo West, Shaki East and one in Kwara State that is, Kaiama. The topography of the Park area has a beautiful uniqueness since it lies in plain lowland between 300m to 500m above the sea level. Few notable hills such as Yemoso and Gbogun, however rise several meters above their general surrounding. The greater part of the park is watershed and is well drained by two river systems. Ogun River, flowing southwards to the Atlantic ocean, and the Tessi flowing northwards to the River Niger. Several tributaries flow south- westwards and eastwards, and north- westwards to join these two main rivers respectively.

Annual rainfall in the park ranges between 900mm and 1500mm and main annual temperature is between 12^0C and 37^0C. The rainy season begins in April through September with the highest rainfall record between July and August. The dry season runs from October to early April and the driest and hottest period is between March and April. The Park experiences the harmattan period from November through February. The animals commonly found in the park include Western kob (*Kobus kob*), Western hartebeest (*Acelaphus buselaphus*), Bush buck *(Tragelaphus scriptus*), Red river hog *(Potamochoerus porcus*), Buffalo *(Syncerus caffer)* and are concentrated between Ibuya and confluence of River Iwawa and River Ogun. However, water dependent wildlife such as: Water buck *(Kobus ellipsiprymmus defassa*) and Kobs *(Kobus kob*) are well distributed along the course of River Tessi, River Owu, and River Ogun.

Materials and Method

Data collection

Data for the study was collected using a combination of structured questionnaire and oral interview methods to elicit information on the indigenous knowledge of protecting the protected area. Due to the fact that the study area became a full-fledged national park in 1991, the group of people interviewed were those above 20 years, these were reckoned to have settled around the protected area before the establishment of the park. Five communities were randomly selected from the five ranges of the park making a total of twenty five (25) communities. The selected communities are: Imodi, Aba-nla, Sepeteri, Kanga, Lukutu (Marguba range), Igbope, Igboho, Alaguntan, Abaja, Kufiji , Tessi Garba, Sooro, Opa, Igbeti, Ogundiran, Tede, Alakuko, Ajebamidele, Balelayo, Abaowu, Oloka, Ikoyi, Gboguro,Yawota and Esinele.

Five respondents were chosen for the interview in each community making a total of one hundred and twenty five (125) copies of questionnaire. The questionnaire was individually administered and the questions not understood explained to them.

Interview was held with the same group of people to further obtain information on how the area was traditionally conserved. An officer from the park was present during the interview to allay fears of the respondents. The data collected were descriptively analyzed and results presented in form of frequency, table, percentage, and bar chart.

RESULTS AND DISCUSSION

Demographic characteristics revealed that the percentage of male is higher than that of the females with 58.4% males and 41.6% females. Males are more involved in farming, being the major occupation and source of livelihood/income for most families in the support zone communities of the Park however hunting, traditional medicine and other activities which contradict conservation were also part of occupation in the area. The age range of respondents of >50years was highest with 64.8% while respondents between 40-50years were 35.2%. These comprise of indigenes and non-indigenes that have settled around the park before its designation as a National Park.

Marital status showed that the married class has the highest percentage with 92.0%, followed by widow/widower with 4.0%, divorced 3.2% and single has the lowest percentage with 0.8%. The married people greatly affect the use of forest product and land because they depend largely on the farm products for their survival. Muslims form majority of the respondents of with 58.4% while Christians were 37.6%, and African traditionalist was represented by 4.0% (Table 1). The Islamic and Christian religions are the major practicing religions among the respondents

Table 1: Demographics characteristics

Characteristics	Frequency	(%)
Gender		
Male	73	58.40
Female	52	41.60
Age		>50
>50	81	64.80
<50	44	35.2
Religion		
Muslims	73	58.40
Christians	47	37.60
Traditional religion	5	4.0
Marital status		
Married	115	92.0
Widow(er)	5	4.0
Divorced	4	3.2
Single	1	0.8
Occupation		
Hunting	66	52.8
Farming	47	37.6
Traditional Practice	12	9.6

Traditional land use

Information obtained revealed that the occupations practiced majorly are farming, hunting and traditional medical practice. Farming has the highest percentage, this is because they all believed that farming is their primary occupation and they use it to support their families (Figure 2). This was followed by hunting, which was said to be inherited from their forefathers and they depend on it as a source of income. Others also see hunting as a secondary occupation while some engage in it for pleasure rather than a primary occupation. Finally, traditional medicine ranked lowest because of the introduction of modern healthcare facilities which made percentage of the respondents practicing it low. Traditional land use from the selected communities shows that farming is the predominant land use in the area, this is followed by usage for hunting expeditions, collections of herbs, leaves and roots, logging as well as medicinal plants usage with 39.6%, 23.2%, 14.4%, 14.4% and 8.8% respectively. (Figure 2)

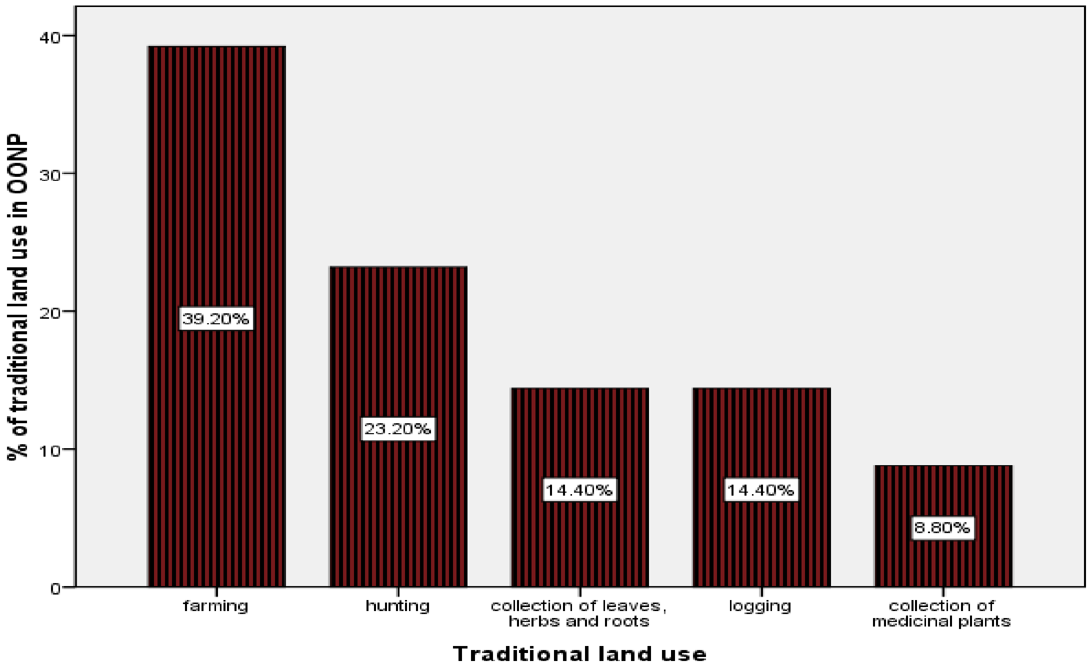

Figure 2: Traditional land use in Old Oyo National Park (OONP)

Discussion

Indigenous knowledge of protected area is vital to the success of any protected area and conservation of biodiversity in general. The culture or way of life, occupation and the various activities of the indigenous people of a conservation site determines to a great extent the sustainability and continuity of the area. Although there was no official mean of managing the protected area before the establishment of the park, it was however deduced from the study that communal efforts were used to manage and protect certain areas of interest to the local communities and this is in agreement with submission of International Union of Conservation of Nature and Natural Resources that indigenous peoples and local communities played a critical role in conserving variety of natural environment and species. The traditional land use systems practiced include: farming, hunting and collection of roots, herbs and leaves for medicinal purpose. These traditional land use systems are believed to have adverse impact on protected area; and this impact not only involve changes in forest ecosystem, species composition, genetic structures but also potential extinction of plants and animals.

Religious/spiritual/Cultural importance of the protected are to the communities

The park was of spiritual significance in only two ranges (Oyo-Ile and Marguba). Information gathered in Oyo-Ile revealed that Baara, the cemetery where past kings of Oyo Empire (Alaafins) were buried was of great cultural significance to them. People are prevented from carrying out normal activities around this area. It was believed to be sacred with ancestral spirits guarding the place. Information also revealed that one out of the communities surrounding Marguba range (sepeteri) has a river called Ibuya that they used to worship before the establishment of the park. Ibuya river was of great spiritual significance to this community as the god of the river was worshipped every year by making sacrifice to the god with different things depending on what is requested by the chief priest, but it is always within the range of ram, pigeon and local food made from cooked maize (egbo).

Old Oyo National Park as a festival ground

It was a festival ground for people of Sepeteri before, where they pay homage to the sacred groove, people do come to make their request from the god, get together and dancing were also the part of activities that usually takes place, other cultural practice include throwing baby into the river to ascertain if the baby is the true child of the family or not.

Park entry for spiritual purpose

After the establishment of Old Oyo National Park, people of that community (Sepeteri) were restricted from entering the park to perform any cultural or spiritual activities in the park.

CONCLUSION

The study on the indigenous knowledge for management of Old Oyo National Park has shown that the villages surrounding Old Oyo National Park protected the area through communal efforts before the establishment of the park. This they did through Ibuya river and other areas which were of high religious/spiritual significance to people of support zone communities Sepeteri as the river was worshipped. The area was also considered sacred hence it was forbidden to go into the forest

Although, the villagers are no longer allowed into the park for either religious/spiritual or any other purpose; their cooperation is however needed to reduce and stop farming, hunting and other activities that are inimical to conservation. The usage of the some ranges of the park as festival ground, a sacred forest, burial ground/cemetery for past kings of Old Oyo Empire serves to further prevent people from accessing thereby preventing resources therein from exploitation

RECOMMENDATIONS

The management of Old Oyo National Park should intensify community support programs to further improve the lives of the people whose their lands were taken. Conservation awareness programs should be strengthened to educate the people on the need to conserve/preserve the natural and heritage in Old Oyo National Park. This can be achieved through radio and television programs in the local language in addition to school conservation clubs already in existence. The cooperation of the support zone communities of the park is needed to achieve conservation goals; hence, it is important that the support zones be involved in park programs at every stage. Alternative means of livelihood should be provided for the people in the area since their major occupation is farming and hunting. Training of the teeming youths in the support zones on entrepreneurial skills and acquisition programmes should be embarked upon towards poverty alleviation/reduction.

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Comparison of Avifauna Composition of Artificial and Natural Water Bodies: A case study of Elemi River and Ureje Dam, Ekiti State

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Abstract

Small water bodies, either natural or artificial are considered a refuge for biodiversity survival and correct and updated information on the status of waterbird species utilizing these water bodies is vital for effective conservation programs. This study was done to assess the diversity in aquatic avifauna of Elemi River and Ureje Dam, Ekiti State. Data were subjected to detailed analysis including Simpson index, Shannon Weiner's index, Species richness index, and Species evenness index using the Computer software Programs PAST Version 3™ model (Hammer et al 2001) and Students' t-test analysis was used to compare the mean of the two sites using SPSS version 21 statistical packages The results revealed a total of 73 bird species in 35 families identified in the two study sites. Ureje dam recorded 51 bird species totalling 923 individuals in 30 families while Elemi River had 63 bird species summing up to 947 individuals from 31 families during the study period. The Simpson_1-D index of Elemi River (0.98) shows that the diversity of bird species is higher than bird species diversity in Ureje Dam (0.96). The effective number of species shows that the diversity in Elemi River (53) almost double the diversity in Ureje Dam (31) and Kolmogorov-Smirnov test shows significant difference ($p \leq 0.05$; $p = 0.037$) in bird species diversity of Elemi River and Ureje Dam. The study has established that natural and artificial wetlands do provide important habitats for avifauna and these sites should be managed with biodiversity resources conservation in mind. It is therefore recommended that the management programme for the Ureje dam should incorporate avian conservation in the area and human activities that could be detrimental to the conservation of bird should be discouraged in these wetland areas.

Key words Biodiversity, Natural, Artificial, Elemi River, Ureje dam, Aquatic.

INTRODUCTION

Wetlands and water bodies are biodiversity pools (Ghermandi, *et al*., 2010; Gray *et al*., 2013; MEA, 2015). In recent times, the continued loss of water bodies and degradation of natural wetlands as a result of the expansion of agriculture (Mitsch *and* Gosselink, 2015,) and urbanization boundaries have made them become one of the most threatened ecosystems in the world (Kingsford *et al*., 2016). However, loss of water bodies and wetlands fragmentation has led to species loss and biotic homogenization with effects on the integrity and functioning of the ecosystem (Harris, 1988; Lougheed *et al*., 2008). The modification of the aquatic vegetation and surrounding forest cover of wetlands changes the availability of nesting and feeding resources for birds and alters the key ecological processes for the functioning of ecosystems (Gibbs, 2000; MEA, 2005). Natural wetlands and many man-made wetlands have become important habitats for birds (Bellio *et al*., 2009). Several studies have compared bird diversity between natural and man-made wetlands, most of them in the United States (Desrochers, *et al*.,2008; Hapner *et al*., 2011), Asia (Bellio *et al*., 2009; Ma *et al*., 2004) and the Mediterranean (Kloskowski, *et al*., 2009; Sebastan-Gonzalez, and Green, 2016). These studies illustrate the high ecological value of man-made wetlands for birds' diversity. In Colombia, the importance of man-made wetlands including constructed lakes (Rosselli and *and* Stiles, 2012a) and rice crops (Johnston-Gonzalez, Castillo, *and* Murillo-Pacheco, 2006), has been emphasized for the reproduction of some aquatic and endangered wetland birds.

It is worthy of note that Nigeria is blessed with many species of birds distributed throughout the different ecological regions. In recent decades, many man-made wetlands of different types have been created throughout the Southwestern region in Nigeria, and human pressures on natural wetlands have grown significantly (Lasso, *et al*., 2014). However, correct and updated information on the status of waterbird species is essential for successful conservation programs yet the importance of natural and man-made (lentic) wetlands for the maintenance of bird diversity in human-dominated landscapes is not well known in this part of the country. Bird diversity has a strong relationship with the type and origin of wetlands with significant variations in species composition among different types which show high local and landscape heterogeneity. It is suggested that small lentic wetlands whether natural or artificial are important for the maintenance of local and regional bird diversity (Pacheco, 2017). Therefore, the main objective of the study is to evaluate the diversity of water birds species in natural and artificial water bodies of the Elemi River and Ureje dam in Ekiti state in other to improve our understanding of the role of artificial wetlands in the protection of biodiversity in the context of increasing pressures on water resources in the States.

METHODOLOGY

The Study Area

The study areas, Ureje River (005°18'25.8" E and 07°36’ 23.82” N) and Elemi River (005° 18.683’E and 07° 36.603’N) are located within Ado-Ekiti in Ado Ekiti Local Government Area of Ekiti State. Ado Ekiti is a city in southwest Nigeria, the state capital and headquarters of the Ekiti State. The population in 2006 was 308,621 and the people of Ado Ekiti are mainly of the Ekiti sub-ethnic group of the Yoruba (, NPC, 2006, Orimaye, 2016). Ado-Ekiti is located between latitude 7°3 and 7°49 north of the equator and longitude 5°7 and 5°7 East of the Greenwich Meridian and is bounded in the north and west by Irepodun/Ifelodun local government Areas, East and South by Gbonyin, Ikere and Ekiti South West Local Government Area. Ado-Ekiti has a plan metric area of about 884km2. Geologically, the region lies entirely within the pre-Cambrian basement complex rock group, which underlies much of Ekiti State.

Figure 1: Google map of Ureje Dam, Ado-Ekiti

Climate

The temperature of this area is almost uniform throughout the year, with very little deviation from the mean annual temperature of 27°C. February and March are the hottest 28°C and 29°C respectively, while June with a temperature of 25°C is the coolest (Adebayo, 1993). The mean annual total rainfall is 1367mm with a low co-efficient variation of about 10%. Rainfall is highly seasonal with well-marked wet and dry seasons. The wet season lasts from April to October, with a break in August (Owolabi, 2016).

Vegetation

The vegetation of Ado-Ekiti is similar to Ekiti State vegetation with two distinct types of vegetation which are predominant in the study area. The derived savannah vegetation to the northern borders and the rain forest belt covering a larger percentage of the total land area to the south.

Method of Data Collection

At the study site, the birds were recorded through direct observations during visits to each wetland. The survey was carried out using fixed transects which involves walking slowly around the wetland, stopping regularly for observations, and listening for birds' sounds. Surveys were performed between 6:00 am and 11:00 am, and from 2:00 to 6:00 pm when birds' activities were very pronounced. All the species observed and heard in the water and associated vegetation within the 200 m buffer were identified using binoculars (10 x 42 mm) and recorded. Data were collected for two days in a week for three months (October, November and December) during the dry season of 2019. Bird species were classified into three guilds based on habitat use, water adaptation, and behaviour, following Ruiz-Guerra (2012) for aquatic and semi-aquatic birds. Bird guilds are:

i. Aquatic birds (Aq), including all the strictly aquatic species that depend on or use ecosystems dominated by water bodies in part or all of their life cycle and that have anatomical and physiological adaptations to the water.
ii. Semi-aquatic birds (S-Aq) are aquatic birds without morphological adaptations to aquatic environments, but they are strongly associated with aquatic habitats such as shores and aquatic wetland vegetation.
iii. Land birds (LB), which are non-aquatic, terrestrial birds and use the non-aquatic wetland habitats, such as the arboreal and herbaceous vegetation and the air.

Data Analysis

The data were subjected to detailed analysis including Simpson index, Shannon Weiner's index, Species richness index, and Species evenness index using the Computer software Programs PAST Version 3™ **model (**Hammer *et al*., 2001**)** and Students' t-test analysis was used to compare the mean of the two sites using SPSS version 21 statistical packages

Shannon Wiener diversity index relates to the number of the different species and the number of individuals of each species within any community. Shannon Wiener index was calculated using the formula

$$\mathbf{H^1} = \sum(\boldsymbol{Pi}) \ \mathbf{ln}\,\boldsymbol{Pi}$$

Where H^1 = diversity index

P_i = the proportion of the *i*th species in the sample

$\ln Pi$ = is the natural logarithm of the species proportion

Species Richness (Menhinick's index) is a measure of the number of species found in a sampled area. The more species present in a sampled area, the "richer" the area and is calculated using the formula

$$\mathbf{D} = \sqrt[s]{\boldsymbol{N}}$$

Where 's' = the number of different species represented in the sample area,

N = the total number of individual organisms in the sample area.

Sorenson's coefficient (β) = $\frac{2c}{S1+S2}$

Where C = the number of species in the two study areas

S1 = Total number of species found in community 1

S2 = Total number of species found in community 2

Kolmogorov Smirnoff test was used to compare the mean of data between sites, Descriptive statistics such as frequency tables and percentages were used to describe results.

RESULTS

The total number of Birds' Species Identified in the Study Sites

The list of bird species identified in both study sites is presented in Table 1. A total of 73 bird species in 35 families were identified in the two study sites. Ureje dam recorded 51 bird species totaling 923 individuals in 30 families while Elemi River had 63 bird species summing up to 947 individuals from 31 families during the study period. The commonly encountered species in Ureje includes Village weaver *Ploceus cucullatus* (96), Common bulbul *Pycnonotus barbatus* (75), Lesser-striped swallow *Hirundo abyssinica* (69), African palm swift *Cypsiurus parvus* (55), Lizard Buzzard *Kaupifalco monogrammicus* (55), and Red-eyed dove *Streptopelia semitorquata* (40) while African thrush *Turdus pelios*, Black-winged oriole *Oriolus nigripennis*, Intermediate egret *Ardea intermedia*, Laughing dove *Spilopelia senegalensis*, Northern grey-headed sparrow *Passer griseus*, and Red-headed Malimbe *Malimbus rubricollis* were encountered once during the study period. Also, Village weaver *Ploceus cucullatus* (38), Little bee-ea*ter Merops pusillus (35), and* Senegal coucal *Centropus senegalensis* (28) were the most encountered species in Elemi River while African jacana *Actophilornis africanus*, Chestnut-breasted Nigrita *Nigrita bicolor*, Green-backed heron *Butorides striata,* and Squacco heron *Ardeola ralloides* were encountered once. However, Out of the 73 bird species were present in the two study sites, Ureje dam recording 63 bird species and the remaining10 species were absent. Conversely, 51 bird species were present in the Elemi River and the remaining 22 bird species were absent (Appendix 1) during the study period.

Table 1: Bird Species identified in the Study Area

SN	Common Name	*Scientific Name*	Ureje Dam	Elemi River
1	Abyssian rollers	*Coracias abbyssinicus*	10	17
2	African harrier hawk	*Polyboroides typus*	2	6
3	African jacana	*Actophilornis africanus*	12	1
4	African palm swift	*Cypsiurus parvus*	55	5
5	African paradise flycatcher	*Terpsiphone viridis*	4	9
6	African thrush	*Turdus pelios*	1	12
7	Barn swallow	*Hirundo rustica*	21	3
8	Bearded barbet	*Lybius dubius*	0	17
9	Black-headed weaver	*Ploceus melanocephalus*	0	17
10	Black-and-white manikin	*Spermestes bicolor*	0	12
11	Black-rumped waxbill	*Estrilda troglodytes*	0	7
12	Black-shouldered kite	*Elanus axillaris*	0	8
13	Black winged oriole	*Oriolus nigripennis*	1	9
14	Blue-breasted Kingfisher	*Halcyon malimbica*	19	5
15	Blue-billed Malimbe	*Malimbus nitens*	0	11
16	Blue-spotted wood dove	*Turtur afer*	10	22
17	Broad-billed roller	*Eurystomus glaucurus*	34	18
18	Chestnut-breasted Nigrita	*Nigrita bicolor*	0	1
19	Collared sunbird	*Hedydipna collaris*	5	16
20	Common bulbul	*Pycnonotus barbatus*	75	25
21	Didric cuckoo	*Chrysococcyx caprius*	9	21
22	Emerald cuckoo	*Chrysococcyx cupreus*	0	23
23	Forest chestnut-winged starling	*Onychognathus fulgidus*	6	23
24	Fork-tailed Drongo	*Dicrurus adsimilis*	0	20
25	Giant kingfisher	*Megaceryle maxima*	12	23
26	Great cormorant	*Phalacrocorax carbo*	2	4
27	Great egret	*Ardea alba*	0	16
28	Green Crombec	*Sylvietta virens*	5	0
29	Green Turaco	*Tauraco persa*	12	6
30	Green-backed heron	*Butorides striata*	18	1
31	Green-headed sunbird	*Cyanomitra verticalis*	17	8
32	Grey-backed Camaroptera	*Camaroptera brevicaudata*	13	0
33	Grey-headed nigrita	*Nigrita canicapillus*	0	5
34	Intermediate egret	*Ardea intermedia*	1	15
35	Klaas' cuckoo	*Chrysococcyx klass*	0	23
36	Laughing dove	*Spilopelia senegalensis*	1	11
37	Lesser striped swallow	*Hirundo abyssinica*	69	0
38	Little bee-eater	*Merops pusillus*	12	35
39	Little Greenbul	*Andropadus virens*	3	24
40	Little swift	*Apus affinis*	12	24
41	Lizard Buzzard	*Kaupifalco monogrammicus*	55	18
42	Long-crested eagle	*Lophaetus occipitalis*	0	15
43	Malachite kingfisher	*Alcedo cristata*	11	13
44	Northern grey-headed sparrow	*Passer griseus*	1	12
45	Sulphur -breasted bush shrike	*Chlorophoneus sulfureopectus*	0	9

46	Pied crow	*Corvus albus*	11	17
47	Pin-tailed whydah	*Vidua macroura*	13	0
48	Purple glossy starling	*Lamprotornis purpureus*	4	22
49	Red-eyed dove	*Streptopelia semitorquata*	40	25
50	Red-headed bluebill	*Spermophaga ruficapilla*	38	0
51	Red-headed Malimbe	*Malimbus rubricollis*	1	2
52	Senegal coucal	*Centropus senegalensis*	22	28
53	Senegal thick-knee	*Burhinus senegalensis*	0	20
54	Simple leaf-love	*Chlorocichla simplex*	0	17
55	Splendid sunbird	*Cynnyris coccinigastrus*	0	12
56	Spur-winged lapwing	*Vanellus spinosus*	12	8
57	Squacco heron	*Ardeola ralloides*	10	1
58	Swamp palm bulbul	*Thescelocichla leucopleura*	0	24
59	Tawny-flanked prinia	*Prinia subflava*	32	22
60	Village weaver	*Ploceus cucullatus*	96	38
61	Vinaceous dove	*Streptopelia vinacea*	0	21
62	Western grey plantain eater	*Crinifer piscator*	2	14
63	White-faced whistling duck	*Dendrocygna viduata*	22	0
64	White-headed lapwing	*Vanellus albiceps*	0	12
65	White-rumped seedeater	*Crithagra leucopygia*	0	8
66	White-throated bee-eater	*Metrops albicollis*	0	25
67	Winding Cisticola	*Cisticola marginatus*	27	0
68	Woodland kingfisher	*Halcyon senegalensis*	6	12
69	Yellow-billed kite	*Milvus aegyptius*	28	0
70	Yellow-billed shrike	*Corvinella corvina*	9	0
71	Yellow-fronted Tinkerbird	*Pogoniulus chrysoconus*	13	25
72	Yellow-throated Longclaw	*Macronyx croceus*	17	0
73	Yellow-throated Tinkerbird	*Pogoniulus subsulphureus*	12	24
Total			**923**	**947**

Table 2 shows the diversity indices of Bird Species in the Study Area. The table revealed that the Simpson_1-D index of Elemi River (0.98) shows that the diversity of bird species of this site is higher than bird species diversity in Ureje Dam (0.96). The magnitude of this diversity is revealed by the effective number of species derived from Shannon diversity indices in the study sites which shows that the diversity of bird species in Elemi River (53) is almost twice when compared to bird species diversity in Ureje Dam (31). The Kolmogorov-Smirnov test of these two sites shows that there is a significant difference ($p \leq 0.05$; $p = 0.037$) in bird species diversity between the Elemi River and Ureje Dam.

Table 2. Diversity Indices of Bird Species in the Study Area

	Ureje Dam	Elemi River
Taxa_S	51	63
Individuals	923	947
Simpson_1-D	0.96	0.98
Shannon_H	3.44 (31)	3.97 (53)

Table 3 shows the family of Bird species in the study area. A total of 35 families of bird species were recorded in the study areas. Ureje Dam recorded 31 families with an additional four (4) families exclusively present while Elemi River has 30 families with five (5) additional families in the exclusive list of the study site during the study period. The families most encountered in Ureje Dam include Alcedinidae (4), Accipitridae (3), Ardeidae (3), and Columbidae (3) while families Anatidae, Anomalospiza, Apodidae, Charadriidae, Corvidae, Estrildidae, Jacanidae, Laniidae, Meropidae, Motacillidae, Muscicapidae, Oriolidae, Passeridae, Phalacrocoracidae, Ploceidae, Turdidae, and Viduidae were encountered once during the study period. Also, Elemi River recorded Accipitridae, Alcedinidae, Ardeidae, Columbidae, Cuculidae, Estrildidae, and Pycnonotidae as having four (4) encounters while the families Anomalospiza, Burhinidae, Corvidae, Dicruridae, Fringillidae, Hirundinidae, Jacanidae, Malaconotidae, Muscicapidae, Oriolidae, Passeridae, Phalacrocoracidae, Sylviidae, and Turdidae were encountered once during the study period.

Table 3: The Family of Bird Species in the Study Area

SN	Families	Frequency	
		Ureje Dam	Elemi River
1	Accipitridae	3	4
2	Alcedinidae	4	4
3	Anatidae	1	0
4	Anomalospiza	1	1
5	Apodidae	1	2
6	Ardeidae	3	4
7	Burhinidae	0	1
8	Charadriidae	1	2
9	Cisticolidae	2	0
10	Columbidae	3	4
11	Coraciidae	2	2
12	Corvidae	1	1
13	Cuculidae	2	4
14	Dicruridae	0	1
15	Estrildidae	1	4
16	Fringillidae	0	1
17	Hirundinidae	2	1
18	Jacanidae	1	1
19	Laniidae	1	0
20	Lybiidae	2	3
21	Malaconotidae	0	1
22	Meropidae	1	2
23	Motacillidae	1	0
24	Muscicapidae	1	1
25	Musophagidae	2	2
26	Nectariniidae	2	3
27	Oriolidae	1	1
28	Passeridae	1	1
29	Phalacrocoracidae	1	1
30	Ploceidae	2	3
31	Pycnonotidae	2	4
32	Sturnidae	2	2
33	Sylviidae	2	1
34	Turdidae	1	1
35	Viduidae	1	0
	Total	51	63

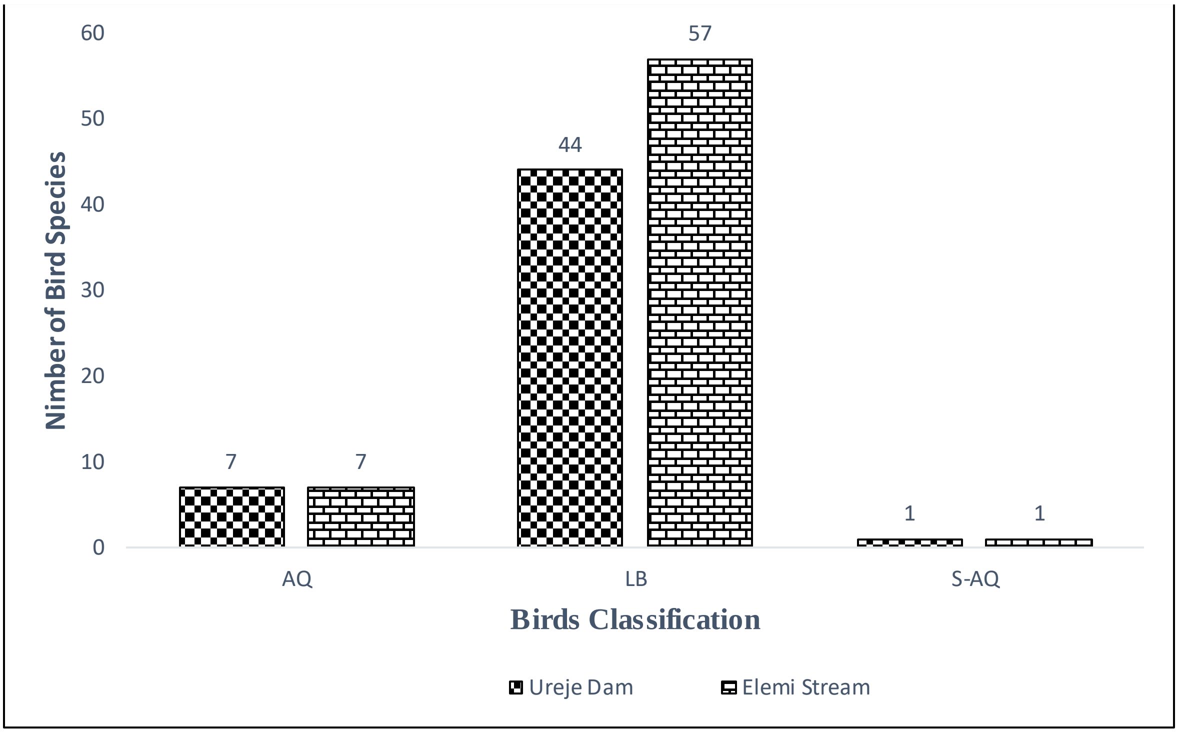
Table 4 presents the diversity indices of the family of Bird Species in the Study Area. The Simpson_1-D index of the family of bird species in Ureje Dam (0.96) shows that the diversity of bird species of this site is almost equal to the family of bird species diversity in the Elemi River with 0.955. This slightly equal diversity is revealed by the effective number of species derived from Shannon diversity indices of the family of Bird species in the study sites which shows that the diversity in Ureje Dam (28) is very close to the diversity in Elemi River (25). The Kolmogorov-Smirnov test of these two sites shows that there is no significant difference ($p \leq 0.05$; $p = 0.323$) in the diversity of the family of bird species between the Elemi River and Ureje Dam. Sorenson's coefficient of 0. 98 further shows that there are 98% similarities in the families found in the two sites within the study period.

Table 4: Diversity Indices of the Family of Bird Species in the Study Area

	Ureje Dam	Elemi River
Taxa_S	31	30
Individuals	51	63
Simpson_1-D	0.96	0.955
Shannon_H	3.326 (28)	3.238 (25)

Bird Species Utilizing the Natural and Artificial Water Bodies in the Study Areas.

Figure 2 shows the graphical representation of Bird Species Utilizing the Natural and Artificial Water Bodies in the Study Areas. The figure shows that seven (7) bird species each in Ureje Dam and Elemi River were recorded as aquatic birds that utilizing these two water bodies during the study period. Forty-four (44) and fifty-seven (57) bird species were recorded as land birds in Ureje Dam and Elemi River respectively while one (1) Semi-aquatic bird each was recorded at Ureje Dam and Elemi River during the study period.



LB = Land Birds, AQ = Aquatic Birds, S-AQ = Semi-Aquatic Birds

Figure 2: Bird Species Utilizing the Natural and Artificial Water Bodies in the Study Areas.

DISCUSSION.

Natural and artificial water bodies are of great importance in terms of the services they render to bird through the provision of breeding sites, roosting materials, cover, and food. However, the growing pressure on wetland resources due to human activities, climatic and edaphic changes has caused great threats to wetland fauna especially water birds throughout the world (Laurance, 1999). This study suggests that natural wetlands had higher waterbird diversity than artificial wetlands because 65 bird species were recorded in the Elemi River and 51 species in Ureje Dam and some of which are dependent on the wetland. This observation in agreement with the work of Hartzell *et al*., (2007) and Gucel *et al*., (2012) where they also found that the site with the highest diversity of plant and bird species was a natural wetland. A total of 73 bird species in 35 families were identified in the two wetlands which sum up to1, 870 individual bird species. This observation differs from what was recorded by Lameed, (2011) in recorded in Hadejia-Nguru Wetlands where he recorded 135 bird species of 40 families, Sulaiman *et al*., (2014) also recorded 119 bird species of 43 families in the same study area. However, Sabo (2016) also obtained the sum of 164 bird species from 50 families in a similar survey carried out in Hadejia-Nguru Wetlands in Northern Nigeria. This wide margin may be due to vegetation bloom that is prevalent in the Southwestern Nigeria which impede the visibility of foraging birds compared to sparse vegetation in the North which permit visibility of birds. The commonly encountered species, village weaver *Ploceus cucullatus* is an indication of the encroachment of the wetlands by humans because village weavers love to colonize environment close to man.

This study shows that the diversity of bird species around natural water was higher than artificial water. This observation is contrary to the results of Giosa *et al* (2018) in their study of the importance of artificial wetlands for birds in Cyprus where they reported that there is significant differences between the numbers of bird species found in artificial and natural wetlands with fewer individuals of most species found in artificial wetlands compared to natural ones. This research work further shows that more land bird were recorded in the two wetlands during the study period which might be connected to the availability of vegetation which provides food foraging materials, nesting materials and cover from predators. This observation corroborates the work of Walwert and Muhlenberg (2004) in Indonesia on the effects of land use on bird species richness where they reported that the higher number of birds in terrestrial habitats may be attributed to the availability of food and nesting materials.

Although all the bird species recorded in both the Ureje Dam and Elemi river were under the Least Concern category of IUCN Red Data List (Odewumi *et al* 2017), yet, it is highly necessary to ensure that the birds are conserved so that the local population does not decline.

CONCLUSION AND RECOMMENDATION

The preservation of our water bodies is crucial for the survival of both resident and migratory birds because these water bodies provide birds with specialized microhabitats and different kinds of food sources. This study has established that natural and artificial wetlands do provide important habitats for avifauna and these sites should be managed with biodiversity resources conservation in mind. Caliskan (2008) also mentions that the protection of natural wetlands should be maintained as a high priority because functions provided by these natural wetlands may not be replaced by artificial wetlands. Only where natural wetland loss is unavoidable artificial wetland should be considered as a replacement for these valuable ecosystems. It is therefore recommended that the management programme for the Ureje dam should incorporate avian conservation in the area. Human activities that could be detrimental to the conservation of birds should be discouraged in the area. Regular monitoring of the sites should be carried out to control changes in the state of the wetland ecosystem.

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SUB-THEME 5

Gender Perspectives on Forest Ecosystem in Nigeria

Role of Women in Sustainable Forest Management

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Abstract

Research has showed that women are critical actors in the management of forest resources. This paper aims at identifying the role of women in sustainable development. Agricultural, Forestry and rural development that is equitable, effective and sustainable cannot be pursued without an explicit recognition of the tremendous contribution of rural women to food and agricultural production. Women's role is crucial in discerning and guaranteeing food security and wellbeing for the entire household, in a global atmosphere of increasing poverty, insecurity of forest products and environmental degradation. Forest and trees play multiple roles in the landscapes and climate context, by serving as climate mitigation function in form of carbon sinks, through regulating water, sustaining agriculture and providing livelihoods and energy resources for women and men. Sustainable forest management projects aim at decreasing forest degradation and deforestation, and contribute to poverty reduction/alleviation and other socioeconomic benefits such as through fostering sustainable production practices and improved access to forest value chains and markets.

Keywords: Forestry, women, sustainable development, forest resources and management

INTRODUCTION

Sustainable development could be defined as the development that meets the needs of the present without compromising the ability future generations to meet their own needs. Reducing the gender gap in access to productive assets, inputs and services in the forestry sector can help create significant development opportunities, not just for sustainable forest management but also for the overall welfare of families, communities and national economic studies. Agarwal (2010). Sun *et al*., (2011), Coleman and Mwangi (2013) suggest that if women constitute one-quarter to one-third of the membership of local forest management institutions, there will be a dynamic change in favour of the consideration of women's use of and access to forest resources and also towards more effective community forest management decision making and management as a whole. Forests have played a great role in supporting livelihoods directly for over 1.6 billion people, including around 350 million people living in or near dense forests who use forest resources for income and subsistence (FAO, 2015). It is important to recognize the fact that women and men differ in their knowledge, preferences and use of forest resources, and that these preferences will eventually shape the priorities and concerns of the different groups within forest communities (Colfer *et al*., 2016). It is noteworthy to know that neglecting women's role in forest decision-making can jeopardize project outcomes, as women's specific livelihood needs and preferences can be overlooked (UN-REDD, 2011). Therefore, this paper focuses on the role of women in sustainable forest management.

Gender Issues Across the Project Cycle

There is need for adequate planning and the project teams need to consider the type of forest resources available, the legal framework and informal gender norms, power dynamics, economic and domestic roles and sex disaggregated demographics to develop a strategy that supports and motivate women in the different phases of sustainable forest management project.

Contribution of Women to Sustainable Forestry Development

According to the world Bank , women in forest communities derives 50% of their income from forests (World Bank *et al*., 2009).The livelihoods and employment of women living around forest areas depend on their access to forest resources, which are mainly determined by laws and socio-cultural norms. Laws and socio-cultural norms tend to prevent women from accessing resources and land, having control and ownership rights and restrict their participation in decision-making processes. Furthermore, lack of tenure rights also impacts women's access to financial resources and women's income-generating opportunities (Kiptot, 2015). It is noteworthy to recognize that, women make specific contributions to forestry and agroforestry value chains. These are important for their incomes, and in turn for the well-being and food security of their households. However, women's roles in value chains tend to be poorly supported by policy-makers and extension services. The perpetual lack of gender disaggregated data hampers the development of policy interventions to address the issue. So many women have highly specialized knowledge of trees and forests in terms of biological diversity, sustainable management and use for various purposes, and conservation practices. It is particularly important during food crises. Policies and practices empowering women and it is of great interest to know that women are aware of the food and medicinal values of forest products, and how the forest sector yield significant benefits to food security and nutrition and the sustainable management of forests. Facilitating women's participation in forest user groups, improving their access to modern sources of energy, and enhancing their access to processing techniques and markets have been found to make a major difference in the livelihoods of forest dependent people and their societies which has led to a positive change in their lives.

Forestry Policies Support on Women

It is now widely known that mainstreaming gender in policy processes can improve both developmental and environmental outcomes. Ultimately, policies and programmes that empower women in the forest sector are an essential prerequisite for building economies based on social justice and environmental conservation. Specifically, forestry policy-makers should concentrate on the following items: ensuring that women's work in forestry (both paid and unpaid) is captured in national statistics, and increasing the availability and use of sex-disaggregated data for the forest sector; improving women's safe access to fuelwood, supporting the use of healthier, more energy-efficient technologies and equipment (e.g. improved stoves), and enhancing access to alternative energy sources (e.g. solar energy, electricity); designing forestry and agroforestry programmes that recognize women as users of forests (along with men) and acknowledge women's valuable knowledge, experience, and specific needs; enhancing the understanding of gender roles along forestry value chains, supporting value chain activities performed by women, and working with existing processing and marketing groups in which women participate; aiming to achieve gender balance in forestry associations and forest user groups, and enabling women to participate fully in decision-making within these associations/groups, such as through formal education, training, and support for income generation; systematically integrating gender into policy frameworks through gender-specific needs assessments, gender audits, gender-sensitive data collection systems and budget allocations, and support to women's active participation in policy processes

IMPACT OF WOMEN IN SUSTAINABLE MANAGEMENT

Recently, some research focused on explaining why gender matters in environmental collective action and what type of differences women can make to the management of forests (Mai *et al*., 2011; Agarwal, 2000, 2010b). A higher presence of women may indeed generate different outcomes. Agarwal (2009a) analysed how the gender composition of community based groups affect forest conservation and management rules. The results revealed that groups with a higher presence of women show improvements in forest conditions. Sun *et al*. (2011) look at correlations between the gender composition of a sample on property rights and forestry management. They find that groups with a balanced presence of women and men tend to participate more in decision-making processes within the group, but do not find any effect on firewood collection. On the contrary groups where women are the majority (i.e., more than two thirds) tend to collect more firewood, though participating less in decision-making. This result may be attributable to the particular conditions under which groups with a large majority of women are formed. Also, Female involvement in the decision-making process would also help to spread awareness of the rules among village women, generating an informational flow.

Responsiveness of Women in Sustainable Development

In forest management, community participation (both men and women) around the forest is very influential. The perspective of conservation of natural resources, community participation in program management is a fundamental factor that determines the success of program implementation. Programs that involve communities in forest management provide significant results in supporting the achievement of sustainable development (De yong *et al*., 2018). Even though community participation is very influential in forest management, inequality between men and women is still found, especially their access to forests, and how they use forest resources (Manfre, 2012). Furthermore, the role of men is more dominant in productive activities and decision making, while women are more dominant in reproductive activities. Therefore, a gender responsive forest management policy is an urgent demand that both forest men and women can manage and utilize forest products fairly and equally. Basically, efforts to ensure justice and gender equality have received support both at the global and national levels. At the global level, at the UN General Assembly meeting, the Convention on the Elimination of All Discrimination Against Women (CEDAW organized by the United Nations in Beijing-China, was approved. Then at a conference Research related to forest management, the focus was still on the study of communication of participation in forest management , policy reform, environment and agriculture , evaluation of forest management policy models, women's perspectives in ecosystem services Yang *et al*., (2018), gender challenges in the forestry industry Andersson and Lidestav (2016), chaos theory on forestry policy , political deliberative in forestry policy reform, sustainable forest management and access and control between men and women in managing community forest resources.

Forest-Gender Linkages: Old Issues, New Endeavors

The fate of forests is coincidentally linked to gender issues. In rural areas, women play critical roles within forests, as users and custodians: women's knowledge and practices of forests sustain household economies and healthy ecosystems alike. Yet forestry is a male-dominated sector, with men leading the key economic and policy decisions related to forests. This paradox is further aggravated by persistent socioeconomic, cultural and legal barriers that prevent women to fully participate in, contribute to, and benefit from forest policy and management efforts. The only way ahead is, first, to acknowledge the differentiated and valuable knowledge, skills and roles of women and men in forest resources and management; and then, to integrate such gender differentiated perspectives into policy and programme responses. Such a forest-gender nexus will support the achievement of various Sustainable Development Goals (SDGs), including gender equality, climate action and life on land. As gender gaps and barriers do not rest on a multitude of issues, undertaking gender mainstreaming cannot be a one-off activity. It is rather a cross-cutting issue, with multiple entry points to pursue.

This systematic gender approach is particularly being employed in new policy and financial instruments for forest conservation, namely in REDD+, an innovative, international incentive mechanism to address deforestation. The policy process that underpins REDD+ offers a fresh ground to break down gender inequalities: here follows a synthesis of experiences and practices that the UN partnership for REDD+, the UN-REDD Programme, has undertaken or promoted within its multi-pronged approach on gender. Such endeavours foster forest-gender alliances, which help promote progress across various SDGs targets, such as ensuring women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life; Undertaking reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial services, inheritance and natural resources, in accordance with national laws; Adopting and strengthening sound policies and enforceable legislation for the promotion of gender equality and the empowerment of all women and girls at all levels; Promoting mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities); and by 2020, to promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestatio n globally).

Conclusively, a review of the literature suggests that because women are more dependent on forest resources, spend more time in the forest, and have built strong norms of cooperation, they are more likely to display behaviors, e.g., governance arrangements and technology adoption that have a positive effect on forest sustainability

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Socio-economic Importance of Biodiversity to Rural Livelihoods of People in Odeda Local Government, Ogun State, Nigeria

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Abstract

Biodiversity plays a vital role in the livelihoods of people especially in rural areas across the globe. This study was carried out to assess the economic importance of biodiversity in the welfare of rural dwellers in Odeda Local Government Area (LGAs), Ogun State. Multistage random technique with three steps design was used for this study. A structured questionnaire was used to obtain information from 120 respondents across Alabata, Agbede, Olokemeji, Olugbo, Orile Ilugun, and Odeda, with 20 respondents in each locality within Odeda Local Government area. Data collected were analyzed with descriptive and inferential statistics along with the econometric tools of the Gini index to determine income inequality, while Foster-Greer-Thorbecke Indices(1984) was used to determine the poverty line among the respondents as well as incidence, depth, and severity. The results revealed that the respondents were gender sensitive as the majority of about 55% were males and 45% females. The result of age shows that was the 50years was the highest age with a mean age of 35years. Education result shows that 35.8% of the respondents had primary education which is the dominant education level. Only 60% of the respondents had a family size of <4 with an average of 5. The poverty line was calculated at 107,050 with 5.8% respondents are beneath the poverty line, the poverty harshness and this indicates that individuals were not harshly poor because the value is <1. The major income had a Gini index of 0.001 and this indicates that the distribution income suggested among the respondents is unequal since the value is far from 1. The result shows that majority of respondent of about 29.6 % were involved in exploitation and this helps their livelihoods. Chi-square analyses explain that there is a major association between biodiversity with a rural livelihood. It is recommended that forest policy should advocate for forest protection from over-exploitation through biodiversity utilization and also strong publicity through forest extension programs should be organized.

Keyword: Socio-Economic, biodiversity, rural, livelihood, forest protection

INTRODUCTION

Biodiversity is the variety and variability of life on Earth. Biodiversity is typically a measure of variation at the genetic, species, and ecosystem level (Joanna, 2010). Biodiversity is not distributed evenly on Earth, and is richest in the tropics (Gaston and Spicer, 2014). It is a gauge of the diversity of organisms present in different ecosystem, level of variation in species, and involving ecosystems on the earth's surface as it is essential to mankind (UNEP, 2005). In a nutshell, known numbers, as well as a variety of plants, animals and other organisms that survive, are known as biodiversity with an important component of nature and it warrants the survival of human species by providing food, fuel, shelter, medicines, and other resources to mankind. (Millennium Ecosystem Assessment, 2005) The luxuries of biodiversity depend on the climatic conditions and area of a region. Biodiversity creates a systematic framework for analyzing the problem and searching for possible solutions (Miller et.al. 1995). Biodiversity serves as a form of insurance to meet the challenges of responding to new technology, biological changes such as the development of resistant varieties to pest, diseases, and pathogens, environmental stress and offer opportunities for increase productivity and nutrient contents (Imenet and Adebola, 2010). Biodiversity in all its variety of forms stabilizes the natural environment and make it possible for life to persist under varying circumstances through maintenance of essential ecological processes and life support system (NASAP, 2014). It is essential to preserve and maintain the gene reservoir of the natural heritage of biodiversity. The spatial distribution of biological diversity has likewise assembled broad interest because geographic regions can differ extremely in species richness and thus no sample better demonstrates this than the latitudinal gradient in species diversity (Hillebrand, 2004). There is also increasing evidence that biodiversity increases the stability of ecosystem functions through time. Diverse communities are more productive because they contain key species that have a large influence on productivity" (Cardinale *et al*, 2012). Population pressure, overexploitation of resources, alter the land use system, pollutions, land degradation, and genetic erosion constitute major threats to biodiversity (Ola-Adams, 1977 and 1981). Forest biological diversity is wide terms that refer to all life forms of living and non-living thing found within forested areas and the ecological roles they perform. However, forest biological diversity encompasses not just trees, but the multitude of plants, animals, and micro-organisms that inhabit forest areas and their associated genetic diversity (Braulio, 2016). Forest organic diversity can be measured at different levels, including the ecosystem, landscapes, species, populations, and genetics *(*Rabosky, 2009). Forests are much more than trees as the most biologically diverse ecosystems on land, forests are home to more than 80 percent of the terrestrial species of animals, plants, and insects. It play a vital role both in adaptation and mitigation of climate change, as well as it provides local ecosystem services relevant for adaptation as well as the global ecosystem service of carbon sequestration, relevant for mitigation (Nathaniel, 2011). It also helps guard against natural hazards such as landslides, reduce soil erosion, and provide short-term relief efforts, long-term recovery, and prevention of future disasters. It also protect water resources, helps to ensure a supply of safe clean water for the largest cities, approximately one-third of which obtain a major proportion of their drinking water directly from forested protected areas. A growing population with a high demand for natural resources will undoubtedly place undue stress on forest ecosystems and their vital ecosystem functions. It is estimated that by 2030, the world will face a 40 percent global water deficit under the business-as-usual climate scenario. Ecosystem services are crucial for human being wellbeing; it provides food, water, energy, and other benefits. Thus it is important to connect ecosystems to global development priorities (Crawley, 1997). According to CBD (2015) the United Nations General Assembly accept the 2030 Agenda for Sustainable Development, composed of 17 goals and 169 targets and goal 6 aims by 2030 to achieve universal and equitable access to safe and affordable drinking water for all and also to access sufficient and just sanitation and hygiene for all (Nigeria fifth national biodiversity report, March 2014). Therefore the socio-economic importance, characteristic of consumers, identification of basic diversity component, inequality income, and determination of poverty life with the impact of biodiversity on the welfare of the rural people was assessed.

METHODOLOGY

Study Area

Odeda Local Government is one of the twenty (20) local Government areas in the Ogun State of Nigeria. Its headquarters is at Odeda located on Abeokuta -Ibadan road about 20 kilometers from Abeokuta the State capital of Ogun state. It was created out of Egba divisional council in October 1955 by the action group controlled Western Nigeria during the tenure of Late Chief Obafemi Awolowo, the first premier minister of the region. The council area has an extensive landmass mostly grassland with an area of 1263.45sq km and a population of 109,449 according to the 2006 population census figure with an annual growth rate of ten percent and upward increase of 10,334 to that 1991 population census figure, of 99,115 people.

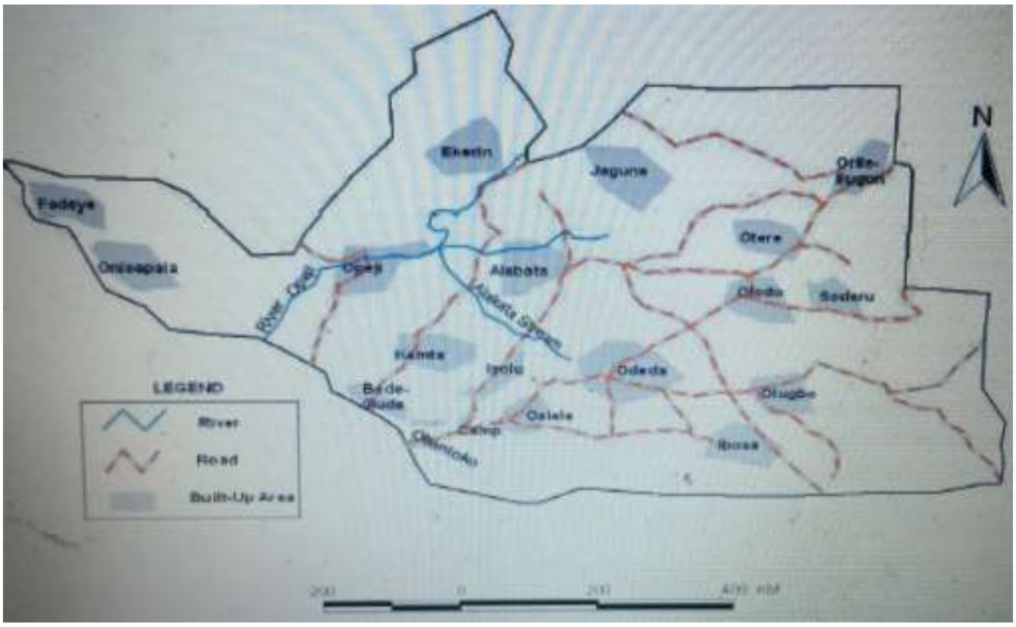

Figure 1: Map of Odeda, Ogun State

Sampling Technique and Analysis

The respondents used for this study include farmers, hunters and marketers that relied on basic biodiversity components for their livelihood. Multistage random technique with a three stage design was used in this study design. Structured questionnaire was used to collect information from 120 respondents across Alabata, Agbede, Olokemeji, Olugbo, Orile Ilugun and Odeda. 20 respondents in each location within Odeda L.G.A. The Data gathered were analysed using descriptive and inferential statistics along with econometric tool of Gini index to determine income inequality, while Foster-Greer-Thorbecke Indices (F-G-T) was used to verify poverty line, incidence, depth and severity among the respondents.

RESULTS AND DISCUSSION

Biodiversity are plants and animals that are of value to humanity. The earth's biodiversity consist of important natural resources in economic, social, cultural, aesthetic, scientific and educational. The terms provide a significant amount of monetary and non-monetary benefits to human kind (Leverington *et al*., 2010). The socio-economic of the respondents were categorized into different age. It revealed that (27.5%) of the respondents were in age class of 50 – 59 years, this might have being as a knowledge had on biodiversity components by this group than the others. 55% of the respondents were male; shows that male dominant had better understanding of biodiversity in relation to livelihoods than the female counterpart. This shows how gender equality relates with social problem as affected the access to biodiversity in rural areas. The dominance of Christianity was more pronounced than other religions. The results further shows that 84.2 % of the respondents are married, 8.3% were single and 7.5% were widowed. This information reflects how biodiversity served the people as a source of livelihood for household over the years. Primary education (35.8%) was predominant educational level among the respondents indicating low literacy level among the people and indirectly affecting conservation. All the respondents (100%) were Yoruba. In terms of years of experience, majority (50%) of the respondents had 21 -30 years of experience in biodiversity usage in their locality. Furthermore, majority of the respondent (82.5%) strongly agreed that biodiversity contributes to rural livelihood. About 57.9% strongly agreed that biodiversity protects ecosystem, 46.7% strongly agreed that biodiversity provides employment in the study area, 46.7% strongly agreed that biodiversity contributes to food security. That biodiversity reduces poverty among rural dwellers in the study area, 36.7% strongly agreed and 74.2% strongly agreed biodiversity doesn't fetch them income and is only significant in personal consumption. Majority (89.2%) accepts that biodiversity aids better output of agricultural products and 69.2% confirms that it is through soil fertility. The item of the biodiversity components includes firewood which is mostly used in households, while timber, bush meat, and mixed varieties generate income. The most pre - dominant floral types of biodiversity are *Gmelina arborea* (Teak), *Parkia biglobosa* (locust beans) and *Azardirata indica* (neems) tree. And bulks of the fauna in the study area are *Rattus fuscipes* (Bush rat) and Python regius(Royal python). The trees are mostly used for medicine, in terms of their leaves, seeds, bark, and roots.

The result of the impact of the biodiversity on livelihood shows that (73.3%) were involved in exploitation and 25.8% in processing and packaging, 14.2% marketing and 4.2% transportation. Chi square analysis explain that there is significant association between biodiversity and rural livelihood at ($p < 0.05$) and also that there is significant association between biodiversity and ecosystem protection ($p <0.05$). The marketing channel shows conformity but with a little variation because it's a natural resource products that illustrated the relationship between retailers, wholesalers, self-collectors and their various collection points. i.e. forest, farms, major market, and collection centres. Only 7 of the respondents (5.8%) fall below the poverty line. Also, the poverty gap showed that an average person living in poverty requires 49.6% of N178, 416.00 to make poverty line (₦88, 494). The poverty strictness (0.0004) indicates that the people were not sternly poor because the value is distant from 1. The Gini index of (0.001) indicates that the distribution of income among the respondents is less unequal since the value is less than 1. Consequently, the result of this study shows that biodiversity contributes positively to the livelihood of rural communities.

Table 1: Respondents Socio economic characteristics

Variables	Frequency	Percentage	Mean/Mode
Age (Years)			
< 20	31	25.8	
20 – 29	20	16.7	
30 – 39	19	15.8	35yrs
40 – 49	15	12.5	
50 – 59	33	27.5	
>60	2	1.7	
Total	120	100	

Sex			
Male	66	55	Male
Female	54	45	
Total	120	100	
Marital status			
Married	101	84.2	Married
Single	10	8.3	
Widow	9	7.5	
Total	120	100	
Religion			
Christianity	57	47.5	Christianity
Islam	40	33.3	
Traditional	23	19.2	
Total	120	100	
Level of Education			
No formal	33	27.5	
Adult literacy	15	12.5	
Primary	43	35.8	Primary
Secondary	24	20	
Others	5	4.2	
Total	120	100	
Ethnic group			
Yoruba	120	100	Yoruba
Years of experience			
5 – 10years	9	7.5	
11 – 20 years	24	20	20yrs
21 – 30 years	60	50	
31 - 40 years	11	9.2	
>40 years	16	13.3	
Total	120	100	
How did you get into the job			
Inheritance	97	80.8	Inheritance
Training	23	19.2	
Total	120	100	
House hold size			
<4	72	60	
5-7	36	30	5
8-9	12	10	
Total	120	100	
Major Occupation			
Farming	70	58.3	
Fishing	5	4..2	
Herdsman	4	3.3	
Hunting	14	11.7	Farming
Marketing	10	8.3	
Trader	17	14.2	
Total	120	100	
Minor Occupation			
------	64	53.3	_______
Garri production	31	25.8	
Trader	11	9.2	
Herbalist	9	7.5	
Transporter	5	4.2	
Total	120	100	

Annual income (#)			
<100000	2	1.7	
100000 - 130000	11	9.2	
130100 - 160000	40	33.3	
160100 – 190000	27	22.5	₦ 178,416
190100 - 220000	18	15	
>220000	22	18.3	
Total	120	100	
Number of months worked in a year			
10	105	87.5	
11	10	8.3	11 months
12	5	4.2	
Total	120	100	
Number of days worked in a week			
5	38	31.7	
6	60	50	6 days
7	22	18.3	
Total	120	100	

Source: Field Survey, 2016

Biodiversity and rural livelihood

	O	**E**	**O - E**	**$(O - E)^2$**	**$(O - E)^2$ / E**
Strongly agreed	99	60	39	1521	25.35
Agreed	**21**	**60**	**–39**	**1521**	**25.35**
					Chi-square 50.70

Degree of freedom =(r-1) (c-1)

Chi-square cal = 50.70
Chi-square obs/tab/stat ($p < 0.05$) = 3.841
Source: Field survey, 2016

Biodiversity and livelihood activities

Activities	**Number of respondents**	**Frequency %**
Exploitation	*88	29.6
Processing	*50	16.8
Packaging	*51	17.2
Transportation	48	16.2
Marketing	*60	20.2
Total	297	

NB : * Multiple response

Scientific name	Family	Common name	Local name	Type	1 2 3 4 5 6	Parts used
Tectona grandis	Verbanaceae	Teak	Teeki	Plant	X X X X	stem, leaves
Milicia excelsa	Moraceae	African teak	Iroko	Plant	X X X X	bark, stem
Triplochiton scleroxylon	Malvaceae	Obeche	Arere	Plant	X X	leaves, stem
Khaya senegalensis	Meliaceae	African mahogany	Oganwo	Plant	X X X X	leaves, bark
Azadirachta indica	Meliaceeae	Neem tree	Dongoyaro	Plant	X X X	leaves, bark
Elaeis guineensis	Palmae	Oil palm	Ope	Plant	X X X X	fruits, leaves
Gmelina arborea	Verbanaceae	Gmelina	Melina	Plant	X X X X	leaves, stem
Parkia biglobosa	Leguminosae	African locust bean	Irugba	Plant	X X	seed, stem
Vitellaria paradoxa	Sapotaceae	Shea butter tree	Oori	Plant	X X X	stem, fruits
Thryonomys swinderianus	Thryonomidae	Grass cutter	Oya	Animal	X X X X	whole animal
Eudorcas thomsonii	Bovidae	Antelope	Eran igbe	Animal	X X X	whole animal
Rattus fuscipes	Muridae	Okete	Bush rat	Animal	X X X X X	whole animal
Alligator mississipiensis	Alligatoridae	Alligator	Ahonrihon	Animal	X X X	whole animal
Pyton regius	Pyhonidae	Royal python	Ojola	Animal	X X X	whole animal
Oryctalogus cuniculus	Leporidae	Rabbit	Ehoro	Animal	X X X X X	animal
Potamocheorus larvatus	Suidae	Bush pig	Elede igbo	Animal	X X X	whole animal

Perception of respondents on biodiversity and their livelihoods in the study area

Perception statements on use of biodiversity to improve livelihood	Strongly Agreed	Agreed	Undecided	Disagreed	Strongly disagreed	Mean	Inferences
Biodiversity contributes to rural livelihood	99(82.5)	21(17.5)	-	-	-	4.61	Strongly agreed
Biodiversity protects ecosystem:	71(59.2)	42(35)	7(5.8)	-	-	4.39	Agreed
Biodiversity provides employment	56(46.7)	57(47.5)	7(5.8)	-	-	4.30	Agreed
Biodiversity contributes to food security in this area:	56(46.7)	57(47.5)	7(5.8)	-	-	4.30	Agreed
Biodiversity reduces poverty among rural dwellers:	44(36.7)	29(24.2)	42(35)	5(4.2)	-	3.84	Agreed
Biodiversity contributes to health and promotes tradition:	89(74.2)	21(17.5)	10(8.3)	-	-	4.50	Strongly agreed
Biodiversity preserves the cultural and aesthetic value in the area:	63(52.5)	40(33.3)	12(10)	5(4.2)	-	4.40	Agreed
Biodiversity helps in climate adaptation:	68(56.7)	47(39.2)	5(4.2)	-	-	4.38	Agreed
Biodiversity generates income for rural dwellers in this area:	56(46.7)	37(30.8)	27(22.5)	-	-	4.13	Agreed
Biodiversity serves as a tourist attraction:	70(58.3)	45(37.5)	5(4.2)	-	-	4.39	Agreed

CONCLUSION

Rural areas are known for the maximum composition of biodiversity components. This study reveals information on the socio-economic importance of biodiversity, both flora, and fauna in Odeda local government area. Biodiversity components are well known in the area and all the 120 respondents have either direct or indirect access and benefit personally from biodiversity. Biodiversity serves as a source of livelihood for people and ecosystem protection in the study area while also serving as a source of income. Some of the goods and services benefit in the study area are for consumption, construction, recreation, medicinal value, etc. Thus, Biodiversity contributes to rural livelihood, protects the ecosystem and provides employment to some, while it also contributes to food security, health, prevents erosion and also used in spiritual purposes. Biodiversity also preserves the cultural aesthetic value in the area, helps in climate adaptation, serves as a tourist attraction, aids better output of agricultural products, improves soil fertility, contributes to soil conservation and helps in water amelioration. Majority of the respondents in the study area sell the products themselves through appropriate channels to make ends meet.

RECOMMENDATION

Based on the findings of this study, it is recommended that:

- Awareness and education on the consequences of over-exploitation biodiversity through forestry extension services.
- Forest policy should ensure enforcement conservation laws to reduce overexploitation of biodiversity.
- Forest policy should enforce conservation practices among the rural populace to ensure the sustainability of biodiversity.

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SUB-THEME 6

Forest Ecosystem Services for Mankind in Nigeria

Phytochemical Screening of *Tetracarpidium conophorum* (African Walnut) Seeds

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Abstract

Tetracarpidium conophorum (African Walnut) seeds were analyzed for proximate analysis, phytochemical screening and mineral composition. Five grams of dried seeds were used for the analysis. The result of the proximate analysis of fresh Tetracarpidium conophorum seeds showed that the fresh seeds have low crude fat content (5.10%) and moderate quantities of carbohydrate (29.61%) and crude protein (18.32%). The seeds also contain crude fibre (9.02%), crude ash (4.11%), and moisture content (33.83%). The result of the phytochemical (qualitative) screening of the fresh Tetracarpidium conophorum showed that the seeds contain high concentrations of alkaloids, oxalate, and phytate, while tannin, phenol and saponin were present in moderate quantity. There were no tra ces of flavonoids, steroids, phlobotannins and glycosides. The result of the mineral composition of fresh Tetracapidium conophorum seeds showed that the fresh seeds have Sodium contents of (145.00mg/kg), Potassium (182300.00 mg/kg), Calcium (912.00 mg/kg), Iron (283.67 mg/kg), Zinc (67.33 mg/kg), Manganese (67.33 mg/kg) and Phosphorus (1111.00 mg/kg). Data from this study showed that Tetracarpidium conophorum seeds contain some bioactive compounds and have good nutritional composition. They could be useful in Pharmaceutical formulations and as food.

Keywords: African walnut, food nutrient, phytochemical screening, proximate analysis.

INTRODUCTION

Plants have been a great source of nutrients to human and animals. Humans in general have relied mostly on plants for nutritional and medicinal needs (Babalola, 2011). The plant is known in Africa especially in the Eastern and Western parts of Nigeria for its antibacterial efficacy (Okerulu and Ani, 2001). The use of plants by people for treatment of diseases and ailments has being in practice for a long time such as toothache, syphilis, dysentery, and as an antidote to snake bite (Odugbemi and Akinsulire, 2008). Nutritional discoveries of the 1990s showed that frequent eating of nuts greatly lower the risk of heart diseases (Anderson and Gobielle, 2001). There are two types of walnuts. The temperate walnut, known as Juglansregia L and the tropical African walnut, known as *Tetracarpidium conophorum*. The characteristic furrowed kernels are the cotyledons of the seeds with no endosperms. Their kernels are eaten raw; and the young fruits are a rich source of ascorbic acid. The leaves are astringent, tonic and antihelmintic, and they yield an essential oil (Pandey, 2007). However, *T. conophorum* is a tropical, woody, perennial, climbing plant with open branches. It twines around any support, especially trees in its vicinity (Janick and Paul, 2008). It is an alley farmed crop, grown alongside cocoa and kola nut and uses these trees as support for its growth. The economic importance of the species lies in the edibility of its oil-rich endospermous seed, which is consumed by diverse populations in Nigeria, Sierra Leone and the Lower Congo region. It grows along the African Coastline and is thought to originate in South-Western Nigeria (Janick and Paul, 2008). It is usually cultivated by subsistence farmers in the hot and humid zones of tropical Africa in compound gardens and backyards, just for the family and local market consumption. Tropical walnut belongs to the Euphorbiaceae Family (spurge) and locally in Nigeria, it has various names such as Asala or Awusa

(Yoruba), it is known in the Southern Nigeria as "ukpa" (Igbo) and Western Nigeria as "awusa" or "asala" (Yoruba),"gawudi bairi" (Hausa). This plant is cultivated principally for the nuts which are usually cooked and consumed as snacks (Enujiugha, 2003) and the plant is a climbing shrub of about 10-20 ft long. Walnuts are shown to decrease endothelial dysfunction associated with high fat diets (Anderson and Gobielle, 2001) and several researchers has reported several importance of the plant such as it increases fat oxidation and reduces carbohydrate oxidation without affecting total consumption, improving the use of body lipids in overweight adults. *T. conophorum* is also useful in treating rheumatism, gout, cold, kidney pain, heavy menstrual bleeding, as a blood cleanser and to expel worms (Ekhuosuehi, 2008). This study examined the chemical composition and nutritive values of T. *conophorum*.

MATERIALS AND METHODS

Sample Collection and Preparation

The seeds used for this study were extracted from the air dried pods of the *T. conophorum* plant, the seeds used were collected from a farmland at Owo in Owo Local Government Area of Ondo State, Nigeria. The de-hulled seeds sample was dried and ground to a fine powder using a milling machine, 2g of the powdered sample was defatted with 100ml of diethyl ether using a soxhlet apparatus for 2 hours.

Proximate Analysis

This was carried out according to the method of AOAC (1990). This following proximate analysis was carried out. Moisture content was determined by drying to constant weight at 60-80^{0}C in an oven, ash content by ignition at 550^{0}C in a muffle furnace for 4hr, oil content by soxhlet extraction with hexane as solvent, protein by the kjeldahl method, and crude fibre by the acid and alkaline digestive methods. The carbohydrate content was estimated by difference, subtracting the sum of water, protein, fat, crude fibre and ash percentages from one hundred.

Phytochemical Analysis: The following phytochemicals analysis was carried out;

Alkaloids Determination

Five grams of the sample was weighed into 250 ml beaker and 200 ml of 20 % acetic acid in ethanol was added and covered to stand for 4 hours. This was filtered and the extract was concentrated to one quarter of the original volume. Then concentrated ammonium hydroxide was added drop wise to the extract to precipitate the alkaloid. This was done until the precipitation was complete. The whole solution was allowed to settle and the precipitate was collected by filtration, dried and re-weighed. The percentage alkaloid was calculated as the difference in weight (Harbone1973) and (Obadomi and Ochuko, 2001)

$$\frac{W2 - W1}{W} \times 100$$

W=weight of the sample

W1= weight of empty filter paper

W2= weight of sample + empty filter paper

Saponin Determination

Twenty grams of ground sample was dispersed in 200 ml of 20 % ethanol; the suspension was heated on a water bath for 4 hours with continuous stirring at about 55^{o}C. The mixture was filtered and residue re-extracted with another 200 ml of 20 % ethanol. The combined extracts were reduced to 40 ml over water bath at about 90^{o}C. The concentrate was transferred into a 250ml separating funnel and 20 ml of diethyl ether was added and shaken vigorously. The aqueous layer was recovered while the ethanol layer was discarded. The purification process was repeated. 60 ml of n-butanol was added. The combined n-butanol extracts were washed twice with 10 ml of 5 % aqueous sodium chloride. The remaining solution was heated in a water bath. After evaporation the sample was oven-dried to a constant weight. The saponins content was calculated in percentage as difference in weight (Okwu, and Josiah, 2006).

Tannins Determination

Five hundred milligram of sample was weighed into 100 ml plastic bottle. 50 ml of distilled water was added and shaken for 1 hour in a mechanical shaker. This was filtered into a 50 ml volumetric flask and made up to mark. Then 5 ml of the filtrate was pipetted out into a tube and mixed with 3 ml of 0.1 M $FeCl_3$in 0.1N HCl and 0.008 M potassium ferricyanide added. The absorbance was measured in a spectrophotometer at 120 nm wavelength within 10minutes. A blank sample was prepared and the colour also developed and read at the same wavelength. A standard was prepared using tannin acid to get 100 ppm and measured (Van-Burden and Josiah, 1981).

Total Phenols

The extraction of the phenolic content: The fat free sample was boiled with 50 ml of ether in 15 min. 5 ml of the extract was pipetted into a 50 ml volumetric flask. Then 10ml of distilled water added. 2 ml of ammonium hydroxide solution and 5 ml of amyl alcohol were also added. The mixture was made up to mark and left to react for 30 min for colour development. The absorbance of the solution was read using a spectrophotometer at 505 nm wavelength (Obadomi and Ochuko, 2001).

Mineral analysis

The AOAC method was used for the determination of minerals in the seeds sample of *T. conophorum*. Calcium, sodium, potassium were determined by flame photometric method while iron, zinc, manganese were determined by atomic absorption spectrophotometric method.

Data Analysis

All the data collected statistical analysis was performed using statistical package for social science package (SPSS 16.0). All experiments were determined in triplicates and mean ± SD were calculated from triplicate determination.

RESULTS AND DISCUSSION

The result of proximate analysis of the fresh *Tetracarpidium conophorum* seeds shows that the seeds have moderate quantities of carbohydrate (29.61%) and crude protein (18.3%), and low crude fat (5.10%) content as shown in table 1 below. The seeds also contain crude fiber (9.02%), crude ash (4.11%), and moisture (33.83%) respectively. Therefore, *Tetracarpidium conophorum* seeds could play a role, considering its crude protein (18.3%) and carbohydrate (29.61%) contents. The low crude fat content (5.10%) of the fresh seed suggests its exploitation as an oil seed. In this regard, it has been used for the generation of dry oil (Akpuaka *et al*., 2000; Tchiegang, 2001).

Table 1. The Result of proximate analysis of fresh *Tetracapidium conophorum* seeds.

Proximate	Value (%)
Moisture Content	33.83±0.04
Ash	4.11±0.01
Crude Protein	18.3±0.01
Crude Fat	5.10±0.01
Carbohydrate	29.61±0.02
Crude Fibre	9.02±0.01

The result of the phytochemical (qualitative) screening of the fresh *Tetracarpidium conophorum* seeds shows that the seeds contain high concentrations of alkaloids, phytate and oxalate, and also contain moderate quantity of tannins, phenol and saponin. This is in agreement with the woks of Nwaoguikpe *et al*., (2012) and Ojobor *et al*., (2015) which reported the presence of alkaloids and tannins in the phytochemical analysis of raw *Tetracarpidium conophorum* seed samples. Phytochemicals are biologically active compounds, found in trace amounts, which are not established nutrients, but which nevertheless contribute significantly to protection against degenerative diseases as reported by (Dreosti, 2000). Alkaloids have been associated with medicinal uses for centuries, and one of their common biological properties is their cytotoxicity (Han *et al*., 2015). Several workers have reported the analgesic, antispasmodic and antibacterial properties of alkaloids (Cushnie *et al*., 2014). This is why the seed is believed to stop asthma and is prescribed to be taken between bouts of asthma, but not for acute asthma. It is also used for the elderly as a constipation cure (Okwu, 2001). Alkaloids have been implicated for its detoxifying and antihypertensive properties (Matsuura *et al*., 2014; Porto et al. 2014). The presence of tannins in the fresh seeds of *Tetracarpidium conophorum* supports its anti -inflammatory properties and its use for healing haemorrhoids, frost bite and varicose ulcers in herbal medicine (Lorenzi *et al*., 2002). The presence of tannins suggest the ability of this plant to play a role as antidiarrhoeic and antihaemorrhagic agent. Parekh and Chanda, (2007), Senchina *et al*. (2014) and Han *et al*., (2015) reported that tannins are known to react with proteins to provide the typical tanning effect which is important for the treatment of inflamed or ulcerated tissues. Tannins bind to proline –rich protein and interfere with protein synthesis. Herbs that have tannins as their main components are astringent in nature and are used for treating intestinal disorders such as diarrhea and dysentery (Dharmananda, 2003).

The result also shows no traces of steroids. Steroids have been reported to have antibacterial properties (Raquel, 2007), and they are very important compounds especially due to their relationship with compounds such as sex hormones (Okwu, 2001). Ajaiyeoba and Fadare, (2006) reported that the nut has been shown to cure male infertility problems.

Some plant steroids are also useful for their effects when consumed by human beings, because their presence decreases the amount of cholesterol in the blood stream. (Wisegeek, 2013). In all, the result of phytochemical screening obtained (Table 2 above) suggests that the identified phytochemical compounds present in the fresh *Tetracarpidium conophorum* seeds could be the bioactive compounds that confer medicinal qualities to the seeds. These observations support the use of *Tetracarpidium conophorum* seeds in herbal cure remedies or traditional medicines.

Table 2. Phytochemical composition (qualitative) fresh *Tetracarpidium conophorum* seeds

Phytochemicals	Bioassay
Saponin	+
Phenol	+
Tannin	+
Oxalate	++
Phytate	++
Alkanoids	++
Flavonoids	-
Steroids	-
Phlobatannin	-
Glycosides	-

Key: + = Present in moderate amount. ++ = Present in high amount. - = No trace/ not detected.

Table 3. Result of phytochemical analysis of *Tetracapidium conophorum* seeds.

Phytochemicals	Values
Saponin (%)	0.24±0.01
Phenol (mg/100g)	0.43±0.01
Tannin (mg/100g)	0.83±0.01
Oxalate (mg/g)	1.38±0.01
Phytate (mg/g)	3.07±0.01
Alkaloids (%)	4.10±0.01

The result of the mineral analysis of *Tetracarpidium conophorum* showed that it contains calcium (912.00mg/kg), potassium (182300.00mg/kg), sodium (145.00mg/kg), iron (283.67mg/kg), zinc (67.33mg/kg), manganese (19.50mg/kg), and phosphorus (1111.00), which are very useful in the body. This is in conformance with previous reports (Ayoola *et al*., 2011), who reported that *Tetracarpidium conophorum* seed contain rich sources of mineral elements. The sodium and potassium content of *Tetracarpidium conophorum* seed is an added advantage, because of the direct relationship of sodium (Na). This may be the reason why the plant is used to prevent and control high blood pressure (James, 2000). The manganese content shows that the plant can be used to protect bone disease (James, 2000). Manganese is necessary for the functioning of the pituitary gland, the pineal gland and the brain, it promotes hepatorenal function, combats anemia and is also essential for growth (Chang *et al*., 2009). Manganese is used in the management of diabetes (Edem *et al*., 2009). The copper content is important for cellular defense and protection of the mucous membrane, is anti-anaemic and is essential for the formation of hemoglobin from iron. The presence of copper maybe responsible for the absorption of iron, it is therefore often seen with iron naturally (Chang *et al*., 2009). The presence of zinc suggests that the seed may have some effect on the nerve function and male sterility. This supports the works of (Ajaiyeoba and Fadare, 2006) that the use of *Tetracarpidium conophorum* seeds cures male infertility problems. Zinc is important for normal sexual development, especially for the development of testis and ovaries. It is also essential for reproduction. Zinc stimulates the activity of vitamins, formation of red and white corpuscles, healthy functioning of the heart and normal growth (Lichten *et al*., 2009).

Table 4: Result of minerals analysis of fresh of *Tetracapidium conophorum* seeds.

Minerals	Values (Mg/Kg)
Sodium (Na)	145.00±1.00
Potassium (K)	182300.00±1.00
Calcium (Ca)	912.00±1.00
Iron (Fe)	283.67±0.58
Zinc (Zn)	67.33±0.58
Manganese (Mn)	19.50±0.50
Phosphorus (P)	1111.00±0.07

CONCLUSION

This study has shown the phytochemical (qualitative), proximate and mineral compositions of fresh *Tetracarpidium conophorum* seeds. It revealed that the fresh seeds contain high concentrations of alkaloids, oxalate, and phytate, and also contain moderate quantities of tannins, phenol, and saponin. These bioactive compounds could be responsible for the reported medicinal properties of *Tetracarpidium conophorum* seeds. The study has also shown that the fresh *Tetracarpidium conophorum* seeds contain moderate quantities of crude protein and carbohydrate, and a low crude fat content. Thus, the seed is a source of cheap dietary protein and calories. Therefore, this study reveals that the fresh *Tetracarpidium conophorum* seeds contain some bioactive compounds and have good nutritional value. They could be useful in pharmaceutical formulations and as food. Its low crude fat content suggests exploitation as an oil seed. Further studies should be carried out to isolate, characterize and elucidate the structures of the bioactive compounds contained in the fresh *Tetracarpidium conophorum* seeds, to elucidate their mechanism of action and use in pharmaceutical formulations.

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Contribution of *Adansonia digitata* (Boabab) to the Socio-Economic Development of Community in Wurno, Sokoto, Nigeria

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Abstract

Boabab tree as an available indigenous resource has been underutilized in Nigeria for several years ago, even though, many parts of it been fresh or dried leaves, branches, seeds and fruits provide revenue and generate income to many local women especially in drought and famine season. Most of the diverse local communities in Wurno are not aware of its benefits and value attached to the socioeconomic development as a result of unsustainable and poor harvesting method as well as serious negligence of the important tree species. The main objectives of the study was to determine various contribution of boabab tree to the community, part used and management strategies on conservation. The information generated would be justifiable in bringing out the appropriate part of baoabab tree consuming in the study area. Study was carried out to generate information on the community consumption of boabab tree in the study area. It covered two selected village areas of Wurno local government (Dinawa and Chacho).Semi structure questionnaire was purposively administered to 50 respondents in the study area and normal descriptive statistics were used to describe the result with the aids of frequency and percentage tables, bar and pie charts. The results indicated that the leaves has the highest number of utilization, followed by fruits, seeds and bark in the range of 46%, 26%, 14% and 14%, respectively. They were used it to generate income, provision of foods, nutrition and medicine (34%, 26%, 26% and 14%, respectively). They were however, sold its products to earn money less than ₦365 (US$ 1/per day). Majority of the respondents believed that, it contributed financially, socially and politically by spending their cash income to buying foods for themselves, clothing, shelter and payment of school fees. Despite the inability of government on conservation projects, they were found to protect their important tree by individual owner and Public (96% and 4%), and the results revealed that, respondents within the study area harvested their boabab tree by pruning, thinning, clear cut and by main felling (50%, 34%, 12% and 4%, respectively). Consequently, the conservation management by the respondents were to allow for natural regeneration, planting, replanting and none (56%, 10% 8% and 26%, respectively).Study suggested that, Government should encourage artificial regeneration by giving free seeds and seedlings to farmers, provision of public enlightenment on simple silvicultural principles, provision of funds for research education on Adansonia digitata tree in order to promote species uses and expansion through bio-engineering science.

Keywords: Boabab(*Adansonia digitata*) tree, value, socioeconomic development, utilization, management, conservation.

INTRODUCTION

Food and Agricultural Organization FAO estimates about 805 million people around the world are chronically undernourished (FAO, 2014) and 162 million children under five years of age are stunted, particularly in poor families living in rural areas (UNICEF, 2014). Out of the 21 high-burden countries with child stunting rates of 40 %, as many as 15 are located in sub-Saharan Africa (UNICEF 2013). Poverty and food insecurity are well defined, and use of NTFPs by local people has continued to play important roles in food and nutritional supplement (Muok *et al*., 2000).Non-Timber Forest Products (NTFPs) include any products other than timber derived from forest or trees and plants such as bark, fruits, gums and leaves (Schumann, et al., 2012).*Adansonia digitata* is one of the most important NTFPs providing species with significant ecological and socio-economic significance. It is among the nine global species of baobab in the genus *Adansonia* from the family Malvaceae and subfamily Bombacaceae (Venter and Witkowski, 2010) that are remarkably understood as a tree of the world (Pakenham, 2002;and Bynum, 2014).It is an important multipurpose food tree of arid and semi-arid areas in sub-Saharan Africa, which provides a variety of foodstuffs (Kabore *et al*., 2011) to local communities, fibers for weaving and rope-making, seed oil (Kamatou *et al*., 2011), natural medicine, materials for dishes and water storage, shelter and a gathering point for humans and their livestock (Gebauer and Ebert, 2002).

Despite the ecological and socio-economic importance of the baobab, there has been concern about the occurrence of the plant in many landscapes (Dhillion and Gustad, 2004). In particular, there is a paucity of information on the current status, part used, management strategies and contributions of baobab to local livelihoods in many parts of Africa including Nigeria. Within the Nigerian humid savanna region, a number of threats including human pressure, fire, uncontrolled livestock grazing and wild animals have continuously threatened the prevalence and sustainability of the tree's contributions to local communities' livelihoods. In view of the foregoing, this study focused on the uses, management strategies and part used of African baobab in a sahel savanna community of Dinawa and Chacho village areas of Wurno Local Government, Sokoto. The objectives of the study were to document the part used and management of the baobab, as well as to assess its contribution to the socioeconomic development in the study area. This is expected to generate knowledge that will contribute to enhancement of conservation and economic potentials of the plant in the area.

RESEARCH METHODOLOGY

Study Area

The study was conducted in two village areas (Dinawa and Chacho) in Wurno Local Government Area of Sokoto State, North-West of Nigeria. It is geographically located on latitude N 13˚ 17′ 03" and longitude E 005˚ 25′ 39'' and altitude of 350mm above the sea level. The mean annual rainfall in the area is 600 mm (NIMET, 2019). The rainy season normally commences from May and ends in September, followed by a dry season from October to April. The village is set within the Sahel savanna vegetation zone characterized by scattered trees and woodland savannas. The people in the community are of Hausa Fulani descendants with a population of 219,200 (NPC, 2016). The primary occupation of the people was agriculture, with commonly cultivated crops made up of millet, sorghum and okra in scattered stand on farmlands. African baobab (*Adansonia digitata*) is naturally scattered and planted around the house and on farmlands.

Data Collection and Analysis

The targeted population for the study was marketers and farmers/cultivators. Questionnaire surveys were carried out on purposive sample with the aid of traditional assistant leader to identify the target population (marketers and cultivators). A total of fifty (50) respondents were interviewed using the interview schedule (IS) approach. Nineteen males (19) and thirty one (31) females were sampled during the course of the study and a structured open ended questionnaire was used to assess the contribution of boabab (*Adansonia digitata*) tree to the socioeconomic development of community, most suitable part used and management practices adopted to ensure sustainable utilization of ecosystems.

The data collected were analyzed and interpreted using descriptive statistics such as frequency, percentages tables, bar and pie chart.

RESULTS AND DISCUSSION

Table 1 showed that, people within the average age participated more in boabab tree product utilization having the highest number of female with small scale business. Fifty percent of the communities were secondary school drop-out with a few numbers of them that attended tertiary education.

CONTRIBUTION OF BOABAB TREE DEVELOPMENT

Majority of the community within the study area sold their boabab tree products and earn nothing more than ₦365 per day (Fig. 1.0). They were living in less than US$ 1 per day. The study revealed that, commercial utilization of this important tree could not compete to generate anything more than ₦ 5000 per day. Similar analysis was reported by (Wynberg *et al*.,2012) conducted by Overseas Development Institute (ODI, 2006) projected that, the European market for baobab products could initially generate more than US$750 million annually for producer countries in Southern Africa per year, making it the highest earner of all traded NTFPs in the region.

Table 1: Socio-economic characteristic of the respondents (n=50)

Parameters	Category	Frequency	Percentage
Age	18-25years	11	22
	26-32	12	24
	33-39	16	32
	40 and above	11	22
	Total	**50**	**100**
Gender	Male	19	38
	Female	31	62
	Total	**50**	**100**
Level of education	Primary	9	18
	Secondary	13	26
	Tertiary	3	6
	Never attend	25	50
	Total	**50**	**100**
Occupation	Farmer	35	70
	Trader	15	30
	Civil servant	-	-
	Total	**50**	**100**

Source: Field survey, 2019

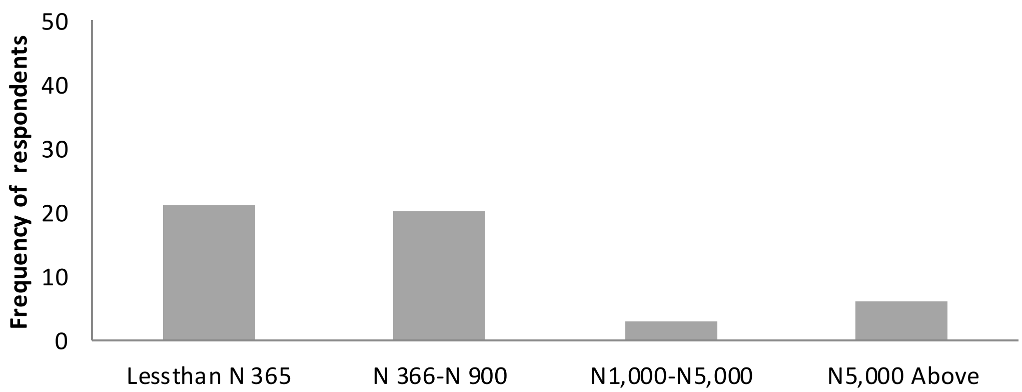

Figure 1.0: frequency of the respondents to cash earn per/day from selling boabab

Henceforth, many of the respondents in the study area revealed that, they used money generated from boabab product sold to buy foods for themselves, clothing, Shelter and schools, which indicated the potentiality of this trees and its contribution to socioeconomic development. They further stated that, it contributed economically and socially to the wellbeing of their community (Table 2).The result indicated consistency and evidently reported by (Schumann *et al*., 2010). It was reported that, baobabs have the potential to provide additional income to farmers, especially women, and it is one of the tree species with most valuable food by quantity in markets

Table 2: Contribution of Boabab tree products from sales (n=50)

Parameters	Category	Frequency	Percentage
Cash used for	Buying foods	30	60
	Buying Cloth	11	22
	Shelter	2	4
	Schools	7	14
	Total	**50**	**100**
Contribution of Boabab	Economically	40	80
	Socially	7	14
	Politically	3	6
	Total	**50**	**100**

Source: Field survey, 2019

Utilization of Parts of Baobab Tree

The leaves, Fruits, tree bark and pulp seeds were widely utilized in the study area; where leaves being the most part of the tree were used for either, medication, nutrition and others. Leaves were reported for preparation of locally made soup called "Miyar Kuka" to which every household made with other additive and take as food (Fig 2.0). Secondly fruits and its pulp seeds were processed, packed and sold as powder for nutrition.

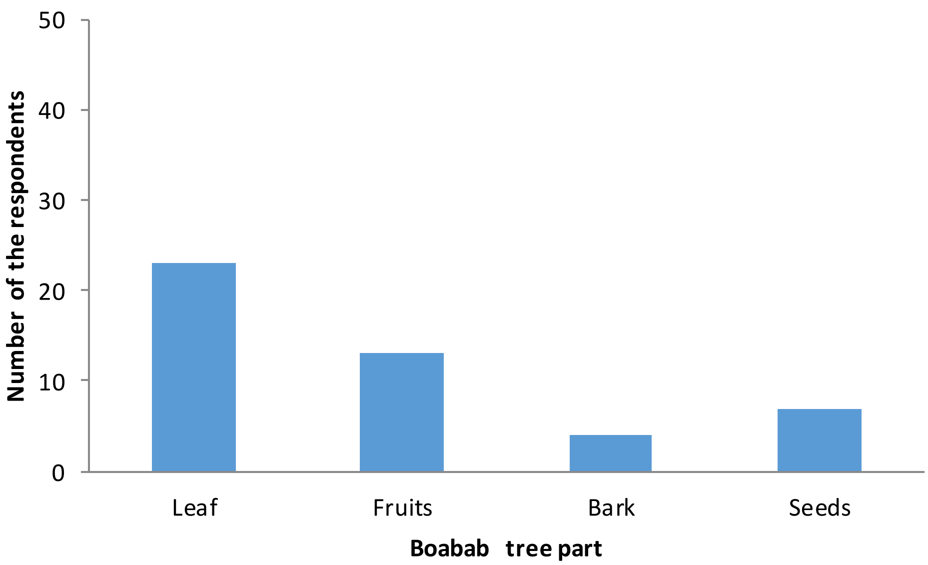

Figure 2: Percentage number of boabab tree parts used by the respondents

Leaves of boabab tree have a significant number of mineral contents such as Mn, Ba, Ca, Cu, Mg, Ma, Mb, P, K, and S (Rabi'u, T., 2010). Several research findings showed that a dried baobab leaves contains 13-15% protein, 60-70% carbohydrate, 4-10% fats, around 11% fiber, and 16 % ash. The energy value varies from 1180-1900kj/100g of which 80% is metabolisable energy (Gebauer *et al*., 2002). However, the study analyzed the various uses of boabab tree in the community, where the majority of the respondents believed that, the boabab tree were widely used as a source of income followed by food, nutrition and to a fewer extent used this important tree for medicine in the study area (Figure 3.0). Sidibe and Williams (2002) pointed out that the baobab products are normally sold in local, informal markets with the main products being leaves and fruits. The fruit is processed *in situ* and sold to local companies which are the intermediaries that make oil from the seeds and package the fruit pulp. Cosmetic and food ingredients industries are the target markets where the processed baobab products are sold (Venter and Witkowski, 2010).This is supported by Wynberg *et al*. (2012) who found that the residents of Nyanyadzi and Gudyanga sell the baobab fruits in the urban areas or sell the extracted pulp via export or to national confectioneries.

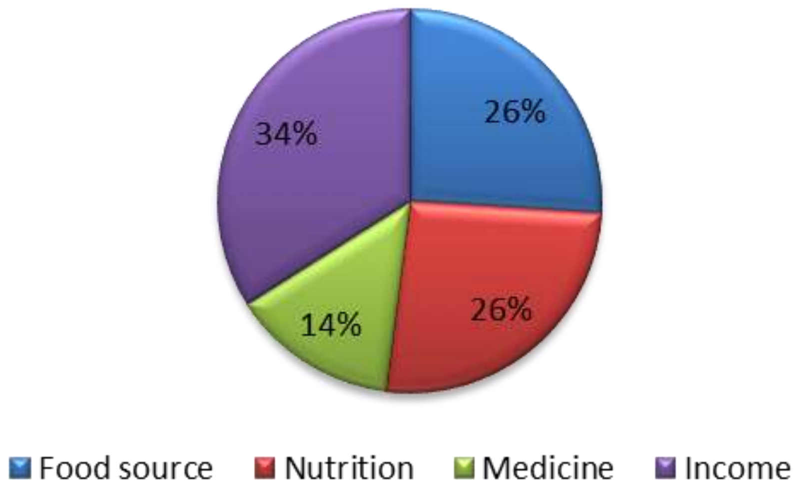

Figure 3.0: Percentage of boabab tree uses in the study area

Boabab Tree Management

Table 3 showed the boabab protection, access of harvesting and harvesting time, harvesting method and conservation strategies. Results revealed the protection of boabab tree by individual owner, public and government as 96%, 4% and 0%, respectively. This indicated that, no any effort had ever been made by government in the study area to protect their culturally important tree. Individual owner protects his farm within which boabab tree are located, only few trees being common in protection. Study further revealed that, majority of the respondents allowed for harvesting and only a few were restricted (92% and 8%). This showed that, there was no formal restriction to cultivation on whatsoever, despite the biodiversity losses as a result of unsustainable utilization. Communities harvested their farm products seasonally, quarterly and everyday (46%, 42% and 12%, respectively) when leaves and fruits are matured during dry season and practiced pruning method (50%) of harvesting which is the easiest and socially method in harvesting while other within the study area used thinning method, clear-cut and by main felling (34%, 12% and 4%, respectively). The leaves were sun dried and grinded with pestle and mortar to pack and sell to the respective customers. Majority of the respondents responded that, there was no formal management and conservation effort made on planting, replanting and nursery operation. They however, allowed for natural regeneration (50%) which means that no silvicultural activities were practiced in the study area.

Table 3: Management and conservation strategy on Boabab tree (n=50)

Parameters	Category	Frequency	Percentage
Protection	Government	-	-
	Public	2	4
	Owner	48	96
	Total	**50**	**100**
Access for harvesting	Yes	46	92
	No	4	8
	Total	**50**	**100**
Harvesting time	Every day	6	12
	Quarterly	21	42
	Seasonally	23	46
	Total	**50**	**100**
Harvesting method	Pruning	25	50
	Thinning	17	34
	Clear cut	6	12
	Main felling	2	4
	Total	**50**	**100**
Conservation strategy	Planting	5	10
	Natural regeneration	28	56
	Replanting	4	8
	Non	13	26
	Total	**50**	**100**

Source: Field survey, 2019

CONCLUSION

The wellbeing of community within the study area was not fully satisfied with Millennium Development Goal (MDGs) since they are living in marginalized environment of less than US$ 1 per day and sustainable management was also not fully explored despite the fact that, baobab could have a high potential for enhancing nutrition, security and income generation of rural communities in Nigeria. It is recommended that artificial regeneration should be encouraged by giving farmers free seeds and seedlings. The community should be educated on the other uses of baobab as found in other places to increase the potentials of the plant. The people should also be enlightened on simple silvicultural activities that could be carried out in the management of the plant.

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Impact of Degradation of Mangrove Forest to Human Well-Being in the Ondo Coastal Zone, Nigeria.

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Abstract

Mangrove ecosystems have been exploited and marginalized over the years with little or no knowledge of the residents and relevant stakeholders on the extant of the effect of this degradation to human well-being. Mangroves are vulnerable ecosystems that provide numerous benefits to people both locally and globally. These benefits include but not limited to Water, Food, Fibre, Recreation Opportunities, Climate regulation, Disturbance regulation, Waste treatment, and Erosion prevention. Attempts are yet to be made to quantify in monetary terms the impact of degradation of the mangroves in the Ondo State coast, Nigeria. This paper seeks to assess the spatio-temporal extent of the mangrove ecosystem from 1984 to 2019, identify the services the mangrove ecosystem provides to human well-being with the aid of historical satellite imageries and conduct an economic valuation of the mangrove ecosystem services. The study area was delineated as a GIS polygon which was overlaid on a spatially disaggregated ecosystem dataset combined with historical Landsat imageries for years 1984 and 2019. The use of supervised maximum likelihood classifier was undertaken with ArcGIS 10.5 to determine changes in the mangrove ecosystem measured in hectares. The simple benefit transfer technique with the aid of The Economics of Ecosystems and Biodiversity dataset was used to value the swamp ecosystem monetarily using the simple benefit transfer method and the inflation rate calculator to express the value in 2019 International Dollar rate. Results show that about 13.87% of the mangrove ecosystem of the Ondo coastal zone has been degraded from 1984 to 2019 resulting in a loss of $24,065,681,072 (₦8,663,645,185,920) per year in benefits. Conservation approaches among scientists and institutions to the planning process were recommended to ensure cooperation and coordination in mangrove ecosystem management.

Keywords: Mangrove ecosystem, ecosystem services, ecosystem services valuation, human well-being

INTRODUCTION

The mangrove ecosystem is a marginal ecosystem inhabiting the estuarine and intertidal regions or the interface between land and sea (Vannucci 2000; Das, Samantaray, & Thatoi, 2014). Mangroves are an important source of livelihood for people living around the mangrove forest (Kerry, Das, & Patra, 2017). Ecosystem services are the benefits that people, society and the economy receive from nature (Millennium Ecosystem Assessment (MA), 2005). Modifying ecosystems to facilitate socioeconomic development is necessary but how can we avoid damaging important ecosystem services? As a prerequisite, the need to understand how ecosystem services contribute to people's livelihoods and wellbeing, who benefits and who loses from changes arising from development interventions, is essential (McCartney, Finlayson, de Silva, Amerasinghe, & Smakhtin, 2015). Ecosystem services are the relative contribution of natural capital to human well-being but they do not flow directly– it is only through interaction with the social, built and human capital that natural capital can provide benefit (Costanza, *et al*., 2014).

The uniqueness of the mangrove ecosystems is its protection against erosion; mangrove forests can decay into peat deposits because of fungal and bacterial processes as well as by the action of termites (Popoola, Olajide, & Ajayi, 2018). Despite the vital ecosystem services they provide, mangroves are threatened worldwide. In many parts of the world they are rapidly being converted to salt evaporation ponds, aquaculture, housing developments, roads, ports, hotels, golf courses, and farms. The mangroves that survive conversion are often threatened by oil spills, chemical pollution, sediment overload, and disruption of their sensitive water and salinity balance (Warne, 2001). Mangrove forests are threatened because they are public-good, non-market nature of many of the ecosystem goods and services they provide (Brander, Florax, & Vermaat, 2006). Nevertheless, almost all economic activities in the Ondo State coastal community are resource-based activities which are greatly dependent on natural environment. Thus, it is fair that the environment should be conserved to maintain the livelihoods of the local community. One of the ways towards achieving and management of wetlands is putting the right value for the wetlands (Jamilah, Nik Fuad, & Ibrahim, 2005).

The extensive and over-exploitation of the mangrove ecosystem is slowly taking the shape of an irreversible change which might cost mankind a great deal in the future (Kerry, Das, & Patra, 2017). Major drivers of loss and degradation have been (and continue to be) increasing urbanisation infrastructure development, port construction, industrial developments and aquaculture (Russi, *et al*., 2013). Ignoring the ecosystem services provided by the natural infrastructures of the mangroves and degrading them by constructing man-made ones can often cause major impacts on the welfare and livelihoods of local communities (Russi, *et al*., 2013). By overlooking the connections between ecosystem services and society's overall reliance upon their supply, many decision-makers threaten the sustainability and overall success of their development decisions (Pagiola, von Ritter, & Bishop, 2004). There is a need to conduct ecosystem service assessment before any development is carried out just like the Environmental Impact Assessment (EIA) to ensure that development is not exchanged for poverty and bad human wellbeing in the bid to solve economic concerns (Popoola, Olajide, & Ajayi, 2018).

However, since the mangrove ecosystem is complex and uncertain, there is a need for the ecosystem to be utilized in a more efficient and equitable way to ensure that the services provided by the mangroves generate the greatest net benefit to stakeholders (Jamilah, Nik Fuad, & Ibrahim, 2005). A more ecosystem-conservative future requires a different approach to the way decisions are made about the use of nature's resources, one where the benefits and services provided by ecosystems are understood, evaluated and appropriately represented within the decision-making arena (Hancock, 2010). A reconnaissance survey of the study area shows the depletion of the mangrove ecosystem in striking ways. Therefore, this paper examines the extent of the depletion of the mangrove ecosystem and the services it contributes to the welfare of the people with the purpose of quantifying the loss incurred through the depletion of these services in monetary terms. The key to efficient utilization of the ecosystem is achieving a balance between the exploitation of natural resources for socio-economic development, and conserving ecosystem services that are critical to everyone’s wellbeing and livelihood (Falkenmark, *et al*., 2007).

MATERIALS AND METHODS

Study Area

Ilaje is a Local Government Area in the South Senatorial District of Ondo State, Nigeria (Figure 1). The Ilajes are a distinct phonological group of Yoruba people that live in the coastal ecosystem and spread out along the beaches and swampy terrains of the Atlantic Ocean coast. Ilaje is located between latitude 4◦30´E and 5◦00´E and longitude 5◦45´N and 6◦15´N (Figure 2). It occupies an area of 1,318 sq.km and a population of 290,615 as at the 2006 census. Projections cannot be made for its current population as there is the possibility of de-population caused by the riverine nature of the area. The main occupation of the residents of Ilaje is fishing, due to its prime location close to the sea. Other activities they involve in include canoe making, lumbering, net making, mat making, farming and trading. Apart from several natural resources found in the land amongst which are petroleum, glass sand, bitumen, agricultural products such as palm oil, timber, raffia, banana are also grown there. Ilaje is located 75km away from Lagos and its dynamic aquatic environment makes it suitable for tourism and research. Its location also makes it a prime spot to attract traders from Nigeria and other West African and Central African countries such as Benin, Togo, Ghana, Cameroon and Gabon.

Ilaje has been home for many generations and those who migrate from the area settle in areas where there are rivers. This highlights that the water body is an essential means of livelihood for the Ilajes and should be preserved in an efficient manner. Recent development activities have been ongoing in Ilaje and there is a need to incorporate an ecosystem-based framework in the spatial planning process in order to ensure sustainability of Ilaje.

Figure 1: Map of Nigeria showing Ondo State
Source: Adapted from ESRI Data, 2019

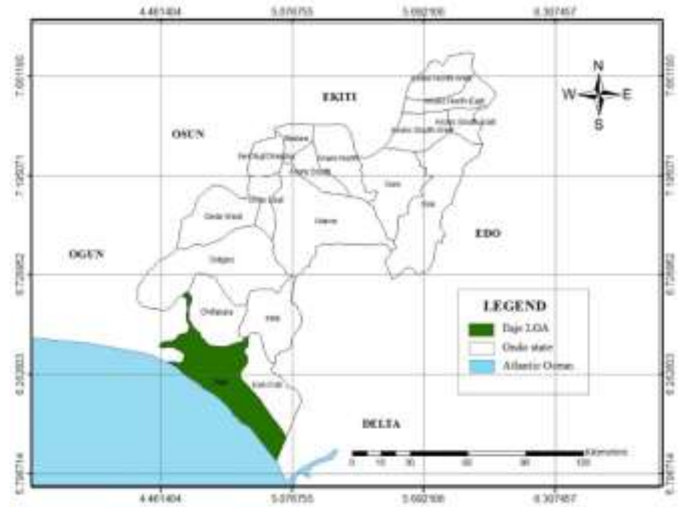

Figure 2: Map of Ondo State showing Ilaje
Source: Adapted from ESRI Data, 2019

Data Collection

A case study research design was adopted for this study as it allows for an in-depth approach to assessing the impact of the degradation of the mangrove ecosystem and its services to human well-being in the Ondo coastal zone. This involves establishing the baseline information on mangrove ecosystem in Ilaje as well as determining the extent of the progressive changes in the ecosystem and its services over a period of time. Additionally, it assesses the monetary value of the mangrove ecosystem and the services illustrating the effect of these changes in the ecosystem to human well-being. Geospatial techniques, valuation dataset, and questionnaires were employed for the impact assessment.

In this study, secondary data was obtained through historical satellite imagery – Landsat imageries was obtained from the United States Geological Survey (USGS) and a high quality spatially disaggregated ecosystem dataset was used. Valuation dataset from The Economic Ecosystem and Biodiversity (TEEB) was used for the economic qu antification of the ecosystem and its services. The research population for this study are the several ecosystems in Ilaje identified from the Landsat imagery which include Open Ocean, Swamp Forest, Mangrove Forest, Evergreen Rainforest, Littoral Rainforest, Woodland and Grassland. The sample size is the mangrove ecosystem in the study area.

Research Procedure

The study started by using delineating the study area – Ilaje Local Government Area using an imagery collected from Google Earth. Geographic Information Systems and Remote Sensing (GIS &RS) techniques were used to determine the extent of change in the mangrove ecosystem in the study area for the base year 1984 and the cardinal years 1999 through 2019. This was digitized using a polygon feature class using ArcGIS 10.5, and then overlaid on the spatially disaggregated ecosystem dataset and on the historical Landsat datasets for years 1984, 1999, 2009, and 2019.

The Millennium Assessment (2003) has identified four major categories of ecosystem services that directly influence human well-being: provisioning, regulating, cultural and supporting services. The economic value of the mangrove ecosystem and its services through the study years are estimated by utilizing the simple benefit transfer valuation technique. This was applied with the help of The Economics of Ecosystems and Biodiversity (TEEB) database that made available the worth of environmental resources and ecosystems monetarily expressed in US Dollars 2007 and estimated to US Dollars 2019 using the inflation rate calculator. The value of the mangrove ecosystem is estimated first for the base year 1984, then 1999, 2009 and 2019. Subsequently, the value of the mangrove ecosystem and the services lost through the year was estimated.

RESULTS AND DISCUSSION

Using a base year of 1984, the Ilaje mangrove ecosystem covers a total land area of 101477 ha of the 145420 ha land area. The mangrove ecosystem is the largest ecosystem inhabiting Ilaje occupying 69.78% of the total land area. In 1999, the mangrove ecosystem occupied a land area of 97576.6 ha which is 67.1% of the land area (or which is down by 2.68%). By 2009, the mangrove ecosystem had decreased to a land area of 92409 ha which was 63.68% of the total land area while by 2019, the mangrove ecosystem had reduced to a land area of 81313 ha which was 55.91% of the total land area. In total, the mangrove ecosystem had decreased by 13.87% from the initial land area in 1984.

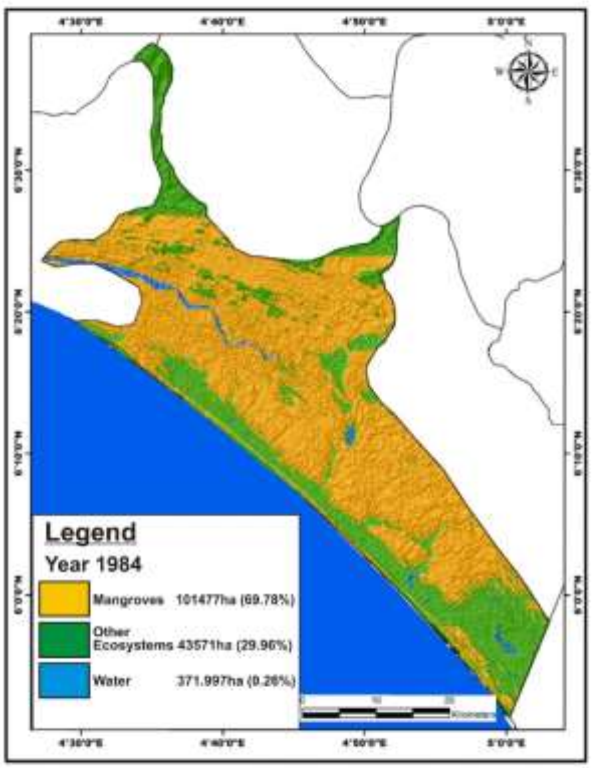

Figure 3: Spatio-temporal Extent of the Mangrove ecosystem in Ilaje in 1984
Source: USGS Landsat Imagery 1984

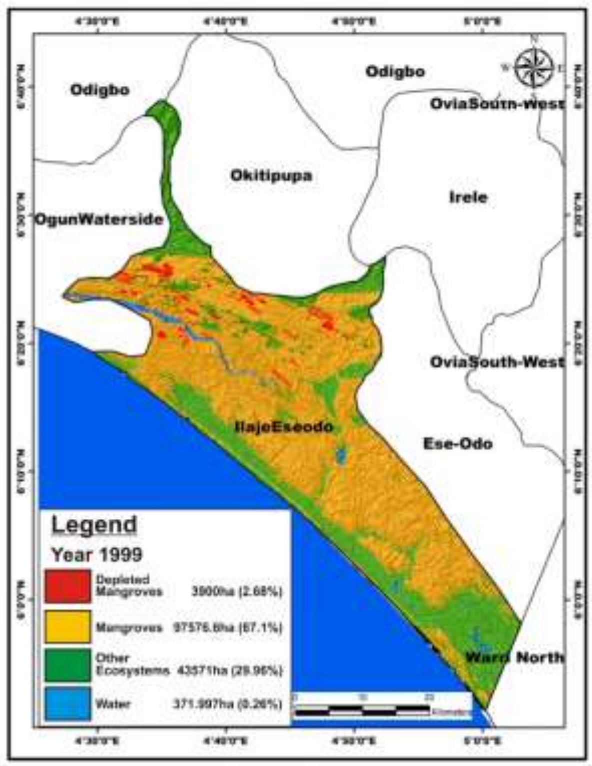

Figure 4: Spatio-temporal Extent of the Mangrove ecosystem in Ilaje in 1999
Source: USGS Landsat Imagery 1999

Therefore, a 13.87% loss in mangrove by 2019 implies that there could be a 13.87% loss in the 13 benefits the mangrove ecosystem contributes to human well-being. The implication of this loss includes a reduction in the ecosystem's capacity to contribute in food provision, access to portable water, plants that serve medicinal purposes, and waste treatment. An increase in erosion points to the fact that mangroves are depleting because mangroves prevent erosion by forming a barrier that slows the movement of water and traps sediments and affects land and other construction on it. This depletion also affects climate regulation through a reduction in capacity to trap carbon and exchange carbon dioxide to methane in the atmosphere. The ability to provide a nursery for young plants and animals is not unaffected. The number of recreation activities that take place in the study area has also experienced a nosedive as the water are getting polluted from oil spills and buildings are located close to the coastline such that tourism in the area is non-existent in a structured form.

Benefits Derived from the Mangrove Ecosystem

From the research conducted, 14.6% of the respondents said they enjoyed fish and other aquatic animals from the mangrove ecosystem, 58.2% of the respondents used purposely the mangrove ecosystem for fish and other aquatic animals, fuel in the form of firewood and water for domestic as well as industrial uses. 2.3% of the respondents said that they derived multiple benefits in the form of provisioning services and cultural services in form of protected areas and sacred forest while 4.4% of the respondents said that they enjoyed fish and other aquatic animals, water, herbs and natural medicines, and timber in form of bamboo which is used for construction purposes. 20.5% exploited the mangrove ecosystem for other benefits such as recreation (swimming and boat riding), a sense of ownership as they now have a place to call home irrespective of their economic standing and the migration of other people from different walks of life to the area.

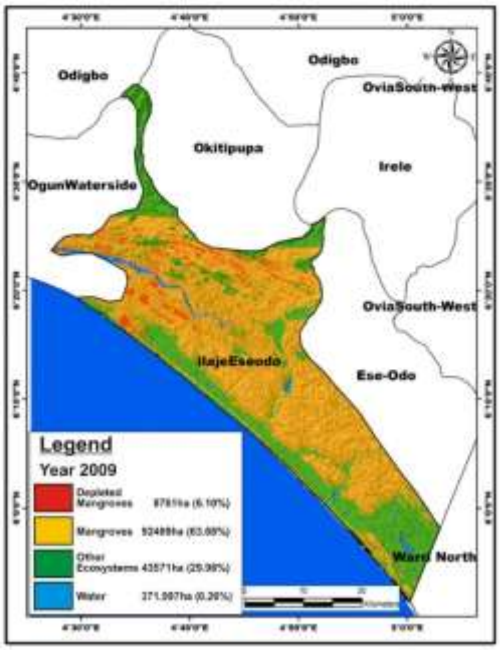

Figure 5: Spatio-temporal Extent of the Mangrove ecosystem in Ilaje in 1999
Source: USGS Landsat Imagery 1999

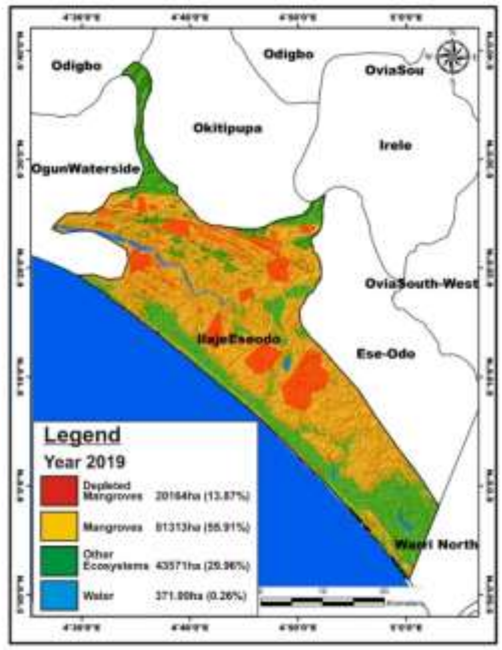

Figure 6: Spatio-temporal Extent of the Mangrove ecosystem in Ilaje in 2019
Source: USGS Landsat Imagery 2019

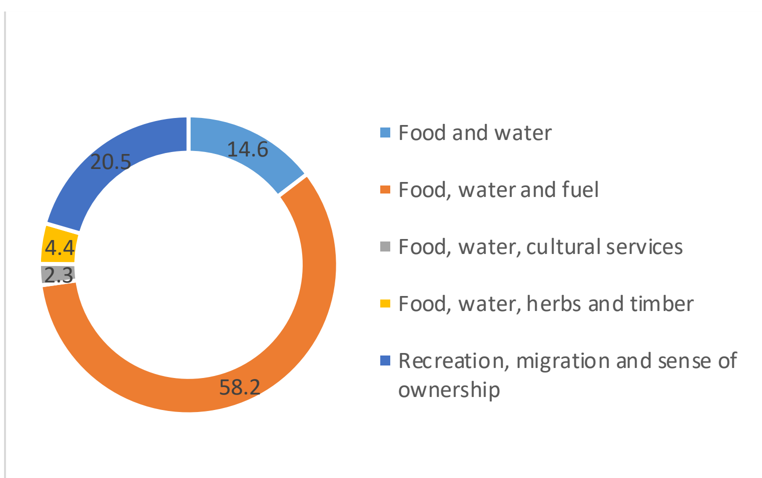

Figure 7: Benefits derived from the mangrove ecosystem by the residents of the study area
Source: Author's field work, 2019

The attendant decrease in the mangrove ecosystem in the study area over the study years can be attributed to a number of factors. From this result, there was an increase in demand for food, water, raw materials, genetic resources, medicinal resources, climate regulation, disturbance regulation, waste treatment, erosion prevention, nutrient cycling, nursery service, genetic diversity and recreation which the mangrove ecosystem provides. This increase in demand was a result of increase in migrating population to the coastal area in order to provide for their basic needs and welfare. While this led to an increase in the standard of living, this was short lived as more people migrated and the demand on the ecosystem services rose higher than the capacity of the ecosystem to supply the services. The influx of population came with construction activities that led to land use change, overfishing and other activities that were detrimental to the state of the ecosystem and contributed to its degradation rather than conservation and management.

Value of the Mangrove Ecosystem and Its Services

The ecosystem services mangroves provide include food, water, raw materials, genetic resources, medicinal resources, climate regulation, disturbance regulation, waste treatment, erosion prevention, nutrient cycling, nursery service, genetic diversity and recreation. These ecosystem services are essential for human well-being.

Table 1: Mangrove ecosystem services and the monetary value as at 1984

Ecosystem services		Value[1] (Int. $/ha/year)	Value[2] (Int. $/ha/year)	Ecosystem land area (ha)	Total Flow Value ($/year)	Percentage
Provisioning services		2998	3668	101,477	372,202,823	1.55
1.	Food	1111	1359	101,477	137,931,066	0.57
2.	Water	1217	1489	101,477	151,091,006	0.63
3.	Raw materials	358	438	101,477	44,445,834	0.18
4.	Genetic resources	10	12	101,477	1,241,504	0.01
5.	Medicinal resources	301	368	101,477	37,369,263	0.16
Regulating services		171,515	209,837	101,477	21,293,651,507	88.48
6.	Climate regulation	65	80	101,477	8,069,774	0.03
7.	Disturbance regulation	5351	6547	101,477	664,328,655	2.76
8.	Waste treatment	162,125	198,349	101,477	20,127,879,489	83.64
9.	Erosion prevention	3929	4807	101,477	487,786,822	2.03
10.	Nutrient cycling	45	55	101,477	5,586,767	0.02
Habitat services		17,138	20,967	101,477	2,127,689,121	8.84
11.	Nursery service	10,648	13,027	101,477	1,321,953,189	5.49
12.	Genetic diversity	6490	7940	101,477	805,735,931	3.35
Cultural services		2193	2683	101,477	272,261,772	1.13
13.	Recreation	2193	2683	101,477	272,261,772	1.13
Total		193,845	237,154		24,065,681,072	100.0

1: The monetary value of the ecosystem services was based on the 2007 price levels (de Groot, et al., 2012)
2: The monetary value of the ecosystem services using the inflation calculator to estimate the 2019 price level
Source: Author's field work, 2019

In the study area, the total flow value of the mangrove ecosystem in its pristine state is estimated to be 24billion US Dollars per year which equates to 8.7 trillion Naira per year at the rate of 1USD = ₦360. According to MA (2003), human well-being is considered to have multiple constituents which include basic materials for good life, security, health, freedom and choice and good social relations. Basic material for good life refers to the ability to access resources to earn income and gain a livelihood. It relates to provisioning services and regulating services (benefits obtained from the regulation of ecosystem processes). In its pristine state, the economic value of the mangrove ecosystem services that contribute to the basic material for good life is $21.7 billion. This accounts for 90.03% of the ecosystem services.

Security refers to the ability to live in an environmentally clean and safe shelter and the reduction in vulnerability due to ecological shocks and stress. Provisioning services, regulating services and cultural services are linked to this constituent of human well-being. The economic value of this constituent of human well-being is $21.9 billion accounting for 91.16% of the ecosystem services. Health refers to the ability to be adequately nourished, free from avoidable disease, have adequate clean drinking water, clean air and energy to keep warm or cool. This accounts 90.03% of the ecosystem services and have an economic value of $21.7 billion in the Ondo State mangrove zone.

Likewise, good social relations refer to opportunity to express aesthetic and recreational values associated with ecosystems, to express cultural and spiritual values associated with ecosystems and to observe, study and learn about ecosystems. Linked to good social relations are cultural services, regulating services, habitat services and provisioning services. Therefore, this accounts for the total ecosystem services mangroves provide and have a total value of $24 billion. Finally, freedom and choice refer to opportunity to achieve what an individual values doing and being. This opportunity of habitat services refers to supporting services that are necessary for the production of all other ecosystem services. From the analysis carried out, by 1999, the mangrove ecosystem had depleted by 3900 ha, this implies that a 2.68% depletion in the mangrove ecosystem and could mean the loss of $925 million (₦333 billion) in food, climate regulation, waste treatment, provision of raw materials and water which are necessary for human well-being.

Table 2: Monetary value of mangrove ecosystem depleted over the study years

Ecosystem		**Total Ecosystem**	**Ecosystem Depleted in 1999**	**Ecosystem Depleted in 2009**	**Ecosystem Depleted in 2019**
Mangrove	Area (ha)	101477	3900	8761	20,164
	Percentage (%)		2.68	6.10	13.87
	Value ($/year) at $237,154/ha/year)		924,900,600	2,077,706,194	4,781,973,256

Source: Author's field work, 2019

In 2009, the mangroves depleted by 8761ha which is 6.10% loss in the ecosystem. This invariably implies a loss of $2.1 billion (₦748 billion) in regulating, habitat, cultural and provisioning services. Furthermore, by 2019, the mangroves had depleted by 20,164ha which is $4.8 billion (₦1.7 trillion). The effect of this steady depletion of the mangrove ecosystem shows that in the 36 years of the study, 13.87% of the mangrove ecosystem had depleted resulting in the loss of valuable ecosysetm services required for good life, security, health, freedom and choice and good social relations. The impact of this loss, like its degradation is steady, evolves beyond the local scale to national and global scale of impact.

CONCLUSION

Mangrove ecosystem is a very rich and diverse ecosystem that provides numerous functions to human well-being ranging from security, basic material for good life and health to good social relations. Unfortunately, this vital ecosystem in the Ondo coastal zone has faced vulnerabilities and loss over the decades with each decade signaling a worse turn for the ecosystem. Although, the residents of the area as well as the world in general benefits directly and indirectly from the benefits the mangrove ecosystem provides, a structure for the conservation and effective management of this vulnerable ecosystem has not been put in place. Over the 36 years period that was studied, $4.8 billion has been lost to the depletion of the mangrove ecosystem. This depletion of the mangrove ecosystem and its services has led to the loss of some of the vital services they provide such as Nursery service, Erosion prevention, Waste treatment, Climate regulation, Medicinal resources and Food necessary for human well-being and environmental sustainability. Currently, the management measures put in place are weak and incapable of conserving and sustainably managing the mangrove ecosystem. Therefore, there is a need for conservation measures such as the ecosystem-based management framework and the concept of wise use of wetlands to influence spatial planning decision making in the use and management of mangroves in the Ondo coastal zone.

RECOMMENDATION

The following recommendations were suggested: Establishment of mangrove seedling protection in the study area by the community so that the plants can be transported to other vulnerable mangrove areas after reasonable growth. Preparation of a legislation for mangrove-protected areas by passing a Mangrove Park and Reserve Act. Identification of ecologically sensitive areas for the conservation and management approach. Adoption of multi-disciplinary approach among scientists and institutions to the planning process to ensure cooperation and coordination in mangrove ecosystem management.

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Urban Forests and Pollution Mitigation: An Insight into Urban Forest Ecosystem Services in Nigeria

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Abstract

This paper aims at reviewing the ecosystem services of urban forests in Nigeria with focus on the efficacy of urban forests for mitigating pollution. A brief review of the literature identifies some pollution mitigation measures provided by ecosystem services of urban forests. Some of the important functions of the ecosystems include purification of air and water, mitigation of floods and droughts, detoxification and decomposition of wastes, generation and renewal of soil and natural vegetation, pollination of crops and natural vegetation, control of potential agricultural pests and diseases, dispersal of seeds and translocation of nutrients, maintenance of biodiversity, protection from the sun's harmful ultraviolet rays among others. Examples of the urban forest ecosystem services of air quality and carbon dioxide sequestration which are used to illustrate issues associated with assessing their efficacy in mitigating urban pollution. Development of urban forest management alternatives that mitigate pollution should consider scale, contexts, heterogeneity, management intensities and other social and economic co-benefits, tradeoffs, and costs affecting stakeholders and urban sustainability goals. This report considers only the tree component of the urban forest and focuses on four scale-based elements: 'isolated tree', 'line of trees', 'cluster of trees' at (<0.5 ha) and 'woodland' at (>0.5 ha). Integrating ecosystem services of urban forests into environmental quality strategies makes it possible to identify the type and composition of trees that maximizes people's overall quality of life in a specific city at least cost. This analysis can make explicit the tradeoffs associated with different management strategies, which is necessary for the sustainable management of urban forests and to address urban environmental pollution problems and enhance urban quality of life. However, increasing rates of urbanization, lack of prioritization of tree preservation by city officials, inclusion of trees by decision makers in environmental policies, and a widespread neglect of the costs associated with urban forests call into question the assumption that the net effect of urban forests on environmental quality is always positive.

Keywords: Urban forest, ecosystemservices, pollution mitigation, air quality, Nigeria

INTRODUCTION

The use of ecosystem services as a concept and term in environmental disciplines has gained recognition in the urban forest and pollution literature (Dobbs *et al*., 2011; Escobedo *et al*., 2010; Young, 2010). High per-capita energy and material consumption patterns and large resource inputs have contributed to increased pollution levels in urban areas and emissions of greenhouse gases and aerosols that contribute to regional and global climate change (Kroeger, 2010). Literature from such researchers as (Escobedo *et al*., 2008 Nowak *et al*., 2006) on urban forests, pollution, and sustainability promotes and advocates the positive contributions of trees in maintaining environmental quality. In general these studies have led to a normative assertion by environmental managers that any increase in urban forests is desirable and will mitigate pollution problems. However, increasing rates of urbanization, lack of prioritization of tree preservation by city officials, inclusion of trees by decision makers in environmental policies, and a widespread neglect of the costs associated with urban forests call into question the assumption that the net effect of urban forests on environmental quality is always positive (Francisco *et al*., 2011).

This paper reviews literature on the role of trees in mitigating urban pollution and maintaining quality of life by integrating the concept of ecosystem services into urban forest management. The paper also looks at s ome of the disservices posed by urban forests. Specifically, the article presents a connection between the ecosystem services of urban forests and their efficacy in mitigating urban environmental pollution problems. This is achieved by first reviewing the literature on urban forests and pollution mitigation; then using existing literature ecosystem services is defined and applied to urban forests. The review considers only the tree component of the urban forest and focuses on four scale-based elements: 'isolated tree', 'line of trees', 'cluster of trees' (<0.5 ha) and 'woodland' (>0.5 ha).

Role of Urban Forest in Pollution Mitigations

Substantial urban forest literature has focused on the effects of urban forest ecosystem structure on functions such as air pollution removal, storm water interception, and tree shading (Cavanagh *et al*., 2009; Jim and Chen, 2009). The ecological literature generally links ecosystem functions in natural landscapes directly to resulting benefits for human well-being (Millennium Ecosystem Assessment, 2005).

Studies by Harris and Manning (2010) measured individual canopy and trees and pollutant dynamics while Paoletti (2009) analyzed the role of geographically distinct urban forests and their effects on air pollution problems. Zhao *et al*. (2010) and Escobedo *et al*. (2010) also analyzed the efficacy of urban forests for offsetting CO_2 emissions.

McHale *et al*. (2007) determined street trees to be cost-effective in sequestering carbon only in areas with high tree growth rates. Zhao *et al*. (2010) also found out that carbon sequestration by urban forests was comparable to carbon emissions from several industrial sectors in Hangzhou, China and offset urban industrial carbon emission by 18%. So, urban forests were just as effective at offsetting annual CO_2 emissions relative to other reduction strategies. Escobedo *et al*. (2010) found that additional, city-wide tree plantings would have little effect in offsetting carbon emissions.

Although many studies present city-level tree cover and pollution effects, Escobedo and Nowak (2009) found that ecosystem services were heterogeneous in that tree cover (i.e. structure) varied from 12 to 26 percent and particulate matter less than 10 microns in diameter (PM_{10}) concentrations differed from 59 to 84 mgm3 across the city. Furthermore, function or pollution removal by trees (7.9g PM_{10}/m^2 tree cover) in lower income areas of the city was similar to shrub removal rates in the high income areas (8.5g PM_{10}/m2 shrub cover). Also percent PM_{10} air quality improvement (an ecosystem service) by trees was 1.6% in areas with 26% tree cover to 6.1% in areas of 100% tree cover and varied according to socioeconomic strata, season, and pollutant concentration. This does not imply that urban forests remove the greatest total PM_{10} but rather that at the margin, their cost-effectiveness is within range of other reported technologies and policies (Francisco *et al*., 2011).

Urban forests ecosystems

Urban forests can be defined as the sum of all urban trees, shrubs, lawns, in public and private spaces, along linear routes and waterways and in amenity areas which are located in highly altered and extremely complex ecosystems where humans are the main drivers of their types, amounts, and distribution (Dobbs *et al*., 2011). These urban forests contribute to green infrastructure and the wider urban ecosystem.

The 'isolated tree' in our cities is the smallest scale-based element of an urban forest; it is managed on an individual basis; the largest element is 'urban woodland' (measuring at least 0.5 ha in area and with a minimum width of 20 m (Forestry Commission, 2011), where trees are managed en masse using techniques more closely related to silviculture (Kenney *et al*., 2011). In between are a 'line of amenity trees', and a 'cluster of amenity trees', in which trees are typically managed on an individual basis under arboricultural techniques (Kenney *et al*., 2011), but are likely to be considered and valued together as a whole.

Ecosystems as defined by the Millennium Ecosystem Assessment (2005) are spatially and temporally explicit units that include all living organisms, the abiotic environment, and the interactions between the two in a given location. They are highly complex systems of which Nigeria's forest systems are no exception.

Ecosystem services

Ecosystem services have been defined differently by many authors (Fisher and Turner, 2008; Fisher *et al*., 2009), but always are defined with reference to humans (Tallis and Polasky, 2009). It is this attribute that distinguishes them from ecosystem functions. The Economics of Ecosystems and Biodiversity (TEEB, 2010) defines ecosystem services as - "the direct and indirect contributions of ecosystems to human well-being" – thus

Ecosystem functions occur whether or not there are any humans who may benefit from them (Tallis and Polasky, 2009). For example, if a tree intercepts air or water borne pollutants, it is an ecosystem function; if that function improves local air and water quality then the air and water quality improvement is the ecosystem service that benefits human's health. Based on this distinction between functions and services, Brown *et al*. (2007) define ecosystem services as "the specific results of ecosystem functions that either directly sustain or enhance human life." Similarly, Fisher *et al*. (2009) define ecosystem services as aspects of ecosystems utilized actively or passively, directly or in directly to produce better human well-being. Boyd and Banzhaf (2007) and Kroeger and Casey (2007) narrow the definition further by arguing that it is only components of nature that are directly enjoyed, consumed or used to produce human wellbeing should and be counted as final ecosystem services.

It is pertinent to note that the most useful definition of ecosystem services in a specific case depends on the goals of the analysis. For this paper, the definition given by Boyd and Banzhaf's (2007) and Kroeger and Casey's (2007) will be adapted because it is well-suited to measuring environmental quality and estimating the value of other ecosystem services. ***Hence, we define ecosystem services as the components of urban forests that are directly enjoyed, consumed, or used to produce specific, measurable human benefits.***

This does not mean that intermediate ecosystem functions are not important; rather their importance is embodied in the value of the final ecosystem services. For example, air quality, an ecosystem service that contributes to human health, a benefit, is a result of atmospheric deposition, an ecosystem function; temperature amelioration, an ecosystem service that contributes to human health and comfort and to reduced heating and cooling costs, all benefits, results from tree shade effects on absorbed solar radiation, an ecosystem function. As urban forest structure varies, so do ecosystem functions and services and the resulting benefits (Escobedo and Nowak, 2009).

A second category of ecosystem services derived from ecosystem functions is those that produce highly relevant end-products such as biomass, food, raw materials, energy and other resources (Popoola and Ajewole, 2001) as shown in Table 1 below These "production function" based ecosystem services (de Groot *et al*., 2002) are generally associated with the primary productivity of ecosystems. For example, urban trees and green spaces accumulate above and below ground biomass and influence atmospheric CO_2 concentrations through accumulation and loss of this biomass.

In a study carried out by Faleyimi *et al* (2014) in Okitipupa, the major functions performed by the identified trees were given as; provision of shade, aesthetics and other beautification functions, protection of buildings from wind and water erosion, production of edible fruits and vegetables, utilization of the parts as medicine and utilization of dead and fallen branches as firewood.
In a related studies by Ajibola *et al* (2015) ecosystem services identified in the Wetlands of the Niger Delta were food supply, freshwater supply, raw materials for production, climate regulation, groundwater recharge, erosion control, flood control, cultural heritage and amenity, spiritual and inspiration, recreational, educational and aesthetic services.

Table 1. Ecosystems services provided by Urban Forests in Nigeria

Ecosystem service	Urban forest components			
	Single tree	Line of trees	Tree cluster	Woodland
Provisioning				
Food provision				
Fuel wood				
Wood provision				
Regulating				
Carbon sequestration				
Temperature regulation				
Storm water regulation				
Air/water purification				
Noise mitigation				
Maintenance of biodiversity				
Pollination of crops and natural vegetation				
Control agricultural pests & diseases				
Aesthetic beauty and intellectual stimulation				
Cultural				
Nature and landscape connections				
Social development				
Education and learning				
Economy				
Cultural significance				

Modified from Ambe and Onnoghen, (2019) and Francisco *et al*. (2011)

Classification of ecosystem services

The Economics of Ecosystems and Biodiversity (TEEB, 2010) and Hansen *et al* (2015) categorized ecosystem services broadly into four main types, they are; Provisioning services, Regulating services, Cultural services and Supporting services. However, supporting services are often excluded from ecosystem service assessments to avoid double-counting and because their value is most easily defined through their contributions to provisioning, regulating and cultural services (Haines-Young and Potschin, 2013). This report therefore focuses on the latter categories only, and thus biodiversity, as a supporting service, is not vividly covered.

1) **Provisioning services:** These services refer to material outputs to the environment such as food supply, raw materials supply, water supply, medicinal resources, etc., obtained from ecosystems products such as food, fresh water, wood, fiber, genetic resources and medicines (Hansen, *et al*., 2015).

2) **Regulating services:** These services are defined as the benefits obtained from the regulation of ecosystem processes such as climate regulation, natural hazard regulation, water purification and waste management, pollination or pest control. Hansen, *et al*. (2015) described ecosystem processes that serve as regulators of ecological systems local climate regulation, air quality regulation, carbon sequestration and storage, noise reduction, run-off mitigation, moderation of extreme events, waste-water treatment, erosion prevention and maintenance of soil fertility, and pollination.

3) **Cultural services:** These services include non-material benefits that people obtain from ecosystems such as spiritual enrichment, intellectual development, recreation and aesthetic values. Non-material benefits obtained from human contact with ecosystems recreation and mental and physical health, tourism, esthetic appreciation and inspiration, spiritual experience and sense of place, education and learning.

Ecosystem disservices of urban forests

The ecosystem disservices are additional costs that cities incur when managing urban forests. For example, increasing the number of urban trees can enhance the provision of ecosystem services such as reducing building energy use through shading; however, they may also cause negative consequences that degrade the quality of life, such as an increase in water use in semi-arid areas (Lyytimäki and Sipilä, 2009). Common disservices include; fruit and leaf fall, animal excrement, blocking of light/views, decrease in air quality, allergies pests and diseases vector, spread of invasive species, damage to infrastructure, creation of fear tree and branch fall. Nevertheless, often the social benefits provided by urban forests outweigh the environmental and economic costs of maintaining them (Dobbs *et al*., 2011).

CONCLUSION

From the literature reviewed, it can be concluded that urban forest ecosystems play important functions in the environment, these functions include: purification of air and water, mitigation of floods and droughts, detoxification and decomposition of wastes, generation and renewal of soil and natural vegetation, pollination of crops and natural vegetation, control of the vast majority of potential agricultural pests, dispersal of seeds and translocation of nutrients, maintenance of biodiversity, protection from the sun's harmful ultraviolet rays among others.

The paper focused on the air and climate pollution mitigation ecosystem services provided by human-altered urban forests. However, since pollution mitigation is just one of several services provided by urban forests, management also needs to consider other relevant ecosystem services if the goal is to maximize human well-being.

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Strategies to Enhance Forest Ecosystem Services for improved Rural Livelihood in Nigeria

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Abstract

The forest ecosystem system services offer great benefits to man and has potentials in supporting rural livelihood in Nigeria. It is however, sad to note that the potentials of forest ecosystem in supporting rural livelihoods in Nigeria has been reduced greatly by activities of man. These include, deforestation, encroachment into the forest, illegal felling, bush fire, peasant farming and urbanization. It is therefore, important that strategies must be put in place in order to reduce the activities of man that bring about degradation of forest ecosystem. These strategies will help to enhance the contributions of forest ecosystem to improved rural livelihood in Nigeria. These strategies include, reduction of rural poverty, improved forestry extension, involvement of rural dwellers in forest protection and discouraging excessive use of fuel wood by rural dwellers. States governments and NGOs in the country will do well to promote these strategies so as to enhance forest ecosystem services for improved rural livelihood in Nigeria.

Keywords: Strategies, forest ecosystem services, rural livelihood, conservation, Nigeria

INTRODUCTION

The forest ecosystem is an ecological system of inestimable value to man. This is as a result of complex interaction that takes place in the forest ecosystem which leads to the production of ecosystem services. Ecosystem services are "the benefits that people obtain from ecosystems -the direct and indirect contributions of ecosystems to human wellbeing" (TEEB 2010). The concept "ecosystem goods and services" is synonymous with ecosystem services. This interaction between the biotic components as well as with the abiotic component of the forest ecosystem is what brings about the production of useful products and services that is valuable to man referred to as forest ecosystem goods and services. It is however, sad to note that the proper functioning of the forest ecosystem has been greatly impeded due to alterations in the forest ecosystem. The alterations in the forest ecosystem are brought about by activities of man. These include deforestation, encroachment into the forest, illegal felling, bush fire, peasant farming and urbanization. It is therefore, important that the alterations in forest ecosystem occasioned by the activities of man must be stopped or reduced to the barest minimum. It is in view of this that this paper seeks to examine the strategies that can help to enhance forest ecosystem services towards improving rural livelihood in Nigeria.

Rural Livelihood in Nigeria

A livelihood comprises the capabilities, assets and activities required for a means of living (Warner, 2000). Rural livelihoods therefore, are those activities or things that rural dwellers do to earn a living. These include farming, hunting, fishing, carpentry, basket/mat/hat weaving, wood carving, blacksmithing as well as keeping of animals like goats and sheep in open range. Majority of rural livelihood in Nigeria has to do with primary production. This is the reason why farming, fishing, hunting and open range animal rearing are the commonest form of rural livelihood in Nigeria. Common characteristics of rural livelihood in Nigeria are that they are small scale in nature, low capital investment and low turnover. Adedayo (2018) noted thatcommon rural livelihoods in Nigeria include farming,hunting, fishing, handcraft, goldsmithing and blacksmithing. One prominent characteristics of these livelihoods is that theyare small scale and of low income (Adedayo, 2002). This has not augured well with many rural dwellers in Nigeria. As a matter of fact this has been the core reason why many rural dwellers are poor andlive in a state of hopelessness. It is therefore, very important that forest ecosystem services must be enhanced for improved rural livelihood in Nigeria.

CONTRIBUTIONS OF FOREST ECOSYSTEM TO RURAL LIVELIHOOD

The forest ecosystem can help to support the livelihood of rural dwellers in many ways. This can be grouped into two broad ways. These are direct and indirect contributions.

Direct Contributions of Forest Ecosystem to Rural Livelihood

1. **Increase in Soil Fertility:** An important contribution of forest ecosystem services to rural livelihood especially farming is improvement in soil fertility. The forest through leaf litter fall helps to generate humus which helps to increase soil fertility. Through this way the forest ecosystem helps to support the livelihood of many farmers in the rural areas of the country. This is part of the reason why many farmers encroached into the forest reserve to get fertile land. Adekunle (2005) noted thatland under forest are being clear felled for agricultural purposes as a result of the availability of fertile land under forestcover.

2. **Prevention of Erosion:** Erosion is one of the major problems being faced by farmers in Nigeria. This is because erosion washes away the top soil where the bulk of nutrients are located. Erosion therefore renders many land areas infertile and unsuitable for farming. Forest treeshelp to prevent erosion by helping to reduce run-off water through their extensive root system and large canopy thereby helping to support the livelihood of farmers in the rural areas.

3. **Conservation role of the Forest:**The forest ecosystem also perform conservation role. The forest helps to conserve genetic resources by acting as a genetic bank. This therefore increases the resilience of the forest against perturbation. As a result the forest continues to serve as a home for wild animals thus supporting the livelihood of hunters in rural communities. In addition, the forest by helping to protect the watershed of water bodies especially rivers, streams and lakes help to support the livelihood of fishermen in the inland waterways. The resilience of the forest ecosystem also helps to boost the livelihood of many rural farmers.

Indirect Contributions of Forest Ecosystem to Rural Livelihood

1. **Medical Benefits of Forest Ecosystem:** The forest ecosystem play prominent role in the maintenance of the health of rural dwellers in Nigeria. The reason for this is not unconnected with the fact that many forest plant parts are used for medicinal purposes. Adedayo and Oyun (2017) noted that forests and trees are valued by agrarian communities for their supply of medicinal products even more than orthodox drugs. This is because many rural dwellers in Nigeria cannot afford to buy orthodoxdrugs or pay for the services of a medical doctor. Medicinal products they obtain fromthe forest is what they use to maintain their health. This is what has been helping majority of the rural dwellers to face the rigour of their livelihood daily. In this way the forest ecosystem helps to support many rural livelihoods indirectly. Table 1 shows the list of forest tree species used for medicinal purposes in Nigeria. The Table below showes that wide varieties of forest plant species are used for medicinal purpose in Nigeria.

2. **Provision of Food and Food Materials:** One of the indirect contributions of forest ecosystem to rural livelihood is the provision of food to the people. For a man to carry out his livelihood very well he needs food. Not just any food but balance diet that will give adequate energy and strength to an individual that will enable him cope with the daily rigour of his livelihood. The food provided by the forest ecosystem to man can be in terms of fruits and nuts, edible leaves that serves as vegetables, snails, mushrooms, honey and bush meat. There is a direct link between forest trees, their products (i.e. leaves, fruits, roots and flowers) and rural household food security in Nigeria. Forests are endowed with many plants that can be used for food and medicine (Kallas, 2010). It shouldbe noted that these plants provide succor to rural dwellers in times of food shortage because they enhance livelihoods survivalstrategies and support household economies.Sene (2000) noted that foods from the forests and other tree systems in Africa constitute an important component of household food supply. He noted further that in many villages and small towns the contributions of forests and trees to food supply is essential to food security as they provide a number of important dietary elements that the normal agricultural produce does not provide adequately. Forest ecosystem provides critical supplies of food during periods when agricultural crops fail or are otherwise scarce. The forest ecosystem is so important to the food supply of rural households in Nigeria to the extent that they help to reduce dietary deficiencies and the usual monotony of diet that is experienced in rural communities of the country. The food provided by forest ecosystem to rural dwellers in Nigeria is the reason why rural community dwellers are not showing any obvious sign of malnutrition despite the poor nutrition status of their food. The reason for this is

due to the fact that what the rural dwellers lacked in their normal diet they are able to complement from the food they get from the forest ecosystem in form of forest fruits, bush meat, snails and mushrooms.

Table 1: Forest Tree Species used for medicinal purposes in Nigeria

S/N	Name of tree species	Parts used	Ailment cured
1	*Cassia siamea*	Flowers, roots	Malaria
2	*Annona senegalensis*	Leaves	Low sperm count
3	*Calotropis procera*	Leaves	Rashes
4	*Gossypium barbadense*	Green leaves	Cough, Malaria
5	*Daniela oliveri*	Bark	Malaria, Diabetes
6	*Pilostigma thonningi*	Leaves, bark	Malaria
7	*Cola nitida*	Bark	Low sperm count
8	*Terminalia avicenoioides*	Leaves, bark	Cough, Diarrhea
9	*Jatropha curcas*	Exudates, root	Mouth diseases, Sore
10	*Colocynthis vulgans*	Fruits	Gonorrhea
11	*Phyllanthus amaraus*	Leaves, seeds	Fever, high blood pressure
12	*Khaya senegalensis*	Bark	Pile, malaria
13	*Azadiractha indica*	Bark, Leaves	Malaria
14	*Parkia biglobosa*	Bark	Skin Rashes
15	*Pupalia lappacea*	Leaves ,seeds	Women sterility
16	*Garcinia cola*	Seed	Asthma, cough
17	*Morinda lucida*	Leave	Malaria
18	*Psedium guajava*	Bark	Skin Rashes
19	*Alstonia boonei*	Bark,	Rashes, Fever
20	*Carica papaya*	Fruits, exudates	Typhoid

Source: Adapted from Adedayo *et al* 2015

The contribution of forest ecosystem to diets varies considerably from one ecological zone to another. Some foods obtained from trees are consumed during seasonal food shortages when agricultural crop supplies dwindle. Table 2 shows a list of plant species that provide either edible fruits or vegetables to the people in Nigeria (majority of these plants are obtained from the forest ecosystem).

Table 2: List of Forest Plant Species that provide edible Fruits or Leaves to the people in Nigeria.

S/N	Name of Plant Species	Type of Food
1	*Adansonia digitata*	Fruits and Leaves
2.	*Artocarpus cuminis*	Fruit
3.	*Blighia sapida*	Fruit
4.	*Borrassius aetopium*	Fruit
5.	*Chrysophyllum albidum*	Fruit
6	*Dacryodes edulis*	Fruit
7.	*Garcinia cola*	Fruit
8.	*Gongronema latifolium*	Leaves
9.	*Irvingia gabonensis*	Fruit
10.	*Moringa oleofera*	Leaves
11.	*Morus mesozygia*	Fruit
12.	*Ocimum gratissimum*	Leaves
13.	*Parkia biglobosa*	Fruit
14.	*Spondias mombin*	Fruit
15.	*Tamarindus indica*	Fruit
16.	*Tetracapidium conophorum*	Fruit
17.	*Treculia africana*	Seed
18	*Vernonia amygdalina*	Leaves
19.	*Vitellaria paradoxum*	Nuts
20.	*Vitex doniana*	Leaves

Source: Adapted from Fuwape, 2005 and Babalola and Agbeja, 2008

3. Provision of Income: The forest ecosystem provides income to many people especially in the rural areas. This is through the direct sale of some forest products for cash. This include sale of forest tree fruits (e.g. fruits of *Chrysophyllum albidum, Irvingia gabonensis,, Parkia biglobosa* e.t.c.), sale of forest leaves like *Thaumatoccoccus danielli,* stakes and firewood. Adedayo (2017) noted that forest trees can help to grow the economy especially in agrarian communities. This is based on the amount of income agrarian communities derived from the forest compared to other sources. Falade*et al*. (2014) noted that 11.3% of rural households in Ondo State earned more than ₦60, 000.00 per annum from forest ecosystem. The significance of the income earned by rural dwellers from the forest ecosystem lies on the fact that this income helps them to sustain, promote or even diversify their livelihoods.

Strategies to Enhance Forest Ecosystem Services for improved Rural Livelihood in Nigeria

In view of the far reaching importance of the forest ecosystem in supporting rural livelihood, disruption of forest ecosystem services must not be allowed to continue. Strategies that will help to enhance proper functioning of the forest ecosystem must be put in place. These strategies will help to ensure that the forest ecosystem continue to provide quality services that will help to promote rural livelihood. These strategies include:

1. Reduction of Rural Poverty: Poverty has been identified as the driving force behind forest ecosystem degradation and overexploitation of forest resources in the rural areas of Nigeria and all over Africa (FORMECU, 1989 and Jdumah,2001). This is because majority of the rural poor in the country and all over Africa need forest resources to survive and to earn income. Reddy and Chakravarty (1999) noted that the poorest households generally have the highest degree of reliance on forest products for income and food as they have the least access to cultivable land. It therefore follows that forest laws meant to protect the forest ecosystem against degradation and mis- use of itsresources seems doomed when placed against a growing tide of the rural poor who need and use these resources to meet their basic necessities of life. It therefore follows that strategies must be sought that can help to reduce rural poverty in order to reduce degradation of forest ecosystem to the barest minimum in the country. These strategies include;

(a) **Increased Agricultural Productivity:** In Nigeria the poverty assessment study carried out in 1982 showed that 87% in 1985 and 67% in 1992 of the core poor were in agriculture and all basically reside in the rural areas (Canagarajah *et al*,.1997). Idumah (2001) noted that many of the rural poor lack basic land inputs such as chemical fertilizers and as such experience declining agricultural productivity which leads to low income and increased poverty. As such when agricultural productivity of the rural dwellers is increased it goes a long way in helping to reduce their poverty level and by extension help to reduce the destruction of the forest ecosystem.. Agricultural productivity of the rural dwellers can be increased by;

i. Making fertilizers available to them at subsidized rate. The use of chemical fertilizers will help to boost soil fertility and increase farm productivity. This will help to reduce the poverty level of the rural dwellers.

ii. Encouraging rural farmers to plant trees or practice agroforestry. Agroforestry is known to increase land productivity per unit area. It will thus help to increase agricultural productivity of the rural dwellers.

iii. Government and some Non-Governmental Organisations (NGOs) should provide storage facilities in the rural areas to encourage rural farmers to increase their productivity. Provision of modern storage facilities can encourage rural farmers to increase their productivity because they know that whatever they produce cannot be a waste.There are storage facilities to keep their excess farm produce.

b. Creation of non-farm employment in the rural areas: Another strategy through which rural poverty can be reduced in the rural areas is for both the state and the Local Government to create non-farm employment in the rural areas. The non-farm employment is meant for those that might not be interested in farming especially some of the youths. This will help to reduce rural – urban migration. To create non-farm employment government must provide electricity, good roads and water to the rural areas. Examples of non-farm employment in the rural areas include electronics repairing, goldsmithing, blacksmithing, handicraft, e.t.c. It is believe that these non-farm employments can provide more income to the rural dwellers than farming that will enable them come out of absolute poverty.

C. Improved Rural Education: Education in the rural areas of the country need to be improved to meet up with what is obtainable in the urban centres. It should be noted that rural areas lacked tertiary educational instructions why many of the secondary and primary schools in the rural areas lack qualified teachers. This is because many of the teachers prefer to stay in urban schools. As such the quality of education in the rural areas is very low. It therefore follows that many of the indigene of rural areas in the country lacked quality education. It is a known fact that education has a great potential in reducing poverty.

d. Provision of Soft Loans to Rural Dwellers: For some rural dwellers to come out of poverty (absolute poverty) government need to provide for them soft loans. Soft loan is a loan given with a very low interest rate and a long period of moratorium. Government officials from the State ministry of Rural Development can be used to assess individual's ability to manage the loan and pay back. Such loans will help the beneficiary to come out of poverty and by extension it will help to reduce the destruction of forest ecosystem. Rural dwellers should be the main target of government to give soft loans because evidences all over the country have associated degradation of forest ecosystem with high level of rural poverty. Shepherd (1992) noted that to solve forest degradation problem, decision makers need to understand both the dynamics of the situation and that the political, social and economic causes of the problem are also part of the solution. This therefore means that concern must be shown by government to the political, social and economic well-being of the rural dwellers who are the force behind degradation of forest ecosystem. Provision of soft loans by government will go a long way in improving the social and economic well-being of the rural dwellers in the country and by extension reduce degradation of forest ecosystem.

e. Provision of Infrastructural Amenities to Rural Areas: The provision of infrastructural amenities to rural areas will help to boost business activities in the rural areas. It will also help to boost marketing opportunities to many rural dwellers. It will therefore help to increase their income and reduce poverty in the rural areas and hence reduce degradation of forest ecosystem.

f. Training of Rural Dwellers on how to improve sales of products they offer for sale: It is essential that rural dwellers be trained on how they can improve the sales of the products they offer for sale. Government and NGOs should endeavour to train rural dwellers on how to improve the sales of the products they offer for sale and by extension improve their income earnings. This can be done by organizing workshops for the rural dwellers on how to add more value to their products. Many rural dwellers deal with agricultural products or forest products. More value can be added to these products through processing. Taylor (1999) noted that local processing of forest fruits can increase returns through value addition. Adedayo (2002) also noted that local processing of the fruits of *Parkia biglobosa* and *Vitellaria paradoxum* added more value to these fruits and brought more income through improved sales of the fruits. In addition the Local Government areas in the country should make concerted efforts to upgrade rural market facilities. For example providing shelter in the market can help to encourage sales and by extension increase income which will then help to reduce degradation of forest ecosystem. Rural traders can also be helped by government or NGOs to increase their sales outlets to urban centres. This will help to boost their sales and income.

2. Improved Forestry Extension: Forestry extension is an out of school educational service directed towards informing people about forestry activities especially about innovations in forestry. Today in many parts of the country forestry extension is yet to be well developed. As such many people in the country especially the rural dwellers are still ignorant of forestry activities especially on the need to conserve the forest or use forest resources wisely. That is why many rural dwellers in the country today are involved in massive over-exploitation of forest resources resulting in the degradation of forest ecosystem.

There is therefore, the need to improve forestry extension in order to get many people educated and enlightened about forestry activities and more specifically about the danger of degrading forest ecosystems. It is important to let people know the dangers of forest ecosystem degradation to the livelihood of rural dwellers in the country.

3. Involvement of Rural Dwellers in Forest Protection: It is important that rural dwellers be involved in the protection of forest reserves in the country. This will help to curtail all manners of illegal activities inside the forest reserve and by extension help to reduce degradation of forestecosystem. Evidences all over the country have shown that uniform men arefinding it difficult to curtail illegal activities inside forest reserves. Adetula (2008) noted that in many communities in Ondo State some youths have constituted themselves into gangster making it difficult for forest uniform men to curtail illegal forestry activities. He noted further that some uniform staff have been attacked sometimes resulting into death.

The use of rural dwellers in forest protection can be very effective because they live very close to forest reserve. They know the terrain of the reserve and they can easily be on the tail of any forest offender.

Discouraging excessive use of fuelwood by rural dwellers: Adedayo *et.al*. (2008) and Gwandu (2001) noted that rural dwellers use enormous quantity of fuel wood in Nigeria. In their search for fuel wood rural dwellers strip off the land of trees, shrubs and other vegetative covering leading to soil exposure and deforestation. It is therefore important that ways be sought on how the quantity of fuel wood used by rural dwellers can be reduced and this will help to reduce degradation of forest ecosystem. Some of the ways by which the use of fuel wood by rural dwellers can be reduce include;

i. Giving out fuel efficient stove by government to rural women.

ii. Making alternative energy to fuel wood available and cheaper to the rural dwellers especially kerosene.

iii. Encouraging rural communities to establish communal wood lots where members of the community can get fuel wood easily.

When these strategies are put in place it will go a long way in helping to reduce forest ecosystem degradation and by extension help to enhance forest ecosystem services for improved rural livelihood.

CONCLUSION

This study has shown that forest ecosystem has both direct and indirect contributions to rural livelihoods in Nigeria. The direct contributions of the forest ecosystem to rural livelihoods include soil fertility improvement, prevention of erosion and conservation of genetic resources. The indirect contributions include provision of medicinal materials, provision of food and provision of income. In view of these, the following strategies can help to enhance the support of forest ecosystem services to rural livelihoods. These include reduction of rural poverty, improved forestry extension, involvement of rural dwellers in forest protection and discouraging excessive use of fuel wood by rural dwellers. State governments in Nigeria will do well by promoting these strategies so as to enhance forest ecosystem services for improved rural livelihood in Nigeria.

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Water Ecosystem and Food Security Around Ona River, Oyo State- A review

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Abstract

This paper reviews the water ecosystem and food security as associated with Ona River in Oyo State, Nigeria Access to rainfall is fundamental for food security and for poverty alleviation. About 70 percent of the Nigerian population live in rural areas and depend on the essential ecological, economic and social benefits provided by river. Feeding the world at a time of climate change, environmental degradation, increasing human population and demand for finite resources requires sustainable ecosystem management and equitable governance. Ecosystem degradation undermines food production and the availability of clean water, hence threatening human health, livelihoods and ultimately societal stability. With 10 million people dying from hunger each year, the linkages between ecosystem and food security are of paramount importance.

Keywords: Rainfall, Ecological, Climate change, Ecosystem, Food security

INTRODUCTION

In the developing countries, 70 % of the poor live in rural areas where productions rely on rain-fed agriculture (Akinyemi *et al*., 2014). Freshwater availability is seen as a limiting factor in food production and livelihood improvement. Meeting the Millennium development goals MDGs particularly in poverty-stricken, water scarcity prone regions such as the semi-arid and dry sub-humid savannah regions in Africa were challenging. Poverty alleviation and reduction of inequalities have been some of the Government's major development objectives with the government putting in place a number of policies and programmes, which emphasize rapid economic growth. This is reflected in various government policy documents such as development plans, sessional papers and strategy papers. After four decades of trying to implement the development plans, the social and economic inequalities still persist. The number of poor people increased from 3.7 million in 1973 to 15 in year 2000. (FAO, WFP, IFAD 2012) The poor are clustered into certain socio-economic categories that include small-scale farmers, pastoralists, agricultural and casual labourers, unskilled and semiskilled workers, female-headed rural households, the physically handicapped, HIV/AIDS orphans and street children (FAO, WFP, IFAD ,2012) Most people in these clusters are landless and lack formal education. Water availability is an increasingly critical constraint to expansion of food production in many of the world's agro ecosystems (Wood *et al*., 2000). In most developing countries, people are faced with water shortage and health related problems due to non-availability of clean water. Many factors influence water quality including soil type, geology, vegetation, ground water and flow conditions (Akinwande *et al*., 2013).The only natural input to other sources of water (surface and ground water) is rainfall. The total quantity of water available at any given time is an important consideration. Rainfall is relied on for both surface and groundwater (Taylor, 2011).

Climate change has caused a shift in the seasonal variability of rainfall and thus a shift in the normal timing and length of wet and dry seasons and increase in seasonal fluctuation of the water bodies (Odjugo, 2010). Climate change over the past several decades has resulted in shifting rainfall pattern and modifying rain-fall intensity, which has exacerbated hydrological processes and added the uncertainty and instability processes (Wood *et al*., 2000).Climate change has altered the patterns of net primary production and change growing conditions for many crops and livestock systems (IPCC, 2007). The situation of water supply and management in Nigeria is complex as majority of people are poor and sometimes have to travel several distances in order to get portable water for their household (Nnodu, 2008). Predicted changes in total annual precipitation are inconsistent under different future climate change scenarios, although, soils are predicted to become drier due to elevated temperatures. In addition, models consistently predict an intensification of the hydrological cycle with increased inter-annual variability in rainfall and, possibly of greater importance, altered within-seasonal rainfall patterns such that rain events will be fewer but larger with longer intervals between rains (Singh *et al*., 2013). Reservoirs/dams are fast becoming degraded due to pollution arising from domestic wastes, industrial effluent, agricultural run-offs and bad fishing practices. The free style way of disposing agricultural, industrial and domestic effluent into natural water bodies have cause serious contamination of the reservoirs. However, declining water quality due to environmental perturbations threatens the stability of the biotic integrity and therefore hinders the ecosystem services and functions of aquatic ecosystems. (Ajani and Omitoyin, 2004).

Water quality

Pollution has become a universal problem that affects rivers, lands, seas, and atmosphere. Improper disposal of untreated wastes has been without regards for the consequences. Rivers are worst affected and the damaging effect of improper disposal of untreated wastes, human sewage, waste water from residential arears,abattoirs to rivers and seas and the people drinking the water is obvious (Ajao and Fagade, 2002). Degradation of water quality can arise from widespread non-point sources of contaminants such as precipitation or dust from the air, surface runoff from the land, sediments on river and lake bottoms and groundwater seepage.Using burning forests, fossil fuels, agriculture and industrial activities are ways contaminants can be released to the atmosphere that can in turn affect water quality (Olson *et al*., 2005). All organisms depend on water for their survival (Smith *et al.,* 2017). Freshwater bodies are important wetlands located in and around human habitations as they are generally semi natural ecosystems constructed by man in landscape suitable for water stagnation (Yadav *et al*., 2013). The quality of drinking water is essential for life. Contaminants such as bacteria, viruses, heavy metals, nitrates and salt have polluted water supplies as a result of inadequate treatment and disposal of waste from humans, livestock, industrial discharges, domestic discharge and extensive use of limited water resources (Onwughara *et al*., 2013). Physio-chemical analysis is the prime consideration to assess the quality of water for its best utilization like drinking, irrigation, sheries, and industrial purpose are helpful in understanding the complex processes, interaction between the climatic and biological processes in the water (Salve and Hiware, 2006).

Inter-Linkages between Food Security and Water Ecosystems

The rural poor farmer depends heavily on water ecosysytem for their food security. Such farmers often very poor in monetary terms, may have rich biodiversity at the farm level, with mixed cropping systems involving different types of annual and perennial crops, including trees and a diversity of farm animals. These farmers need mechanism of support, potentially in the form of payment for ecosystem services (PES) (Akinyemi *et al*., 2014), to facilitate their role in maintaining ecosystem functions. The rural poor rely directly on ecosystem services for clean and reliable local water supplies. Ecosysytem degradation often results in water of both lower quality and quantity for people, crops and livestock, so reducing yields and is associated with higher risks of natural disaster.

International attention to ecosystems and biodiversity often focuses mainly on rare, endemic and endangered species and specific ecosystem services. Less widely recognized is the centrality of ecosystems to food security and livelihoods of everyone, but particularly the poor. Low-income rural people rely heavily on the direct consumption of wild foods, medicines and fuels, especially for meeting micronutrient and protein needs, particularly during periods of food shortages. Hunger itself reduces labor productivity, and the need to meet food needs during periods of food shortage can lead to depletion of household and community capital, compromising future potential.

An estimated 350 million poor people rely on forests as safety-nets or for supplemental income. Farmers earn as much as 10 to 25% of household income from non-timber forest products. Bushmeat is the main source of animal protein in West Africa. The poor often harvest, process and sell wild plants and animals in order to buy food (Akinyemi *et al*., 2014)

CAUSES OF RAINFALL PATTERN DISTRIBUTIONS

Climate Change and Natural Disasters

Global changing climate is another important driver of food insecurity that cannot be underestimated. Amongst other impacts, climate change is responsible for biodiversity loss in the ecosystem as well as other physical access (Adeagbo, 2012). Climate change has become one of the key divisors that is redefining the global food equation and thus having so much impact on the food security of particularly developing nations. (Behnassi *et al*., 2011).The impact of such phenomenon as drought, flood and land slide is more pronounced in regions where agriculture highly depends of rainfall (Ilaboya *et al*., 2012). Drought and land slide constitute a major threat for the food availability, excessive rain or flood has had a significant impact on the current hike in food prices. Though advancement in technology has resulted in increases in supply of food in developed countries, the production of food crops still rely heavily on climate and weather conditions like rainfall (Behnassi *et al*., 2011).

ENVIRONMENTAL PROBLEM

Impacts of industrial effluents on plant and soil showed that industrial effluents significantly deplete the nutrient content of soil which reduces the growth, yield, and nutrition of agricultural products (Islam *et al*., 2006). Around Ona River, industrial effluents have consistently constituted a scourge for the agricultural sector, crippling productivity.

Effluents from industries, human wastes, run-off from agriculture farms, automobile workshops and oil from transformers are directly discharged into the Ona river channel that empties into the lake which pollutes the water with heavy metals (Adeogun *et al*., 2016). Toxic substances and high populations of certain microorganisms can present a health hazard on drinking purposes and other uses such as irrigation, swimming, fishing, rafting, boating, and industrial uses. These conditions may also affect wild life, which use the water for drinking or as habitat.Though importance of fertilizers and agrochemicals in today's agricultural practice cannot be over emphasized., They however have their associated environmental consequences (Elliot, 2015). Where nitrogen from fertilizers washes into water bodies it causes eutrophication, killing aquatic lives. Phosphorus can also make algae to accumulate in water bodies. Thus depriving fishes of oxygen leading to suffocation and thereby affecting the supply or availability of fish for consumption around the river (Engel, 2014)

Urbanization

Increasing urbanization, population growth and associated land use and management changes have resulted in the alteration of the hydrology and water chemistry of Eleyele Lake, thereby causing the water quality to deteriorate (Akinyemi *et al*., 2014). The consequent increase in the building density around the reservoir enlarges the impervious area as well as modifies the natural drainage system due to increased paving in the area (Fourchard, 2003). In the past three decades, rapid expansion of the city due to population growth has caused encroachment on the surrounding forest reserve of Ona River thereby causing reduction in the perimeter protection of the lake (Tijjani *et al*., 2011)

Contribution of rainfall to the development of food security

Rainfall is particularly effective in the rural areas because rural population depend on rainfall for the production of agriculture for their survival. The Farmers in Nigeria are highly informal with casual approach to farming activities. This makes them highly vulnerable to exploitation. Policies and programmes should be implemented to facilitate the usability of dams for agricultural production which in turn will assist in food security

Sustainable development and increased food production in agricultural based developing countries require availability of sufficient water and fertile land. Water especially affects greatly the prosperity of people and their development potential and health. The availability of this vital resource is not guaranteed for large sections of the world‟s population. Over 40% of the extra food required to meet the growing food demands by 2025 will have to come from intensified rain fed farming in sub-Saharan Africa region. In contrast, almost quarter of Sub-Saharan Africa (SSA) population live in water-stressed areas. (World Bank, 2005; UNDP, 2006). Only 10-20% of the country‟s surface water resources access to the population (MOARD, 2008). Water as insufficient and commonly shared resource may become a cause of conflict. To provide adequate water to the users, in the right quantities.

CONCLUSION

In this paper water ecosystem play an essential role in enhancing food security. Water quality is used to express the suitability of water and sustainable to various uses or processes. Water ecosystems supply the fundamental units of life support, by providing ecosystem services that enable us to produce or utilize food and water. They also provide clean air , shelter and medicines, cultural and aesthetic wellbeing, and can have a vital role in disaster risk reduction. These water ecosystem services are however under increasing pressure and threat of further degradation. Problems of rain fed agriculture in semi-arid areas, which are characterized by low productivity, degraded natural resources due to deforestation and desertification, widespread poverty due to livelihood insecurity, acute water scarcity can be addressed effectively by Watershed Management Programme. Hence Watershed Management Programme must get the foremost priority among the various objectives, in our National Rural Development policy for the overall development of rural areas

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Mitigating Environmental Hazards through Urban Forestry in Nigeria

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Abstract

This study examines the types, spatial distribution, causes and consequences of environmental challenges facing some states in Nigeria and how it can be mitigated through urban forestry. The study also probed into several environmental challenges that are facing each state of the geo-political zones in Nigeria. The review pointed out some of the resultant impacts of man's interaction with his environment in order to enumerate their contribution to U.environmental problems. Environmental hazards are not concentrated in any specific location. The most common environmental problems in Nigeria are anthropogenic in nature. They result from human interference (interaction) with the environment. They occur as a result of human intent, negligence, error or failure of human-made system. Vegetation in cities and suburbs are important in making built environments more liveable, economically and ecologically more sustainable. Urban forestry benefits include erosion control, flood control, fruits and some fuel wood supply. Urban forest development in Nigeria is presently been threatened due to rapid urban population growth, human activities, limited land area and poor implementation of government policies. To this end, the study advocates for, environmental education, governance of nature, formulation and implementation of stronger laws or/and penalties, as well as the use of environmentally sound technology for the monitoring of the environment. Inaddition, there is an urgent need to establish a substantive urban forestry unit/ agency to orchestrate urbanforestry development efforts in all the states engaged in urban greening.

Keywords: Urban forestry, environmental education, urban population, environment, hazard

INTRODUCTION

Nigeria is faced with myriads of environmental problems that are constituting hazards to the lives of the people. Hazards are occurrences that are dangerous or potentially harmful to man and his environment (Jay and Scott, 2011). Petters (1995) described it further as any situation in nature or in the environment which is destructive or probably detrimental to man or any other component of the environment. It results from the deterioration of environmental quality. The environmental problems are inter-related and inter-connected. In terms of frequency, anthropogenic challenges are more prevalent in the country. However, in the process of harnessing environmental resources for the use and benefit of mankind, many calamities originate. According to Santra (2011), these hazards emerge from rapid increase in human population, significant rise in human use of resources, advancement in technology, the emergence of free-market economies, as well as poor attitude of people towards the environment.

Environmental hazards are not concentrated in any specific location. The most common environmental problems in Nigeria are anthropogenic in nature. They result from human interference (interaction) with the environment. They occur as a result of human intent, negligence, error or failure of human-made system. Anthropogenic hazards can be broadly classified under the titles of sociological/societal hazards, technical, transportation , hazardous materials and environmental hazards Examples of sociological challenges are crime, arson, juvenile delinquency, civil disorder, terrorism, arms race, and war. Likewise, technical environmental challenges include industrial, structural collapse, power outage, fire, as well as hazardous materials. Other types of environmental challenges are pollution, air and water contamination, household hazards, overgrazing, overfishing, dangerous agricultural practices and household waste.

Human activities in Nigeria have resulted into environmental challenges like biodiversity loss, oil spillage, bush burning, urban housing problem, water scarcity, as well as pollution (water, soil, air, marine, noise, thermal, radioactive and vehicular). Broader worries have also arisen about the environmental challenges of deforestation, urban flooding, destruction of aquatic habitats, over-exploitation of forest resources, illegal mining activities and dereliction, as well as solid waste problems. Environmental challenges are classified under the broad titles of natural and artificial, based mainly on their mode of occurrence. Natural events occur suddenly and swiftly and consequently cause severe damage to the society and surrounding (Santra, 2011). Over time urban areas in Nigeria have witnessed serious environmental hazards like flooding, storm, air ,pollution and severe hot weather that would have been ameliorated if urban forestry was in place. The artificial environmental challenges refers to human actions (anthropogenic) which had been ealier discussed.

A lot of research had been conducted on contribution of urban greening to environmental sustainability, environmental challenges and repercussions but little or no work has been done on mitigating environmental hazards through urban forestry. This paper highlights is going to investigate how urban forestry can be used to mitigate environmental hazards in our cities.

Causes and effects of Environmental Challenges

Environmental challenges are caused mainly by natural forces and human influences, or a combination of the two. Anthropogenic challenges are caused mainly by human interference with the environment. Miller and Spolman (2011) identified population growth, wasteful and unsustainable resource use, poverty, as well as insufficient knowledge of how nature works as the major causes of environmental problems in Belmont, United State of America . Human activities like agriculture, deforestation, fishing, livestock rearing and hunting are mounting pressures on the environment.

Furthermore, other activities like mining and exploration for petroleum, overfishing, overgrazing, hunting, as well as the use of pesticides and herbicides are responsible for many environmental hazards. Many problems concerning environment and biosphere are simply there because so many people contribute little bits and pieces to it, all of which put together assume enormous dimensions (Asthana and Asthana, 2013). For example, environmental challenges like flooding, pollution and erosion are caused mainly by poor drainage system, building along river channels, breakdown of dams and embarkments, as well as poor urban planning. Likewise, the side effects of environmental calamities are determined by the causative factor, frequency, magnitude, space and time of occurrence among other influences. However, notable consequences of environmental challenges include loss of lives, loss of properties, loss of genetic resources, environmental degradation, loss of habitats, climate change and global warming, biodiversity loss, as well as epidemiological threat. Others are disturbance of human activities, reduction in ecosystem adaptability, impoverishment of communities that rely on environmental resources as their means of livelihood, as well as threat to Millennium Development Goals

Environmental problems in Nigeria are not restricted to any particular ecological zone of the country. Like the harmattan wildfire, it acts across all regions and different geopolitical zones of the country-rural and urban. The most common natural disasters in the country are desertification, landslides, flood, and erosion. These problems are distributed across the country based mainly on the prevailing geological, vegetal, hydrological or climatic condition. For instance desert encroachment is a major problem in the Sahel vegetation region of Nigeria. Also, coastal erosion is peculiar to some states in the southern parts of the country. It is common in states like Lagos, Delta, Bayelsa, Akwa Ibom, Rivers and Cross Rivers. Likewise gullies are prominent in the south east and south west part of the country. Likewise, urban flooding is ubiquitous in major cities like Lagos, Ibadan, Port Harcourt, Calabar, Yenagoa, Asaba and Benin City (Petters, 1995).Effects of environmental challenges are complex and multi-dimensional. They vary from place to place and from time to time. Freeman *et al*. (2003) submitted that natural disasters can have more negative effects on man and his environment. The consequences affect man, animals, properties and other components of the environment.

Other aftermaths of environmental challenges are climate change, hydrological upset, disease outbreak, and stratospheric ozone depletion. Modern technologies of dam construction, mining, and highway engineering are doing more damages to the environment. The effects include stress (short term and chronic), neuropsychological impact, panic, anxiety, depression, loss of life, injury, and damage to infrastructure. Human activities are now so pervasive and profound in their consequences that they too affect the earth on a global scale in complex interactive and accelerating ways (Mahatma, 2009).

Petters (1995) reported that the effects of environmental challenges in Nigeria include damage of infrastructure, loss of life, injury, loss of housing, loss of crops, breakdown of social order, disruption of communication, as well as epidemiological threat, as seen in Ogunpa flood in Ibadan where several properties, houses, lives were being lost. Environmental challenges are giving increasing concern to individuals, government and non-governmental organizations at local and global levels. For instance, desertification is responsible for the attendant depletion of resources base in the affected areas. It exacerbates poverty, brings about decline in soil fertility, and causes population displacement. Flooding causes aesthetic pollution of the environment, destruction of farm lands, damage to road pavement, as well as interruption of socio-economic activities. In the same vein, while pollution degrades the quality of the environment, soil erosion leads to reduction in farm productivity, loss of farm land, damage to road pavement and rail lines etc.

Addressing Environmental Challenges in Nigeria's Urban Areas: The Urban Forestry Approach

The Nigerian environment not only plays a vital role in life support system, it particularly provides the basic resources for virtually all socio-economic activities in the country (Nwachuckwu, 2002). Nevertheless, the life support system has been subjected to series of devastations as a result of natural catastrophes and human activities. In order to save the environment from further degradation of the rich and exhaustive resources, it becomes inherent to address the challenges by maintaining appropriate integrated management approach so as to be able to achieve environmental sustainability. Addressing environmental challenges in our urban areas and cities requires the role of the government (at national, state and local levels), non-governmental organizations, and community based organizations, as well as individuals. It also necessitates the collaborative efforts of international organizations, law enforcement agencies, academics and technocrats, the youth, the press as well as national and multi-national companies. Hazard control process is concerned with recognizing, evaluating and eliminating/mitigating hazards that occur because of human errors and physical deficiencies in the environment (Jain and Rao, 2011). One of the ways environmental problems can be ameliorated in our cities is through the introduction and adoption of urban forestry.

CONCEPT OF URBAN FORESTRY

Urban forests defined as the sum of all woody and associated vegetation in and around dense human settlements, ranging from small communities in rural settings to metropolitan regions considered as one of the major land uses especially in human settlements. (Munishi *et al*. 2004). Urban forestry involves planting and maintaining group of trees within a built environment.. Urban forestry and its management can have big potential in mitigating Carbon emissions and performing other environmental services. There is however a limited number of studies that have quantified the potential of urban forest ecosystems in Nigeria to mitigate CO2 emissions. Urban greening is seen as a strategy for simultaneously making our cities more enjoyable, liveable and sustainable (Onilude, 2013). Trees have been planted in urban areas for many centuries (Bradshaw *et al*. 1995). But little attention has been paid on the important roles they play in mitigating environmental hazards. Their environmental contribution in terms of reducing air pollution (CO2 gas emission) wind and other factors are equally important although difficult to quantify.

Urban forestry also known as urban greening is a strategy for simultaneously making our cities more enjoyable, inhabitable and sustainable. Collins (1997) noted that the benefits of urban trees/forests are such that, in major centres throughout the world, urban trees/forests are no longer regarded simply as aesthetic elements of the urban landscape; rather they have become a vital component of the urban infrastructure, essential in maintaining a habitable and sustainable environment. According to Jim(2000),introducing trees into built-up areas fulfils many environmental, social and economic functions, as well as satisfying an innate human need. Therefore, nurturing of greenery in urban centres can be equated with the provisions of an essential urban infrastructure.

FEATURES AND ADVANTAGES OF URBAN FORESTRY

The urban environment is generally characterised by impervious surfaces, and highly reflective and radiating materials like concrete, asphalt and metals. These are in addition to the presence of heavy industrial and economic activities, such as heating, cooking and transportation. Urban forestry and greening provides critical ecosystem services which contributes substantially to human health, livelihood and environmental qualities. The high rates of population growth and rapid urbanization have had negative impact on urban forest and are responsible for vicious cycle of environmental degradation in urban areas in Nigeria.

Trees can be used in urban design to provide shade and shelter, create and define spaces, complement architecture, separate conflicting land uses and screen unpleasant views, among other things (Webb 1999).Furthermore, urban trees/forests have a positive impact on air quality through deposition of pollutants on the vegetation canopy, sequestration of atmospheric CO_2 in woody biomass and reduction of (summertime) temperatures and associated ozone formation. Trees act as filters and leaves have a surface area up to twelve-times greater than the ground they overshadow, helping to trap dust and carbon particles and absorb harmful gases. Therefore, leafy town parks and tree-lined streets help to clean the air we breathe and make it healthier.

Urban trees/ forest canopies reduce soil erosion by diminishing the impact of raindrops on barren surfaces. By virtue of their proximity to people, urban trees/ forests can provide substantial environmental and recreational benefits to urban dwellers. Trees in the urban environment provide a psychological link beyond the purely social environment of the city. They provide an important connection for city dwellers to the living forces of nature. Stress seems to be a fact of life for those who live and work in cities. It is discernible and measurable in muscle tension and blood pressure, and research has shown that there is significant stress relief when we have access to trees and greenery for as little as 3 minutes (National Urban Forestry Unit, 2001). Therefore, the stressfulness of urban living can be reduced through investment in urban forestry. Whether as single specimens, continuous lines, small groups, or large masses, trees can be seen as objects in the overall visual landscape of a city, where they play an important aesthetic role. Most planted urban vegetation contains some of the aesthetic quality of a garden, and this makes a city a pleasant place to be enjoyed in a relaxing way.

Bradley (1995) viewed the benefits of urban forests as being both global in nature, such as the potential for reducing urban heat island effects, and very personal, since they answer the human need for exposure to green spaces in order to maintain a sense of well-being. He submitted that the soothing and settling psychological effects that green experiences have on humans provide a renewed sense of well-being. Moreover, opportunities for reflection, undisturbed thought, and invigorating sights provided by urban forests make an individual refreshed and renewed for daily activities. Therefore, as cities continue to grow, urban trees will play a prominent role as essential infrastructure, making urban life more conducive and productive. For this reason, it becomes imperative to understand how these trees/forests can be planned and managed to provide optimum benefits for city dwellers.

STATUS OF URBAN FORESTRY IN NIGERIA

The status of urban forestry has witnessed a paradigm shift from what it was during the colonial era from what it is today. Because of the love for trees and ornamental plants, the colonial masters designed the major cities in Nigeria like Lagos , Kaduna , Enugu with trees creating very beautiful landscape as well as cool and conducive environment. The drive for rapid urbanization has resulted in the demand for land by rural–urban immigrant for housing projects thus leading to destruction of trees gardens, recreational parks, peri-urban plantations for establishment of housing units, common in Nigeria especially the south eastern Nigeria. There is also destruction of urban and peri-urban forest to create land for infrastructural development. Some rural urban migrants illegally cut down trees along the streets and botanical gardens and bush for fuel wood. Some recreation parks and gardens have been converted into refuse dumps due to poor waste management. There is little or no fund for urban forestry management as most of the fund available is prioritized towards provision of education and health care, etc.

Incorporating green areas into urban planning is not a new concept in Nigeria; usually, green areas are conspicuous in the city plan and design, however, it is mostly not executed in the development of cities across the country (Adeponle, 2013). The state and local government agencies are largely responsible for avenue trees and trees in public sites while private individuals shoulder the maintenance of green areas in residential homes. Traditionally in Nigeria, urban forests occurs as home gardens, community forests ,sacred grooves and shrines, shade trees in local markets and village squares amongst others. Cultural taboos and laws are usually employed to protect such forest from over exploitation and destruction (Ezeabasili *et al*, 2015). Various punishments and spells await any offender from the perceived inhabiting spirits and ancestors according to traditional beliefs. In most cases physical protection measures such as forest guards or protection officers are not in place, they rely exclusively on spiritual protection which is believed to transcend the ordinary punishments but spiritual spells. With this method urban forests are protected for centuries, however, modern development hinged on provision of socio infrastructures, industrialization and modern housing estates have led to the destruction of numerous urban forests. In Accra (Ghana), Ibadan, Sokoto, Maiduguri and Uyo (Nigeria), vandalization and nonchalant attitude towards urban forest projects by poor rural-urban migrants have been reported (Fuwape and Onyekwelu, 2011). Tree seedlings planted as avenue trees were uprooted and destroyed over night while already established trees are cut for firewood. Urban forest have been seen by most people as a home for insects, rodents and reptiles which inhabit trees close to the buildings, from where they easily made their ways into the roofs and crevices of buildings and most often become dangerous to the inhabitants and properties.

Factors such as urbanization, poor farming practices, exploitation for firewood, uncontrolled logging, bush fire which is caused by farmers, smokers and hunters who look for game have adversely affected urban forests in many cities. Through these avoidable practices, thousands of hectares of our forest are lost every year especially during the dry seasons. Furthermore, the natural and manmade features that combined together to make urban forest made Nigeria one of the most environmentally stressed regions include deforestation, soil erosion, air pollution, solid waste. Deforestation, the continuous removal or destruction of significant areas of forest cover for constructions and other use has resulted in a highly degraded environment with attendant reduction in biodiversity. Pollution, municipal and industrial pollution is a major environmental problem in some states in Nigeria as we lack proper solid waste management scheme and monitoring and control of industrial waste rarely practiced.

Notwithstanding, the benefits derived from urban forestry are innumerable, economic benefit, environmental and benefits of aesthetic/ improve scenery. Cities with designated areas for urban forests, landscaped roads and residential outlets surrounded by urban trees will experience a more stable environment and of course a reduced surface runoff during very high flood incidences. These will result to control of environmental problems of diverse kinds.

PROSPECTS OF URBAN FORESRY IN MITIGATING ENVIRONMENTAL HAZARDS

Trees play a major role in moderating the environmental conditions in any area. Urban and peri-urban forests and trees help mitigate environmental hazards by directly absorbing atmospheric carbon dioxide and releasing Carbon. Also, trees provide shade and reduce wind speeds, thereby indirectly lowering carbon emissions by reducing the need for air conditioning and heating and thereby cutting emissions from power plants (Nowak *et al*., 2013). Shaded surfaces can be 11–25 °C cooler than the peak temperatures of unshaded materials (Akbari *et al*., 1997); shading, therefore, can extend the useful life of street pavement by as much as ten years, thus reducing emissions associated with petroleum-intensive materials and the operation of heavy equipment required to repave roads and haul away waste (McPherson and Muchnick, 2005).People in urban areas face many potential climate-related risks, such as the increased incidence and severity of storms and flooding. Rainfall water run-off can be reduced by the tree canopies and through transpiration, and storm water quality can be improved by the retention of pollutants in soils and plants (Stovin, Jorgensen and Clayden, 2008). By increasing social cohesion, urban and peri-urban forests can help prevent deaths related to climate change.

CONCLUSION

The environmental problems in Nigeria are acute, pervasive and increase rapidly. This should be a source of great and justifiable concern for all today. The continued existence and well-being of all living things, plants and animals depend to a large extent on the ability of man to enhance, protect, conserve, and manage the natural resources in the environment. These life supporting means are threatened by natural and anthropogenic challenges or a combination of the two. The human induced challenges are aggravated by high population growth rate, poverty, unemployment and over-reliance on natural resources. The effects include health hazards, global warming, ozone layer depletion, climate change, pollution, environmental degradation, over-exploitation of natural resources as well as reduction in ecosystem complexity and diversity. This study has shown that the potential of urban forests in providing essential products and services could be maintained if appropriate integrated management approach is adopted for sustainability of the environment.

RECOMMENDATIONS

To ensure the realization of the goal of full implementation of urban forestry in Nigeria, government should develop a policy framework spelling out how urban forestry can be carried out in the country . This should be supported by the following:

1. Environmental education, governance of nature, formulation and implementation of stronger laws or/and penalties, as well as the use of environmentally sound technology for the monitoring of the environment.
2. Urban forestry curricula which must be flexible enough to ensure that sufficient courses from supporting areas are included and designed, and professional courses in urban and environmental forestry need to be floated in the Nigerian universities.
3. There is an urgent need to establish a substantive urban forestry unit/ agency to orchestrate urban forestry development efforts in all the states engaged in urban greening.
4. A law mandating house owners to plant trees and ornamental plants within and around their houses in our towns and cities should be enacted. This will go a long way to address some environmental challenges in our cities .
5. Town planners should ensure that areas are set apart for parks and gardens in our cities while trees and ornamental plants are planted along major streets for beautification of our urban areas.

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Phytochemical Analysis and Antioxidant Activity of *Gacinia kola* seeds

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Abstract

Garcinia kola Heckel (Clusiaceae), known as bitter kola and it is a multipurpose tree indigenous to West and Central Africa. This particular specie is also referred to "wonder plant" because all of its parts can be used as medicine; its seeds are commonly eaten to prevent or cure gastric disorders and for their typical astringent taste. The seeds can serve as alternative medicine to treat or prevent severe illnesses such as malaria, cough, hepatitis and immune-destructive diseases. But there is no sufficient scientific evidence to support its uses for prevention or treatment of oxidation related medical conditions and its ability to scavenge free radicals is not so much known. Therefore, this study is to evaluate the phytochemical profile as well as the in vitro antioxidant and the iron-chelating activity of the G. kola seeds. Phytochemical screening in the respective methanolic aqueous extracts of G. kola seeds were determined by established procedures. Antioxidant activity was also evaluated by superoxide anion and Iron chelating activity was assessed using a ferrozine-based assay. The phytochemicals present were alkaloids, saponins, steroids, flavonoids and phenolics while tannins and terpenoids were absent. The iron chelating activity is in the order EDTA < 200 < 100 < 300 < 400 < 500 µg/ml with the fifth concentration (500 µg/ml) of the G. kola seed extract having the highest iron chelating activity. There was significant difference between the concentration at 500 µg/ml and the rest of the concentrations. All the fractions exhibited significant hydrogen peroxide scavenging activities while the second and fourth concentrations (200 and 400 µg/ml) are significantly higher than the first and third concentrations (100 and 300 µg/ml). The phenolic concentration increases as the weight of the G. kola seeds extract increases. From the result obtained in this research, it is clear that all the fractions of G. kola studied possess antioxidant activities in the in-vitro models.

Keywords: *Gacinia kola*, phytochemicals, antioxidant, iron chelating activity, seeds

INTRODUCTION

The importance of plants in our day to day living and sustenance cannot be overemphasized. The benefits they provide to man ranges from foods, to raw materials for many industrial products (such as cloth, foot wears and raw materials for buildings and in the manufacture of pesticides) and drugs (Manickam *et al*., 2017). Man, also explore the forests for their survival, sanitary and nutritional needs because the forests contain thousands of plant species capable of synthesizing essential substances, with the aim of eliminating pains, control suffering and counteract diseases. Some of these plants are known for their uses in traditional medicine (Odugbemi *et al.* 2007).

The information on medicinal value of plants conventionally was passed from generation to generation. This passing information somehow has led to preservation of the knowledge. However, the trend is changing with many communities abandoning their cultural practices, this therefore creates the need for the documentation of the information on traditional medicine in both the traditional way and also provide scientific rationalization in order to increase the confidence on the use of plants as alternative means of treatment since time immemorial, plants have been used as novel source and reservoir of chemical agents with great restorative activities (Mensah *et al.*, 2009).

Garcinia, belongs to the diverse pan tropical family clusiaceae which consist of important fruit and medicinal trees species. *Garcinia kola* (*clusiaceae*), commonly known as bitter kola plays an important role in African ethnomedicine and traditional ceremonies as a sign of acceptance and respect for a person (Oliver, *et. al.*, 2016). The species is sometime referred to as a wonder plant because each of its part can be found to be of medicinal importance. The seed of *Garcinia kola* is commonly called bitter kola in Nigeria, Aki ilu in Ibo, Orogbo in Yoruba and Namiju goro in Hausa. The bitter kola plant is found in countries such as Nigeria, Ghana, Cameroun, Sierra leone, Togo, Democratic Congo Republic e.t.c. Some of the phytochemical compounds that can be isolated from *G. kola* include oleoresin, tannins, saponins, alkaloids, cardiac glycosides, and bi-flavonoids such as kolaflavone and 2-hydroxybi-flavonols (Okunji and Iwu, 1991; Terashima *et al.*, 1999; Okunji *et. al.*, 2002).

The bio-active compounds present in *G. kola* are no doubt responsible for the treatment of various health disorders such as liver disorders, hepatitis, diarrhea laryngitis, lung problems (bronchitis) and some STIs such as gonorrhea. The seed is masticatory and it can also be used to prevent and relieve indigestion, chest colds, cough and treatment of headache (Ayensu, 1978; Agbor and Naidoo 2015). It is also effective in the treatment of some other disorders such as jaundice and high fever (Iwu 1993; Iyamah and Idu 2015). The bark and seeds of the plant is also useful in the treatment of stomach pain, gastrointestinal complications, throat infections, acute fever and inflammation of the respiratory tract. (Ajebesone and Aina, 2004; Chiyere *et. al.*, 2013).

The interest in natural antioxidants in relation to their therapeutic properties, has increased considerably in the recent years. Myriad scientific researches have been developed for the extraction, identification and quantification of these compounds from natural sources which include medicinal plants and food products (Hafiza *et. al.* 2017). A compound is said to have antioxidant activity when it is discovered to have the capacity to resist oxidation, neutralize or prevent oxidative processes. Most known antioxidants are β-carotene (provitamin A), ascorbic acid (vitamin C), tocopherol (vitamin E) and phenolic compounds. These antioxidants possess hydroxy-phenolic groups in their structures, which is essentially responsible for the scavenging of free radicals such as hydroxylic radicals (OH•) and superoxide (O_2•) (Elnour, *et. al.* 2018).

This study is aimed at examining the phytochemical constituents of *G. kola*. The research objectives are to carry out the phytochemical screening of some major constituents present in the *G. kola* seed extract and to carry out quantitative analysis of the phytochemicals responsible for its anti- oxidant activity.

METHODOLOGY

Collection of Sample

The plant sample was collected form Odofin forest in Owo, Ondo State, Nigeria and certified at the Department of Forestry and Wood Technology, Rufus Giwa Polytechnic, Owo, Ondo state, Nigeria. This is because of the proximity of the forest to the research laboratory that was used for the research.

Preparation of Plant Materials

Seeds of *Garcinia kola* was air dried for about two months and was processed into powder by mechanical means. The powered sample was then stored in polyethene bags and tightly covered. The plant sample was then treated with two solvents; distilled water and ethanol. The samples were measured with weighing balance and the extract was soaked in 70% of Ethanol and 30% of distilled water, after which the filtrate was separated from the residue using filter paper and then air dried for 24 hrs. The collected extracts were weighed again with weighing balance.

Biochemical assays

Total phenolic content analysis

The total phenolic concentration of the samples was estimated according to the method of Ou, *et al*., (2002). 0.4 ml of 7.5 % sodium carbonate was added to 100 µL of the extract and 0.5mls of dilute 10% Folin-Ciocalteau reagent was added to the resulting solution. The reaction was then left in the dark for 30 min at room temperature. The absorbance of the blue colour solution was read at 765 nm using a spectrophotometer and distilled water as blank. Garlic acid was used as the control.

In-vitro Hydrogen Peroxide Scavenging Activity

This was done by adding 250 µL of acidified 1mM ferrous ammonium sulfate to 100 µL of the extract. Then, 63 µL of 5mM hydrogen peroxide was added to the resulting solution. The mixture was incubated in the dark for 5 min at room temperature. 1.5 ml of aqueous 1,10-phenanthroline was added and the solution was mixed thoroughly. The solution was then incubated for 10 min in the dark at room temperature. The absorbance of the solution was read at 510 nm by a spectrophotometer, using two blanks. Blank: 1-a mixture of 0.25 ml of ferrous ammonium sulfate, 1.56 ml of distilled water and 1.5 ml of aqueous 1,10-phenanthroline. Blank: 2-1.5 ml of aqueous 1,10-phenanthroline (Mukhopadhyay *et. al*. 2016).

Determination of Iron Chelating Ability

The ability of the extract to chelate iron II was determined using a modified method of Minotti and Aust (1987). A 150 µl of 150 mM $FeSO_4$ was added to a reaction mixture containing 165 µl of 0.1M Tris HCl pH 7.4, 215 µl saline with the extract and the volume is made up to 1 ml with distilled water. The reaction mixture was incubated for 5 min, before the addition of 13 µl of 1, 10-phenantroline and the absorbance read at 510 nm. Tris EDTA was then used as the control.

Phytochemical Screening of Methanolic Extract of *Garcinia kola* Seeds.

The extracts of *G. kola* seeds were screened to establish the presence of some specific phytochemicals (alkaloids, saponins, tannins, flavonoids, terpenoids, steroids, and phenols) using standard phytochemical procedures to identify the constituents as described by Trease and Evans (1989); Harborne, (1998) and Sofowora, (1993). The qualitative results are expressed as (+) for the presence and (-) for the absence of phytochemicals (Sofowora, 1993).

Statistical Analysis

The antioxidant and free radical scavenging studies for each experiment was done three times. Where appropriate, representative values were expressed as means ± SEM and data were subjected to analysis of variance (ANOVA). Significance was set at $P < 0.05$.

RESULTS AND DISCUSSION

The iron chelating activities of the various extracts at different concentrations are shown in Figure 1. The result reveals the iron chelating activity of the extracts in ascending order. Ethylenediaminetetraacetic acid (EDTA) served as the positive control. The iron chelating activity is in the order EDTA < 200 < 100 < 300 < 400 < 500 µg/ml with the fifth concentration (500 µg/ml) of the *G. kola* seed extract having the highest iron chelating activity. There was significant difference between the concentration at 500 µg/ml and the rest of the concentrations. This is in agreement with the work done by Okoko (2009). The hydrogen peroxide scavenging activities of the fractions at different concentrations are shown in figure 2. All the fractions exhibited significant hydrogen peroxide scavenging activities. The second and fourth concentrations (200 and 400 µg/ml) are significantly higher than the first and third concentrations (100 and 300 µg/ml). The hydrogen peroxide scavenging activities is in the order of 100 < 300 < 400 < 200 µg/ml and was significantly different from one another ($P < 0.05$). This is in correspondence with the work of Okoko, (2009). Hydroxyl radical attacks all proteins, membrane lipids and any biomolecule it touches (Aruoma, 1999). The hydroxyl radical scavenging activities of the various concentrations of *G. kola* is an indication that they may also prevent the bio-membrane and biomolecules from being attacked by free radicals (Farombi, 2000).

The total phenolic content was determined using Folin-Ciocalteu reagent assays, it provides absolute measurements of the amounts of the phenolic compounds in the extracts as displayed in Figure 3. Furthermore, the determination of total phenolic content is based upon their chemical reducing capacity relative to gallic acid (Sheikha, 2015).

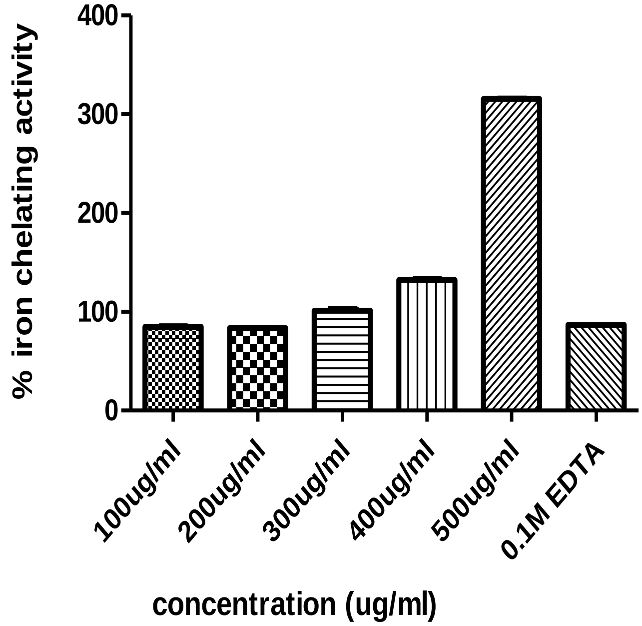

Figure 1: Iron Chelating Activity of *Garcinia kola* compared with EDTA

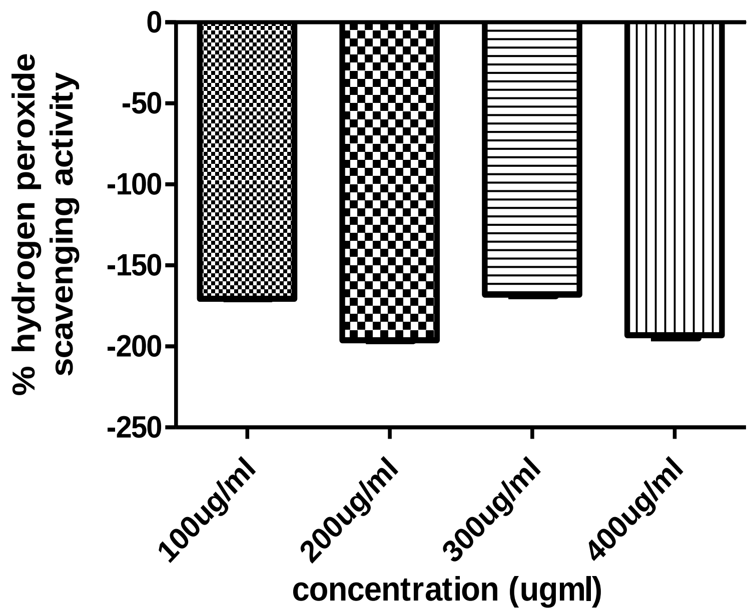

Figure 2: Hydrogen Peroxide Scavenging Activity of the fractions of *G. kola* seed extract

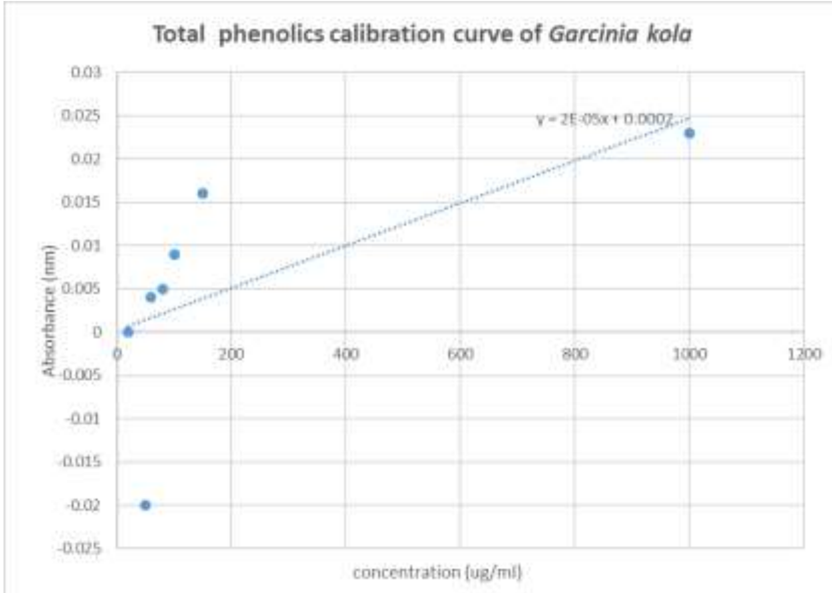

Figure 3: Gallic acid standard calibration curve

Table 1 shows the result of the total phenolic concentration of *G. kola* seeds. The phenolic concentration increases as the weight of the *G. kola* seeds increases. Table 2 shows the result of phytochemical screening of *G. kola* seeds. This result reveals that tannins and terpenoids are absent while alkaloids, saponins, steroids, flavonoids and phenolics are present. This is similar to the work of Adesuyi *et al*. (2011) who carried out phytochemical screening of *G. kola* seeds and concluded that they showed a high level of saponins, flavonoids and cardiac glycosides and that alkaloids and tannins were present in considerable amounts. Tannins are metal chelators and can form complexes with macro molecules. It has been recognized that flavonoids show antioxidant activity and their effects on human nutrition and health are considerable (Ebrahimzadeh *et al*. 2008). The mechanisms of action of flavonoids are through scavenging or chelating process (Kessler *et al*., 2003; Cook and Samman, 1996). Phenolic compounds are a class of antioxidant compounds which function as free radical terminators (Ebrahimzadeh *et al*. 2008).

Table 1: Total phenolics concentration of *G. kola* seeds

Concentration	GAE (mg/g)
100 µg/ml	25.70
200 µg/ml	27.30
300 µg/ml	30.00
400 µg/ml	31.70
500 µg/ml	34.10

Table 2: Result of phytochemical screening of the seeds of *G. kola*

TEST	RESULTS
Alkaloids	+
Saponins	+
Tanins	-
Steroids	+
Flavonoids	+
Terpenoids	-
Phenolics	+

Key: + = present; - = absent

CONCLUSION

Studies have shown that *G. kola* seeds have great medicinal potentials and characteristics. However, the objective of this study was to primarily highlight the existence of promising antioxidant potentials inherent in phytochemicals of *G. kola* seeds. It is clear that all the fractions of *G. kola* studied possess antioxidant activities in the in-vitro models.

RECOMMENDATIONS

There is a dearth of information concerning the biochemical potentials of *G. kola* for anti-cancer activities. It is however important to stress that efforts should be made in conserving the *Garcinia kola* species available, isolating and characterizing the specific bioactive constituents in *G. kola* seeds responsible for antioxidant activities for pharmaceutical and nutraceutical purposes. This could be of great value on a global scale.

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Influence of Forestry on Sustainable Environmental Management

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Abstract

Sustainable environmental management is a response to human actions considering the increasing seriousness and significance of today's disastrous human impact on natural ecosystems. It is comforting to know that with a large global population causing environmental degradation through mining, deforestation, air pollution, water pollution and solid waste. The environment might be able to recuperate on its own from human misuse and abuse, but it is now widely recognized fact that in many cases positive intervention through forestry practices is necessary if the environment is to be recovered. This paper highlights the causes and consequences of environmental degradation namely Drought, Desertification and Water Scarcity, global warming and ozone layer and measure to sustainable environmental management to resilient the environmental degradation such as forest protected, agroforestry practices thus, Protect biological diversity, Ensuring breeding grounds for wildlife and fish, critical to food secu rity.

Keywords: Forestry, sustainable, environmental, degradation, management

INTRODUCTION

Forests are essential for human survival and well-being, they harbor two thirds of all terrestrial animal and plant species *(FAO, 2001)* .They provide us with food, oxygen, shelter, recreation, and spiritual sustenance, and they are the source for over 5,000 commercially traded products, ranging from pharmaceuticals to timber and clothing. (Nigel and Sue, 2003) The biodiversity of forests variety of genes, species, and forest ecosystems underpins these goods and services, and is the basis for long term forest health and stability. Promoting ways to use forest biodiversity in a sustainable way, and with clear social and economic benefits for the poor.*(Barret et, al 2012).* There is a long history of protection of forests in mountain areas, where they help to prevent soil erosion, landslides and avalanches, and where they are important in maintaining the water quality of rivers draining forested catchments *(*Bergkamp *et al*. 2003*)*.

The availability and the quality of water are strongly influenced by forests, therefore, forested ecosystems catchments serve as guarantors of high value surface and drinking water *(Carina, 2008)*. Tropical rainforests play a vital role in the functioning of the planet's natural systems. The forests regulate local and global weather through their absorption and creation of rainfall and their exchange of atmospheric gases. Trees and shrubs play a vital role in maintaining an ecological balance and improving the livelihood of people in the arid regions. Clear felling of rainforests changes the reflectivity of the earth's surface, which affects global weather by altering wind and ocean current patterns, and changes rainfall distribution. If the forests continue to be destroyed, global weather patterns may become more unstable and extreme *(Rhett, 2012)*. Forested catchments area supply a high proportion of the water for domestic, agricultural, industrial and ecological needs in both upstream and downstream areas *(Calder et al. 2007)*.

Forest ecosystem goods and services

Cultural Services ▪ Spiritual and religious values ▪ Knowledge system ▪ Education / inspiration ▪ Recreation and aesthetic alue	Provisioning services Genetic Resources ▪ Biochemicals ▪ Fresh Water ▪ Food, Fiber and Fuel
Regulating Services ▪ invasion resistance ▪ Herbivory ▪Pollination ▪Seed dispersal ▪Climate regulation ▪Pest regulation ▪ Disease regulation ▪ Natural hazard protection ▪ Erosion regulation ▪ Water purification	**Supporting Services** ▪Primary production▪ Provision of habitat ▪Nutrient cycling ▪Soil formation and retention ▪Production of atmospheric oxygen ▪Water cycling

Source :(FAO, 2001)

FOREST SUSTAINABLE DEVELOPMENT

Sustainable development has been variously defined by different authors. It refers to meeting the needs of the present generation without compromising the ability of the future generations to meet their needs *(FAO, 1978; FAO, 2001)*. This is the basis for restoration of biodiversity loss. Sustainable development preaches controlled hunting, lumbering, fishing etc. It is a progressive economic and social department of human society through maintaining the security of livelihood for all people and enabling them to meet their present needs together with the quality of life in accordance with their dignity and well-being, without compromising the ability of the future generations to do like-wise *(Wolfensohn and Fuller, 1998)*.

Sustainability requires that growth must not exceed the capacity of the larger system to generate resources and absorb waste at sustainable rates and without disrupting other vital natural services such as photosynthesis, nitrogen fixation, etc. Sustainable development implies integrating traditional economic concerns with often ignored social and environmental consideration *(Salim and Ullsten, 1999)*. Forestry allows sustained yield management if all the parties are well informed and actively participate in the process. Economies cannot remain healthy unless the resources on which they depend are sustainably managed. Economies which degrade their environments for short-term gains are rarely stable and never sustainable *(Salim and Ullsten, 1999)*. *(Salim and Ullsten 1999)* maintained that sustainable development requires integrating economic, viability and human development with the necessity to protect the environment and sustain indefinitely the natural resource base. Nigeria has a long history of forest management and the formal goal is to achieve self-sufficiency in all aspects of forest production. Nigeria, once a significant exporter, is now a net importer of primary forest products *(FAO, 1978)*.

Environmental Degradation

The environment affects our health in different way, the interaction between human health and the environment has been extensively studied and environmental risks have been proven to significantly having impact on human health either directly by exposing people to harmful agents, or indirectly, by disrupting life-sustaining ecosystems (FAO, 1978). Environmental degradation may be defined as any change or disturbance to the environment perceived to be deleterious or undesirable. Environmental degradation is one of the Ten Threats officially cautioned by the High Level Threat Panel of the United Nations. The United Nations International Strategy for Disaster Reduction defines environmental degradation as “The reduction of the capacity of the environment to meet social and ecological objectives, and needs”. The degree of the environmental impact varies with the causes, the habitat, and the plants and animals that inhabit it. Humans and their activities are a major source of environmental degradation.

Environmental degradation is the deterioration of the environment through depletion of resources such as air, water, and soil, the destruction of ecosystems and the extinction of wildlife. When the environment becomes less valuable or damaged, environmental degradation is said to occur. There are many forms of environmental degradation. When habitats are destroyed, biodiversity is lost, or natural resources are depleted, the environment is hurt (Everett and Neu, 2000). Environmental degradation can occur naturally, or through human processes. The largest areas of concern at present are the loss of rainforest, air pollution and smog, ozone depletion, and the destruction of the marine environment. Pollution is occurring all over the world and poisoning the planet's oceans. Even in remote areas, the effects of marine degradation are obvious. In some areas, the natural environment has been exposed to hazardous waste. In other places, major disasters such as oil spills have ruined the local environment. Consequently, (*World Bank, 2007)* argues that damage caused by environmental degradation is costly for an economy and is equivalent to 8%of GDP across a sample of countries representing 40%of the developing world's population.

Causes of Environmental Degradation

The major causes of the environmental degradation are the human activities such as bush burning, mining, urbanization, industrialization, over-population growth, deforestation etc. These has led to changes in environment that have become harmful to all living beings(Chakravorty, 2001).. The smoke emitted by the vehicles and factories increases the amount of poisonous gases in the air. Mostly, we can see pollution in urban areas where population is increasing rapidly.

- Unplanned urbanization and industrialization have caused water, air and sound pollution. Urbanization and industrialization help to increase the degradation of the environment.Similarly, the smoke emitted by vehicles and industries like Chlorofluorocarbon, nitrogen oxide, carbon monoxide and other dust particles pollute air. and another cause of environmental degradation is sound pollution. The main cause of sound pollution are vehicles, loud speaker, mill etc. the excessive use of natural resources diminishes these resources and creates imbalance of the environment. These resulted in the over consumption of natural resources.
- Deforestation, over use of pesticides, chemical fertilizer and insecticides, unmanaged urbanization, industrialization and production of litters, sewages and garages etc. are the major problem to deteriorate quality of the environment. Deforestation provokes the wildlife and other organism to the verge of extinction. The forest areas has been cleared for agricultural land, settlement and to collect the useful herbs. *(Krut and Gleckman,1998)*.
- Air pollution is unfortunately the common causes of environmental degradation. Pollution introduces contaminants into the environment that can maim or even kill plant and animal species. Industry and automobiles are the primary and secondary contributors to air pollution worldwide *(Kay, 1999)*. Air pollution is a major environmental risk to health and is estimated to cause approximately two million premature deaths worldwide per year *(Krut and Gleckman, 1998)*.. A reduction of air pollution is expected to reduce the global burden of disease from respiratory infections, heart disease, and lung cancer , however, for every gallon of gasoline manufactured, distributed, and then burned in a vehicle, 25 pounds of carbon dioxide are produced, along with carbon monoxides, sulfur dioxide, nitrogen dioxide, and particulate matter; these emissions contribute to increased global warming (*Donohoe, 2000; Mark, 1997)*. In the United States, there is one car for every two people, in Mexico one for every eight, and in China one for every 100. The global auto population is expected to double in the next 25–50 years *(Mark, 1997)*. The average number of miles traveled/car/ year in the United States has more than doubled, from 4570 in 1965 to 11,400 in 1999 *(Amicus Journal Staff, 1999a)*.
- **Water pollution :**Microbe contamination of groundwater due to sewage outfalls and high concentration of nutrients in marine and coastal waters due to agricultural runoff are among the most serious threat . Contact with unsafe drinking or bathing water can impose serious risks to human health *(Kluger, 1999)*. While tap water is subject to treatment and is required to meet detailed testing and purity standards, it is not always disinfected of diarrhea inducing microorganisms, as illustrated by waterborne disease outbreaks such as that caused by Cryptosporidium in Milwaukie in 1993, which affected over 400,000people. Furthermore, fecal coliforms are not prohibited in bottled water *(Nation Staff, 1996)*, and water bottled and sold within the same state is not subject to Food and Drug Administration standards *(Gross, 1999*). Today 40% of waters are unfit for fishing or swimming, and levels of mercury in fish in 40 states. Clean Water Act of 1972 states to publish a list of all bodies of water that fail to meet water quality standards, and for the states to set pollution limits and scale back pollution in watersheds until standards are met, compliance is negligible and enforcement weak. Discharge of untreated sewage is the single most important cause for pollution of surface and ground water in the India. There is a large gap between generation and treatment of domestic waste water in the India *(Kluger, 1999)*. *(Nation Staff, 1996)* reported that effluents are another by-product of industries which poses threat to the environment, leather and tanning industries, petroleum industries and chemical manufacturing industries create major waste products which are released directly into nearby streams without treatment, creating river pollution and causing harm to aquatic life. According to a World Health Organization study, out of the India's 3,119 towns and cities, just 209 have partial sewage treatment facilities, and only 8 have full wastewater treatment facilities. Over 100 Indian cities dump untreated sewage directly into the Ganges River.] Investment is needed to bridge the gap between 29000 million litre per day of sewage India generates,

and a treatment capacity of mere 6000 million litre per day. Toxic pollutants Every year 25 billion pounds of toxic pollutants are added to the environment by factories and mines *(Fagin & Lavelle, 1999)*.

- **Solid Waste** Solid waste has become the number one serious environmental problem facing the country with its consequent effects on the pollution of water, air and land, not to mention its hazards to women's health and their social well-being *(Uchegbu 2002)* The problem of solid waste in our urban rural areas can be said to be a recent development. The oil boom era with its high pace of consumption and population opened the floodgate for serious waste generation. At the moment, virtually all our major cities and towns across the country are faced with the problems of solid waste management. In Lagos State, for instance, these heaps limit the roads to single narrow lanes, resulting in perennial traffic jams as well as the production of offensive odour. Apart from that, a number of communicable diseases such as typhoid, dysentery, cholera, malaria, yellow fever, and relapsing fever that affects women are associated with improper disposal of wastes. The mode of transmission can either be through biological vectors, physical and mechanical means, air-borne disease, water supply, food supply, direct contact or other means related to socio-economic status of women and her households. In addition water supply by leaching and run-off during rains and others may kill valuable and rare vegetation of wildlife *(Uchegbu 2002)*.

CONSEQUENCE OF ENVIRONMENTAL DEGRADATION

(i) Drought, Desertification, and Water Scarcity

Drought and water scarcity is the third main climate change impact that may significantly contribute to climate-related migration. Droughts, desertification, and water scarcity are likely to increase because of global warming. These phenomena are projected to affect about one-third of the world's current population. Droughts are likely to displace millions of people all over the world, affecting food insecurity and human livelihoods. Sea level rise will extend areas of salinization of groundwater and estuaries, resulting in a decrease in freshwater availability for humans and ecosystems in coastal areas. Moreover, changing precipitation patterns create pressures on the availability of clean water supplied (Kluger, 1999).

(ii) Global Warming

"The foremost evidence for worldwide climate change has been global warming." It is one of the consequence of environmental degradation and disasters. Evidence indicates that the Earth"s climate system is warming in a way that has no precedent in the history of human civilization. The continuing temperature acceleration might break the balance of a human ecosystem that has been long established at a lower temperature (Seagle, 2010).." The latest report of the IPCC estimates a rise in the global average surface temperature from 1990 to 2100 of between 1.8° C and 4° C, although it could possibly be as high as 6.4° C. The sea level has risen between 1993 and 2003 at a rate of 3.1 millimeters per year due to melting polar ice caps and seawater expansion (due to warmer climate); rainfall patterns have been changing with increased droughts in some areas and heavier rain in others; glaciers and snow melting have been increasing water in rivers at certain times; winds are increasing in power and cyclones are shown to be increasing in frequency ;and ocean temperatures have been rising. (Seagle, 2010).

Global warming is likely to influence the average weather patterns by gradual changes in weather patterns and "increased variability of extreme weather events associated with changes in surface temperature and precipitation. In the last few decades, ninety percent of natural disasters have been caused by climate-related natural hazards; and there is scientific evidence that most of them have their roots in global warming (Seagle, 2010).. The effects of warming and drying in some regions will reduce agriculture potential and undermine "ecosystem services" such as clean water and fertile soil. (McDonald and Martin, 2000) hus, the environmental impacts as a result of global warming have a deleterious effect on the living environment of large populations, which ultimately leads to mass migration.

(iii) Ozone Layer Depletion

The ozone layer is basically found at a height of about 20 – 30km above sea level. The ozone layer provides a protective layer, which prevents the penetration of the sun harmful ultraviolent rays. The pollution of the atmosphere from the release of Chlorofluoro carbons (CFCS) gases causes the depletion of the ozone layers and this results in environmental degradation .According to *Ukpong (1994)*, most of the skin diseases and the low productivity in agriculture are caused by ultra- violet rays. Also an increase in ultra-violet radiation effects water bodies, disturbs aquatic life, which supports the food chain, and causes the death of fishes that feed us. It also causes the deterioration of synthetic materials such as paints, and other products used in the building industry, invariably causing deterioration delivery to our ever- increasing human population.

It is estimated that deforestation and forest degradation account for approximately 17 percent of global greenhouse gas (GHG) emissions. (McDonald and Martin, 2000)

MEASURE TO SUSTAINABLE ENVIRONMENTAL MANAGEMENT

(i) Forest Protected area

Forest Protected area can be defined as "an area of land and/or sea especially a dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means" *(IUCN,2004))*

Forest protected areas can help safeguard a range of ecosystem goods and services, and are therefore a vital tool in managing for resilient forest ecosystems, and forest dependent communities.

Forest protected areas provide valuable and numerous benefits :

- Protect biological diversity and evolutionary processes.
- Prevent and reduce poverty by supporting livelihoods, providing social and cultural governance and subsistence values.
- Ensuring breeding grounds for wildlife and fish, critical to food security.
- Provide medicinal plants, biochemical components for the pharmaceutical
  Industry and ecological balance that controls and acts as a barrier for diseases (e.g. malaria)
- Filter and supply fresh water for both rural and urban populations around the world.
- Mitigate the effects of natural disasters by acting as barriers and buffer zones for storms, floods and drought.
- Generate tremendous direct economic benefits, and serve as a key asset for the tourism industry critical to many developing economies
- Hold irreplaceable and immeasurable spiritual value for particular communities
- Protect the territories and rights of indigenous and local communities, which provide them with the resources and space to continue traditional lifestyles.

(ii) Agroforestry practices

Agro forestry practices offer practical ways of applying various specialized knowledge and skills to the development of sustainable rural production systems. Agro-forestry is recognized as a land use option in which trees provide both products and environmental services. In agro forestry systems, the trees grown on different farmlands in the same locality when aggregated can bring about improved wooded situation thereby enhancing environmental protection *(Otegbeye, 2002)*. In most agro forestry systems, the trees grown do not have the usual silivicultural recommendations in terms of spacing *(Owonubi, 2002*). Given the reality of awareness among the farmers of multiple land use management, the need to improve on the existing agro forestry practices becomes necessary in the face of increasing population and limited nature of land. Rural people have been discovered to have a wealth of indigenous knowledge and have incorporated trees in production systems in areas where they lived for a very long period of time (*Evans and Alexander, 2004)*.

Agro forestry has both protective and social-economic benefit.(*Kang , et,al. 1990)* reported that besides direct agricultural benefit, trees exhibit social - economic values. The benefit of the tree components derived by farmers from agro forestry was evaluated from a social-
economic and ecological perspective (*Anderson and Sinclair, 1993)*.

CONCLUSION

Environmental degradation is the destruction of the environment through the depletion of natural resources either natural or artificial phenomenon ,leading to loss of entire ecosystems *(Donohoe, 2000*). However, developments of forest management over the past decade have focused on progress towards Sustainable Environmental Management, an approach that balances environmental, socio-cultural and economic. Objectives of management in line with the "Forest Principles" adopted at the United Nations Conference on Environment and Development in 1992. Parallel efforts in environmental conservation, particularly within the framework of the Convention on Biological Diversity, have lead to the development of the Ecosystem Approach as a framework and holistic approach for the conservation and sustainable environmental management.

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Farmer's Perception and Socio-economic Importance of *Adansonia digitata* in Savanna Ecological Zones of Nigeria.

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Abstract

Forest food tree species have immense indigenous, socio-economic, nutritional and traditional importance, especially to the rural areas that depends on them. This paper reports on farmer's perceptions and the socio-economic importance of A. digitata in three savannaecological zones of Nigeria. From each savanna ecological zone, data was collected from the people that are involved in the use of non-timber forest products. Ten (10) communities with population of A. digitata were purposively selected in each savanna ecological zones. In each community, two (2) set of semi-structured questionnaire were used to gather information about the socio-economic importance, source and processing, seasonality of the A. digitata, of A. digitata from ten (10) respondents and one (1) key informant (a farmer) was interviewed in each community to gather information on development, flowering and fruiting period of A. digitata, making a total of 330 respondents in all the savannaecological zones. The data obtained was subjected to descriptive analysis such as frequency, mode and percentages. Findings from the results revealed the economic importance of the species to the people, fruiting and flowering periods and evidence of domestication of A. digitata. A. digitata fruit tree is economically important in all the savanna ecological zones and contributes to the sustenance of livelihood of the rural populace. Furthermore, all parts of the tree have medicinal value, curing different ailments. Thus, extension services could help farmers obtain greater benefits from this resource by promoting participatory domestication and advice on tree management.

Keywords: *A. digitata*, Socio-economic, Farmer's perception, Savanna ecological zone, Nigeria

INTRODUCTION

Forest food tree species have immense indigenous, socio-economic, nutritional and traditional importance (Ayuk *et al*., 1999), especially to the rural areas that depends on them. In West African countries, forest food trees play vital roles in livelihood security for many rural community members, especially during the period of drought and scarcity (Akinnifesi *et al*., 2004). Aberoumand (2009) opined that about one billion people depend on wild foods (mostly from plants) globally. It has been estimated that between 300 and 350 million people depend almost entirely on forests for their nutrition and livelihood support (Chao, 2012). These fruit trees become increasingly important that serve as alternative sources of food especially during the hungry season and to supplement diet in better times (Elago and Tjaveondja, 2015) and thus contribute to food security and increase the diversity of foods necessary to reduce monotony in the diet of rural people (Bolanle-Ojo, and Onyekwelu, 2014). Forest fruit trees remain one of the major options for coping with hunger, nutritional deficiency in diets and poverty as a source of food and a means of generating cash income essential for purchasing the required households' goods in rural areas (Campbell *et al*., 2002). In addition, the edible parts (e.g. fruits and /or seeds) of these tree species could be processed into conventional products like jams, marmalade, alcohol, soaps, candles, jelly and chewing gums, table oil, margarine etc (Adisa, 2002). *Adansonia digitata* is a multipurpose tree species, belongs to the Bombacaceae family. It is a native deciduous tree from the African savannas and generally known as the African Baobab. Almost all parts of *A. digitata* are used as medicines and also possess high nutritional value. Leaves, bark and fruits of this plant are traditionally employed as food stuffs and for medicinal purposes, and for that reason baobab is also named "the small pharmacy or chemist tree" (Rabi'u and Murtala, 2013). Moreso, *A. digitata* has been reported to be a highly economic tree species and the leaves are used in the preparation of soup, flower is eaten raw and the seeds provide flour which is very rich in vitamin B and protein (Rabi'u *et. al.,* 2013). Despite their importance, *A. digitata* and other forest fruit tree species have been greatly neglected, especially with respect to their regeneration and improvement. Currently *A. digitata* is suffering from drought and desertification and fear has been expressed about its regeneration (Siham, 2005). *A. digitata* at present is facing a crisis of survival and is enlisted as an endangered species in the Red data book with only 30 to 40 trees available in India (Johri, 2008). Most of the edible indigenous species are becoming endangered due to large-scale deforestation of the natural ecosystem. This problem may affect the reproductive potential, species extinction and genetic resources, which would be used for future, tree improvement (ICRAF, 2003). Fruits of *A. digitata* are becoming increasingly difficult to collect due to deforestation and old tree age, and the fact that they have been harvested for decades (Bolanle-Ojo, and Onyekwelu, 2014). These species are still considered wild (ICRAF, 2000). Thus, if the current practice of allowing *A. digitata* to grow in the wild (i.e. natural regeneration) is allowed to continue, the probability of obtaining its much valued fruit on a sustained basis will be very low. Due to the lack of care and old age, a lot of the trees of the species have died or are in the process of doing so. Because of this, fruits and nuts for consumption, sale or processing are still collected from the wild, raising questions of full and sustained exploitation (Ugese *et. al.,* 2005). Consequently, this study was carried out to determine the socio-economic importance and ascertain the level of domestication of savanna ecological zones of Nigeria.

METHODOLOGY

Study Area

They study was conducted in three savanna ecological zones of Nigeria which are Oyo state (Derived savanna), Kaduna (Northern Guinea savanna) and Kano (Sudan savanna). The Derived savanna (in Oyo State) located between the latitude 8°7'21.9"N and longitude 4°14'36.92"E, Northern Guinea savanna (Kaduna State) lies between latitude 11°40'41.25"N and4°4'10.36"E while the Sudan savanna (Kano State) between latitude 12°0'7.85"N and longitude 8°35'31.04"E.

Data Collection

From each savanna ecological zone, data was collected from the people that are involved in the use of non-timber forest products. Ten (10) communities with population of *A. digitata* were purposively selected in each savanna ecological zones. In each community, two (2) set of semi-structured questionnaire were used to gather information about the socio-economic importance, source and processing, seasonality of the *A. digitata*, of *A. digitata* from ten (10) respondents and one (1) key informant (a farmer) was interviewed in each community to gather information on development, flowering and fruiting period of *A. digitata*, making a total of 330 respondents in all the savanna ecological zones. Global Positioning System (GPS) device was used to obtain the coordinates of the communities visited during the field work. Figure 1 shows the distribution of communities visited (red dots) in the three savanna ecological zones of Nigeria. The data were subsequently analyzed using descriptive statistics.

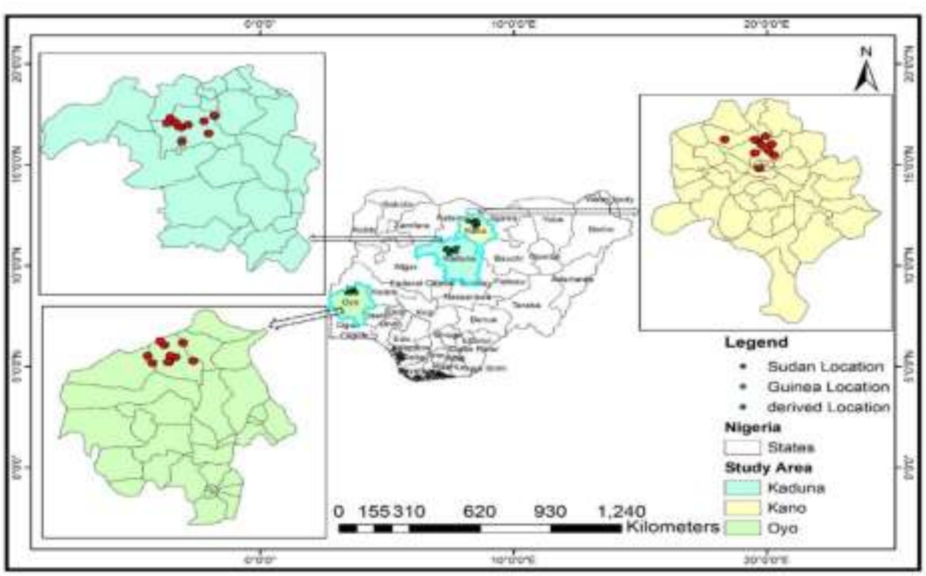

Figure 1: Map of the study area showing the sampled Communities in the savanna ecological zones

Data Analysis

Descriptive statistical method such as percentage and frequency was used to analyze and summarize the socio-demographic characteristics of the respondents across the three savanna ecological zones. Information was gathered on the species such as food security, ailment cured, and the economic benefits of the species, were analyzed using descriptive statistical analysis. QGIS software was used to produce the maps (Figure 1).

In order to determine the relative healing potential of *A. digitata* against a particular ailment, fidelity level was calculated using the formula employed by Houessou *et al.*, (2012). The formula is expresses as:

$$FL = \frac{S}{N} \times 100$$

Where,

S = The number of informants who had positive answer to the use of *A. digitata* for a given use category. It also represents the number of informants who had positive answer to the use of a particular plant part (leaves, fruits, bark, roots and seed) for a particular ailment treated.

N = Total number of informants.

RESULTS AND DISCUSSION

Socio-economic Characteristics of Respondents

The study covered a total of 30 communities and 330 respondents from the savanna ecological zones in the study area. Table 1 presents the socio-economic characteristics of the respondents. It shows that, 67% of the respondents were male and 33% were female in the derived savanna, 81% and 19% were male and female respectively in the Guinea Savanna, while in the Sudan Savanna, 75% and 25% were male and female respectively. Their age ranged between 41 and 60 years.

Table 1: Distribution of Respondents According to Socio-economic Characteristics

	Variants	Derived Savanna (n=100)		Guinea Savanna (n=100)		Sudan Savanna (n=100)	
		F	%	F	%	F	%
Age of Respondents	20-30 years	1	1	0	0	1	1
	31-40 years	22	22	24	24	27	27
	41-50 years	29	29	43	43	37	37
	51-60 years	43	43	27	27	31	37
	61-70 years	5	5	6	6	4	4
State of Origin	Oyo	100	100	0	0	0	0
	Kaduna	0	0	100	100	0	0
	Kano	0	0	0	0	94	94
	Kebbi	0	0	0	0	6	6
Gender of Household Head	Male	100	100	100	100	100	100
	Female	0	0	0	0	0	0
Marital Status	Single	0	0	0	0	0	0
	Married	100	100	100	100	100	100
	Widowed	0	0	0	0	0	0
Religion of Respondents	Christianity	34	34	0	0	0	0
	Islam	61	61	100	100	100	100
	Traditional	5	5	0	0	0	0
Highest Education Attained	No formal Education	0	0	5	5	29	29
	Primary Education	4	4	14	14	31	31

	Secondary Education	36	36	52	52	37	37
	Tertiary Education	60	60	29	29	3	3
Major Occupation	Farmer	27	27	22	22	45	45
	Employed	50	50	32	32	2.0	2.0
	Business	23	23	46	46	53	53

The results on the individual characteristics of the respondents showed that farmers have *A. digitata* on their farms are mostly males in all the savanna ecological zones (Derived, Guinea and Sudan savanna respectively). Reason being that males are more likely to have access to land for production of tree crops while the women participates mainly in the collection/harvesting, processing and marketing of NTFPs (Adekunle, 2009). They are married implying that these farmers have a sense of responsibility by engaging in the cultivation of this species to earn extra income for the welfare of their families (Afolabi, 2010). The age bracket of the respondents were between 41 and 60 years (Table 1). This age range is active and will thus ensure active labour force for the domestication of the species as confirmed with the findings of Bolanle-Ojo and Onyekwelu (2014), and their major occupation is farming, in both vegetation zones. The high percentage of middle aged (i.e. working-age adults) found in the two vegetation zones is an indication that they have high tendency to generate higher income from the sales of fruits, which is also similar to the view of Ajibefun *et. al*. (2006). Respondents with no formal education are higher in the Sudan savanna than in Derived and Guinea savanna respectively.

In Derived savanna, majority of the respondents have up to tertiary education (60%). The higher educational level of the respondents in the Derived savanna might have contributed to higher domestication level for the improvement on the production of *A. digitata* in the savanna ecological. The low educational status observed among the farming populace is supported by earlier studies such as Adams *et. al*. (2000) and Adhikari, *et. al*. (2004). Stoian (2005) opined that, education is one of the important human capitals, which plays important role in determining status in the society. Education is expected to contribute to people's ability to read and understand instructions and hence help them to adopt new technologies (Chigbu *et. al*., 2011). Prominent level of illiteracy in the savanna zone can lead to deforestation of the forest resources as it was noted by Adekunle *et. al*., (1999), which is the major threat factor of the species in the savanna ecosystem. Educational level may also affect future domestication of the forest fruit tree species, this is because it is easier to create awareness among educated people than among the non-educated (Bolanle-Ojo and Onyekwelu, 2014).

Habitat where *A. digitata* can be found in the Study Area

All the respondents (100%) in the three savanna ecological zones (Derived, Guinea and Sudan Savannas) were familiar with *A. digitata*, but have different local names for the species. In Derived savanna, *A. digitata* is known as "igi ose"; it is known as "kuka" in both Guinea and Sudan savanna. All the respondents (100%) in the three savanna ecological zones (Derived, Guinea and Sudan Savannas) claimed that *A. digitata* is an alternative source of food. The leaves of *A. digitata* was used to prepare soup which is known as "Miyar kuka" in Hausa and it is medicinal. The results obtained in this study shows that 100% of the respondents had *A. digitata* on their farmland in both Derived and Sudan savanna respectively, while majority of the respondents (98%) in Guinea savanna had *A. digitata* on their farmland (Figure 2). The result (Table 1) revealed that 0%, 5% and 29% of the respondents in Derived, Guinea and Sudan savanna respectively that owned *A. digitata* either on their farmlands or home gardens had no formal education. Education is known to have a positive effect on farmer's attitude which may lead to improvement in productivity (Okwu, *et al*., 2018).

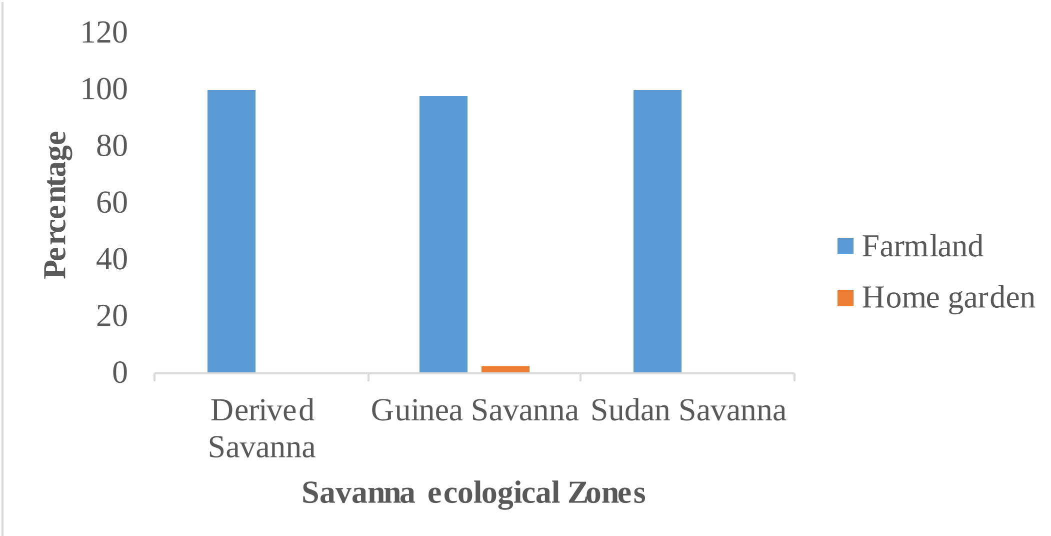

Figure 2: Habitat where *A. digitata* can be found in the Study Area

Farm Characteristics and Reasons for retaining of *A. digitata* trees in the Study Area
The result revealed that, relevant information that were obtained on a farm characteristics and practices managed on the farmer's field. All respondents (100%) in the three savanna ecological zones (Derived, Guinea and Sudan savanna respectively) had naturally regenerated trees of *A. digitata* on their farm land. There is no plantation of *A. digitata*, because the respondents were never involved in deliberate planting of *A. digitata*. Majority of the respondents in the savanna ecological zones claimed that *A. digitata* occurred naturally and multiplied. Respondents in Derived savanna claimed that *A. digitata* tree is demon- possessed coupled with other beliefs that were not shared which kept them away from deliberate planting of the species.

The number of *A. digitata* trees owned by respondents across the vegetation zones is presented in Figure 3. The number of *A. digitata* trees distributed in each of these farmer's farm ranged between 1 to 5. The highest number of trees owned by respondents across all the savanna ecological zones were 5 trees. In derived savanna, majority of the respondents (36.4%) had only one tree of *A. digitata*, 33.3% had two trees, 21.2% had three trees and 9.1% had five trees of *A. digitata*. In Guinea savanna, majority of the respondents (40%) had two and three trees of *A. digitata*, 8.6% had one and five trees and only 2.9% had four trees of *A. digitata*. In Sudan savanna, majority of the respondents (46.3%) had two trees of *A. digitata*, 23.2% had one and three trees, 6.3% had five trees, and only 1.1% had four trees.

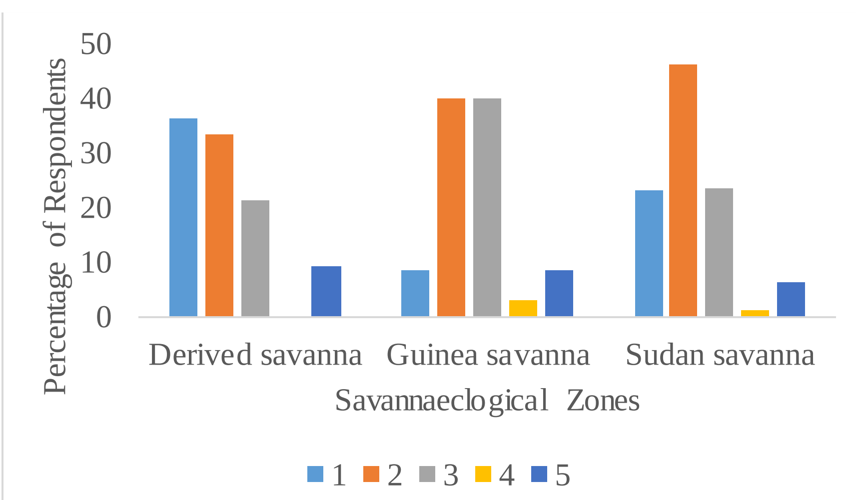

Figure 3: Number of *A. digitata* Trees owned by the Respondents in the study area.

Figure 4 shows the domestication strategy of *A. digitata* species in the three savanna ecological zones. For *A. digitata* in derived savanna, 29% of the respondents claimed to retained *A. digitata* species in their farmlands and home gardens while 71% of the respondents claimed not to retain *A. digitata* species in their farmlands and/or home gardens as a result of urbanization and medicinal purposes. In guinea savanna, 35% of the respondents claimed to retained *A. digitata* species in their farmlands and/or home gardens and 65% of the respondents did not. Also, in Sudan savanna, 94% of the respondents claimed to retained *A. digitata* species in their farmlands and/or home gardens and only 6% did not retained *A. digitata* species in their farmlands and/or home gardens. The result obtained in this study revealed that majority of the respondents (21%) in derived savanna, claimed to retained *A. digitata* species for only medicinal purpose for curing different ailments and solving problems traditionally, 2% retained *A. digitata* only income, 1% retained *A. digitata* for both income and medicine, 1% retained *A. digitata* for both income and food and 2% of the respondents retained *A. digitata* for both medicine and income purposes. In guinea savanna, majority of the respondents (21%) claimed to retained *A. digitata* species for both income and food respectively while 14% retained *A. digitata* for only income benefits. In Sudan savanna, majority of the respondents (70%) claimed to retained *A. digitata* species for only income purpose, 22% retained *A. digitata* species for both income and food, and only 2% retained *A. digitata* for both income and medicine (Figure 5).

The result showed that, *A. digitata* trees were found more on the farmlands in the three savanna ecological zones (Derived, Guinea and Sudan savanna). None of the respondents had been deliberately involved in planting of *A. digitata* trees. Dominant reasons by the respondents in the savanna ecological zones for not planting the trees was that *A. digitata* occurred naturally and multiplied. Respondents in derived savanna claimed that *A. digitata* tree is demon-possessed coupled with other beliefs that were not shared which kept them away from deliberate plating of the species.

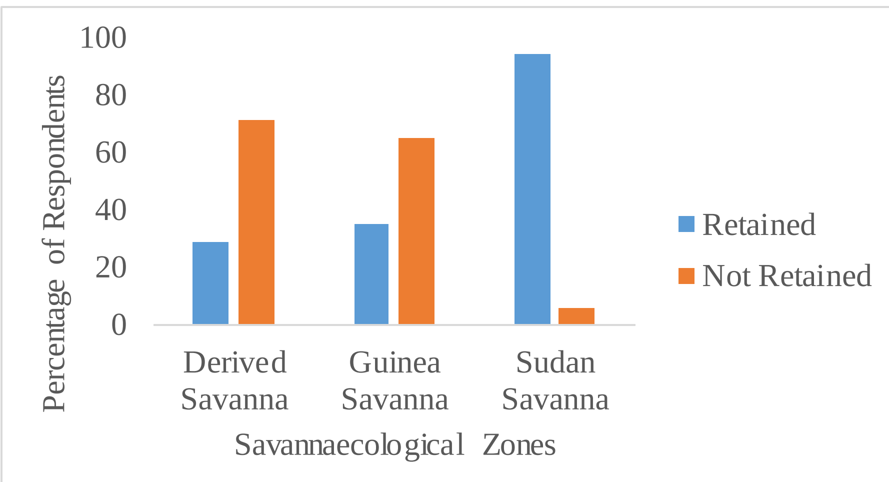

Figure 4: Domestication strategy of *A. digitata* trees

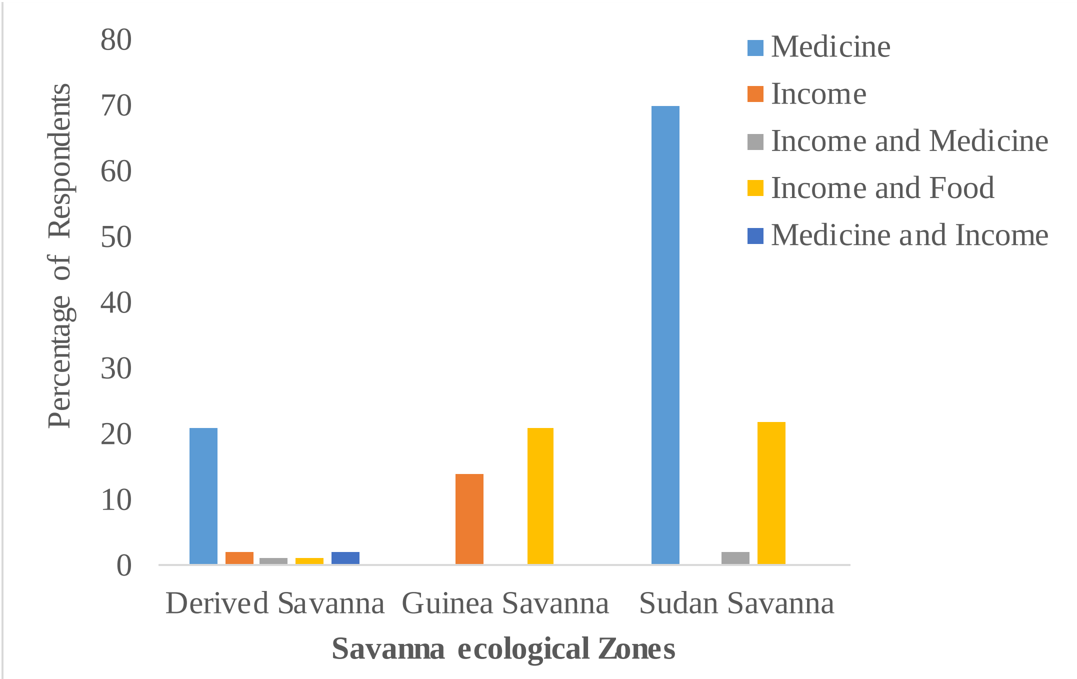

Figure 5: Reasons for retaining of *A. digitata* trees

In the savanna ecological zones (Derived, Guinea and Sudan savanna), all respondents (100%) claimed that the collection of *A. digitata* species (fruits and leaves) was by youth/children. Respondents in derived savanna do not process *A. digitata* species, though they claimed that adult women are involve in processing of *A. digitata*. All respondents in Guinea and Sudan savanna, all (100%) claimed that adult females are involved in the processing of *A. digitata*. The study also revealed the yield of *A. digitata* per annum (Figure 6). Majority of the respondents (87.9%) in derived savanna claimed that their trees yields <200 fruits per annum, and 12.1% claimed that their trees yields between 200 and 600 fruits per annum. In guinea savanna, majority of the respondents (71.4%) claimed that their trees yield <200 fruits per annum, 22.9% claimed their trees yields between 200-600 fruits per annum, and 5.7% claimed that their trees yield between 600-1000 fruits per annum. In Sudan savanna, majority of the respondent (75.8%) claimed that their trees yield <200 fruits per annum, whereas 24.2% claimed that their trees yields between 200-600 fruits per annum.

Income realized and Production/Yield of *A. digitata* in the Study Area

The annual income realized from the sales of *A. digitata* species by the respondents is presented in Figure 6. Majority of the respondents (36.8%) in Derived savanna realized between ₦10,000-₦20,000 as the annum income from the sales of *A. digitata* species, 36% realized between ₦5,000-₦10,000, 18.2% realized between ₦20,000-₦30,000 and 9% realized over ₦30,000 as the annum income from the sales of *A. digitata* species. In Guinea savanna, majority of the respondents (60%) realized between ₦10,000-₦20,000, 31.4% realized between ₦20,000-₦30,000 and 8.6% realized over ₦30,000 as the annum income from the sales of *A. digitata* species. In Sudan savanna, majority of the respondents (67.4%) realized ₦10,000-₦20,000, 3.2% realized between ₦5,000-₦10,000, 28.4% realized between ₦20,000-₦30,000 and 1% realized over ₦30,000 as the annum income from the sales of *A. digitata* species. The mean annual income realized from the sales of *A. digitata* species were ₦30,000, ₦34,857, and ₦32,737 for Derived, Guinea and Sudan savanna respectively.

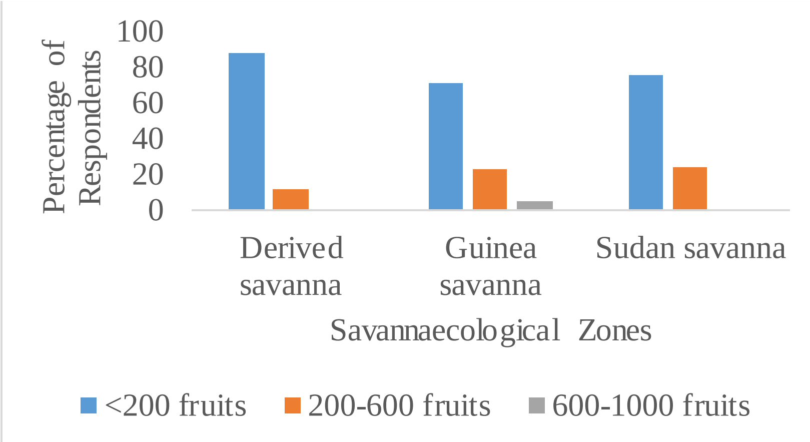

Figure 6: Yield of *A. digitata* Fruits Per Annum

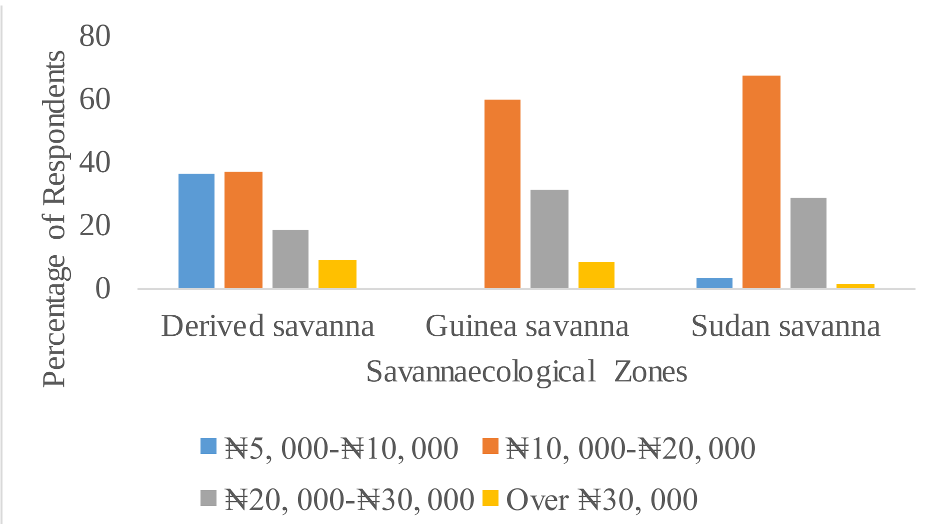

Figure 7: Annual income from the sales of *A. digitata* species

Figure 8 presents the income from the sales of *A. digitata* species during raining season. Majority of the respondents (42.4%) in Derived savanna realized <₦5,000, 36.4% realized between ₦5, 001-₦10,000, 9.1% realized ₦10, 001-₦20,000, 6.1% realized ₦20, 001-₦30,001 and 6% over ₦30,000. In Guinea savanna, majority of the respondents (57.1%) realized ₦5,001-₦10,000, 5.7% realized <₦5,000, 25.7% realized ₦10,001-₦20,000, 5.7% realized ₦20,001-₦30,000, and 5.8% realized over ₦30,000. In Sudan savanna, majority of the respondents (62.1%) realized ₦5,001-₦10,000, 21.1% realized <₦5,000, 16.8% realized ₦10,001-₦20,000. The mean of income from the sales of *A. digitata* species during raining season in all the savanna ecological zones were ₦19,697, ₦24,857, and ₦19,579 in Derived, Guinea and Sudan savanna respectively. Likewise, income from the sales of *A. digitata* species during dry season is presented in Figure 10. Majority of the respondents (45.5%) in Derived savanna realized ₦10,001-₦20,000, 36.4% realized ₦5, 001-₦10,000, 15.1% realized ₦20,001-₦30,000 and 3% realized over ₦30,000. In Guinea savanna, majority of the respondents (60%) realized ₦10,001-₦20,000, 5.7% realized ₦5,001-₦10,000, and 34.3% realized ₦20,001-₦30,000. In Sudan savanna, majority of the respondents (62.1%) realized ₦10,001-₦20,000, 10.5% realized ₦5,001-₦10,000, 26.3% realized ₦20,001-₦30,000, and 1% realized over ₦30,000. The mean of income from the sales of *A. digitata* species during dry season in all the savanna ecological zones were ₦28,485, ₦32,857 and ₦31,789 in Derived, Guinea and Sudan savanna respectively.

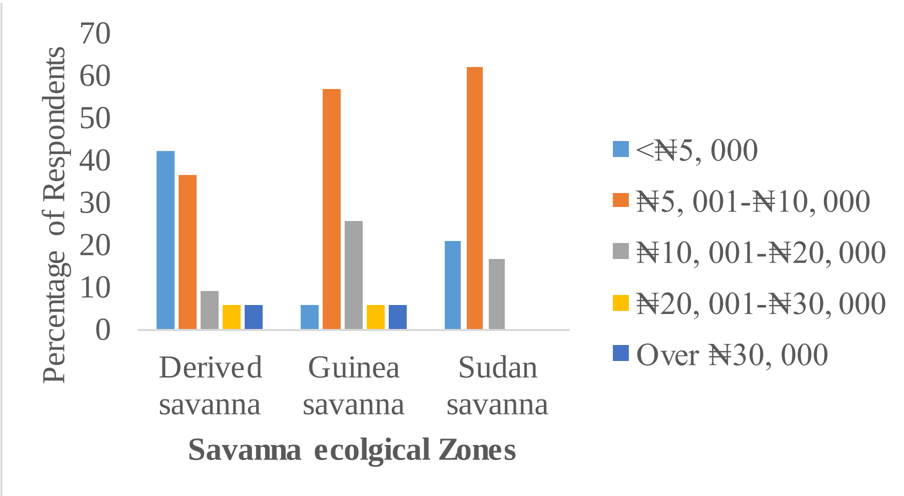

Figure 8: Income from the Sales of *A. digitata* Species During Raining Season

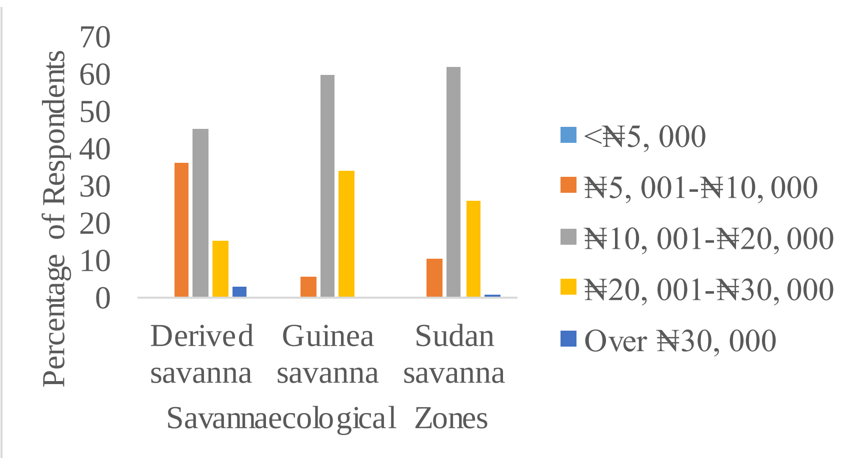

Figure 9: Income from the Sales of *A. digitata* Species During Dry Season

From the results, 100% of respondents in the three savanna ecological zones were aware that *A. digitata* has a high economic importance; majority of the respondents (53%) in Derived savanna claimed to use *A. digitata* solely as medicine, 34% use *A. digitata* as medicine and food, 8% use *A. digitata* as medicine, food and juice while 5% of the respondents use *A. digitata* as medicine, food and rope for animals. In Guinea savanna, majority of the respondents (86%) use *A. digitata* as medicine and food, 12% use *A. digitata* as medicine, food and drink while 2% use *A.digitata* as medicine, food, and rope for animals. Whereas in the sudan savanna, majority of the respondents (86%) use *A. digitata* as medicine and food, 10% use *A. digitata* as medicine, food, and drink while 4% use *A. digitata* as medicine, food and rope for animals (Figure 10). Table 2 shows different ailment cured by *A. digitata* parts. The results also captured the different flowering and fruiting period of *A. digitata* trees. All respondents (100%) in Derived savanna claimed that the flowering season was in the September. In Guinea and Sudan savanna, majority respondents (80% and 50%) claimed that the flowering season was in the month of August/September, while 20% and 50% of the respondents claimed that it's in the month of September (Figure 11).

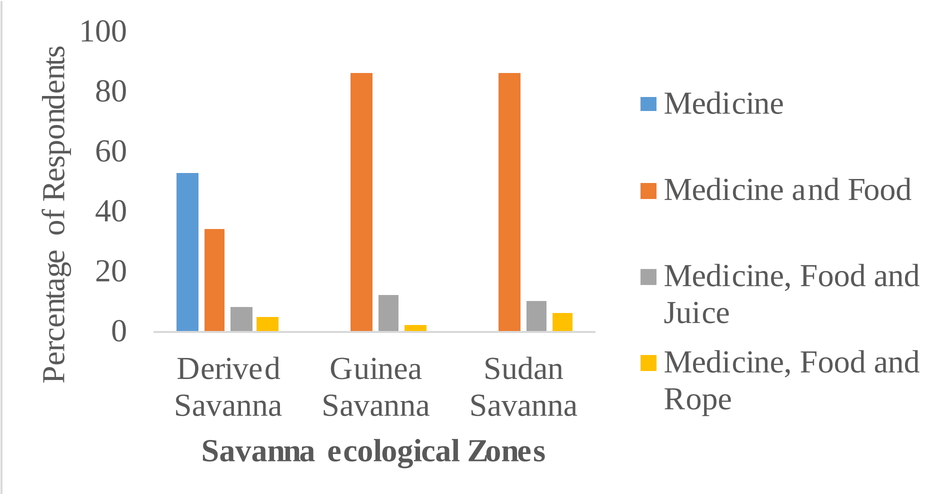

Figure 10: Respondents uses of *A. digitata*

All respondents (100%) in the savanna ecological zones (Derived, Guinea and Sudan savanna) claimed that *A. digitata* species produces fruits only once in a year. Majority of the respondents (90%) in Derived savanna claimed that the fruit set out in the month of October and only 10% of the respondents claimed the fruits set out between the months of October and November. In Guinea savanna, majority of the respondents (70%) claimed that *A. digitata* fruits set out between months October and November, while 30% of the respondents claimed the fruits set out in the month of October. In Sudan savanna, all respondents (100%) claimed that the fruits of *A, digitata* set out between the months of October and November (Figure 11). Majority of the respondents (90%) in Derived savanna claimed that the fruits matures in the month of March, only 10% of the respondents claimed the fruits matures in the month of April. In Guinea savanna, majority of the respondents (90%) in Derived savanna claimed that the fruits mature in the month of April, only 10% of the respondents claimed the fruits matures in the month of March. But in Sudan savanna, all of the respondents (100%) claimed that the fruits of *A. digitata* matures in the month of April (Figure 12).

Table 2: *A. digitata* Parts and Ailment Cured

Plant Parts	Names of Diseases/Ailments
	Malaria
	Dysentary
	Urinary Problem
Leaves	Insect Bites
	Blood Cleansing
	Kidney
	Asthma
	Fever
Back	Antidote for poison
	Dysentery
	Smallpox
Pulp	Measles
	Diabetes
	Antidote for poison
	Antidote for poison
	Diarrhea
Seed	Fever
	Cough
	Dysentery

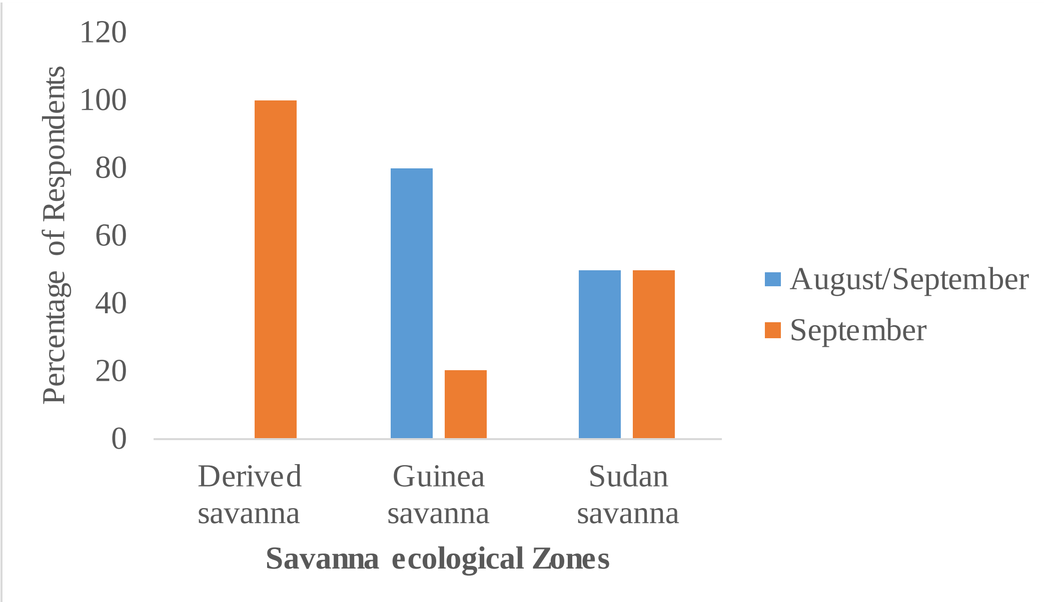

Figure 12: Flowering Season of *A. digitata*

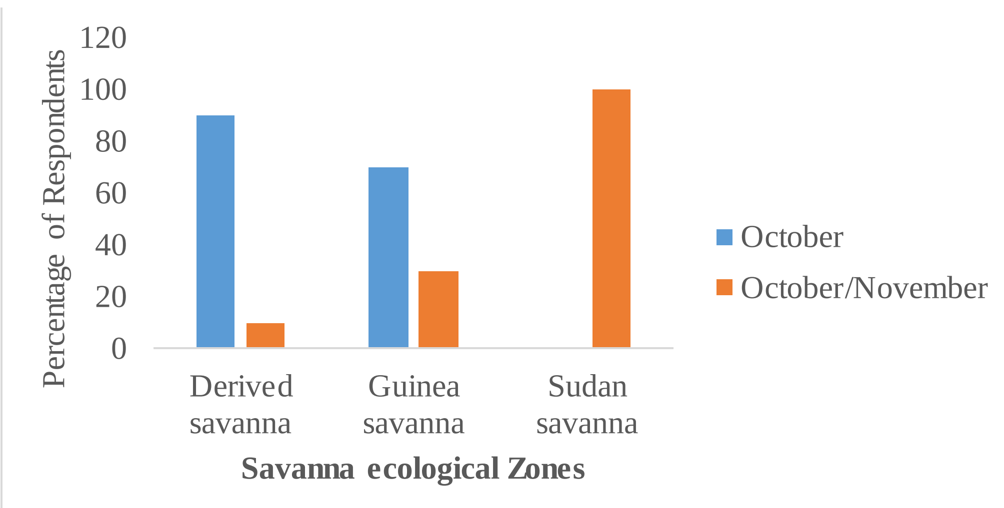

Figure 13: Fruit Setting of *A. digitata* in the study area

Use Forms of *A. digitata*

This study highlights the multipurpose uses of *A. digitata* in the study area. Interviews emphasize the high importance of both *A. digitata* for local people. This is consistent with other studies that have shown that the baobab is one of the most important species for rural communities in West Africa (Kristensen and Lykke, 2003; Gustad *et. al.*, 2004; Assogbadjo *et. al.*, 2008; De Caluwe´ *et. al.*, 2009; Buchmann *et. al.*, 2010). All different parts of the baobab and sheabutter are used for several use categories. The use categories of *A. digitata* in the study area were food, income and medicine (Figure 9). Medicine and income emerged as most dominant use categories among the respondents in all the savanna ecological zones (Derived, Guinea and Sudan savanna). In the past decade, it has attracted the interest of several pharmaceutical companies and researchers due to various medicinal, nutritional and cosmetic properties of *A. digitata*. Fruits, seeds, leaves and bark contribute to the livelihood of many tribal populations in Africa as it is a source of food, fibre and medicine (Codjia *et. al.*, 2001; Sidibe and Williams, 2002; Chadare *et. al.*, 2009; De Caluwe *et. al.*, 2009). More than three hundred traditional uses of *A. digitata* have been collectively documented in Benin, Mali, Zimbabwe, Cameroon, the Central African Republic, Kenya, Malawi, South Africa and Senegal (Buchmann *et. al.*, 2010).

The variety of medicinal uses was greater than that of food uses. Nevertheless, use-diversity values demonstrated that baobab plays a more important role for nutritional than for medicinal uses. This is in concordance with the results of Buchmann *et. al.,* (2010) for several West African countries that also showed that the use of baobab products as nutrition was significantly more often cited than other uses and that baobab fruits carry the greatest variety of uses. Especially the use of baobab leaves and seeds for sauce and the uses of the fruit pulp for beverages and porridge are of great importance. In the traditional use of various parts of the Baobab plant in the prevention and cure of ailments such as measles, small pox, dysentery, diarrhea, and in the management of the sickle cell anemia has been reported (Ramadan *et al*., 1993; Tal-Dia *et al*., 1997), as showed in this study (Table 2). All respondents (100%) in Derived savanna claimed *A. digitata* fruits was not locally eaten. In Guinea and Sudan savanna, 100% of the respondents claimed that *A. digitata* fruits was eaten locally. The result showed all the respondents (100%) in the savanna ecological zones (Derived, Guinea and Sudan savanna) claimed that the harvesting method of *A. digitata* fruits and/or leaves was by climbing the tree with sticks, sometimes handpicking when the fruit falls down.

Fidelity level of *A. digitata* Parts Used in Treatment of Ailments

The fidelity level of *A. digitata* parts used in treatment of ailments in the three savanna ecological zones (Derived, Guinea and Sudan savanna) was calculated and presented in Table 3. Different *A. digitata* plant parts were used in folk medicine. Result showed that, leaf of the species was the most used part by the informants in the savanna ecological zones (Derived, Guinea and Sudan savanna) for ailments treatment (FL= 95%, 85% and 78% respectively), followed by the seed (Derived savanna, FL= 76%, bark (Guinea savanna, FL=66%), pulp (Sudan savanna; FL=24%), and then the pulp (Derived savanna, FL=75%), pulp (Guinea savanna, FL= 65%), bark (Sudan savanna, FL=15%), lastly, the bark (Derived savanna, FL=67%), seed (Guinea savanna and Sudan savanna; FL=40%, FL=1%).

Table 3: Fidelity level of *A. digitata* Parts Used in Treatment of Ailments

		Derived Savanna			Guinea Savanna			Sudan savanna		
Disease Treated	**Plant Parts**	**S**	**N**	**FL (%)**	**S**	**N**	**FL (%)**	**S**	**N**	**FL (%)**
Malaria	Leaves	95	100	95	85	100	85	78	100	78
Dysentery	Leaves	72	100	72	73	100	73	28	100	28
Urinary Problem	Leaves	40	100	40	39	100	39	12	100	12
Insect Bites	Leaves	0	100	0	13	100	13	14	100	14
Blood Clearing	Leaves	57	100	57	47	100	47	11	100	11
Kidney	Leaves	63	100	63	45	100	45	8	100	8
Asthma	Leaves	42	100	42	60	100	60	17	100	17
Fever	Back	67	100	67	66	100	66	25	100	15
Antidote for poison	Back	30	100	30	49	100	49	14	100	14
Dysentery	Pulp	43	100	43	30	100	30	23	100	23
Smallpox	Pulp	75	100	75	39	100	39	18	100	18
Measles	Pulp	80	100	80	62	100	62	16	100	16
Diabetes	Pulp	65	100	65	65	100	65	24	100	24
Antidote for poison	Pulp	39	100	39	48	100	48	4	100	4
Antidote for poison	Seed	76	100	76	40	100	40	5	100	5
Diarrhea	Seed	52	100	52	56	100	56	10	100	10
Fever	Seed	60	100	60	55	100	55	13	100	13
Cough	Seed	70	100	70	43	100	43	9	100	9
Dysentery	Seed	55	100	55	50	100	50	1	100	1

The leaf has the highest level of utilization among respondents. The leaves are a staple food source in some parts of the African continent while the flowers are consumed raw (Obizoba and Anyika, 1994; Nordeide *et al*., 1996; Delisle *et al*., 1997). In some parts of Sudan, the Baobab seeds were pounded and included in local dishes (Dirar, 1993). All the respondents in the study area claimed to use *A. digitata* in preparing a sauce called "luru" or "miyan kuka" in the local language of Guinea and Sudan savanna. The sauce produced from baobab leaves accompanies millet gruel for daily consumption. Baobab leaves are a significant protein and mineral source, especially of calcium, iron, and magnesium (Yazzie *et. al*., 1994). In addition, leaves are also used as anti-asthmatic, and are known to have antihistamine properties. Leaves are further reported to treat kidney and bladder diseases, general fatigue, diarrhoea, inflammations, insect bites and guinea worm (Wickens, 1982; Burkill, 1985), which is consistent with the findings of this study. From the result, the bark and root are put into two uses namely medicinal and rope making. This is in agreement with Igboeli *et al*., (1997) findings. The medicinal use is carried out by making the bark and root into concoction which is used to birth baby with small body size at birth in order to accelerate weight gain. Furthermore, it was revealed that to make the concoction effective the pot used for preparation must not be put directly on the floor. *A. digitata* seeds are used to cure ailment such as diarrhea, which is consistent with the findings of Burkill (1995), that reported that seeds of *A. digitata* are used in cases of diarrhea and hiccoughs.

CONCLUSION AND RECOMMENDATION

Farmer's perception and socio- economic importance of *A. digitata* is revealed in this study. Baobab trees in the study area has not been well explored, as the level of usage was low. This fruit tree has proven to possess socio-economic values which will boost income especially for women and youth; and further serves as safety net particularly during shortfall in agricultural production and reduce malnutrition in children. Also, while the baobab trees occur in sizeable population within the community, the regeneration potential of the plant was a major concern. Climbing and pruning of the branches, debarking and root digging of baobab trees may negatively impact the plant in the long run. So, awareness should be further created on the various uses and benefits of the baobab plant through the various agricultural extension agencies in Nigeria;

It is recommended that artificial regeneration of *A. digitata* should be encouraged by giving farmers free seeds and seedlings. The community should be educated on the other uses of baobab as found in other places to increase the potentials of the plant. The people should also be enlightened on simple silvicultural activities that could be carried out in the management of the plant. Therefore, establishing a participatory domestication programme for this species in addition with some priority indigenous forest fruit trees in the study area will go a long way in promoting the benefits of this species which could significantly contribute in the sustenance of livelihood and income generation by small scale farmers especially in the rural areas in Nigeria.

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Utilization Pattern and the Export Potential of Bamboo in Nigeria

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Abstract

Forest resources are experiencing increasing pressure due to the growing population and improving living standard. Bamboo is a viable, indispensable forest product in the forest ecosystem in the world today, seen as a good alternative to wood, as it provides livelihood opportunities to millions in the rural industries. The paper reviewed the abundance of Nigeria bamboo resources used for construction of houses, handicraft, pulp and paper, bio base energy, ornamental benefits, employment opportunities, eco-tourism and its role in biodiversity conservation. The challenges facing the development of bamboo industries due to continuous neglect by the government to tap into this potential value chain and its role as asubstitute to wood in major application towards diversification and tapping into the socio- economic and environmental benefits of bamboo production are discussed. The paper explores the export potentials and benefits of bamboo to the Nigerian economy and makes appropriate recommendations. These recommendations will be very useful to a large section of stakeholders, policy makers, funding agencies and other organizations embarking on bamboo utilization and export.

Keywords: : Forest, Bamboo, Utilization, Industries and Export

INTRODUCTION

Forest is a land area of more than 0.5ha, with a tree canopy cover of more than 10% which is not primary under agricultural or other specific non forest land use (FAO, 2010). The forest today is experiencing increasing pressure due to the rapid development of the global economy, growing population and improving living standard which makes the overall demand for wood and wood based composite on the increase. The forest is depleting fast with the shortage of timber resources making bamboo an alternative. Bamboo is a perennial woody grass plant of subfamily Bambusoideae with the grass family (Poaceae), formally called Gramineae (Clark *et al*, 2015). Its morphological features include rhizomes, roots, culms, branches, leaves and flowers. Some example of bamboo genera are Bambusa, Dendrocalamus, Oxytenanthera, Phyllostachys, Gigantochloa, Schizostachyum etc. Bamboo is a viable, indispensable and fast growing forest product in the forest ecosystem in the world today and is seen as a good alternative to wood, because it is inexpensive, fast growing, easily available, a high renewable resource and having comparable physical and mechanical properties to that of wood. Its growth depends on species but generally they all mature quickly. The fast growth characteristic of bamboo is an important incentive for its utilization. It can reach a maximum height in 4 to 6 months with a daily increment of 15 to 18cm. It might have 40 to 50 stems in one clump which adds 10 to 20 culms yearly (Aminudin *et al*, 1991). It takes 3 to 6 years to mature which makes bamboo more rapid than any other plant. Bamboos are found in diverse climates from cold mountains to hot tropical regions. They are found across East Asia from 50^0N latitude in Sakhalin in Russia through to Northern Australia, and to India and the Himalayas. About

65% of bamboo grown area is dominated in Asia (Paridah, 2013). Bamboo is also found in sub-Saharan Africa, and in the Americas from the Mid-Atlantic United States, south to Argentina and Chile (Gratania *et al*, 2008).

Bamboo Regions in Nigeria

Raw Materials Research Development Council (RMRDC, 2004) reported that bamboo is widely distributed in the South and Middle belt region of Nigeria. According to the report, distribution of bamboo is related to ecological conditions with the rainforest area having the most abundant. Bamboo is found abundant in all the states of southern Nigeria except Lagos and Bayelsa where the distribution is considered relatively less. The most endowed States in Nigeria where bamboo occurrences are observed are Ogun, Oyo, Osun, Ondo, Edo, Delta, Rivers, Akwa Ibom, Cross River, Abia, Ebonyi, Enugu, Anambra and Imo. The report indicates that 10% of the natural vegetation in these states is dominated by bamboo. In Lagos, Ekiti, Bayelsa, Kogi, Kwara, Benue, and Nasarawa state, bamboo distribution were observed to be frequent; indicating that between 6.0 to 9.0% of the natural vegetation was occupied by bamboo. Pocket of bamboo clumps were also reported in Niger, Taraba and Plateau state as well as within the Federal Capital Territory. According to Ogunwusi, (2011), there are 12 states where bamboo are rare. There are Adamawa, Bauchi, Borno, Gombe, kano, Kaduna, kastina, Kebbi, Sokoto, Jigawa, Yobo, and Zamfara. From all indications, the distribution pattern of bamboo is particularly tailored to the rain forest belt where it is found inabundances due to high annual rainfall and length of rainy season.

BAMBOO UTILIZATION IN NIGERIA

Building Material: Bamboo is an indispensable building material used worldwide. It is very strong with high tensile comprehensive strength and because of its flexibility, houses built with bamboo can withstand high wind without falling, and apart from this bamboo housing is usually well ventilated which is a benefit for the tropical climate (Janssen, 2011). The bamboo culms are commonly used for scaffolding in the construction of storey buildings. Its culms are used as pillars to provide temporary support for decking. It is used as structural members such as trusses, king post and purlin in modern houses etc. The use of bamboo for these purposes has opened up domestic trade for bamboo culms industries.

Stakes: Bamboo stakes are cheap, light weight, easy to transport and install. In all states in the south-east and south-south, bamboo culms are preferred by farmers as yam stakes. It is very common to see farm lands in these zones having sticks of bamboo as stakes especially for the use of yam ban. Farmers claimed that the choice of bamboo for this purpose is due to availability and durability.

Environmental Amelioration: Bamboo plays paramount roles in the environment as its root has great potential for soil stabilization and control of run-off as it makes water barrier. The plants clumps cast dense shade and produce large quantities of litters which conserve the soil moisture and protect the watershed. The cultivation of bamboo helps in the reclamation of lands that have been degraded by small and medium gullies. In developed climes like India, bamboos are grown in steep hillsides and along river banks. Its interlocking root system and leaf deposit inhibit soil erosion (Pande *et al*., 2015). Where bamboo exists, the network of underground interlocking rhizomes keep saturated topsoil in place. The abundance litter of bamboo on steep hillsides and river bank also serves as sieve for filtration or surface runoff, thereby reducing contamination of stream. Bamboo development reduces pollution; it reduces up to 35% carbon dioxide in the climate and delivers more oxygen (Anon., 2015).

Handicrafts: Bamboo in Nigeria is also used in the handicraft industry. The kind ofhandicrafts involves engraving on the outer part of the culms to make special items such as caps, cups and mat. Other bamboo crafts are weaving, carving and bolt-chisel and bamboo furniture etc. Bamboo craft manufactured products include blinds, birdcages, chopsticks, lampshades and lighting, swords tea trays and toothpicks.

Bamboo Pulp and Paper: Bamboo has a high cellulose (40 - 60%) and low hemicelluloses content, and the fibres are strong long (2.0 - 3.0mm) have a high length to width ratio and thick walls which are beneficial for paper making while bamboo culms are excellent raw materials for processing different kinds of paper (INBAR, 2016). Paper made from bamboo has the same qualities with paper made from wood. Its brightness and optical properties remain stable while those paper made from wood may deteriorate over time. (Ogbanje, 2013) Most bamboo pulp is used in the internal Chinese market while less than 100 tonnes per year is exported worldwide.

Bamboo bio-based energy: Biomass based energy are derived from sources of plant origin such as trees, grasses, agricultural crops and their derivatives as well as animals, waste from food processing, aquatic plants and algae (Duku *et al* 2011). There are several ways to recover energy from bamboo biomass, each process result in different product, which can be utilized in many aspects. Energy production from bamboo biomass is generated through thermochemical or biochemical conversion to produce different energy products like charcoal, syngas, and biofuel, which can be substitution for existing fossil fuel products. These products are utilized in industries and home on daily bases. (An Ha Truong, 2014).

Employment: Bamboo is considered as one of the most sustainable, versatile and manageable plant that provide high yield, for its plethora and potentials. It also helps in generating employment opportunities as means of rural development in the agricultural sector as way of diversifying the economy by contributing meaningfully in the areas of farming, manufacturing industries (pulp and paper making, panels and boards). Handicraft, bucket, ladder, mats, container, tool handles, musical instruments, boats, fishing poles and other articles by local artisans), and in low cost residential housing construction.

Ornamental plants: Bamboo is also suited for production as an ornamental nursery crop for wholesale and retail sale. In landscaping, as potted or balled- and bur lapped. It can be marketed wholesale to garden centres, nurseries and landscape contractors. Bamboo plants are also sold for retail prices at local farmers markets (Tim, 2013).

Eco-tourism: Bamboo resorts are becoming popular in many countries. Bamboo environments are unique environment rarely encountered by most people and many bamboo ecotourism locations include well-tended bamboo species collection. These resorts are also avenue for employment (INBAR, 2017).

Bamboo's role in biodiversity conservation: Bamboo has largely replaced some plant species which were formerly used as raw materials and this have led to the conservation of several plant species that would have been harvested and processed into various wood products. In Costa Rica, one thousand houses of bamboo are built annually with materials obtained from 60 hectares bamboo plantation. If an equivalent project used timber, it would require 500 hectares of diminishing tropical forest. Consequently, using bamboo to replace timber saves the rainforest. With a 10 to 30% annual increase in biomass compared to 2 to 5% for trees, bamboo creates greater yield of raw materials for use (Ogunwusi, 2011).

Export Potential of Bamboo: Bamboo is recognised as an industrial raw material globally and has tremendous potential for the economic development of a nation (Ladapo *et al,* 2017). Bamboo forest covers an estimated area of 37 million hectares (ha) worldwide, equivalent to almost 4% of the world's total forest cover (FAO, 2014). Due to the growing world population, and improved standard of living, forest resources are under fast depletion and bamboo species are seen as good alternatives to wood products owing to their good qualities in physical and mechanical properties. The export trade in bamboo industry has made giant strides and advantages to low income rural communities with little access to investment capital or technology and alleviate poverty (Phimmachanah *et al*, 2015). The International Network for Bamboo and Rattan (INBAR) Trade database Annual report on bamboo in 2000 was valued at about US$2.5 with China, Indonesia and Vietnam shown to be the major bamboo producers and exporters in Asia. In China, it is valuable raw material for the booming bamboo industry (FAO, 2005). The world market for bamboo was valued at 10 billion dollars in 2001 and grew to 29 billion dollars in 2015 (Panda *et al*, 2015). India, China and Myanmar together have 80% of the world bamboo. MCI (2013) reported China as the largest exporter of bamboo globally in 2009 with 57.3% as shown in the table.

Top 10 Exporters of Bamboo Globally in 2009

Countries	Volume of Global Export (%)
China	57.3
Indonesia	14.8

Vietnam	4.6
Eur-27	3.0
Usa	1.7
Philippines	1.6
Thailand	1.0
Singapore	1.0
Myanmar	0.8
Malaysia	0.8

Source: Millennium cities Initiatives (MCI, 2013).

*Nigeria is not among the top 10 countries exporting bamboo considering our rich vegetation.

CHALLENGES FACING THE UTILIZATION OF BAMBOO IN NIGERIA

Bamboo plants grow rapidly and have the ability to propagate easily. It has been keenly observed that Asia countries and some developed climes make use of bamboo very well which contributes to their GDP while the opposite is the case with Nigeria. Many problems have been outlined as constraining bamboo development and impeding its potential to generate income and alleviate poverty in Nigeria. These challenges include lack of public awareness in the use of bamboo as modern technology, unavailability of technical experts for processing bamboo for use, lack of facilities for processing bamboo for domestic and industrial work, the absence of a national policy and strategy programmes to develop, and government attitude towards the use of bamboo in Nigeria.

- **Unavailability of Technical Experts for Processing Bamboo:** It is a fact that due to lack of bamboo research institutes in Nigeria and nonchalant attitude of the government towards the use of bamboo, the technical experts for processing bamboo for use in modern buildings and furniture are lacking. Most sawmills and wood industries in Nigeria do not have the technical staff for processing bamboo.
- **Government attitude towards Bamboo as a Forest Product:** The government seems to have neglected its priority attitude towards bamboo as a forest product when compared to wood products while some developed climes like China rely much on bamboo which has boasted their economy very well due to revenue generated yearly from it. Furthermore, it was revealed that Nigeria is a member of International Network for Bamboo and Rattan but has never exported bamboo nor uses it effectively. The reason why Nigeria is not among the countries exporting bamboo is because of government negligence and neglects towards bamboo as a forest product. It is not surprising because Nigeria has no bamboo research institute and there is no bamboo plantation. It is also good to embrace bamboo instead of relying completely on wood. When bamboo is embraced it will serve as a substitute for wood since wood is used for everything in Nigeria. For instance, building construction, furniture, charcoal and so on and it will boost the country economically just as China.

CONCLUSION AND RECOMMENDATIONS

The tropical forest estates are enormously vital in the conservation of the biological forest resources. As a raw material, bamboo is being accepted globally as a precursor to its multi-purpose application as an alternative to wood products in rural industries in Nigeria. At present, the establishment of bamboo plantations is not a popular practice largely due to its under-utilized, under-developed and untapped potentials. The low level of awareness of bamboo in rural and urban communities as an important plant species in the production of finishing products like ply bamboo, flooring, and wall tiles is also a limiting factor. In order to be able to achieve this fully as an effective mechanism, there would be need for quick awareness, dissemination of information on the potentials of this plant species with adequate government funding through institution and formulation of adequate policy measures and strategy programmes in attempt for bamboo to become one of the most important raw materials in Nigeria.

In an attempt to upgrade and upscale the bamboo industry and tap into these lucrative green economies, strategic synergies are needed for its rapid industrial utilization and processing in the country. For this to be feasible, the following recommendations have to be attended to:

1. There is a need for a national bamboo policy schemes. The policy schemes should spell out the targeted objectives of bamboo development and provide detailed guidelines for the policy implementation.
2. Establishment of bamboo inventory: Since there's a distribution pattern tailored to the rain forest belts, it is imperative that quality of bamboo that currently exists in this part of Nigeria, due to the species stocks in the wild, could help fill the information gap needs before the country can develop a plan for bamboo development. Many studies show the lack of reliable data on Nigeria's bamboo.
3. Establishment of bamboo plantations: there is need for adequate development ofplantation of bamboo and introduction of exotic species to complement locally available ones. This will expand industrial utilization potentials of bamboo locally.

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SUB-THEME 7

Sustainable Development of Value-Addition of Wood Products in Nigeria

Fibre Characteristics of *Manihot esculenta* (TMS 1202 and TME 419 Varieties) and *Manihot utilissima* (T-MU Variety) for Pulp and Paper Production in Makurdi, Nigeria

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Abstract

The study investigated the fibre characteristics of improved varieties of Manihot esculenta (TMS 1202 and TME 419) and Manihot utillisima (T-MU), as potentials for pulp and paper production. Stem varieties of Manihot spp. were collected from Federal University of Agriculture and Benue Agricultural and Rural Development Authority (BNARDA) in Makurdi. The representative samples were chipped, dried and introduced into washed bottles containing equal volume (1:1) of glacial acetic acid and 30 % hydrogen peroxide for maceration. Fibre length, fibre diameter, lumen width and cell wall thickness were measured on a Zeiss light microscope (Standard 25) under 80× while derived indices were calculated and compared. Data were analyzed using one-way analysis of variance. The experimental design employed was Completely Randomized Design. The result showed that fibre length, fibre diameter, lumen width and cell wall thickness of the cassava samples were not significantly different from each other (p>0.05). Fibre lengths were all short ranging from (0.64 - 0.68 mm) for Manihot utillsima and (0.64 - 0.68 mm) and 0.49-0.58 mm for the two varieties of Manihot esculenta. Results also showed that derived indices ranged from 0.72 - 0.80 (Runkel ratio); 56.40 - 59.33 % (elasticity coefficient); 20.44 - 21.84 % (rigidity coefficient); 13.09 - 16.59 % (F-ratio); 0.48 - 0.52 (Luce's shape factor); 148.71 - 206.80 (solid factor) and 26.43 - 32.76 (felting rate). In conclusion, although the varieties of Manihot spp. in this study are suitable for pulp and papermaking, they must be blended with long fibre plant species to produce quality paper because of their short fibres.

Keywords: Fibre, Fibre length, Runkel ratio, Pulp, Paper

INTRODUCTION

Fiber characteristics are the determinant factor for any material suitable for paper production. The increasing demands for paper have increased the need for non-wood pulp as a low-cost raw material for papermaking (Ekhuemelo and Udor, 2016). This has also led to the development of alternative pulping technologies that are environmentally friendly (Ekhuemelo and Tor, 2013). Bio-fibers from agricultural residues are generally distributed, cheap, recyclable, resourceful, and are a biodegradable source of renewable lignocelluloses biomass (McKendry 2002). Most of the residues in common use are annual plants that develop their full fiber potential in one growing season (Ashori, 2006). Such crops include wheat straw, cassava and reed among others. Even waste grass clippings function as an important fiber resource in countries such as China, where there is an extreme shortage of wood (Nemli *et al.*, 2009). In fact, the rapid growth of wood-based manufacturing over the past decades combined with a concomitant global decline in forest resources has driven researchers worldwide to investigate a range of potential alternative raw materials such as non-wood biomass (Akgula and Camibel, 2008).

Tree species that are important for the production of pulp and paper are endangered as a result of the high rate of deforestation and the increasing need of their wood product for other uses. The vast species used as raw material for pulp and paper making are the long fibre exotic softwood such as Gmelina, Pines and Eucalyptus. Lintu, (1991) opined that the high consumption rate of paper has twisted from develop countries in terms of meeting the requirements of paper demand at the end of 21st century. Therefore the increase in paper demand calls for screening of other species as possible alternatives for pulp and paper production (Ogunjobi *et al*., 2013). Paper making process for long has mainly used wood from tree stems that are cut, debarked, chipped and pulped. It is interesting to note that some environment advocates have proposed the use of non-wood fibers in paper making as a way to preserve natural forests. Both wood and non-wood resources are currently exploited for the manufacturing of pulp, paper and soft boards. However, the major source of pulp which meets more than 80 % demand is still wood from forests. Researchers all over the world in the last two decades have been involved in intensive research for the alternative sources of pulp for paper industry (McClosekey, 1995).

The importance of pulp and paper production in modern civilization cannot be overemphasized. Paper making has reached a level of an incredible significance in both developed and developing countries like Nigeria (Onilude, 2011). According to (Hunter, 2001) paper was first manufactured from non woody plants and the current use of non-wood for pulp is included in the grades of papers such as printing, newsprint, linear board and tissues. As a result of these, almost 95% of paper is made from wood while the remainder consists of fibrous materials such flax, rags among others. Cassava is a basic staple food vital for the livelihood of up to 500 million farmers and countless processors and traders around the world (Plucknett *et al*., 2000). The plant is very robust, resistant to drought and cassava production does not require high inputs. Cassava originated in South America where it was domesticated 2,000-4,000 years B.C. and was introduced into African in the 16th century by the Portuguese (Fauquet and Fargette, 1990). In the 18th century it was introduced to the east coast of African and the Indian Ocean Islands of Zanzibar and Madagascar. Nigeria is the world's leading manufacturer of cassava followed by other producer countries such as Brazil, Zaire, Thailand, Indonesia, China, Malawi, Togo and Tanzania. The total world cassava production in the year 2002 was 184, 852, 540 metric tons, with 100, 689, 149 metric tons being produced in African alone (FAO, 2004). In view of this, several attempts have been made in recent years to develop paper from agricultural wastes. Paper is one of the most fundamental things that are widely used by many people across the globe. The world consumption of paper has grown four hundred percent in the last forty years. Nearly four million trees or thirty-five percent of the total trees fell around the world are used by paper industries on every continent (Ekhuemelo and Tor, 2013).

The search for alternative fibre producing plant material has been initiated in many countries of the world. The generation of fast growing high biomass yielding plant is thought to be one of the solutions to meet the shortage of cellulosic material. However, certain agricultural plants producing higher biomass are found to be suitable substitute for certain fibre based industries (Fahmy, *et al*., 2017). A great deal of research work is available on cassava for their economic potentials, food uses, and nutritional qualities. However, lesser work has been carried out on their morphological to ascertain their suitability in pulp and paper production. It is therefore paramount that researchers pay more attention to agricultural crop alternatives, lesser known wood species to exploring their pulping potentials and thus help prevent overdependence on the scarce forest resources which are almost been exhausted. This study therefore was aimed to determine fiber characteristics of cassava stem grown in Makurdi as a suitable raw material for pulp and paper production.

MATERIALS AND METHODS

Study Area

The study was conducted at the Federal University of Agriculture, Makurdi, Benue state. Benue state is generally regarded as the 'Food basket' of Nigeria, because the ecology of the state supports extensive arable cropping and livestock production as well as fruit, palm, grains, legumes, root and tuber production. Makurdi lies between Latitude 6^o 25' and 8^o 8' N, and Longitude 7^o 47' - 10^o 00' E. The town lies within the guinea savannah vegetation zone and experiences two distinct seasons, the wet/rainy season and the dry/summer season. The rainy season lasts from April to October with annual rainfall in the range of 1,000 -1,500 mm. The dry season begins in November and ends in March. The temperatures fluctuate between 23 - 37 ^{o}C in the year.

Method of sample Collection and Preparation

Samples of two varieties of *Manihot esculenta* and *Manihot utillisima* were collected from different growing stand in October 2019 within Federal University of Agriculture and Benue Agricultural and Rural Development Authority (BNARDA), Makurdi. Samples were collected from different replicates of the same plant species. The collection of the samples was done with a cutlass and felling of desired replicates to cut the stem. Sample collection was done according to the practice in pulp and paper industries where mixed population of trees and branches of different age and sizes are harvested for pulping rather than those rather than those of a particular age or size. Stem samples were taken by cutting chips of stem, dried at room temperature for two weeks.

Determination of Fibre characteristics

Fibre characteristics determination was carried out at the Forest Research Institute of Nigeria (FRIN), Ibadan. Each sample was prepared into slivers of about 2 mm x 2 mm x 2 mm. The slivers were macerated in equal volume of ehanoic acid and hydrogen peroxide (1:1) inside an oven at about 100 °C for 2 hours. After this the resultant solution was agitated in order to separate it into individual fibres. Using a stage micrometer mounted on a Zeiss light microscope (Standard 25) under 80 ×, random samples of macerated fibres were mounted on slides and measured. Fifteen (15) fibres were measured from each representative sample slide, following the approach employed by Jorge (1999) when at least 20 fibres per slide were measured to keep error below 5% for a 95% confidence level. The microscopy was performed in accordance with the ASTM D1413- 48 of 1983 and ASTM D1413-61 procedure of 2007. The fibre for each material was mounted on a slide and the fibre length (L), fibre diameter (D), lumen width (d), and cell wall thickness were measured. From these, derived fibre characteristics were calculated as follows:

$$FC/S = FL/FD \quad (1)$$
$$EC\ (\%) = (LW/FD)100 \quad (2)$$
$$RC\ (\%) = CWT\ /\ FD \quad (3)$$
$$RR = (CWT \times 2)/LW \quad (4)$$
$$LSF = (FD^2 - LW^2))/(FD^2 + LW^2) \quad (5)$$
$$Ff\ (\%) = (FL/CWT)100 \quad (6)$$
$$SF = (FD^2 - LW^2)FL \quad (7)$$

Where:
FL = fibre length; FD = fibre diameter; LW = lumen width; CWT = cell wall thickness; FC/S = Felting rate/slenderness; EC = Elasticity coefficient; RC = Rigidity coefficient, RR = Runkel ratio; Ff = F factor (%); SF = Solids factor; LSF = Luce's shape factor

Data Analysis
Data collected was subjected to one-way Analysis of Variance. Follow up test was carried out using Duncan Multiple Range Test (DMRT) where significant differences exist.

RESULTS

Table 1 shows the mean values of fibre length, fibre diameter, lumen width and cell wall thickness characteristics of the two varieties of *Manihot esculenta* (TM1202, TME 419) and *Manihot utillisima* (T-MU) stems. The result indicates that means of fibre length, lumen width and cell wall thickness of *Manihot utillisima* were not significantly different among stems at $p<0.05$ whereas the fibre diameters was significantly different ($p<0.05$). The mean of fibre length were 0.54 and 0.66 mm in *Manihot esculenta* TM1202 and TME419 varieties and 0.66 mm in *Manihot utillisima* (T-MU) variety. The means of fibre diameter ranged from 20.14 µm to 21.91 µm with TME419 varieties of *Manihot esculenta* having the lowest and TMS1202 having the highest mean values. The means of Lumen width ranged from 10.88 - 13.10 µm whereas the means of cell wall thickness ranged from 4.35 - 4.47 µm.

Mean values of Runkel ratio, elasticity coefficient, rigidity coefficient, F ratio, Luce's shape, solid factor and felting rate of the two varieties of *Manihot esculenta* TM 1202 and TME 419 and *Manihot utillisima* (T-MU variety) stems (Table 2). Also, means of fibre derived indices were not significantly different ($p<0.05$). Runkel ratio, elasticity coefficient, rigidity coefficient, F-ratio, Luce's shape, solid factor and felting rate ranged from 0.72- 0.80, 56.40 – 59.33 %, 20.44 - 21.84 %, 13.09-16.59 %, 0.48-0.52, 148.71-206.80, 26.43 -32.76, respectively (Table 2).

Table 1: Mean values of fibre characteristics of varieties of *Manihot esculenta* (TM1202, TME 419) and *Manihot utillisima* (T-MU)

Species/Variety	Fibre Length (mm)	Fibre Diameter (µm)	Lumen Width (µm)	Cell Wall Thickness (µm)
	Mean±Std	Mean±Std	Mean±Std	Mean±Std
Manihot utillisima (T-MU)	0.66±0.87^{a}	20.55±2.80^{ab}	11.61±2.66^{a}	4.47±0.88^{a}
Manihot esculenta (TMS1202)	0.66±0.11^{a}	21.91±3.86^{a}	13.10±3.65^{a}	4.41±1.12^{a}
Manihot esculenta (TME 419)	0.54±0.10^{a}	20.14±1.44^{ab}	10.88±1.20^{a}	4.635±0.80^{a}

Mean values in the same column with same alphabet are not significantly different from each other (P< 0.05)

Table 2: Mean values of Derived indexes of two varieties of *Manihot esculenta* (TM1202, TME419) and *Manihot utillisima* (T-MU variety)

Species/Variety	Runkel Ratio	Elasticity Coefficient (%)	Rigidity Coefficient (%)	F ratio (%)	Luce's shape factor	Solids factor	Felting rate (Slenderness)
	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std
Manihot utillisima (T-MU)	0.80±0.21[a]	56.40±7.76[a]	21.84±3.85[a]	15.84±6.10[a]	0.52±0.10[a]	191.83±61.10[ab]	32.76±6.18[a]
Manihot esculenta (TMS1202)	0.72±0.24[a]	59.33±9.44[a]	20.44±4.77[a]	16.59±7.87[a]	0.48±0.12[a]	206.80±83.69[a]	31.01±8.03[a]
Manihot esculenta (TME 419)	0.78±0.19[a]	56.75±7.31[a]	21.71±3.69[a]	13.09±4.91[a]	0.52±0.09[a]	148.71±43.03[a]	26.43±6.07[a]

Mean values in the same column with same alphabet are not significantly different from each other ($P < 0.05$)

The Elasticity Coefficient of *Manihot spp*. varieties are elastic fibres (55.40 – 59.33) (Table 3). They have short fibre length (0.54 – 0.66 mm) and good Runkel ratio values (0.72 – 0.80) (Table 4).

Table 3: Fibre flexibility classification of *Manihot utilissima* and *Manihot esculenta* varieties

Species/variety	Elasticity Coefficient	Type of fibre
Manihot utilissima (T-MU)	55.40	Elastic
Manihot esculenta (TMS 1202)	59.33	Elastic
Manihot esculenta (TME 419)	56.75	Elastic

Key: High elastic fibres > 75; Elastic fibres 50 to 75; Rigid fibres 30 – 50; High rigid fibres < 30

Table 4: Suitability for pulp and paper making based on fibre length and Runkel ratio

Species/variety	Fibre length	Fibre class	Runkel ratio	Runkel ratio Ranking
*Manihot utilissima (*T-MU Variety)	0.66	Short	0.80	Good
Manihot esculenta (TMS 1202 Variety)	0.66	Short	0.72	Good
Manihot esculenta (TME 419 Variety)	0.54	Short	0.78	Good

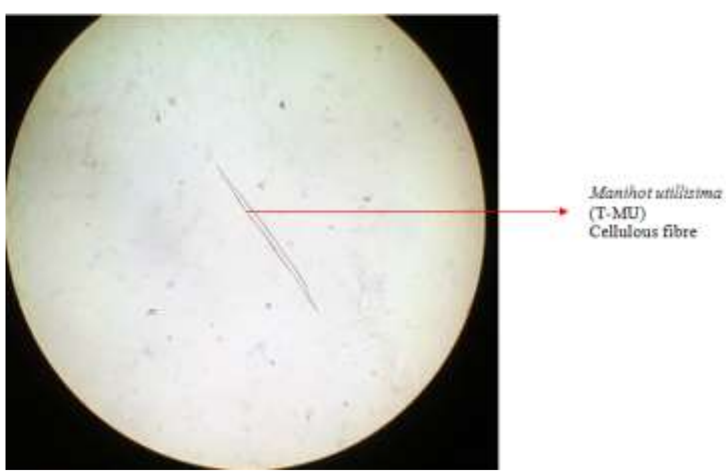

Plate1: Photographs of T-MU variety of *Manihot utillisima* indicating fibre length

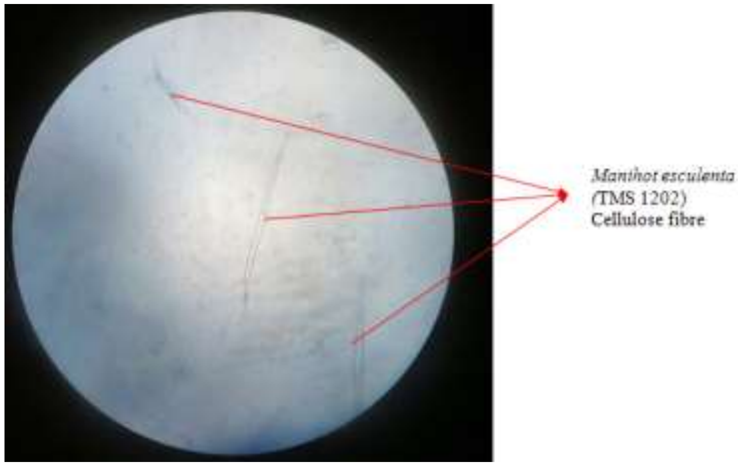

Plate 2: Photographs of TMS 1202 variety of Manihot *esculenta esculenta* cellulose fibre

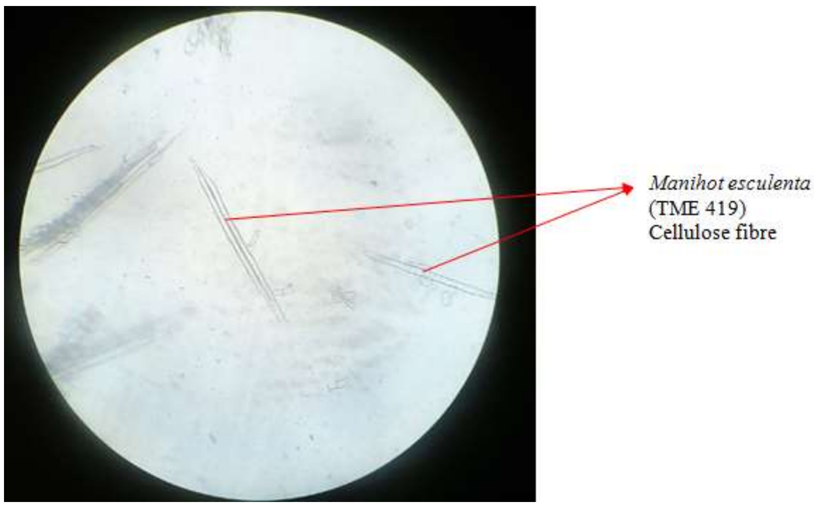

Plate 3: Photograph of TME 419 *Manihot esculenta* cellulose fibre

DISCUSSION

Fibre Characteristics of *Manihot utilissima* and *Manihot esculenta* varieties

Fibre Length

The average mean fibre length obtained from the two species of cassava were between 0.54 - 0.66 mm. Fibres from this study are all short which may be due to genetic factors as well as shorter agronomic characteristics of the cassava (Tembe *et al*., 2010). The mean values fall below 0.75 - 1.75 mm obtained from 10 -12 year-old stands of *Gmelina aborea* in according to Rogue and Fo (2007). However, the values are lower than 1.57 mm for 42 years old *Hevea brazilensis* reported by Tembe *et al*, (2010). Ekhuemelo (2018) reported fibre length of some non wood species as 0.98 mm in *Panicum miliaceum* stalk; 0.93 mm in *Abelmoschus esculentus* stalk; 0.90 mm in *Hibiscus sabdariffa* stalk and 0.77 mm in *Sorghum bicolor* stalk, respectively. Also, fibre length of 0.94, 0.76, and 0.894 mm were reported for *Ananas comosus, Tithonia Diversifolia* and *Cocos nucifera* (Omotoso and Owolabi, 2015) while 0.926 mm was observed in cotton (Sadegh *et al*., 2011) for non wood species.

Fibres below 1.60 mm are classified as short while those above 1.60 mm in length is said to be long fibres (Metcalfe and Chalk, 1983; Anon, 1990). To produce fine papers, both long and short fibres are needed. Short fibre contributes to the properties of pulp blends, especially opacity, printability and stiffness as well as good printability. Papers from these non wood species, if blended with long fibre materials will give good paper properties (Fengel and Wegener 1989; Mc Dougall *et al*.,1993). However, stem fibre length of *Manihot utillisima* (T-MU) and *Manihot esculenta* (TMS 1202 and TME 419 varieties) as obtained in this study are lower than the recommended fibre length for good quality pulp and paper. As a result, it would only produce good quality paper when blended with long fibre materials.

Fibre diameter

Manihot utillisima (T-MU) and *Manihot esculenta* (TMS1202 and TME419) stem varieties had fibre diameter of 20.14 - 21.91µm. Fibre diameter was reported to be associated with molecular and physiological changes that occur in the vascular cambium as well as increase in cell walls during the tree growing process (Plomion *et al.*, 2001; Rogue *et al.*, 2007). These values fall within the range of 20 - 40 µm fibre diameter for hardwood fibres reported by (Usta and Eroghe, 1987). Also, it is comparable to 20.96 µm for bagasse (Hemmasi *et al.*, 2011).

Lumen Width

Result of lumen width ranged between 10.88 and 13.10µm for *Manihot utilissima* (T-MU) *and Manihot esculenta* (TMS1202 and TME419) varieties. Generally, distinction in fibre Lumen width may be attributed to the increase in cell size and physiological development of the wood as the tree grows in girth Rogue *et al.*, (2007). Fibre lumen width affects the beating of pulp in the sense that, the larger the lumen width, the better the beating of pulp due to the penetration of liquids into vascular spaces of the fibres (Panshim and de Zeeuww, 1980). The means are within the range of 19.10, 16.00, 8.10 and 12.15 µm reported for *Ananas comosus, Tithonia Diversifolia, Cocos nucifera* and *Sansevieria liberica* non wood (Omotoso and Owolabi, 2015) and 13.0µm for *Tectonia grandis* reported by Izekor and Fuwape (2011) and 9.87 µm for *Leucaena leucocephala* reported by Ajala (1997) for wood fibres. The mean values recorded for fibre lumen width in *Manihot spp.* `in this study implies that the species would be good during beating up of pulp.

Cell wall thickness

Means of cell wall thickness of *Manihot utilissima* (T-MU) *and Manihot esculenta* (TMS 1202 and TME 419) varieties observed in this research ranged between 4.35 and 4.47 µm. These mean values are within the range of 1.94 and 4.99 µm reported by Ogunkunle (2010) for *Ficus* species and greater than 4.02µm for *Gmelina arborea* (Roger *et al.,* 2007). Also, the values fall within the range of 4.64 µm for *Crotalaria pallid* as reported by Sharma *et al*. (2013). Fibres with thin cell wall are dense and have good paper formation, hence the suitability of *Manihot spp*. varieties as good raw material for pulp and paper making base on their cell wall thickness.

Derived Fibre Morphological indices of *Manihot utilissima* and *Manihot esculenta* varieties

Runkel Ratio

Runkel ratio of wood is one of the determinant factors to be considered when assessing a material for pulp and paper properties (Ohshima *et al.*, 2005). It is invariably related to paper conformity and pulp yield. The result of mean of Runkel ratio obtained in this study shows that *Manihot spp*. varieties had Runkel ratio less than 1 (0.72 - 0.80) and are similar to 0.79 value obtained from tropical pine species (Ajala, 1997). These values are also within 0.64, 0.54, 1.66 and 0.93 values reported for *Ananas comosus, Tithonia Diversifolia, Cocos nucifera* and *Sansevieria liberica* (Omotoso and Owolabi, 2015) for non wood species. Also, 0.50, 0.78, .78, 0.73, 1.16 and 1.18 values were reported for *Abelmoschus esculentus* stalk, *Hibiscus sabdariffa* stalk, *Panicum miliaceum* stalk, *Sorghum bicolor* stalk, *Hyparrhenia involucrate* grass and *Oryza longistaminata* grass (Ekhuemelo, 2018). For wood species, the range of 0.28 and 0.68 were recorded for *Gmelina aborea* and *Ficus spp.*, respectively (Ogunkule, 2010) and 0.59 as reported for *Leucaena leucocephala* (Oluwadare and Sotannde (2007). Runkel ratio should be less than 1 for wood with good quality for pulp production (Kpikpi, 1992). Hence, the suitability of *Manihot spp.* varieties for good for pulp and papermaking.

Elasticity Coefficient

Elasticity coefficient is another important criterion for evaluating fibre quality. Elasticity coefficient (flexibility ratio) is classified into four groups of fibres (Bektas *et al.*, 1999) as high elastic fibres having elasticity coefficient greater than 75; elastic fibres with elasticity ratio between 50 - 75; rigid fibres which has elasticity ratio less than 30-50 and highly rigid fibres having elastic less than 30. High elasticity shows that a material may be suitable to produce paper with greater burst and tensile strength.

In accordance to this classification, elasticity coefficient of *Manihot spp*. varieties in this study is within the elastic fibres (56.40 - 59.33 %). Elasticity ratio between 50 and 70 implies that the fibers can easily be flat and give good paper with high strength properties (Brindha *et al.*, 2012). Also, the values are comparable to 59.5 % and 60.43 % as reported by Ververis *et al*., (2004); Sharma *et al*., (2013) for *Hibiscus canabinus* and *Urena lobata*.

Rigidity Coefficient

The mean values of rigidity coefficient obtained in this study ranged from 20.44 - 21.84 %, for all varieties of *Manihot spp*. These mean values are within the range reported by Hus *et al*., (1975) for juvenile beech wood (22.95 %). High rate of rigidity coefficient affects tensile, tear, burst and double fold resistance of paper negatively (Hus *et al*., 1975). This implies that paper made *Manihot spp*. varieties with low rigidity would have less tensile, tear, burst and double fold resistance making it a suitable raw material for pulp and papermaking.

Solid factor

Manihot spp. varieties in this study of had solid factor values ranged from 148.71- 206.80. This result is comparable to the solid factor for beech juvenile wood of 140.38% and 240.55% for blank pine juvenile wood reported by Akgul, (2009). Solid factor was found to be related to paper sheet density and could be significantly correlated to breaking length of paper (Ona *et al*., 2001). It therefore implies that, solid factor of *Manihot Manihot spp*. varieties is similar to that of beech juvenile wood and beech juvenile wood.

Luce's shape factor

The values of Luce's shape factor obtained in this study ranged from 0.48 - 0.52 for all *Manihot spp*. varietie. These values are within (0.39 to 0.74) reported by Pirralho (2014) as obtained from several *Eucalyptus* species. Ohshima *et al*. (2005) reported Luce's shape factor of 0.37 for *Eucalyptus camaldulensis* and 0.42 for *Eucalyptus globules*, respectively. However, Takeuchi *et al. (*2016) reported lower values 0.08 and 0.09 for Luce's shape factor in *Melaleuca bancana* and *Melaleuca pearsonii*, respectively. Like Solid factor, Luce's shape factor was reported to be directly related to paper sheet density and could be significantly correlated to breaking length of paper (Sharma *et al*., 2012).

Felting rate/slenderness

The Felting/slenderness ratio of *Manihot spp*. varieties obtained in this research ranged from 26.43-32.76 respectively which are all less than 50.06 for *Gmelina arborea* and 42.38-71.99 reported for different *Ficus* species (Ogunkunle 2010). Sharma *et al*. (2012) also reported 39.1 for *Gmelina arborea*. Nevertheless, low Felting ratio means production of weak paper; hence the three varieties in this study would produce weak paper compared to *G. arborea* and some *Ficus* species which can produce strong paper.

F ratio

The values of F ratio obtained in this study ranged from 13.09 - 16.59 for all *Manihot spp*. varieties. The means are lower than 127.81, 400 to 500 and 150 to 300 reported by (Alkan *et al*. 2003, Istek *et al*. 2009**:** Tutus *et al*., 2003).

CONCLUSION

Mean fibre lengths of Manihot spp, varieties obtained in this study were short fibre which are elastic. The values of Runkel ratios of *Manihot spp*. varieties are within the acceptable Runkel ratio values for good paper production. Also, values of rigidity in *Manihot spp*. were low. To produce good pulp and papers from *Manihot spp*., the fibre must be blended for plant species of long fibres.

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Evaluation of Fibre Morphological of Rice (*Oryza sativa)* Varieties Grown in Makurdi, Benue State, for their suitability in Pulp and Paper Production

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Abstract

The study investigated fibre morphological characteristics of the straws of three varieties of rice (Oryza sativa) to determine their potentials for pulp and paper production. Straw of three varieties of rice (FARO 44, FARO 52 and (NERICA-L 47) respectively were collected from Adubu Fadama farm at North Bank area of Makurdi. Representative samples were cleansed, chipped and introduced into a beaker containing equal volume of glacial acetic acid and hydrogen peroxide for maceration. Macerated solutions were agitated to separate fibres and thereafter mounted on slides unto stage micrometer mounted on a Zeiss light microscope (Standard 25) under 80 ×. Fifteen straight fibres from viewed from the slides were selected and measured to obtain fibre features while fibre indices were calculated. Data were analyzed using One-way Analysis of Variance. Results show that fibre lengths of the three rice varieties were not significantly different from each other. However, significant differences existed among fibre diameter, lumen width and cell wall thickness of the three rice varieties at ($p < 0.05$). Fibre lengths were short (0.70 - 0.80 mm), with NERICA –L 47 having highest mean value of 0.80 mm while FARO 52 had the lowest mean value of 0.70 mm. Elasticity coefficients of 34.22, 32.31 and 38.62 were recorded for FARO 44, NERICA L 47 and FARO 52, respectively; rigidity coefficient ranged from (32.89 – 33.80) % while felting rate/slenderness was from (0.11-1.57) %. The rice varieties had Runkel ratio greater than 1. The study therefore indicates that the rice varieties in Makurdi are not suitable raw material for pulp and paper making owing to their short fibre lengths and high Runkel ratio.

Keywords: Rice, varieties, cellulose fibre, fibre length, runkel ratio

INTRODUCTION

Paper as a consumer product has proved critical in driving most sensitive needs of mankind, notably in areas of security, education, sanitation, and communication (EPN, 2018). Paper was first developed in 105 AD in China, and since then, its production and consumption have steadily increased (Ezeudu *et al*., 2019). This is often attributed to two global socio-economic realities such as growing world population, advancement in technology and global economic prosperity. Paper physiochemical properties such as durability and flexibility that have made it possible for it to be fashioned into variety of forms (Suhur, *et al*., 2015). The world's forests are being depleted for the production of wood and paper products. Each year over 4 billion or 35% of the world's trees are felled and used in the production of paper products (Ekhuemelo and Tor, 2013). Global consumption of paper has risen four hundred percent in the last forty years in every continent (Canada, 2014). Consequently, major pulp and paper producing companies worldwide have considered reducing the cutting down of natural forests for paper production (Sizer, *et al*., 2013).

Paper products are used not only for writing and printing, but also for other purposes like card board, wrapping among others. The global production of pulp is 192 million tons of which 10.11 million tones are produced by pulp and paper mills of India (Kulkarni, 2013). The increasing demand for wood raw materials, together with economic and environmental factors, makes it necessary to research alternative sources of lignocellulosic matter (Majid *et al*., 2011). Therefore, much attention has been given to utilization of non-woody sources such as fibrous plant materials as an alternate source for pulp and paper production. These also include utilization of agricultural residue, industrial crops. These materials contain cellulose in their fibers and are considered potential alternative sources for pulp and paper (Ekhuemelo and Tor, 2013). As the demand for pulp and paper becomes a crucial issue, alternative fibres from non-wood sources will provide a good solution to halting the destruction of the forest ecosystem and the environment. There is an abundance of non-wood fibers potentially available for the paper industry. Non-wood fibers have been used in many countries like China, India, Spain, Italy, Turkey, Denmark and Romania (Hurter, 1998). Several agricultural food crop residues including rice straw, corn straw, okra stalks, corn stalk, plantain stalk, pineapple leaf and corn husks which do not have immediate beneficial applications in many communities have been proposed to be potential sources of pulp (Rymsza, 2007). Non-wood plants offer several advantages including short growth cycles, moderate irrigation and fertilization requirements and low lignin content to alleviate energy and chemicals used during pulping (Taiwo, 2014). Rice is very important food crop grown in Nigeria. Rice consumption is rising, both rural and urban dwellers. Shabu, (2013) reported that rice contributes 90 % of the food requirements of the country. Benue State is recognized as Food Basket of Nigeria because of abundance food crops produced in the area. Grains such as rice millet, sorghum among others are hugely grown and the residues and usually burned resulting to environmental pollution. Among different varieties of rice grown in Makurdi, FARO 44 (sippi), (FARO 52 (witta - 4) and (NERICA L-47 are very prominent. Therefore this study focused on assessment of fibre characteristics of *Oryza sativa* varieties grown in Makurdi as a suitable raw material for pulp and paper production.

MATERIALS AND METHODS

Study Area

The study was conducted at the Federal University of Agriculture, Makurdi (FUAM), Benue State. Benue State is generally regarded as the 'food basket' of the nation. The average populace of the region is predominantly farmers who are basically involved in subsistence farming. Benue State is located at the central point of Nigeria, characterized with Guinea Savannah. Benue State falls within the coordinates 7^o 47' and 10^o 00' East, 6^o 25' and 8^o 8' North

Collection and preparation of plant materials

Dried straw samples (plates 1-3) of FARO 44, FARO 52 and NERICA-L 47 were collected from Adubu Fadama farm at North Bank Area of Makurdi. Replication was done by collecting samples from different location on the same farm as shown in plate 1, 2 and 3 respectively.

Plate 1: ***Oryza sativa*** **variety (FARO -52, Witta – 4**

Plate 2: ***Oryza sativa*** **variety (FARO 44, sippi)**

Plate 3: ***Oryza sativa*** **variety (NERICA L- 47)**

Sampling Strategy

Three selected straw samples of rice with 5 replicates was obtained from a farm and from each replicates, 15 readings ((3 rice × 5 replicates × 1 slides × 15 cellulose fibres) of fibre characteristics were assessed.

Determination of Fibre Characteristics

Assessment of Fibre characteristics was carried out at the Forest Research Institute of Nigeria (FRIN) Ibadan as follows. Each sample was prepared into slivers of about 1mm × 2 mm × 2 mm. The silvers were macerated in equal volume of ethanoic acid and hydrogen peroxide (1:1) inside an oven at about 100 ^{o} C for 2 hours. The resultant solution was agitated to separate individual fibres. Using a stage micrometer mounted on a Zeiss light microscope (standard 25) under 80×1, random samples of macerated fibres was mounted on slides and length, fibre diameter, Lumen width, and cell wall thickness measured. Fifteen cellulose fibres were measured from each representative samples slides, following the approach by Jorge (1999) when at least 20 fibres per slide were measured to keep error below 5 % for the 95 % confidence level. The microscopy was performed in accordance with the ASTM D1413-48 (2007) and ASTM D 143-61 (2007) procedures. The fibre for each material was mounted on a slide and the fibre characteristics were measured. From fibre characteristics measured, derived fibre characteristics were calculated as follows:

Felting rate (slenderness) = fibre length÷ fibre diameter----------------------- (1)
Elasticity coefficient (%) = Lumen Width÷ fibre diameter ×100-------------- (2)
Rigidity coefficient= Cell wall thickness ÷ fibre diameter ×100--------------- (3)
Runkel ratio = (Cell wall thickness ×2) ÷lumen diameter----------------------- (4)
F factor (%) = fibre length ÷ cell wall thickness ×100-------------------------- (5)
Luce's Shape Factor = (Fibre diameter^2 - Lumen diameter^2) ÷ (Fibre diameter^2 + Lumen diameter^2) … (6)

Data Analysis

Data collected were subjected to one-way analysis of variance to test for significant differences. Follow up test was carried out using the Duncan's New Multiple Range Test where significant differences exist.

RESULTS

Table 1 shows fibre length, fibre diameter, lumen width and cell wall thickness of the three rice varieties (FARO 44, FARO 52, and NERICA-L 47). In the result, there were no significant differences among the mean fibre lengths of the rice varieties. The means of fibre lengths ranged between 0.70 and 0.80 mm; fibre diameters ranged from 5.73µm to 8.23 µm. However NERICA-L 47 had the highest fibre diameter of 8.23 µm while FARO 44 had the lowest fibre diameter of 5.73µm. Means of lumen widths of the three rice varieties were also significant. The means ranged between 1.98 and 2.69 µm. FARO 44 variety had the lowest mean of 1.98 µm and NERICA-L 47 recorded the highest mean of 2.69 µm. Cell wall thicknesses of the fibers were also significant with the means ranging from 1.88 µm to 2.77µm. FARO 44 showed the lowest mean of 1.88 µm and NERICA L 47 recorded the highest mean of 2.77 µm. Mean values of derived indices of the three rice varieties (Table 2). There were no significant difference ($p>0.05$) among all the derived fibre indices except for Luce's Shape Factor where significant difference exists. Runkel ratio ranged between 1.30 and 2.10. FARO 44 recorded the highest Runkel ratio of 2.10 and NERICA-L 47 showed the lowest Runkel ratio of 1.34. Elasticity ratio was between 32.31 % and 38.62 %; Rigidity coefficient between 32.89 % and 33.80 % and F ratio ranged between 32.08 and 39.80 %. Similarly, Luce's shape factor ranged between 0.79 and 0.81; Solids factor between 25.55 and 627.21 while Felting rate/Slenderness was between 0.11 and 1.57, respectively. Table 3 indicates the elasticity classification of the varieties of *Oryza sativa*. Elasticity values of 32.31 34.22 and 38.62 % obtained for the three varieties of *Oryza sativa* were classified as rigid fibre. Suitability of *Oryza sativa* varieties for pulp and paper production is shown in Table 4. The results indicate that varieties of *Oryza sativa* in Makurdi have short fibre length and poor Runkel ratio.

Table 1: Mean Values of Fibre Characteristics of three Varieties of *Oryza sativa* (FARO 44, NERICA L 47 and FARO 52) Straw

Rice varieties	Fibre Length (mm)	Fibre Diameter (µm)	Lumen Width (µm)	Cell Wall Thickness (µm)
	Mean±Std	Mean±Std	Mean±Std	Mean±Std
FARO 44	0.75±0.22^{a}	5.73±2.24^{a}	1.98±0.98^{a}	1.88±0.76^{a}
NERICA L-47	0.80±0.23^{a}	8.23±2.59^{b}	2.69±1.33^{b}	2.77±0.87^{b}
FARO 52	0.70±0.14^{a}	6.58±2.31^{ab}	2.25±0.72^{ab}	2.20±0.90^{ab}

Mean values in the same column with same alphabet are not significantly different from each other (P< 0.05)

Table 2: Mean values of Derived indices of three varieties of *Oryza sativa* (FARO 44, NERICA L 47 and FARO 52) straw

Rice Varieties	Runkel Ratio	Elasticity Coefficient	Rigidity Coefficient	F factor	Luce's shape Factor	Solids factor	Felting rate (slenderness)
	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std
FARO 44	2.10±0.74^{ab}	34.22±8.35^{ab}	32.89±4.16^{a}	48.28±29.67^{b}	0.81±0.66^{a}	25.55±20.30^{a}	1.57±0.80^{ab}
NERICA-L 47	1.30±0.86^{a}	32.31±8.25^{a}	33.80±4.14^{b}	32.08±15.59^{a}	0.80±0.90^{a}	627.21±55.85^{c}	0.11±0.05^{a}
FARO 52	2.05±0.87^{ab}	38.62±32.08^{b}	33.36±9.17^{ab}	39.80±24.64^{ab}	0.79±0.11^{a}	30.41±19.16^{ab}	0.13±0.94^{a}

Mean values in the same column with same alphabet are not significantly different from each other (P< 0.05)

Table 3: Elasticity Classification of *Oryza sativa* varieties

Rice Varieties	Elasticity Coefficient (%)	Types of fibres
FARO 44	34.22	Rigid fibre
NERICA-L 47	32.31	Rigid fibre
FARO 52	38.62	Rigid fibre

Key: High elastic fibres > 75; Elastic fibres 50 to 75; Rigid fibres 30 – 50; High rigid fibres < 30

Table 4: Suitability of *Oryza sativa* varieties for pulp and paper production

Rice varieties	Fibre length (mm)	Fibre class	Runkel ratio	Ranking
FARO 44	0.75	Short	2.10	Poor
NERICA L-47	0.80	Short	1.30	Poor
FARO 52	0.70	Short	2.25	Poor

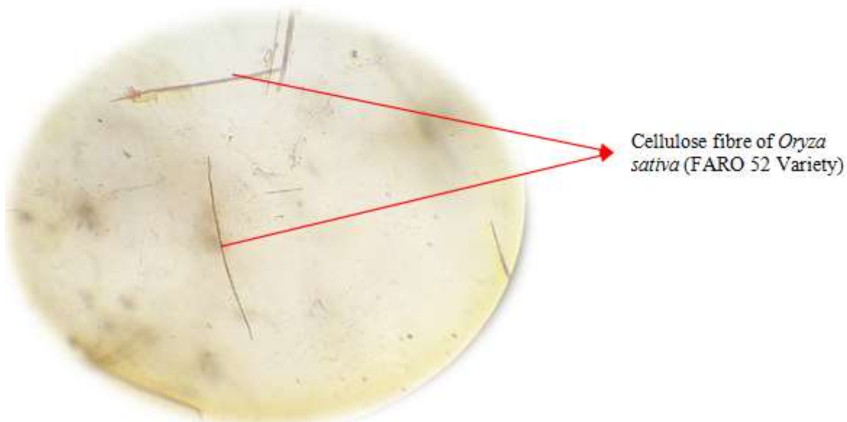

Plate 4: Microscopic photograph of cellulose fibre of *Oryza sativa* (FARO 52)

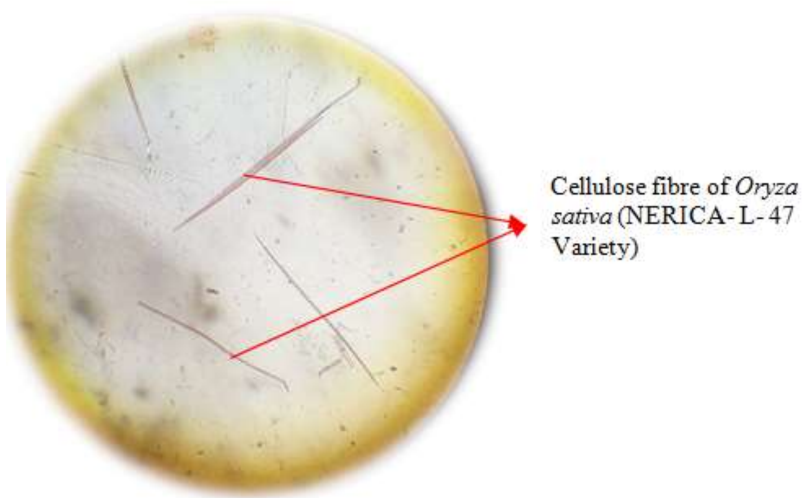

Plate 5: Microscopic photograph of cellulose fibre of *Oryza sativa* (NERICA- L- 47)

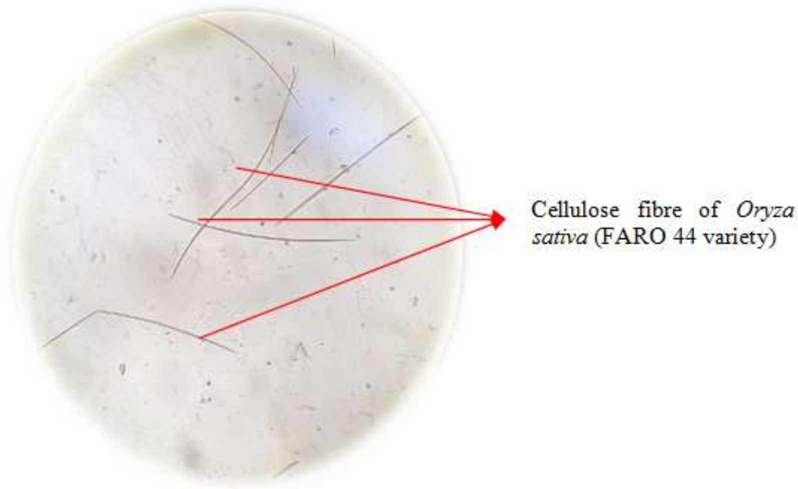

Plate 6: Microscopic photograph of cellulose fibre of *Oryza sativa* (FARO 44)

DISCUSSION

Fibre dimension of Makurdi grown rice varieties

Fibre length

NERICA - L 47 rice varieties had the highest mean of 0.80 mm while FARO-52 had the lowest 0.70 mm. Fibres from the study were all short which may be attributed to genetic composition as well as shorter agronomic features (Tembe, *et al.*, 2010). The values are lower than 1.65 mm - 2.33 mm reported by Izekor and Fuwape (2011) for 25-year-old Teak in Eastern Nigeria and 1.57 m for 42-year-old *Hevea braziliensis* reported by (Tembe *et al.*, 2010). Cellulose fibres length below 1.60 mm are classified as short while those above 1.60 mm in length is said to be long fibres (Metcalfe and Chalk, 1983; Anon, 1984). Ogunkule and Oladele (2008) reported a fibre length of less than 1.60 mm for 12 *Ficus* species. In similar observation, Kpikpi (1992) and Uju and Ugowoke (1997) reported fibre lengths of less than 1.60 mm in some Nigerian hardwood species. Oluwadare and Sotannde, (2007) recorded 0.65 mm as fibre length of *Leucaena leucocephala*. Long fibres are preferred for the manufacture of paper because they give a more open and less uniform sheet structure (Oluwadare and Sotannde, 2007). Short fibres lack formation of good surface content and fibre-fibre bonding (Ogbonnaya *et al.*, 1992). Ademiluyi and Okeke, (1979) reported that the longer the fibre length, the higher the tear resistance and the better the quality of the paper produced.

Fibre diameter

The result obtained among the three rice varieties, NERICA - L 47 had the highest (8.23 µm) mean value of fibre diameter and FARO 52 had the lowest (6.58 µm). These values are within the range of 14.0 - 16.0 µm. *Gmelina arborea* was found to have fibre diameter of 18.5 - 27.5 µm by Rogue and Fo, (2007). Increase in fibre diameter is reported to be related to molecular and physiological variations that occur in the vascular cambium and the increase in cell walls during the tree growing process (Plomion *et al.*, 2001; Rogue and Fo, 2007). Adeniyi *et al*. (2013) reported 18.29 µm for *Ficus exasperata*.

Lumen width

Lumen width was 1.98 - 2.69 µm for the three verities of *O. sativa*. These mean values are within the range of 2.47 µm - 4.49 µm reported for some indigenous hardwood species in the tropical rainforest ecosystem (Awuku, 1994). Usually, variation in lumen width could be attributed to the increase in cell size and physiological development of the wood as the tree grows in girth. Rogue and Fo, (2007) reported a positive relationship in lumen width and cambium age in their study. Fibre lumen width affects the beating of pulp in the sense that, the larger the fibre lumen width, the better the beating of pulp due to the penetration of liquids into the micropores of the fibres (Panshin and de Zeeuww, 1980). The mean values recorded for fibre lumen width from the three rice varieties in this study implies that the species would be good during beating up of pulp.

Cell wall thickness

Cell wall thickness for the three species of *Oryza sativa* ranged between 1.88 and 2.77 µm. The results are within the range of 1.94 - 4.99 µm reported by Ogunkunle (2010) for *Ficus* species and 5.00 -10.00 µm reported for pine by Pulp and Paper Recourses and Information, (PPRI, 2011); and 3.96 µm reported by Adeniyi *et al.*, (2013) for *Ficus exasperata* but lower than 2.82µm for *Gmelina arborea* reported by Ogunkule (2010). Fibres with thin cell wall are dense and having good formation hence the suitability of NERICA L-47 as a raw material for pulp and paper production.

Derived Fibre Morphological Indices of rice varieties Grown in Makurdi

Runkel ratio

Runkel ratio is one of the properties that has been recognized as important traits for pulp and paper properties (Ohshima *et al.*, 2005). It is related to paper conformity and pulp yield. Bektas *et al.*, (1999) stated that higher Runkel ratio gives lower paper strength properties especially lower burst, tear and tensile indexes, this is supported by Oluwudare and Egbewole, (2008) who stated that Runkel ratio is closely associated with cell wall thickness and it influences paper strength properties. Runkel ratio less than one is good for quality pulp and paper production (Kpikpi, 1992). Runkel ratio establishes the suitability of a cellulosic material for pulp and paper production. Therefore, cellulose fibres from FARO 44, FARO 52 and NERICA-L 47 rice varieties may not be suitable raw material for pulp and paper production since they have Runkel ratio greater 1. Runkel ratio is also related to paper conformity, pulp yield and fibre density. High Runkel ratio fibres produce bulkier paper than fibres with low Runkel ratio. Wood species that is meant for pulp and paper production must have its Runkel ratio less than one (Kpikpi, 1992).

Elasticity coefficient

Elasticity coefficients in this study were 34.22, 32.31 and 38.62 for FARO 44, NERICA - L 47 and FARO 52, respectively. Elasticity coefficient is another important criterion for evaluating fibre quality. Elasticity coefficient (flexibility ratio) are classified into four groups of fibres (Bektas *et al.*, 1991) as high elastic fibres having elasticity coefficient greater than 75; elastic fibres with elasticity ratio between 50-75; rigid fibres having elasticity ratio less than 30-50 and highly rigid fibres less than 30. Going by this classification, elasticity coefficient of all the rice varieties in this study are within the rigid fibres. As the rice varieties examined in this study do not have efficient elasticity, they are not suitable for paper production but could be used more on fibre plate, rigid cardboard production (Akgul and Tozkiogu, 2009). Elastic fibres can be stretched making it a suitable raw material for papermaking in other to get high resistance.

Rigidity coefficient

The values of rigidity coefficient obtained in this study ranged from (32.89 – 33.80) % for all the varieties of *Oryza sativa*. These mean values are higher than those reported by (Hus *et al.*, 1975) for juvenile beech wood (22.95 %) and 27.66 % for *Eucalyptus*. High rate of rigidity coefficient affects tensile, tear, burst and double fold resistance of paper negatively (Hus *et al.*, 1975). This implies that rice varieties in this study are not suitable raw material for pulp and papermaking due to high rigidity coefficient which tends to affect tensile, tear, burst and double fold paper negatively.

Felting rate/slenderness

The values of Felting rate/slenderness obtained in this study ranged from (0.11-1.57) % for all the rice varieties. Generally, the acceptable value of felting rate/slenderness for paper making is more than 33 (Xu *et al.*, 2006). One of the criterions that control suitability of wood material for paper production is felting power calculated by comparing fibre length to diameter (Akgul, 2009). Felting power is an important factor which has positive effect on strength, tear, burst, breaking off, doubles folding resistance according to physical test result of the paper. Felting power required for good paper is between 70 – 90 % for softwoods and 40 – 60 % for hard woods. These values are higher than the ones recorded for rice varieties in this study which ranged from 0.11-1.57 %. It therefore implies that these rice varieties under study would not be good enough for paper production.

F factor (%)

The values of F ratio obtained in this study ranged from (32.08 - 48.28) % for all the rice varieties. F ratio **(**%) was found to be related to paper sheet density and could be significantly correlated to breaking length of paper (Ona *et al.*, 2001). F factor for beech juvenile wood was found as 140.38 % and 240.55 % for black pine juvenile wood (Akgul and Tozluoglu, 2009). In related studies of hardwoods, F factor was found to be 235.92 % for *Populu seur Americana* and 206.78% for *Populus tremula* (Kar, 2005). Springwood radial of *Pinus pinnaster* (Izmit, land, Bonitet-1) was determined as 745.40 %, spring wood tangent as 69.81 %, summer wood radial as 603.9 % and summer wood tangent as 493% (As, 1992). It therefore, implies that F factor of FARO 44, FARO 52 and NERICA-L 47 are not similar to that of beech juvenile wood and black pine juvenile wood.

Luce's Shape Factor

The values of Luce's Shape Factor (LSF) of the rice varieties ranged from (0.79-0.81. Luce's Shape Factor is an important fibre index and derived from fibre diameter and lumen diameter. It is directly related to paper sheet density (Sharma *et al.*, 2013). It was found to be related to paper sheet density and could be significantly correlated to breaking length of paper (Ona *et al*., 2001). Similar to Runkel ratio, the trend of variation of LSF might be associated with that of wall thickness, because both the fiber diameter and the fiber lumen diameter were used to obtain the cross-sectional fiber wall area in the equation for Luce's shape factor (Luce 1970). Luce's shape factor for the study conducted by Ogunkunle (2010) on *Gmelina arborea, Ficus mucuso, F. exasperate* were 0.29, 0.25 and 0.16. Ojo (2013) reported LSF for *Gmelina arborea, Afzelia Africana and Detarium senegalense* as 0.20, 0.47 and 0.73, respectively. The data reported by Oluwadare and Sotannde (2007) on *Leucaena lencocephala* gave its LSF 0.41.

Solid factor

The values of solid factor of rice varieties ranged between 25.55 and 627.21 which are above the range of the value computed from the data reported by other researchers. Ojo (2013) gave solid factor for *Gmelina arborea, Afzelia africana and Detarium senegalense* as 1.5×10^{-4}, 1.0×10^{-4} and 4.1×10^{-4}. The data reported by Oluwadare and Sotannde (2007) on *Leucaena lencocephala* gave its solid factor 1.0×10^{-4}. Solid factor for the study conducted by Ogunkunle (2010) on *Gmelina arborea, Ficus mucuso, F. exasperate* were 4.4×10^{-4}, 2.1×10^{-4} and 1.5×10^{-4} Solids factor was found to be related to paper sheet density and could be significantly correlated to breaking length of paper (Ona *et al*., 2001).

CONCLUSION

Fibre lengths obtained from the three rice varieties (FARO 44, FARO 52 and NERICA - L 47) grown in Makurdi are short. Cellulose fibres obtained from this study are mostly rigid owing to their elasticity coefficient that is less than 50 %. Runkel ratio values from the three rice varieties are above the acceptable values, and hence they are not suitable for paper making.

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Sustainable Development of Value Addition of Wood Products in Nigeria

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Abstract

A change in the physical state or form of a product connotes value addition; it is also the production of an item in a manner that enhances its value. Wood is a very versatile raw material in the furniture Industry. Throughout history, people relied on wood needs varying from farm tools to building materials, from fuel to weapons for hunting and warfare. Wood remains virtually the most predominant material used for construction and energy generation until the last half of the 19th century. Value added wood products also called secondary wood products that have been processed into furniture, builder's joinery and carpentry profiled wood and engineered wood products. Wood products in Nigeria include sawn wood, wood based panels, i.e. plywood and particleboards, paper and paperboard i.e. Newsprints, Printing and writing paper and other paper and paper boards i.e. Kraft paper. Value-added wood products are most commonly thought of as being only those products with the highest value such as furniture, flooring or specialized paneling. Value, however, can be added to wood and wood products at various levels of processing.

Keywords: Wood, Products, Value- added, Furniture, Paneling

INTRODUCTION

Wood is a very versatile raw material in the furniture Industry. Generally, people relied on wood needs varying from farm tools to building materials, from fuel to weapons for hunting and warfare (Fawupe, 2001). Wood remains virtually the most predominant material used for construction and energy generation until the last half of the 19th century (Aruofor, 2000). People use timber in the construction of houses, barns, fences, bridges, furniture canoes, mortars, musical instruments, etc. In contemporary times, wood is still widely used for construction purposes. It is also valuable industrial raw materials for production of pulp, paper, paper cellophane, photographic paper, tannin methanol, ethanol, wood adhesive and chemicals derivatives (Aruofor, 2000). The ubiquitous nature of wood has made it valuable material in every stage of human development. Thus man depend on wood right from the cradle to the grave. The versatile nature of wood has endeared it to multiple forms of uses in different forest enterprise in Nigeria (Fuwape, 2000).

The forest products industry in Nigeria was one of the most developed within the Nigerian economy in the 1960's to the early 1970's. During this period, export of wood products and agricultural commodities provided more than 70% of the country's Gross Domestic Product (GDP). However, the oil glut of the 70's led to gregarious exploitation of round logs for export until its ban in 1976. The over exploitation of the wood resources has impacted negatively on the development of the forest products industry. This, coupled with several other factors such as old age of equipment etc.; has resulted in the dwindling fortune of the country's forest industry. Forests have been the major source of livelihood for most Nigerian. The forestry sector is one of the main pivots on which the nation's welfare was built. The forest is not only important for material goods but also as a valuable ecological and cultural resource. The forestry subsector has over the years contributed immensely to the socio-economic development in the country. It ranks among one of the highest revenue and employment generating sectors. It also serves as resource base for many forest industries. The raw materials for the production of timber, pulp and paper are derived from the forest. (Fuwape, 2000). Wood products in Nigeria include sawn wood, wood based panels, i.e. plywood and particleboards, and paper and paperboard i.e. Newsprints, Printing and writing paper and other paper and paper boards i.e. Kraft paper. Value-added wood products are most commonly thought of as being only those products with the highest value such as furniture, flooring or specialized paneling. Value, however, can be added to wood and wood products at various levels of processing. For example, value can be added to a log by properly cutting to the correct length so more products can be produced from straighter, less tapered material. Value can be added to lumber by processing more efficiently or manufacturing for special niche markets. In panel production, value can be added by enhancing certain properties such as dimensional stability or resistance to termites and decay. Value is greatly added when producing engineered wood products, such as building joists, beams and framing made from wood fibers or strands held together with a binder such as glue or resin.

CATEGORIES OF VALUE ADDITION TO WOOD

The first step in adding value to wood is to identify the species of wood correctly. Drying schedules and end-use options of wood are largely governed by the species.

Furniture industries:

The furniture industry is strategic in the use of planks from the saw mills. It forms the major market for wood products in Nigeria and protects the continued existence of primary wood industries such as sawmills and ply mills. The capacity utilization of the furniture industry was 217,700m in 1988. This increased to 250,714m3 in 1992. In 2010, capacity utilization of the industry was 326,172m3 of round log equivalent. More than 400 furniture companies of various sizes exist in the country. The shortfall in large furniture companies is made up by the numerous cottage and small scale furniture makers which numbers more than 10,000 outlets. This category of furniture makers usually operate in the informal sector and are found in the rural and urban areas where middle and low income earners reside. Wooden furniture parts and components are now being manufactured and exported by a few large companies in Nigeria. Wooden furniture represents the major market for wood products in Nigeria. Many of the industries suffer from high cost of production due to energy cost and lack of patronage. One of the major specialties of furniture makers in Nigeria is wooden door; which is very popular in the country. Handmade carved doors are frequently seen exhibited along the roadside by carpenters. Only 5 companies gave their installed capacity. (Ogunusi, 2011)

Safety Match Stick Production:

Wood is modified into sticks for safety matches; a number of industries in this line of business were identified to have been established in the country. These comprised of three (3) in Lagos State, one each in Rivers, Imo, Cross-rivers, Oyo and Kwara States. This has however been decreasing in recent times. While 6 safety matches companies operated in Nigeria in between 1988 and 1996, the number of safety matches companies decreased to 3 from 2002. Capacity utilization in the safety matches subsector increased from 7,500m3 in 1988 to 16,200m3in 1992 and 52,980m3in 1996. Capacity utilization stabilized at 11,494m3in 2002 and 2010 respectively. The importation of wooden matches from Asia is enormous. Most of the matches come from Malaysia, China, India and Indonesia where they are made from *Bombax spp*. The matches are of excellent quality with good appearance and are inexpensive. The continuous importation of cheap wooden matches from Asia is hampering the growth of this sub-sector. It is therefore incumbent on us to be more creative to compete favourably with imported matches. (Ogunusi, 2011)

Wood Treatment:

A very good opportunity for value-added growth in forest products industry is the development of more durable termite- and decay-resistant engineered wood products. The damage to homes and forests caused by Formosan subterranean termites and resulting treatments and repairs is estimated at $2 billion a year nationwide, with $350 million or more of that in New Orleans. Moisture and decay cause additional losses. A major issue is the availability of treated engineered wood products for use in adverse environments. Various treatments are becoming available, but there is a need to develop stronger, more stable, more resistant, but environmentally safe wood-based treated products. Once proven, these products will have great demand in the residential and commercial construction markets. Emphasis should be placed on termite-resistant products to add value to wood produced.

Wood treatment Capacity utilization has been decreasing in Nigeria with time in this subsector. Capacity utilization decreased from 55,100m3in 1988 to 37,750m3in 1992. In 2010, capacity utilization dwindled to as low as 12,370m3in the subsector. The wood treatment plants in Nigeria should by now experience increase in activity with the decreasing supply of durable wood from the natural forests. However, most of the wood treatment plants are no longer operational as a result of lack of spare parts and general maintenance problems. Consequently, most companies now depend on few ones that are working to treat their materials (Ogunwusi, A.A. 2011).

FOREST INDUSTRIES IN NIGERIA

The forest enterprises in Nigeria can be classified into either formal or informal sector enterprises (GWVC, 1994). The formal sector enterprises include the organized wood based industries such as saw mills, plywood mills, particleboard mills and furniture factories. The informal enterprises are small forest based enterprises operating without formal corporate entity, this include enterprises that engage in the production of firewood, charcoal, chewing stick and sculptured wood items. The formal enterprises constitute the forest industries in the country.

There have been some changes in wood based industries in Nigeria between 1974 and 1997. The total number of wood based industries increased from 358 in 1974 to 1483 in 1990 but decreased to 1373 in 1997. The reduction in the number of wood mills between 1990 and 1997 was attributed to deficit in supply of required wood raw material due to over exploitation of the forest for export market. Although the highest quantity of wood is expected to be consumed as firewood in 2010, the highest volume of industrial wood raw material would be required for production of sawn wood (GWVC, 1994).

SAWMILLS

The sawmills account for 93.32% of the total number of wood based industries in Nigeria in 1997 (Fuwape, 1998). These mills are concentrated in the southwestern part of the country, with Ondo, Ogun and Lagos states having the largest numbers. The main type of log conversion machine used in these mills is the CD horizontal band saw. The Lumber recovery factor in most sawmills varies between 45 and 50% (Aliviar, 1983, Fuwape, 1989). This implies that about 50 to 55% of log input into the saw mills is left as wood residues. The poor log conversion efficiency of the mills is partly responsible for the high pressure on the forest and the destruction of forest cover

PLYWOOD AND VENEER MILLS

There were ten plywood and veneer mills in Nigeria in 1997 (Fuwape, 1998). The production capacities of the mills are presented in Table 3. The annual wood requirements in plywood and veneer mils are approximately 170,000m^3. The peeling lathe machine in the plywood mills in Nigeria requires large diameter logs for effective operation. The harvesting and logging operation of these mills have adversely affected the forest ecosystem.

PARTICLE BOARD MILLS

The particleboard mills in Nigeria are integrated with some plywood mills and sawmills. Particleboards are mainly produced from wood residues and plantation tree. The wood requirements of the particleboard mills are not considered to be significantly detrimental to the environment (GWV, 1994).

PULP AND PAPER MILLS

In the bid to meet the growing demand for paper in Nigeria, three pulp and paper mills, namely: Nigerian Paper Mill (NPM) Jebba, Nigerian Newsprint Manufacturing Company (NNMC) Oku-Iboku and Nigerian National Manufacturing Company (NNPMC) Iwopin were established. The NPM Jebba was established in 1969 but was expanded in 1983 to produce 65,000MT of Kraft paper, linerboards and corrugated paper per year. The NNMC Oku-Ikobu was commissioned in 1982 to produce 100,000MT of printing and writing paper. However, the mills were functional for only very few years before they stopped production in 1993. Thus the impact of the mills on the environment in terms of tree harvesting is no longer very significant but the clearing of natural forest for the establishment of *Gmelina arborea* plantation must have disrupted the hydrological cycle of the plantation sites. (GVWC, 1994)

From available evidence, the number of wood based industries in Nigeria has been increasing except for sawmills, which declined from 1700 in 1993 to 1349 in 1997.As at 1993, the General Wood and Veneer Consultant Ltd, Canada who was employed by the Federal Department of Forestry to carry studies on the wood based industries revealed that there were altogether 1715 wood industries in Nigeria consisting of 1700 sawmills, 8 ply mills, 4 particle board mills and 3 paper mills. However, by 1997, the Beak Constants Ltd in collaboration with Geomatics International Canada who was employed by the Federal Department of Forestry to carry out a Forest Resource. Report shows that the number of wood based industry had declined from the level of 1715 in 1993 to 1373. These are comprised of 1349sawmills, 10 Ply mills, 4 Particle Board mills, 3 Paper mills and 7 Match and splints factories. The major wood processing industries in Nigeria are typically large capacity facilities such as large sawmills, plywood mill, pulp and paper plants etc. In particular, the sawmills are designed to handle large diameter logs. The sawmills are essentially distributed between small, medium and large scale in the proportion of81%: 13%: 6%. Though the number of sawmills decreased, production has not decreased commensurately. This is because even though wood industries are finding it increasingly difficult to obtain desirable sizes of popular tree species, like *Mansonia ultissima*, *Milicia exclesa* and *Khaya species* from Nigerian forests, they have been forced to expand the range of exploited species to species which hith erto were regarded as uneconomic. By 1990, the Nigerian sawmill capacity was estimated at 11,684,000m3/year in log equivalent and capacity utilisation was 46% i.e. 5,422,000 m3/year. It was estimated that by 1993 capacity had dropped to 5,842,000 m3 while production was 2,711,000m3. However based on the findings of Beak International and the field survey carried out by the author, it was estimated that by 1997, the capacity would have dropped to4,635,800 with a corresponding output of about 2,000,000 m3. Production also might have gradually declined. The 10 ply mills are integrated complexes with sawmills and four particleboard plants.

The capacity of the 10 mills was estimated at 158,000 m3 by 1997 and capacity utilization then was 35% generally bringing the total production to 55,125 m3. Import of wood based panels have continued to decline from 70,000m3 where it peaked in1980 to 20,000m3 in 1990 and 12,000m3 in 1997.There are at present four particle board mills in the country but some of them are having problems. In 1993, the existing capacity was estimated at 85,500 m3 with a capacity utilisation of 44% and an output of 39,500 m3. This situation has remained largely so. There are three pulp and paper mills in Nigeria with a total installed pulp capacity of102,000 mt per annum and a paper capacity of 207,000 mt per annum. Since 1990,the production of newsprint had been declining from 31,000 mt out of an installed capacity of 100,000 mt per annum, to only 3,000 mt, in 1993. The Nigerian Newsprint Manufactu ring Company (NNMC) had remained shut since 1994, due to problems of spare parts and other logistic problems. The Nigerian Paper Mill (NPM)at Jebba produces industrial grade paper, specifically kraft and kraft linerboard. Theold paper machine had a capacit y of 12,000 mt but since 1994, a new machine with capacity of 65,000 mt has gone on stream. Production of paperboard in 1990 was12,498 mt and declined progressively to 2313 mt in 1992 from where a gradual upturn began. Paperboard production by 1996 was 19,744 mt and production had remained at this level. The third mill is the Nigerian National Paper Manufacturing Company Ltd (NNPMC) Iwopin with a proposed installed capacity of 100,000 mt/yr of printing and writing paper. After a protracted history of delays only 30,000 mt/yr of printing and writing paper was installed by 1995. Test production with imported pulp resulted in 2,500 mt of printing and writing paper in 1995 and 966 mt in 1996.Production has not increased appreciably from this mill ever since.(GWVC, 1994)

STRATEGIES FOR INCREASING VALUE ADDITION TO WOOD

Raw Material Factor:

The ability to produce secondary wood product fromshort length logs, thinning's and branches is one of the beauty of the industry. This is because supply of suitable indigenous species is fast diminishing from the natural forest in quantities that can sustain the wood requirements in the industry (FORMECU, 1994 and 1996). There are good prospects for raw material supply for SPWP production in Nigeria if suitable machin es are procured to convert logging wastes, thinnings, and small diameter logs and off-cuts from sawmill. Research should also be conducted on the utilization of lesser-known species with the same technical characteristics and appearance as those species presently in use.

Machines and Equipment:

One of the greatest strengths of integrating further processing in the Nigerian sawmill is that fixed assets such as buildings and basic machinery necessary for primary processing are already in existence. Few machines such as multiple rip-saw machines, binding machines are required to extend the production line for value addition and increase profitability.

Capacity Building:

Effort should be invested in training man power for wood modification to enhance value ad dition as regards, wood paneling, wood profiling and wood treatment.

Issues and Challenges

The changing patterns of wood usage and demand levels have to be continually studied if Nigeria is to remain relevant in tropical wood supply trade and also to meet the challenges of supplying Nigeria's future wood requirements. It is necessary to anticipate which new industries will be needed and whether there are profitable markets which can be opened up to bring revenue and employment opportunities to the ever increasing unemployed population, both at the urban and rural areas. Jukka (2001) states that, a vibrant, high-value timber processing is the only antidote for tropical forestry's strong presence in export market. The restrictions on export of logs and primary products by the government can only be sustained through the generation of investment capital for domestic industry development by linking log export rights to local investment in further processing machinery.

The wood-based industry in Nigeria suffers from production inefficiency as a result of poor integration, poor cost and returns database and non-reinvestment of profit. In order to raise the value of sawn timber being processed in Nigeria sawmills, additional capital investment of some wood working machineries are required to enhance increase production and quality. It will at the same time help in reducing deficit in import – export in the forestry sector of the economy. The manufacture of further processed product is an instrument for economic development, capable of mobilizing latent resources and promoting the expansion of forest industries for foreign exchange earnings. This is because the products of these industries have an unrestricted market in Europe. Furniture part component manufacturing could be integrated with existing sawmills in Nigeria to increase the value added to sawn timber as well as provide essential material for the furniture and building industry. Unfortunately, very little information exists on techno-economic appraisal of value added to sawn timber.

Many sawmills are unsure whether to invest in further processing. For effective planning, information must be available on the variables to arrive at the best operating performance mode within existing laws and regulations.

CONCLUSION

The industrialization of the wood based forestry sector has been slow because most mills engaged in primary wood processing which ends at sawmill. The value-added and labour absorptive capacities of the further wood processing are lost because most engaged in exporting semi-finished timbers as a means of earning foreign exchange. Unfortunately, the forest industry managers are only concerned about individual company's performance.

However, while some firms are well endowed with machinery and equipment to enhance performance, others suffer from lack of appropriate machine to improve production efficiency. Within both categories is found two classes: the one endowed with forest resources in which production processes are hampered by lack of machines and skilled workers. The others suffer from deficiency in forest resources even though it may be endowed with capital which could enable it to acquire necessary technology.

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Analysis of Crude Fibre and Mineral Element Concentrations in *Typha Latifolia* L. and *Typha domingensis* Pers. as a Measure of their Pulp and Paper Potentials

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Abstract

The major problems militating against the adoption of non-wood plant fibres in paper making are their low bulk density which is a measure of their crude fibre content and heterogeneity of their mineral element concentration. This study therefore, assessed the crude fibre and nutrient element concentrations in T. latifolia and T. domingensis. Both species were harvested at Rufan-Kwuanu located on Hadejia-Nguru wetland in Yobe state, Nigeria. Based on their varied morphological characteristics, the Typha species were harvested from both the shore and the centre of the wetland. The plants were separated into their individual leaves in the laboratory, chopped to about 1cm long and oven dried to constant moisture content. The dried samples were milled to less than 1mm particle size and evaluated for crude fibre, ash, silica, and elemental contents. The results revealed that both Typha species had similar crude fibre and elemental content accumulation irrespective of their point of harvest on the wetland. Conversely, they are significant in terms of their ash and silica content concentration. Both Typha species fall into fibrous plant categories based on their high crude fibre content which averaged, 62.29%. Also, the ash (5.0 – 8.0%), silica (< 1.0%) and elemental contents are low which reduced the threat of chemical recovery problem. Lastly, the close elemental content accumulation in T. latifolia (0.004 and 0.757%) and T. domingensis (0.009 - 1.303%) is an indication of the homogeneity of their mineral element. This offers the possibility of combination in same charge in pulping process.

Keywords: *Typha latifolia*, *Typha domingensis*, Crude fibre, Elemental contents, wetland plant, fibre plant, Hadejia-Nguru wetland

INTRODUCTION

The widespread usage of wood according to Joshi *et al.* (2004), contributes a great deal to the high rates of global deforestation with antecedent environmental repercussion. Also, continuous increase in wood demand as a result of population explosion and industrialization has led to scarcity of many high valued timber species in both natural and plantation forests globally. In view of this, there has been series of efforts at sourcing substitutes for wood, to meet the ever-rising demand for timber resources especially for pulp and paper making, construction, production of wood-based panels and other products. Wood has been the major source of fibre for pulp and paper production. The effort at using non-wood fibre as substitute for wood has gained ground in many countries including Nigeria in the last few decades. Some of the factors driving the search for non-wood fibres for pulp and paper making, fibreboard production include high competition with wood in terms of quality, high yield per hectare, short gestation period and low harvesting and processing cost. In line with this, many researchers have worked on production of quality pulp and paper fibre from variety of natural fibres and crop-based agricultural residues like peanut hulls (Guler *et al.*, 2008), cotton gin (Holt *et al.*, 2009), bagasse fibres (Ashori and Nourbakhsh, 2009), rice straw (Li *et al.*, 2010), maize husks and cobs (Evon *et al.*, 2010) and sunflower seed husks (Cosereanu *et al.*, 2015). Among the potential natural fibre source that have not found much application particularly in Nigeria is typha plant.

Water plants commonly known as hydrophytes are spread extensively mostly in marshes, rivers, ponds, lakes, irrigation channels and areas with high level of underground water globally and in Nigeria. *Typha latifolia* and *Typha domingensis* which is also a hydrophytic plant is a perennial herbaceous plant belonging to the *Typhaceae* family with about twelve different species distributed in the temperate and tropical regions of the world in wetlands and marshes (Mark *et al*., 2010; Kumar, 2012) and grows up to 3-4 meter (Hears, 2006). The plant is widely seen growing on marshes, ponds, lakes and rivers and its suspected to have invaded Nigerian inland wetlands from East Africa (Bajwa *et al*., 2015). More so, it is a plant that is locally referred to as "Kachala" by the people living around the Hadejia-Nguru wetlands in Nigeria (Akinsola, 2000).

Generally, natural wetlands are efficient sinks for minerals and metals. The removal processes of minerals and metal consist of adsorption, uptake by plants, complexation and microbial mediated reactions (Dunbabin and Bowmer, 1992). Typha as a candidate plant can excellently be used as an alternative source for wood, and in the first stage of a transition of a dairy farming in peatlands towards wet agriculture due to its high nutrient removal ability such as phosphorus and nitrogen. The main objective of the study therefore is to carry out quality assessment on the crude fibre content and elemental composition of *T. latifolia* and *T. domingensis* on Hadejia-Nguru wetlands with sole aim of examining its potential for pulp and paper making.

MATERIALS AND METHODS

The stems of *T. latifolia* and *T. domingensis* were harvested at Rufan-Kwuanu located on Latitude10^{o} 22'N and Longitude 12^{o} 46'E of Hadejia-Nguru wetland, in Nguru local Government Area of Yobe State, Nigeria (Fig. 1). The stems were harvested and classified based on the point in which they were harvested on the wetland. The two points are the shore (the bank of the wetland) and the centre which is about 15 km from the shore (Fig. 2). To aid in species classification, harvesting was carried out in July when the full flowering had already taken place and identification possible with the aid of a Botanist. Each group of samples were baled separately and transported fresh to the laboratory for analysis.

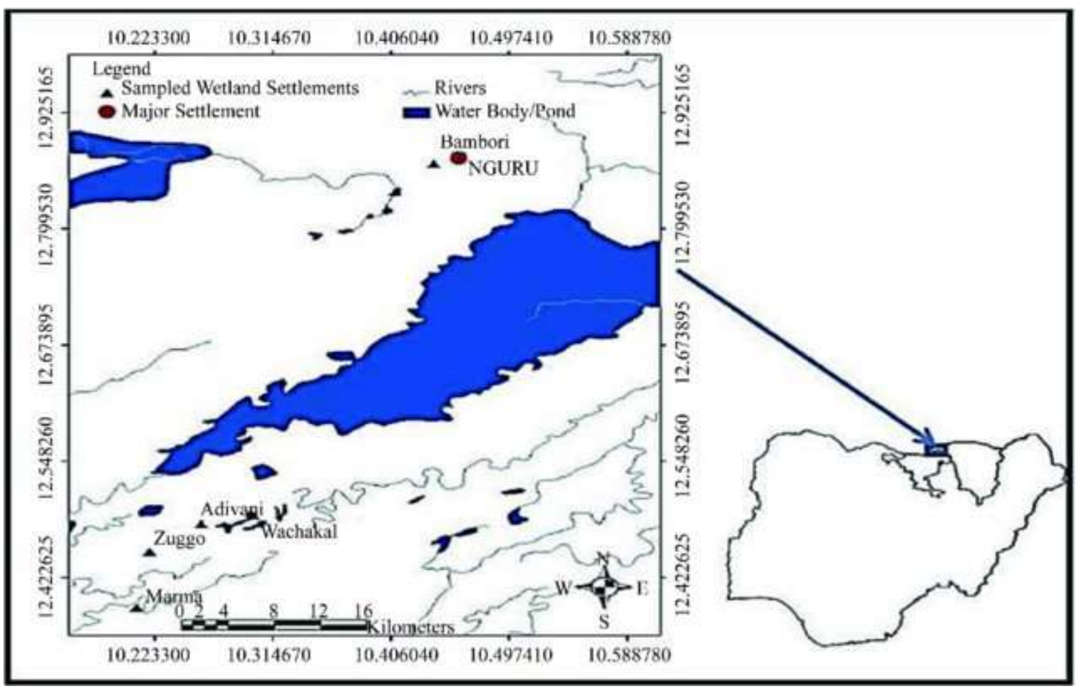

Figure 3: Map of Hadejia-Nguru Wetland

Crude fibre content determination

The crude fibre content was determined based on acid-alkaline extraction method as described in Association of Analytical Chemist (AOAC, 1990). 2g of the milled samples was boiled first in dilute 1.25% H_2SO_4 for 30 minutes followed by 1.25% NaOH for another 30 minutes. The residue, not soluble in the dilute acid-alkali treatment was then measured gravimetrically and the result given as percentage of dry matter in total biomass.

$$\%\ \text{Crude Fibre} = \frac{\text{weigth of Ovendried crude fibre}}{\text{Wiegth of original sample}} \times \frac{100}{1} \qquad (1)$$

Figure 4: Typha harvesting points; A is the shore and B is the centre of the wetland

Ash contents determination

The analysis was aimed at determining the ash content in the plant as expressed as percentage of residue remaining after dry oxidation at 500^0C. It was estimated in accordance with ASTM Designation D1102-50T (1950). 2g of the milled sample was placed in an empty crucible previously dried in the furnace and weighed. The content was later dried in the oven at 100^0C until a constant weight is obtained. The crucible and its content were ignited in the furnace until all the carbon is eliminated. This was done by heating slowly at the start to avoid flaming and protection of the crucible from strong draft to avoid mechanical loss of the sample. The percentage ash content was calculated as follows;

$$\%\ \mathrm{Ash} = \frac{\mathrm{W_0} - \mathrm{W_1}}{\mathrm{W_2}} \times \frac{100}{1} \qquad (2)$$

Where,
W_0 = Weight of crucible and silica
W_1 = Weight of empty crucible
W_2= Weight of original sample

Silica content determination

The silica content from the ash, TAPPI designation T244 0m-93 method was used. 2g of ash obtained was digested 3-times with 5ml of 6M HCl and evaporated each time on a steam bath to dryness. Thereafter, hot distilled water was used to wash the residue on the ash-free filter paper. After washing to removes chlorides sufficiently, the filter paper along with the residue was then placed in the crucible of known weight and dried in the oven at 550^0C for 3 hours. The crucible was then allowed to cool in desiccators and weighed. The percentage of silica was determined as follow:

$$\%\ Silica = \frac{W_0 - W_1}{W_2} \times \frac{100}{1} \qquad (3)$$

Where
W_0= Weight of crucible and silica
W_1= Weight of empty crucible
W_2= weight of original sample

Determination Nutrient Element Concentration

However, for elemental analysis, K, Fe, Mn, Cu, Pb, SiO_4, and Si contents of the samples was assayed in accordance with AOAC (1990) methods using Perkin Elmer 200 Flame Atomic Absorption Spectroscopy (AAS). Phosphorus content was determined using atomic absorption spectrophotometer while the Nitrogen content was also determined using the Kjeldahl method (Tecator, 1981).

RESULTS AND DISCUSSION

Crude Fibre Content

Variation in *Typha species* did not significantly influenced its crude fibre content. Nevertheless, *T. latifolia* had a marginally 0.59% crude fibre more than *T. domingensis* (Table 1). Unlike species difference, the harvesting point on the wetland had significant influence on the crude fibre content. *T. latifolia,* stems harvested on the shore of the wetland had 3.49% crude fibre than more those harvested deep into the centre of the wetland. The crude fibre content in *T. domingensis* was a bit homogenous with only a difference of 0.12% between the stems harvested from shore and those deep into the wetland (Fig. 3). Crude fibre content of a plant gives an idea of the total amount of cellulose content in a lignocellulosic material. For fibre production, high crude fibre content in a raw material is always desirable. The non-significant crude fibre content between the two species is advantageous for pulping purpose since it will afford the opportunity of being combined in the same charge during pulping process. The high crude fibre accumulation in *T. latifolia* stem harvested at the shore (64.33 %) as against 60.84% for those harvested deep into the centre of the wetland implied that the point of harvest had significant effect on the growth of the plants which by extension influenced the crude fibre content. The results obtained in this study revealed that *T. latifolia* and *T. domingensis* could be classified as fibrous plant based on their high crude fibre high crude fibre content (62.59 and 62.0%, respectively) which are more than 33.36% recorded for miraculous berry plant (Sotannde and Oluwadare, 2014) and, 45.3 % and 33.4 % recorded for wheat and reed canary grass, respectively (Pahkala, 2001).

Ash and Silica contents

The result presented in Table 1 showed *T. domingensis* had significant higher ash content accumulation than *T. latifolia* with a mean difference of 2.22%. In terms of points of harvest revealed in Figure 3, *T. latifolia* and *T. domingensis* harvested on the shore of the wetland had ash content of 1.5 and 0.73%, respectively more than those harvested deep into the wetland. Unlike ash content, *T. latifolia* and *T. domingensis* harvested deep into the wetland had higher silica content (0.57 and 0.72%, respectively) compared to those harvested on shore. Also, silica content was observed to be higher in *T. domingensis* than in *T. latifolia,* irrespective of the point of harvest (Fig. 3). Thus, the ash and silica contents in typha plant varied based on species and the harvesting point on the wetland ($P < 0.05$). Among the possible explanations for high silica content in plant harvested deep into the wetland is that silicon is deposited as silica crystals in the epidermis of the plant mostly (Ilvessalo-Pfaffli, 1995) and is not exposed to leaching (Pahkala, 2001). High ash and silica contents are not desirable as they complicate chemical recovery of the cooking liquor (Rodrigueze *et al.*, 2008). The values obtained in this study compared well with those recorded for typha plants from northern and eastern region of Bangladesh (Jahan *et al.*, 2007), *T. domingensis* Stems from Sudan. by Khider *et al.* (2012) and from Bauch State in Nigeria (Hassan *et al.* (2018). The low silica and ash in typha plants is an indication of their suitability for pulp and paper making since it is expected that chemical recovery from the pulping liquor will be high.

Table 1: Crude fibre and nutrient concentration in *T. latifolia and T. domingensis*

Parameters (%)	*T. latifolia*	*T. domingensis*	Mean difference
Crude Fibre content	62.59 ± 4.09^a	62.00 ± 2.55^a	0.59
Ash Content	5.85 ± 2.36^b	8.07 ± 1.94^a	2.22
Silica Content	0.37 ± 1.65^b	0.59 ± 1.49^a	0.22
Nitrogen (N)	0.319 ± 0.12^a	0.357 ± 0.16^a	0.038
Phosphorus (P)	0.143 ± 0.06^a	0.129 ± 0.04^a	0.014
Potassium (K)	0.017 ± 0.03^a	0.017 ± 0.02^a	0.000
Manganese (Mn)	0.004 ± 0.00^a	0.008 ± 0.00^a	0.004
Iron (Fe)	0.588 ± 0.23^a	0.431 ± 0.49^a	0.157
Copper (Cu)	0.096 ± 0.04^a	0.137 ± 0.07^a	0.041
Lead (Pb)	0.714 ± 0.21^b	1.231 ± 0.23^a	0.517
SiO_4	0.133 ± 0.04^a	0.214 ± 0.10^a	0.081
Si	0.017 ± 0.01^a	0.017 ± 0.01^a	0.000

* Values with the same alphabet in each row are not significantly different at $\alpha = 0.05$. Each value is an average of five replicates

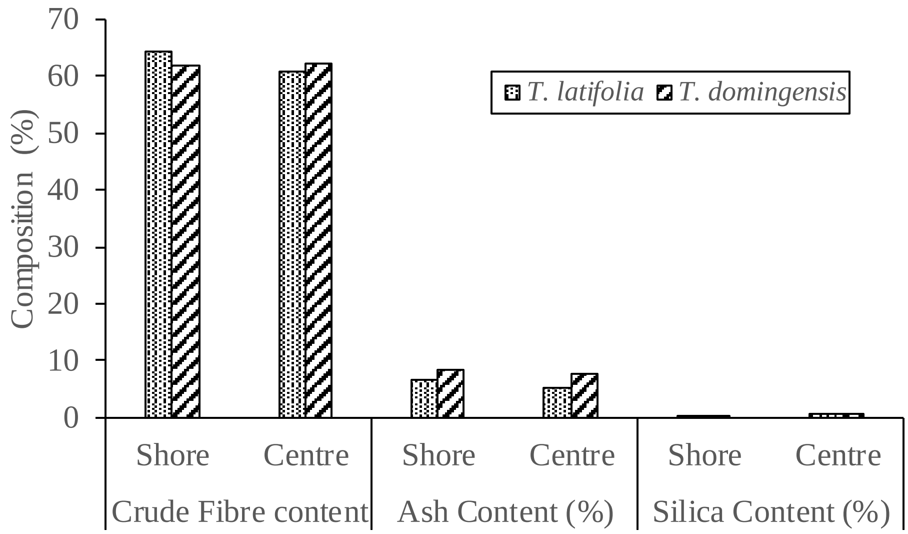

Figure 5: Crude fibre, ash and silica composition in *T. latifolia* and *T. domingensis*

Nutrient Elemental Concentration

One of the major challenges which had been making the paper producers to be reluctant in embracing the use of non-wood plants in paper production is the heterogeneity in their mineral element composition. For a non-wood plant to be qualified for inclusions into global non-wood fibre resource base it must fulfill all the technical requirements for pulp and paper production. Notable among such requirement are high fibre yield and low nutrient element composition (Sotannde and Oluwadare, 2014).

As revealed in Table 1, except for Pb, mineral element concentrations were not significantly different between the two typha species. Potassium and silicon concentrations, averaged 0.017% were constant in both species. Though not significant, stems of *T. latifolia* were marginally higher in phosphorus and iron with mean difference of 0.014 and 0.157%, respectively. In contrast, *T. domingensis* were observed to be higher in nitrogen, manganese, copper, Lead and silicate than *T. latifolia* with mean difference of 0.038, 0.004, 0.041, 0.517 and 0.081%, respectively. The insignificant difference in mineral element accumulation in both typha species suggest a generally stable intake of element content by them. This is in line with the assertion made by Bonanno and Cirelli (2017), that typha plants has comparable capacity for element accumulation. This further buttressed the possibility of combination in same charge during pulping process. Meanwhile, when element content in both *Typha species* from both harvesting points were compared, both *Typha species* showed same pattern of element accumulations in their tissues. Specifically, as revealed in Figure 4, both *Typha species* harvested on the shore of the wetland had marginally higher mineral element concentrations, except Pb compared to those harvested deep into the wetland. Some authors have cited reasons behind the difference in nutrient composition in plant tissues and concluded that the higher element content accumulated in the organ of the plant immediate upland of the wetland is a general trend of several macrophytes, including typha species (Sasmaz *et al*., 2008; Bonanno, 2013; Vymazal, 2011; Lyubenova *et al*., 2013; Bonanno *et al*., 2017). It is therefore suggested that the nutrient holdling capacity of the soil on the shore of the wetland had influence on nutrient availability and uptake by the plant.

Overall, Fe and Pb were the most abundant mineral elements accumulated both typha species followed by N, P, Cu and SiO_4 while K, Mn and Si were the least. The reason for the above trend could be attributed to the growth condition and nature of the plant fibre (Marschner, 1995). For example, nitrogen is an essential component in the formation of nucleic acid, phosphorus also plays significant role in nucleic acid formation while potassium is equally important in osmotic pressure balance and protein production. Furthermore, iron is equally important in chlorophyll formation, photosynthetic process and reactions involving cell division and growth (Curie *et al*., 2008) while Mn has direct influence on sunlight conversion in the chloroplast thereby aiding in splitting of water molecules and oxygen releasing process in green plant (Hagemeyer, 2004) and contribute mainly to production and activation of enzymes (Marschner, 1995). Although, all these nutrient elements are important for the physiological and metabolic growth and development of a plant, they are regarded as impurities in pulp and paper making process and thus, should be removed during pulping or bleaching (Sotannde and Oluwadare, 2014; Pahkala 2001). According to Nussbaumer (2002), high concentration of nitrogen in the spent liquor can lead to generation of NOx in the chemical recovery furnace. Similarly, potassium can react with chlorine (KCl) leading to corrosive effect on metal parts in furnace and boilers (Sotannde and Oluwadare, 2014; Salmenoja and Makela, 2000). Also, high accumulated content of phosphorous in the spent liquor can also prolong thermo-chemical conversion process (Nussbaumer, 2002) thus resulting to extra costs. Manganese and copper according to Gierer (1997), can facilitate the formation of deposits on recovery furnace.

Compared to other plants, the percentage of mineral elements accumulated in both typha species were generally low and compared favourably with other known non-wood plant fibres like *Astragalus armatus* roots (Moussaoui *et al*., 2011), depithed sugarcane bagasse (Agnihotri *et al*., 2010), Reed (Pahkala, 2001) and wheat straw (Mckean and Jacobs, 1997). The mineral contents also fall within the required range of 0.1 to 1.5% of macro nutrient concentration in plant fibres suitable for pulp and paper production (Epstein, 1965). The implication of this is that, the low concentrations of mineral elements in both *T. latifolia* and *T. domingensis* present great advantage because of the expected low NOx and particulate emission, low deposition and corrosion of metal parts in the furnace and boilers and un-prolonged thermo-chemical conversion process during pulping and recovery of liquor.

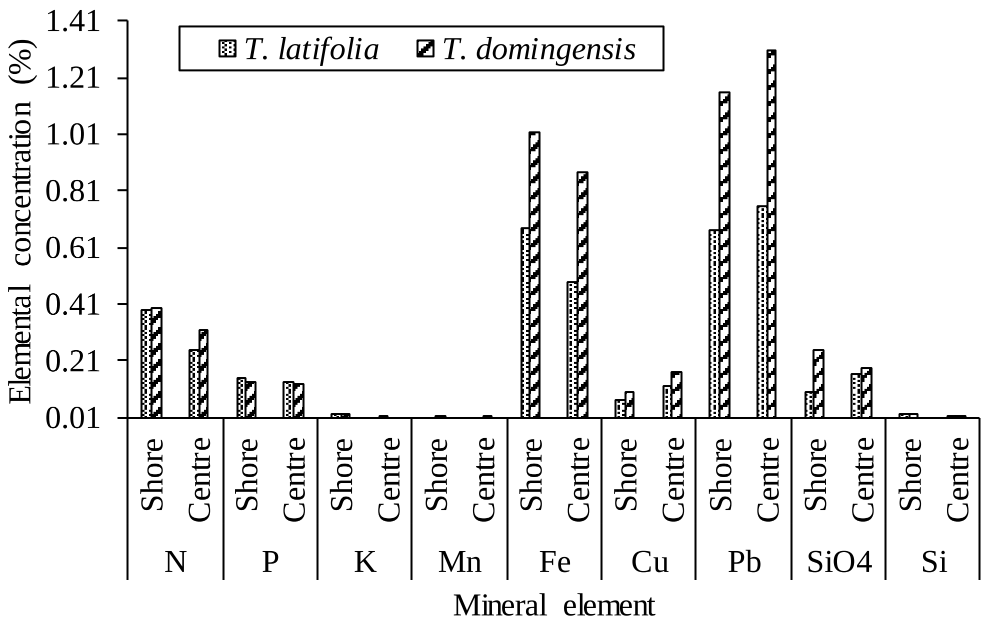

Figure 6: Mineral element composition in the typha species in relation to their point of harvest.

CONCLUSION

Based on the finding from this study, the following conclusions are made:

1. Both typha species could be classified as fibrous plant based on their high crude fibre contents.
2. The mineral element content in both typha species is low with value range between 0.004 and 0.757% in *T. latifolia* and, between 0.009 to 1.303% in *T. domingensis* which possibly suggest their tendency not to pose any threat during chemical recovery.
3. There is insignificant difference in crude fibre contents of typha plant irrespective of their harvesting point on the wetland. This suggest possible combination opportunity in the same charge during the pulping process.
4. Also, the mineral elements in both typha species were relatively homogenous irrespective of where they were harvested on the wetland.

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Lignin from Lignocellulosic Biomass: A Sustainable Source of Bio-renewable Fuel and Chemical

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Abstract

Lignin is highly branched phenolic polymer and accounts 15–30% by weight of lignocellulosic biomass. The acceptable molecular structure of lignin is composed with three main constituents linked by different linkages. However, the structure of lignin varies significantly according to the type of lignocellulosic biomass, and the composition of lignin strongly depends on the degradation process. Thus, the elucidation of structural features of lignin is important for the utilization of lignin in high efficient ways. Up to date, degradation of lignin with destructive methods is the main path for the analysis of molecular structure of lignin. This paper discuss the utilization of lignin as a sustainable source for fuel production in terms of its availability and impact on the environment. Subsequently, the structure of lignin is briefly overviewed. Then, the lignin characterization methods as well as the thermochemical processes by which lignin can be isolated from the biomass are discussed. Moreover, the valorization of lignin through depolymerization and gasification and also the application of lignin-derived compounds as bio-renewable fuels and aromatic chemicals are mentioned.

Keywords: Lignin, thermochemical processes, valorization, bio renewable fuels, aromatic chemicals

INTRODUCTION

The growing global population leads to an increasing demand for fuels and chemicals, resulting in many societal problems, including energy security and environmental concerns (Schutyser *et al*., 2018; Sun *et al*., 2018). To reach a sustainable development of society, bior-efinery operations that employ inedible biomass for the production of valuable products (fuels, chemicals and materials) must be advanced. In this regard, lignocellulose, composition of cellulose, hemicellulose, and lignin, is a promising feedstock for biorefinery to produce biofuels and biochemicals (Rinaldi *et al*., 2016). Lignocellulose is a widely available, carbon-neutral, and inedible bioresource that could be regenerated on a world-wide basis in considerable quantities each year. However, most biorefinery processes currently focus on the utilization of the carbohydrate fractions (cellulose and hemicellulose), while leaving lignin, the second most abundant terrestrial polymer, underutilized.

Lignin, a components of the lignocellulosic biomass constitutes 15–35% of the weight and carries the highest specific energy content of all the other two wood polymers (cellulose, hemicellulose) Brunow (2006)., Saake and Lehnen (2012)., Zakzeski *et al*., 2010. Therefore, economic viability of the future lignocellulosic biorefineries depends upon conversion of lignin to value-added compounds. Lignin is a cross-linked amorphous copolymer synthesized from random polymerization of three primary phenylpropane monomers which are bonded together through several different C–O–C and C–C interunit linkages. The role of lignin in biomass is to provide the plant with structural integrity, water impermeability, and resistance against microbial decay Saake and Lehnen (2012). Although lignin holds great potential as a renewable source of fuels and aromatic chemicals, lignin valorization technologies are substantially less developed than those for the other polysaccharides. Difficulties in catalytic processing caused by the existence of a variety of different interunit linkages, high affinity for the formation of a more condensed structure when thermochemically processed, poor product selectivity, and ease of use as a solid fuel are the major barriers towards the development of a lignin-based biorefining technologies. Owing to the massive amounts of lignin available in the pulp mills and in future biorefineries, establishment of lignin conversion processes will open a new route for the production of low-carbon biofuels and the currently fossil-based aromatics and will, in turn, improve the economic viability of the plant. In order to provide significant amounts of energy while minimizing social and environmental impact, feedstock for any type of biofuel have to fulfill certain prerequisites: firstly, feedstock has to have a high land-use efficiency, i.e. the amount of energy produce per area has to be high in order to produce significant amounts of fuel without impacting global land use Yan *et al*, 2011; Yan, *et al*; 2010. Secondly, feedstock has to have a low water footprint, i.e. the water needed especially irrigation water has to be minimal per energy produced (low L/GJ). Yan *et al* 2011. Thirdly, other detrimental effects on the environment have to be minimized: such as emissions from land-use change when creating new cropland Searchinger *et al* 2008; Hill., *et al*; 2006; Fertilizer use Inderwildi and King (2009) and the carbon footprint of the biomass itself Yan; *et al*., 2010. Last but certainly not least, it has to be ensured that biomass production does not – directly or indirectly – interfere with food production. Lignocellulosic biomass fulfills all the prerequisites as stated.

Lignin Chemistry and Structure

Lignocellulosic biomass is mostly cell wall material that is composed of three principal components: cellulose, hemicellulose, and lignin (Table 1). Lignin constitutes 15–35% of the dry lignocellulose and it is the largest renewable source of aromatics on earth.

Table 1: Average organic constituents of Softwood and Hardwood.

Feed	Cellulose	Hemicellulose	Lignin	Ref.
Softwood	40–44	20–32	25–35	(Abbasi & Abbasi 2010)
Hardwood	40–44	15–35	18–25	(Abbasi & Abbasi 2010)

The lignin content of biomass decreases from softwood to hardwood. The softwood lignin is primarily formed from coniferyl alcohol (guaiacyl structure), whereas almost equal amounts of coniferyl sinapyl alcohol (syringyl structure) constitute hardwood. Generally more than two-thirds of the linkages in lignin are ether linkages. Hardwood lignin contains roughly 1.5 times more β-O-4-linkages compared to that of softwood. There are various functional groups in the structure of lignin including methoxyl, phenolic hydroxyl, aliphatic hydroxyl, benzyl alcohol, noncyclic benzyl ether and carbonyl groups which result in reactivity of the lignin in various chemical reactions. The structure of lignin is also dependent on the source and the isolation technique (Figure 1)

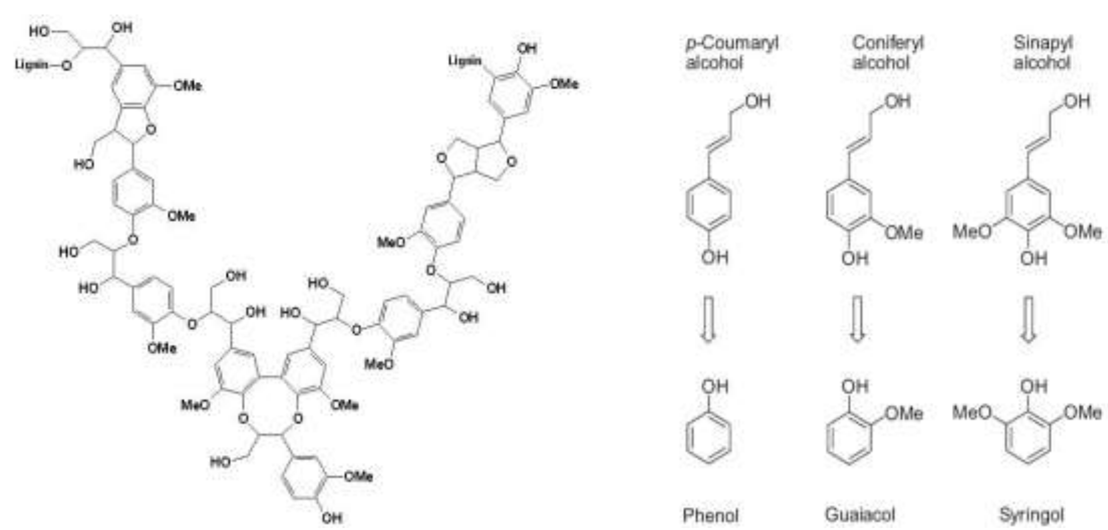

Figure 1: Chemical structure of a piece of lignin molecule, three monomers of lignin, and the respective direct degradation products (Desch and Dinwoodie, (1996).

Lignin Characterization Methods

The complex structure, inherent variation in lignin, and significant structural changes occurring by different isolation methods used, has made the characterization of lignin a controversial subject over the past few decades. However, some of the major methods for the determination of total lignin is the molecular weight and functional groups determination Brunow (2004); Lin and Dence (1992).The method mostly used for the determination of the lignin content in lignocellulosic material is the Klason procedure. In all isolation processes, the lignin in biomass is broken down into smaller fragments. An important attribute for the development of lignin-based products is the molecular weight and polydispersity of these lignin fragments. The most widely used method for the determination of the molecular weight of lignin is gel permeation chromatography (GPC) performed on acetylated lignins dissolved in THF. However, acetylation of lignosulfonates and carbohydrate-containing lignins may lead to erroneous molecular weight data. Other methods used for such purpose include matrix assisted laser desorption ionization/time of flight (MALDI-TOF) Brunow, (2004) Bayerbach, *et al.*, 2006 and vapor pressure osmometry (VPO) Lindner *et al.*, 1990. Spectroscopic methods namely NMR, FTIR and UV absorption has been extensively utilized to shed light into the complex structure of lignin. The assignment of infrared absorption bands and ^{1}H and ^{13}C shifts for several model compounds of lignin are available in Ralph, *et al.*, 2004, respectively. Degradative techniques are also used to quantify the methoxyl, phenolic hydroxyl and carbonyl functional groups of lignin.

Lignin Isolation Processes/ Types of Lignin

There are several different methods by which lignin can be isolated from biomass. These processes can be classified into two general groups:

(i) Processes in which lignin is degraded into soluble fragments and is removed by separating the solid residue from the spent liquor and

(ii) Processes that selectively hydrolyze polysaccharides and leave lignin along with some condensed carbohydrate deconstruction products as a solid residue. The example of former would be all pulping processes: such as kraft, sulfite, soda, and organosolv, and an example of the latter would be dilute acid hydrolysis of lignocellulose to yield sugar monomers, furfural and levulinic acid.

Due to the high reactivity of lignin and its fractions, repolymerization (condensation) reactions forming new C–C bonds usually accompanies lignin extraction, leading to different lignin intermediates with various properties (Schutyser *et al*., 2018). In general, isolated lignin varies in structure due to different feedstocks, extraction methods, and extraction severity.

The current and emerging technologies for the lignin isolation and types of lignin obtained are:

Lignosulfonate lignin

Lignosulfonate lignin is obtained from the sulfite process, where alkaline earth metal sulfite mixture is used. In this lignin, sulfonate groups are mainly present at α-position of the propyl side chain. This type of lignin is water-soluble, which makes it different from the other types of lignin. It can be used as a stabilizer, dispersing agent, surfactant, and adhesive, due to the presence of high dense functional groups with unique colloidal properties. The lignosulfonate lignin is having relatively high molecular weight and contains a large amount of ash with a significant amount of carbohydrates. Lignosulfonate lignin from hard- and softwoods is commercially available.

Kraft lignin

Kraft lignin is tremendously condensed with strong ether bonding and high in refractory C-C bonding such as biphenyl and methylene-bridge. Kraft lignin has impurities in its structure like covalent bonding with sulfur species mainly thiols. These impurities can inhibit further valorization due to the poisonous nature of sulfur which deactivate most of catalyst. Kraft lignin has a large number of phenolic groups with a small amount of ash and carbohydrate. Kraft lignin is also commercially available from hard- and softwoods.

Soda lignin

Soda lignin is profoundly different from kraft and lignosulfonate lignin due to sulfur-free nature and presence of vinyl ethers. The harsh pulping conditions make lignin more condensed and recalcitrant. Soda lignin has a minor amount of ash and carbohydrates. Soda process has the opposite process to kraft lignin in which lignin is gained under acidic conditions. It is commercially available from a small number of annual hardwood crops.

Organosolv lignin

The organosolv lignin structure greatly depends on the pretreatment condition under which it is obtained. Its structure is almost similar to native lignin, as it contains a high number of easily breakable aryl ether linkages (β-O-4). It is homogeneous in structure with low molecular weight and polydispersity. Additionally, it can be chemically changed into soda or Kraft lignin. Organosolv lignin is high in purity with a negligible amount of carbohydrate and ash. It is produced at both pilot and demonstration plant scale from hard- and softwoods, and it is also commercially available.

Lignin Depolymerization

Depolymerization is another approach for the production of fuels and chemicals from lignin. Compared to gasification, the depolymerization processes are typically conducted at milder operating conditions, and the monomeric products have a higher economic value compared to syngas because the aromatic products can be readily blended into current transportation fuels or used in chemical industry. However, the depolymerization processes usually result in low conversions, a wide range of monomeric compounds, and large amounts of oligomeric residues while consuming hydrogen for upgrading and stabilizing the product mixture. There are four common lignin depolymerization processes, namely pyrolysis, catalytic hydrogenolysis, alkaline hydrolysis, supercritical water and solvent depolymerization (solovolysis liquefaction). Two of the techniques are explained below. In general, lignin depolymerization can take place in aqueous phase, organic phase as well as in a dry form. The isolated lignins results in a complex mixture of aromatic compounds.

Pyrolysis of Isolated Lignins

Depending on operating conditions, pyrolysis processes could be classified into two major types: fast pyrolysis and vacuum pyrolysis. Fast pyrolysis is so far the only industrially realized thermo-chemical process for biomass liquefaction. A fast pyrolysis process typically operates at > 500 ^{o}C in an inert atmosphere under a very high heating rate with a short vapour residence time of less than 2 seconds, producing a yield of liquid products (pyrolysis oil or bio-oil) as high as 70-80 % (Bridgwater and Peacocke, 2000, Effendi *et al*., 2008). Compared to fast pyrolysis, vacuum pyrolysis, operating under reduced pressure with a much longer vapour residence time, produces a much lower liquid yield (Bridgwater, 2004). Pyrolysis oil is a complex mixture of water (15-30 wt %) and organics of a high-oxygen content (45-50 wt%). This oxygen content constitutes more than 300 identified compounds, which consist of hydroxyaldehydes, hydroxyketones, sugars, carboxylic acids and phenolics (Effendi and Gerhauser, 2008).

The majority of the phenolics are present as oligomers containing varying numbers of acidic, phenolic and carboxylic acid hydroxyl groups as well as aldehyde, alcohol and ether function. The molecular weights of the oligomers resided in several hundreds to five thousand or more depending on the operation conditions. Therefore, pyrolysis oils are unstable upon storage and require further upgrading, which will result in a high cost. Pyrolysis oil so far mainly been used as an energy source by direct combustion. The liquid product from lignocellulosic materials pyrolysis can be separated into water soluble fraction and water-soluble fraction and water-insoluble fraction. The water-insoluble fraction that usually constitutes 25-30 wt% of the whole bio-oil is often called pyrolytic lignin because it is essentially composed of oligomeric fragments derived from thermal degradation of native lignin (Radlein and Piskorz, 1987; Meier and Scholze, 1997). Although without being commercialized so far, the use of pyrolytic lignin as a source of phenol in PF resins seems to be promising.

Solvolytic Liquefaction Techniques

Liquefaction is another method of converting lignocellulosic biomass into bio-phenolic compounds or precursors for the production of PF resins (Effendi *et al*., 2008). Direct liquefaction of lignocellulosic materials in a suitable solvent at relatively lower temperatures, known as solvolytic liquefaction, is more advantageous than the pyrolysis processes with respect to energy efficiency and the quality of the oily products. As such, the solvolytic liquefaction technologies of lignocellulosic materials have attracted increasing interest for the production of bio-phenol precursors for synthesis of bio-based phenolic resins and heavy oils (bio-crude) for bio-fuel production. In terms of the type of solvents and operating conditions in the liquefaction processes, typical solvolytic liquefaction processes may be grouped into two categories: solvolysis under low temperatures and atmospheric pressure, and solvolysis in a hot-compressed and sub-/super-critical fluid

Advances in Lignin Application for chemical applications

The trending technology in lignin application is the use the intrinsic structural features of lignin to develop value-added products. Several studies have shown that lignin may be well suited for *bio-based* plastics and composite applications, in particular, for lignin resources isolated from biomass using an organosolv extraction protocol. Depending on the exact lignin extraction procedure used, the structure of lignin may be kept mostly intact. Several promising lignin applications include the use of oxypropylated lignin for polyurethane foams (Li and Ragauskas, 2012), inclusion into polystyrene (Henry *et al*., 2012), as a potential green antioxidant (Pouteau *et al*., 2003), or flame-retardant additive (Matsushita *et al*., 2017), as an adhesive for non-formaldehyde wood resins for flooring (Aracri *et al*., 2014), packaging, and composite wood board production (Olayiwola, 2018). The use of lignin has also been leveraged with epoxy resins to yield printed circuit boards (Luukko *et al*., 2013), and for molding (Nam and Son, 2015). Finally, there is a growing interest in using lignin in the polyolefin markets (i.e., polyethylene and polypropylene) as the aromatic unit of lignin provides photo-stabilization, strength enhancement, and elongation effects (Lv *et al*., 2011). In addition to the above advances, the conversion of lignin to chemicals and fungible fuels for ground and aviation transportation is being aggressively developed using thermal and/or catalytic processes (Ben and Ragauskas, 2011; Bi *et al*., 2015). In each of these applications, the structure and purity of lignin play a critical role in determining its chemical and physical properties

Advances in Lignin Application in fuel applications

Gasification

Alike gasification of other biomass species, the decomposition products of lignin would ultimately be a mixture of small permanent gas molecules such as H_2, CO, CO_2, and CH_4 with varying ratios depending on the gasification temperature and pressure, presence of steam and oxygen, heating rate, and the feed elemental composition. The gasification products mixture, collectively known as syngas, already has proven industrial applications for the generation of electricity, pure hydrogen, and synthetic liquid fuels and chemicals. Furthermore, in contrast to pyrolysis, the product selectivity in gasification is inherently less problematic as the syngas composition can be easily adjusted through reformation, water–gas shift, selective oxidation, and methanation.

Nonetheless, it should be realized that the primary products of gasification, at least on a pure basis, are significantly of lower value compared to the aromatics typically found in a pyrolysis bio-oil. The main advantages of gasification include feed flexibility and high product selectivity, allowing for ease of integration within pulp mills and biorefineries alike. Another advantage of gasification is its potential for the carbon capture if using oxygen instead of air, which in turn, will reduce the overall emissions of the mill and will have positive impact on carbon credits. However, conventional gasification is conducted at severe operating conditions and it still requires further development before it is fully commercialized.

End-use Applications

Fuels: The roadmap for the thermochemical conversion of lignin to liquid, gaseous and solid fuels is shown in Fig. 2. There are two different directions for the conversion of lignin to combustible fuel depolymerization and gasification. However, it is expected that higher yields, and hence a better process economy, can be achieved through the process integration. For example, the easier-to-depolymerize fraction of lignin can be processed to produce aromatics while the solid residue is sent to a gasifier to produce hydrogen required for fuel upgrading. The light hydrocarbons can be also catalytically reformed to yield syngas and hydrogen. Lignin and lignin derived compounds can be used as a fuel in the following forms: solid lignin and char, syngas, hydrogen and aromatics.

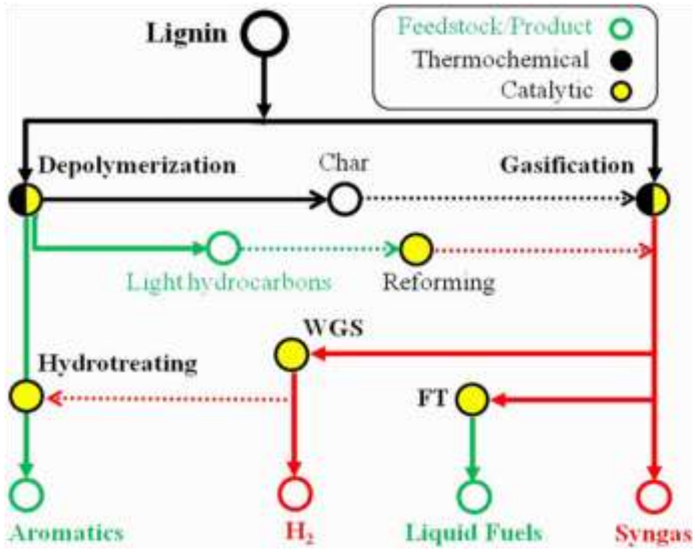

Figure. 2. Roadmap for the conversion of isolated lignin to liquid (green), gaseous (red) and solid (black) fuels. FT: Fischer–Tropsch synthesis, WGS: water–gas shift Solid lignin and char

CONCLUSION

The efficient use of lignin has both direct and indirect benefits with regard to reducing the greenhouse gas emissions. It can directly produce biorenewable fuels and chemicals with a low carbon footprint while imposing a minimal impact on food. Additionally, the conversion of lignin value-added products will improve the viability of the lignocellulosic biorefineries. The under listed factors amongst others will however, collectively demand and motivate researchers and industry to developing more advanced lignin conversion processes in the future.

1. The higher oil prices in the future, caused by the reduction in the supply capacity and the increase in the demand.
2. The ever-tightening environmental regulation will require a smart and efficient use of all fractions of biomass, including lignin, in order to reduce the overall emissions and achieve more sustainable economics.

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Effects of Thermal Modification on the Physical and Mechanical Properties of *Leucaena leucocephala* Wood

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Abstract

This study assessed the effects of thermal treatments on the physical and mechanical properties of Leucaena leucocephala wood. Samples of L. leucocephala were obtained from different sampling heights (10%, 50% and 90%) i.e. the base, middle and top respectively and subjected to heat treatment at different temperature range (140 ^oC, 160^oC and 180^oC) for 30 minutes in a muffle furnace. The statistical design used was 3 × 3 factorial experiment in a complete randomized design. Result showed that visible colour change occurred at 180°C. Temperature had a significant effect ($P<0.05$) on the mechanical properties. Wood samples treated at 180ºC had the lowest mean moisture content of 7.87%. Average mean weight of the treated wood ranged from 92.47 g – 96.64 g which increased from top to bottom. Wood samples treated at 140°C had the lowest (37435.83 N/mm^2) MOE while the highest (42833.86 N/mm^2) was recorded at 180°C. Results of MOR showed that the average mean for the treated wood ranged from 141.51 N/mm^2 – 159.04 N/mm^2. Based on the results obtained from this study, heat-treated wood has greater mechanical and physical properties than the untreated wood as a result of low temperature and duration of exposure to heat.

Keywords: Thermal modification, temperature, physical properties, mechanical properties, *Leucaena leucocephala*

INTRODUCTION

Man's dependence on wood has been from time immemorial. Wood has been useful to man because of its structural, economic, environmental and aesthetic benefits. Even though other structural materials are currently available in the market, wood retains its position as the most acceptable material because of its versatility. Its usage is playing an important role in the world economy and it is the fifth most important product of the world trade (Christophe and Gregoire, 2001). Wood as a renewable natural resource has been used by man for thousands of years since his appearance on earth for fuel, as a construction material, for making tools and weapons, furniture and paper and has contributed to the survival of man and to the development of civilization (Iyiola *et al*., 2019). In Nigeria, more than 80% of the timber products are used for constructional purposes such as building, furniture, railway sleepers, transmission poles, veneer, plywood and composites boards (Akanbi and Ashiru, 2002).
Thermal modification of wood is the application of heat to wood to cause a desired improvement in the properties of the material. Temperature is one of the most important parameters in thermal modification of wood (Korkut and Galler, 2008; Mitchell and Denne, 1997). The thermal modification of wood has long been recognized as a potentially useful method to improve the dimensional stability of wood and its decay resistance.

Thermal modification is a chemical free process, which alters the chemical properties of wood permanently, and also improves its properties. Thermal modification takes place between the temperatures of 180 and 260°C, with temperatures lower than 140 °C resulting in only slight changes in material properties and higher temperatures resulting in unacceptable degradation to the substrate (Hills, 2007). When wood is heated, its chemical and physical properties undergo permanent changes and its structure is transformed (Boonstra *et al*., 2007).

Due to the large amount of tapering in *L. leucocephala* which affect its mechanical properties and in-turn affect its structural integrity, it has become important to improve the longevity and strength of wood and increase utilization potentials. Therefore, this study, determined the effect of heat on the physical and mechanical properties of species of *L. leucocephala* which is a prime species for construction purposes in Ogun State, Nigeria.

MATERIALS AND METHOD

The Study Area

The study was carried out at Federal University of Agriculture, Abeokuta (FUNAAB). The land area of FUNAAB is about 10,000 hectares which is located next to the Ogun-Oshun River Basin
Development Authority (OORBDA) at Alabata road in North Eastern part of the town in Odeda Local Government at Latitude 7º 30'N and Longitude 3º 54'E (Ufoegbune and Fabiyi 2016). The relative humidity is about 82.54% with average temperature of 35.8ºC (Aiboni, 2012). The annual rainfall is about 1113.1mm and the rainfall is very high in June and July.

Sample Collection

A tree of *L. leucocephala* with straight bole and devoid of obvious defects was purposively selected. Wood samples were systematically collected axially at base (10%), middle (50%) and top (90%) of the merchantable height and were labelled accordingly. The samples were then machined into 20mm x 20mm x 300mm to determine the physical and mechanical properties in accordance with ASTM 2009. The weights, moisture content and dimension of the specimens were taken before the thermal treatment. The samples were ramped in a cellophane nylon to avoid moisture absorption before thermal treatment.

Physical Properties

The moisture content of the samples was determined using a moisture meter. The moisture reading were taken both before and after the thermal treatment. The weight and dimension were also taken before and after the treatment using a sensitive weighing scale.

Thermal Treatment Process

The heat treatment was conducted in a closed muffle furnace, a temperature controlled heating chamber. Samples were thermally treated at temperatures of 140˚C, 160˚C, and 180˚C for the duration of 30 minutes. The temperature of the furnace was set to the temperature at which the actual heat treatment occurred before introducing the wood samples. At the end of each treatment period, the samples were removed from the furnace, and their weights, moisture content, and dimensions were taken after cooling.

Mechanical Properties

To evaluate the effect of thermal treatment on the samples, tests were performed on both control and treated samples in accordance with ASTM 2009. The dimensions of wood samples for the test were 20mm x 20mm x by 300mm. Three replicates were tested for each treated wood samples on Tensiometer load cell. Data were collected and processed using statistical package for social science (SPSS).
Equation 1 and 2 were sued to estimate MOR and MOE respectively.

$$MOE = \frac{PL^3}{4bd^{3}Yp}$$ ……………………………………………………………………………Equation (1)

Where P = Load (N)
Y = Deflection (mm)
L = Length (mm)
b = Width (mm)
d = Depth (mm)

$$MOR = \frac{2PL}{2bd^2}$$ …………………………………………………………………………………Equation (2)

Where P = Load (N)
L = Length (mm)
b = Width (mm)
d = Depth (mm)

Statistical Analysis Design
Data obtained in the study were analyzed using 3 x 3 factorial experiment in Completely Randomized Design (CRD). Test of significance of the different treatment variables were estimated using ANOVA.

RESULTS AND DISCUSSION

Physical Properties of Thermally Modified *Leucaena leucocephala* Wood

Color

Color affects the aesthetic properties of the material surface. The color of untreated *L. leucocephala* wood varied from pale creamy to light brown. There was no visible color change at 140°C and 160°C. However, the wood changed from pale creamy to light brown colour at 180°C. This result is similar to the result obtained by Olufemi *et al.*, 2018 and Owoyemi and Iyiola 2016 that the color of the wood becomes darker with increasing temperature and time. The colour change could be attributed to the influence of chemical reaction that took place during the heating process. According to Sundqvist *et al.*, (2006), wood treated at 160°C–220°C can produce acetic acid which will increase the acidic condition of the lignin thereby increasing the degree of wood discoloration.

Weight Loss

Assessment of the weight loss showed that temperature influenced the weight loss of the wood significantly ($p<0.05$). The average mean weight of the treated wood ranged from 92.47 g – 96.64g which is lower compared to the untreated wood 104.31g. It was observed that wood treated at 160ºC had the lowest average mean weight (92.47 g) while those treated at 140ºC had the highest (96.64 g). This result is similar to observation of Iyiola *et al.*, (2019). According to Cademartori *et al.*, (2015), Poncsák *et al.*, (2006) and Esteves, (2008), there is a direct relationship between weight loss and temperature. The weight loss increased with increased temperature. The weight loss percentage increased with increase in temperature (Table 3). Weight loss increases with increasing process temperature and duration of the heat treatment (Esteves *et al*. 2007). The temperature significantly ($p < 0.05$) influenced the weight loss.

Moisture Content

The average moisture content for the treated wood ranged from 7.87 – 8.19, which is comparably lower than the untreated wood (9.61). Wood samples treated at 180ºC had the lowest (7.87) mean moisture content while those treated at 140ºC and 160ºC had the same mean moisture content (8.19), compared to the untreated wood samples. There is decrease in the moisture content of the wood with increasing temperature. This result is similar to the findings of Calonego *et al.*, 2014; Vernois 2001; Esteves *et al.*, 2007; Metsä-Kortelainen *et al.*, 2006; Arnold 2010; Calonego *et al.*, 2012; and Esteves and Pereira, 2009. This could be attributed to the relationship between moisture content and temperature.

Mechanical Properties of thermally modified *L. leucocephala* wood

Modulus of Rupture

Modulus of Rupture (MOR) reflects the maximum load carrying capacity of a member in bending and is proportional to maximum moment or force borne by the specimen. The variation in the MOR of thermally treated *L. leucocephala* ranged from 141.51 N/mm^2 to 159.04 N/mm^2 which is higher than the untreated wood 123.48N/mm^2. Other authors have also reported similar findings (Iyiola *et al.*, 2014; Olufemi *et al.*, 2018; and Percin *et al.*, 2016)
The influence of temperature on the MOR was significant ($p<0.05$). It increased as the temperature increased. This is contrary to Owoyemi and Iyiola, 2016; Iyiola *et al.*, 2019 where MOR of heat-treated wood decreased with increase in temperature and time. Some factors like temperature, duration, rate of heating, species, weight and dimensions of the samples may be responsible for the irregular pattern recorded for the MOR (Vernois, 2000; Kocaefe *et al.*, 2008).

Modulus of Elasticity

Modulus of elasticity (MOE) implies that deformations produced by low stress are completely recoverable after loads are removed. The average mean MOE of heat-treated wood samples varied from 37435.83N/mm^2 to 42833.86 N/mm^2. The MOE increased with increasing temperature. The effect of temperature on the MOE was significant ($P<0.05$). This contradicts the known fact and as reported by other authors that thermal modification leads to reduced MOE(Owoyemi and Iyiola, 2016, Rapp and Sailer, 2000,Dündar *et al.*, 2012). This observed difference may be attributed to the presence of tension wood in the wood of *L. leucocephala*. Also, the short duration of application of heat may be responsible for this. Esteves and Pereira (2009) reported that the modulus of elasticity seems to increase for moderate heat treatments and to decrease for more severe heat treatments.

CONCLUSION

Thermal modification affected both the physical and mechanical properties of *L. leucocephala* wood. The colour of the thermally treated wood changed from pale creamy white to light brown with increasing temperature. Axial position influenced the physical properties but did not exhibit any significant influence on the mechanical properties while temperature significantly ($p<0.05$) influenced all the mechanical properties examined in this study. Axially, there is an irregular pattern of variation in the mean MOR of wood samples which could be as a result of variation in the wood or effect of silvicultural treatment of the wood. Based on the results obtained from this study, weight loss increased with increasing temperature and heat-treated wood exhibited greater mechanical properties than the untreated wood. This could be attributed to the effects of low temperature and low duration of exposure to heat.

Table 1: Axial variation in mean values of Physical and Mechanical properties of thermally modified wood

Heat treatment	Axial position	Weight (g)	Moisture content	Modulus of elasticity (N/mm^2)	Modulus of Rupture (N/mm^2)
140	Top	88.60 ± 5.58	7.63 ± 0.49	45820.55 ± 3768.15	147.49 ± 7.71
	Middle	93.87 ± 13.94	7.90 ± 0.95	33259.11 ± 6371.34	136.13 ± 21.19
	Bottom	107.47 ± 6.30	9.03 ± 1.93	33227.84 ± 2343.34	140.93 ± 10.34
	Average	96.64 ± 11.72	8.19 ± 1.28	37435.83 ± 7390.33	141.51 ± 13.35
160	Top	87.30 ± 4.81	7.77 ± 0.55	43778.26 ± 7305.85	148.73 ± 3.46
	Middle	83.97 ± 0.80	8.47 ± 0.06	36211.56 ± 2604.36	128.55 ± 13.98
	Bottom	106.13 ± 6.92	8.33 ± 2.14	42773.16 ± 7606.43	159.94 ± 13.12
	Average	92.47 ± 11.18	8.19 ± 1.15	40920.99 ± 6493.76	145.74 ± 16.87
180	Top	85.90 ± 1.00	7.50 ± 0.10	40034.33 ± 8856.97	150.56 ± 29.07
	Middle	94.83 ± 8.31	7.67 ± 0.81	51959.30 ± 3264.25	175.61 ± 41.46
	Bottom	103.10 ± 5.07	8.43 ± 0.42	36507.96 ± 7919.33	150.94 ± 8.67
	Average	94.61 ± 10.21	7.87 ± 0.63	42833.86 ± 9334.20	159.04 ± 28.54
Control	Top	94.10 ± 1.20	8.93 ± 0.38	9414.89 ± 714.42	142.80 ± 12.61
	Middle	99.57 ± 9.58	9.73 ± 0.15	7066.12 ± 1070.61	106.02 ± 14.92
	Bottom	119.27 ± 4.05	10.17± 0.65	6231.49 ± 1277.13	121.61 ± 18.86
	Average	104.31 ± 12.60	9.61 ± 0.66	7570.83 ± 1692.73	123.48 ± 20.97

Table 2: Analysis of Variance showing the effect of heat treatment and axial position on the physical and mechanical properties of thermally modified wood

Source of Variation	Df	Modulus of elasticity	Modulus of rupture	Moisture content	Weight
Treatment	3	88.881**	5.327**	5.872**	4.484**
Axial position	2	2.785ns	0.984ns	3.442*	25.131**
Treatment * Axial position	6	4.035**	1.957ns	0.280ns	0.737ns
Error	24				
Total	36				

** Significant at 1% ($p<0.01$) level
* Significant at 5% ($p<0.05$) level
ns = not significant

Table 3: Axial variation in mean values of percentage weight loss and percentage moisture content properties of thermally modified wood

Heat treatment	Axial position	% Weight loss	% Moisture content
140	Top	6.23 ± 0.57	10.6 ± 1.54
	Middle	7.95 ± 3.80	20.0 ± 8.57
	Bottom	14.3 ± 7.16	15.6 ± 6.01
160	Top	6.40 ± 0.81	15.6 ± 6.49
	Middle	6.11 ± 4.41	11.9 ± 7.74
	Bottom	8.38 ± 6.32	12.9 ± 8.07
180	Top	11.0 ± 3.20	17.5 ± 3.06
	Middle	13.6 ± 3.66	19.1 ± 14.8
	Bottom	16.5 ± 6.81	16.9 ± 11.8

Table 4: Analysis of Variance showing the effect of heat treatment and axial position on the percentage moisture content and percentage weight loss of thermally modified wood

Source of Variation	df	% Moisture content	% Weight
Treatment	2	0.599ns	4.748*
Axial position	2	0.205ns	3.002ns
Treatment * Axial position	4	0.458ns	0.382ns
Error	18		

** Significant at 1% ($p<0.01$) level
* Significant at 5% ($p<0.05$) level
ns = not significant

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Effects of Weathering on Mechanical Properties of Wood Plastic Composites

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Abstract

This study was designed to investigate the effect of weathering on mechanical properties of the wood plastic composites (WPC). The variable factors considered for investigation were wood species, plastic/wood ratio and ecological locations. Further investigation was made to examine the effects of weathering exposure at different ecological locations on mechanical properties of the boards. WPCs were prepared from three wood species namely; Ceiba pentandra, Triplochiton scleroxylon, Entandrophragma cylindricum at three levels of plastic/wood ratio; 1:1.0, 1:1.5 and 1:2.3. Following WPC boards production, the samples were exposed to weather conditions for period of 1 year at three ecological locations (Ibadan, Kaduna and Port-Harcourt). The experimental WPC samples were evaluated after 3, 6, 9 and 12 months of weathering exposure for mechanical properties in accordance with ASTM Standards. The result shows that the exposure of the boards to weather conditions at the three different ecological locations significantly affects the strength properties of the boards. The observations shows that the WPC boards exposed at Kaduna gave the highest percentage reduction in strength properties while the boards exposed at Ibadan had the least percentage reduction in strength. The results also revealed that the WPCs made from Entandrophragma cylindricum at mixing proportion of 1:2.3 was stiffer and stronger than others but less durable when exposed to outdoor conditions. This study shows that particles of indigenous wood specie like Entandrophragma cylindricum and plastic packaged water bags can be considered for manufacture of products for structural applications.

Keywords: Weathering, ecological, wood, plastic, composites, mechanical

INTRODUCTION

Wood-plastic composite (WPC) lumber is promoted as a low-maintenance high-durability product (Clemons and Ibach 2004). However, after a decade of exterior use in the construction industry questions have resulted regarding weather-ability potentials of these WPC products. Weathering effect of WPC is becoming one of the main factors of consideration for acceptance in the market, most especially for the outdoor products because it has been well documented that WPCs exposed to weathering may experience colour change, which will affects their aesthetic appeal, as well as loss in mechanical property, which may limits their performance (Falk *et al*., 2002 and Gachter and Muller 1990). Weathering of WPC degraded due to intensity of the UV light (Photodegradation) and water exposure, this is a difficult problem to WPC acceptability by various consumers and manufacturers. It is a known fact that each of the components used for manufacturing of WPC products degraded via a different mechanism (Fabiyi *et al*., 2008). Photodegradation of polymers originates from excited polymer–oxygen complexes reaction; this is caused mainly by the introduction of catalyst residues, hydroperoxide groups, carbonyl groups and double bonds found in polymer during manufacture (Gugumus 1993). Even in the absence of significant UV absorption, small amounts of impurities (Fe_2O_3, Cu_xO and ZnO) can be sufficient to induce polymer degradation (Gachter and Muller 1990).

Degradation of polymers as a result of weathering has undesirable effects, such as loss of strength, stiffness, and surface quality. The individual components of wood (cellulose, hemicellulose, lignin, and extractives) are also in varying degrees susceptible to photodegradation (Hon 2001). Weathering of wood is confined to the wood surface and involves photo-induced breakdown of lignin to water-soluble reaction products, which leads to the generation of chromophoric functional groups such as carbonyls, carboxylic acids, quinones, and hydroperoxide radicals (Fabiyi et al., 2008 and Hon 2001). Exposure to moisture is another weathering variable that can degrade the mechanical properties of WPCs (Joseph *et al*., 1995 and Balatinecz and Park 1997). When WPCs are exposed to moisture, the hydrophilic wood fiber in it swells. This can cause local yielding of the plastic due to swelling stress, fracture of wood particles due to restrained swelling, and interfacial breakdown (Stark 2006). Cracks formed in the plastic can also contribute to penetration of water into the composite (Joseph *et al*., 1995 and Rangaraj and Smith 2000). It was reported that WPCs exposed outdoor to moisture also results in a drop of flexural modulus of elasticity (MOE) and strength by degrading the wood–plastic interface (Joseph *et al*., 1995 and Stark 2001). The strength properties and visual appearance/colour stability of WPC produced from *Gmelina arborea* and exposed to tropical weather within short period were severely affected by solar radiation and precipitation (rainfall and dew) (Fuwape *et al*., 2010) and the authors reported that WPCs made from tropical wood content could as well be severely degraded upon exposure to exterior tropical weathering regimes. The amount of moisture absorbed can be influenced by wood flour content, wood particle size, and processing method (Joseph *et al*., 1995; Lin *et al*., 2002; Clemons and Ibach 2004), as well as certain additives such as coupling agents.

Although weather degradation of both polyethylene and wood exposed to temperate weather have been extensively examined while little have been done on weather degradation of WPC exposed to tropical weather (Fuwape et al., 2010; Aina and Fuwape 2008). Previous research studies by these authors' shows that strength reduction in MOE and MOR from 24 to 47% and 10 to 21% were respectively recorded after a six-month exposure to weather in tropical region. The reduction in the strength properties of WPCs in different regions shows that studies must be properly conducted to ascertain the level of degradation before final product can be acceptable on a global scale. For instance, 43 % reduction in strength of WPC exposed in Dhahan, Saudi Arabia was higher than 20 % reduction in strength at Florida, USA within the same period of weathering exposure but different regions (Hussain *et al*., 2006). WPC products are currently being used in Nigeria for roofing, ceiling and panelling. For consumer's acceptability, information regarding the weather-ability and durability of these products must be known. Due to the increase demand of these products in developing country and abilities to meet up to this challenge, locally sourced raw materials that are readily available and affordable must be considered. Falk *et al*., (2002) reported that several manufacturers are currently producing wood thermoplastic composites from recycled materials, so as to meet up to the larger markets which exists within the building industry. In order to meet up to these challenges, Africa and most especially Nigeria must starts investigation on suitability of their indigenous species for the manufacturing of WPC products and the outcome to weather effects must be known.
Therefore, the main objective of this study was to evaluate the effects of weathering on mechanical properties of wood plastic composites made from used plastic bags with wood species, three different indigenous wood species and three different ecological locations in Nigeria were employed for the study.

MATERIAL AND METHODS

The study was divided into two phases. There were two aspects to the first phase. The first aspect in the first phase was designed to investigate the properties of WPCs including thickness swelling, water absorption, linear expansion, board density, modulus of rupture and elasticity as influenced by plastic/wood ratios and wood species. Based on their densities, three indigenous wood species namely, *Ceiba pentandra (*Araba)*; Triplochiton scleroxylon (*Obeche) and *Entandrophragma cylindricum (*Mahogany utile) were employed. These wood species were obtained from Forestry Research Institute of Nigeria (FRIN) plantation at Onigambari town, Ibadan, Oyo State of Nigeria. After felling and cutting into bolts, the bolts were milled into sawdust particle at the sawmill section of Forest Products Development and Utilization Department, FRIN at Ibadan, Oyo State. Plastic waste from packaged sachets water popularly known in Nigeria as '' pure water sachet'' was employed as binder in this experiment. These plastic wastes from packaged sachets were collected from dumping sites, thoroughly washed, dried and milled into particles using industrial hammer milling machine available at a waste recycling factory, Aleshinloye Market, Jericho, Ibadan, Oyo State, Nigeria.

Production of the Experimental samples

Fresh sawdust particles of each selected wood species and milled plastic particles were thoroughly sieved with wire mesh of size 0.25 mm (250µm). Homogenously screened sawdust particles were oven dried at the temperature of 103 ± 2^{0}C for 24 hours. The wood and plastic particles were thoroughly hand-mixed before feeding into single screw extruder machine with screw diameter and length of 63 mm and 1090 mm, respectively. The machine consists of the following features, feeding hopper, coolant chamber, heater and die. The mixture was heated at the temperature range of 165 – 185 ^{0}C to produce WPC strands. WPC strands of each combination of plastic/wood ratios were conditioned by cooling in water bath before being pelletized. WPCs pellets were oven-dried at 65 ^{0}C for 24 hours before feeding into a mould of 250 mm x 250 mm x 15 mm. The mould tray was place in a hot-press at temperature ranged of 165 – 190 ^{0}C and pressed for the period of 45 minutes. Thereafter the boards were stripped from the mould and cut into test specimens for the determination of mechanical properties in accordance with (ASTM D790)

Experimental Design

The experimental WPC boards were produced at three levels of plastic/wood ratio of 1:2.3, 1:1.5 and 1:1.0. The species of wood employed were *Triplochiton scleroxylon, Entandrophragma cylindricum* and *Ceiba pentandra*. Each WPC sample produced was subjected to weathering exposure tests at three ecological locations viz: Ibadan, Kaduna and Port Harcourt. The experimental design adopted for this study was 3 x 3 x 4 factorial experiments in completely randomised design. Five replicates of WPC samples were made from each combination resulting in a total of 720 samples used for weathering test. The boards were exposed at each ecological location for the period of 12 months. During this period specimens were collected and evaluated for modulus of rupture and modulus of elasticity at every three months interval.

Weathering test

WPC boards produced from each combination of the wood specie and plastic/wood ratio were employed for weathering tests. Board specimens were placed on the roof of a building tilted at angle 45º facing north directly exposing to weathering conditions in accordance with (ASTM D1435). The period of WPC specimens exposed to weather in this experiment started from November 2012 to December 2013. Exposed WPC samples were collected at the end of the period and tested for physical and mechanical properties. The weather reports for each ecological location employed in this study were provided by Nigeria Metrological Department in Lagos State, Nigeria (Table I). The three towns were selected for weathering test and are situated at different ecological zones in Nigeria (Fig 1). The exposure in Kaduna was done at the Savannah Forest Station of FRIN, Afaka (Kaduna) in Kaduna State representing savannah zone. This location lies between lat. 10^{o} 39 ^{1} 59 N and long. 7^{o}23^{1}16E. Weathering test in Ibadan was carried out at FRIN Headquarter (Ibadan) in Oyo State representing the rainforest zone and this lies between the lat. 7^{o} 23 ^{1} N and long. 3^{o}54 E. the third location for the exposure was at the Swamp-Forest Station of FRIN at Onne (Port Harcourt) in River State representing freshwater or swamp zone and this lies between lat. of 4^{o} 50 ^{1} N and long. 7^{o} 03^{1} E.

TABLE 1: Average weather parameters for each location

	January 2013 – May 2013			**June 2013 - December 2014**		
WEATHER PARAMETERS	KADUNA	IBADAN	PORT-HARCOURT	KADUNA	IBADAN	PORT-HARCOURT
Temp minimum (^{o}C)	22.9	22.7	24.3	20.7	22.4	22.3
Temp maximum (^{o}C)	33.7	31.5	33.0	31.0	30.2	30.0
Rainfall (mm)	11.3	53.1	77.7	37.4	51.3	39.7
GDD (day)	202.7	190.7	206.3	178.5	182.8	179.2
RAD (MJ/m^{2}/day)	19.3	17.4	17.5	20.3	17.7	16.7
PET (mm/day)	47.1	41.7	43.1	47.5	41.8	43.0

Source : NIMET (*www.weather.forecast.com/locations/nigeria*) 2014. GDD represents Growing Degree Days; RAD represents Radiation (solar) while PET represents Potential Evapotranspiration

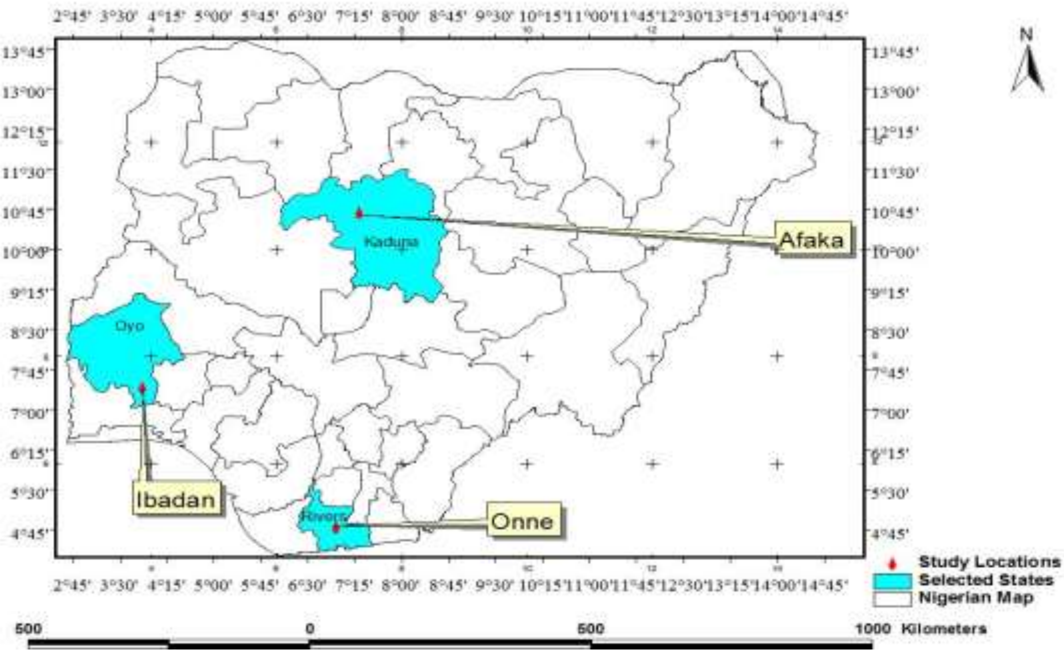

Figure 1: Map of Nigeria showing the selected locations of exposure
***Source:* Centre for Research and Development, FUTA**

Data Analysis
The methods used in processing the data obtained for the appraisal of the study variables included graphical analysis and analysis of variance. Graphical analysis provides an easy means of observing the trend of any relationship which might exist between the study variable and a specific board property. All statistical analysis was conducted as a factorial experiment in completely randomized design by means of a one way analysis of variance to determine significance of the main and interacting effects that could emerg e. The SPSS (Statistical Package for the Social Sciences) version 20.0 package analysis of variance procedure (ANOVA) was used for this analysis. Separations of treatment means were carried out using Duncan's Multiple Range Test (DMRT) and these were done to determine the differences between the means and to choose the best treatment combination from the factors considered. The main effects considered were those due to differences among the wood species, plastic/wood ratios and locations of exposure. In addition the interaction effects between the main effects were also considered.

RESULTS and DISCUSSION

Mechanical properties of WPCs after exposure to weather
The results for modulus of rupture (MOR) and modulus of elasticity (MOE) of WPCs exposed to outdoor conditions at different ecological locations are illustrated in Figures 2 and 3 respectively. The mean values for modulus of rupture for WPCs before and after exposure to different ecological locations ranged from 7.13 to 12.95 N/mm^2. The mean values obtained for modulus of rupture of the composites produced from the three wood species ranged from 7.03 to 9.95 N/mm^2 while for WPC produced at plastic/wood ratio ranged from 7.57 to 9.37 N/mm^2. The mean values obtained for modulus of rupture of composite exposed to outdoor conditions at different ecological locations ranged from 5.70 to 8.91 N/mm^2. The mean values for modulus of rupture of WPCs exposed outdoor at different ecological location for 3 months ranged from 6.17 to 14.24 N/mm^2 at Ibadan, 6.35 to 14.38 N/mm^2 at Kaduna and 6.61 to 13.95 N/mm^{2}at Port Harcourt. For 6 months exposure, MOR ranged from 5.77 to 13.66 N/mm^2 at Ibadan, 6.28 to 12.21 N/mm^2 at Kaduna and 6.61 to 12.74 N/mm^2 at Port Harcourt. At the end of 9th month of exposure, MOR ranged from 5.73 to 13.17 N/mm^2 at Ibadan, 5.91 to 9.89 N/mm^2 at Kaduna and 6.60 to 12.31 N/mm^2 at Port Harcourt. After 12th month of exposure, MOR ranged from 5.73 to 13.17 N/mm^2 at Ibadan, 5.91 to 9.16 N/mm^2 at Kaduna and 6.59 to 12.31 N/mm^2 at Port Harcourt respectively. It was observed in this study that modulus of rupture decrease with increase in exposure period from 0 month (unexposed) to 12 months (Fig 2). Analysis of variance carried out to test for significant differences among the WPCs exposed to outdoor conditions at different ecological locations are presented in Table II. The results showed that the main effects of wood species, plastic/wood ratio and ecological locations on the modulus of rupture of the composite were significantly different at 0.05% level of probability. Similarly, all interactions between the wood species, plastic/wood ratio and ecological locations were significantly different at ($P \leq 0.05$) level of probability. Duncan multiple ranged tests (DMRT) at 5% level of probability was conducted to separate the mean values of MOR as

influenced by each of the study variables (Table IV). The mean values of the modulus of rupture of the exposed WPC, irrespective of the duration of exposure were significantly different among the three wood species. The same is true on the influence of plastic/wood ratio on MOR. The mean values for modulus of rupture for WPCs exposed at Ibadan and Port-Harcourt were not significantly different to each other, while both locations were significantly different when compared with WPCs exposed at Kaduna after 9 and 12 months of exposure to outdoor weathering.

Modulus of Elasticity

The mean values for modulus of elasticity of WPC exposed to outdoor conditions at different ecological locations ranged from 444.03 to 10412.80 N/mm^2. The mean vales obtained for modulus of elasticity of the composites produced from the three wood species ranged from 632.02 to 972.21 N/mm^2 while WPC produced at plastic/wood ratio ranged from 700.37 to 1050.90 N/mm^2. The mean values obtained for modulus of elasticity of the composite following exposure to outdoor conditions at different ecological location ranged from 651.73 to 932.43 N/mm^2. The mean values for modulus of elasticity of WPCs exposed outdoor at different ecological location for 3 months ranged from 449.26 to 1049.60 N/mm^2 at Ibadan, 612.75 to 993.08 N/mm^2 at Kaduna and 559.23 to 1295.20 N/mm^2 at Port Harcourt. For 6 months exposure, MOE ranged from 445.28 to 1007.60 N/mm^2 at Ibadan, 590.41 to 945.83 N/mm^2 at Kaduna and 559.23 to 1067.93 N/mm^2 a t Port Harcourt. At the end of 9th month of exposure, MOE ranged from 444.10 to 997.00 N/mm^2 at Ibadan, 517.35 to 849.40 N/mm^2 at Kaduna and 559.23 to 1032.45 N/mm^2 at Port Harcourt. After 12th month of exposure, MOE ranged from 444.10 to 997.00 N/mm^2 at Ibadan, 517.35 to 849.40 N/mm^2 at Kaduna and 559.23 to 748.46 N/mm^2 at Port Harcourt. It was observed that modulus of elasticity for WPCs decrease with increase in exposure period from 0 month (unexposed) to 12 months (Fig 3). The results of analysis of variance are presented in Table III. The results show that the main effects of wood species, plastic/wood ratio and ecological locations on the modulus of elasticity of the composite were significantly different at 0.05 % level of probability. Interactions between wood species, plastic/wood ratio and ecological locations were also significant at 5 % level of probability. Duncan multiple ranged tests (DMRT) at 5% level of probability was conducted to separate the mean values of MOE as influenced by each of the study variables (Table IV). The mean values of the modulus of elasticity of the exposed WPCs irrespective of the duration of exposure were significantly different among the three species and plastic/wood ratio. The mean values for modulus of elasticity for composite at plastic/wood ratio of 1:1.0 and 1:1.5 were not significantly different, but significantly different when the two ratio levels were compared to 1: 2.3 (Table IV).

Similarly, the mean values for modulus of elasticity of WPCs exposed at Ibadan and Port-Harcourt were not significantly different while the two ecological locations were significantly different when compared to the WPCs exposed at Kaduna after 9 and 12 months of exposure to outdoor weathering. The flexural properties (MOE and MOR) of WPCs decreased with increase in periods of exposure in outdoor conditions (Fig 2 and 3). The observation in this study agrees with previous finding by (Taib *et al*., 2010; Rangaraj and Smith 2000; Balatinecz and Park 1997). The variation in the flexural properties with the exposure time for WPC containing wood particle may be attributed to degradation of interactions bond as a result of water absorption from the environment and from the rainfall (Taib *et al*., 2010). The wood particles that are not encapsulated by the plastic matrix readily absorb moisture during weathering and the moisture in wood particle would result in fibre swelling that leads to micro-cracks in the plastic matrix (Taib *et al*., 2010). WPC readily absorb moisture due to the hydrophilic character of the wood component and has the tendency to undergo swelling and shrinking due to adsorption and de-sorption of moisture during the weathering period (Taib *et al*., 2010). As a result of the bonds between the wood and plastic, which are weakened, this in turns affects stress transfer from plastic to wood. As pointed by (Stark and Matuana 2003) micro-cracks lead to a decrease in MOE and reduce efficiency in stress-transfer from the wood to the plastic matrix thereby causing a decrease in MOR.

The reduction in the MOR and MOE following exposure was influenced by variation in plastic/wood ratio, showing that percentage reduction in the flexural properties increased with increase in wood proportion. The observation may be due to the decrease in plastic that serves as support for the wood filler that provide strength. After weathering exposure, WPC made from plastic/wood ratio of 1:2.3, 1:1.5 and 1:1.0 decreased by 47.8 %, 38.8 % and 11.9 % in flexural-MOR. Similarly, flexural-MOE for WPC made from plastic/wood ratio of 1:2.3, 1:1.5 and 1:1.0 decreased by 31.3 %, 13.9 % and 9.2 %, respectively after exposure. Naghipour (1997) observed that WPC formulated with more than 60 % wood content had a greater reduction in flexural properties than the WPC produced with less than 60 % wood content. The wood species employed in this study showed significant effect on the reduction of MOE and MOR following weathering exposure. WPC made from *Entandrophragma cylindricum*, *Triplochiton scleroxylon* and *Ceiba pentandra* decreased in *MOR* by 59.2 %, 17.3 % and 13.1 %, respectively. While the MOE of the respective wood species decreased by 22.1 %, 13.2 % and 20.9 %. This observation agrees with previous finding by (Danyadi *et al*., 2007) in that the wood in WPC exposed to outdoor conditions aboveground, a complex combination of chemical, mechanical and ultra-violet radiation from sunlight contributes to its weathering effect. As reported by (Fabiyi *et al*., 2008) effect of weathering exposure on WPC produced from different wood species depends on the anatomical, physical and mechanical properties of the individual wood species.

The ecological locations where the WPCs were exposed significantly affect the percentage reduction in MOR and MOE of the boards. This observation may be attributed to different weather conditions at each ecological location of exposure. The MOR for the WPC exposed to outdoor conditions decreased in Ibadan, Kaduna and Port-Harcourt by 12.6 %, 59.2 % and 17.4 % while the MOE of the respective location decreased by 17.3 %, 22.1 % and 15.1 % following weathering exposure. As presented in Table I, the weather report shows that higher values for temperature, solar radiation, evapotranspiration and with lower rainfall are obtained in Kaduna than any other locations of study. This observation agrees with previous finding by (Fabiyi *et al*., 2008) that temperatures with ultra-violet radiation from sunlight are mostly responsible for strength reduction in WPC exposed outdoor. Flexural MOR and MOE observed in this study decreased more in Kaduna than any other locations. This observation is in agreement with previous report by (Fuwape *et al*., 2010) that show 43 % reduction in strength of WPC exposed in Dhahan, Saudi Arabia to 20 % reduction in Florida, USA within the same period of weathering exposure. Similar observation was also reported by (Fuwape *et al*., 2010) that shows reduction of WPC by 24 to 47 % in flexural-MOE and 10 – 21% in flexural-MOR after an exposure to tropical weather in Nigeria.

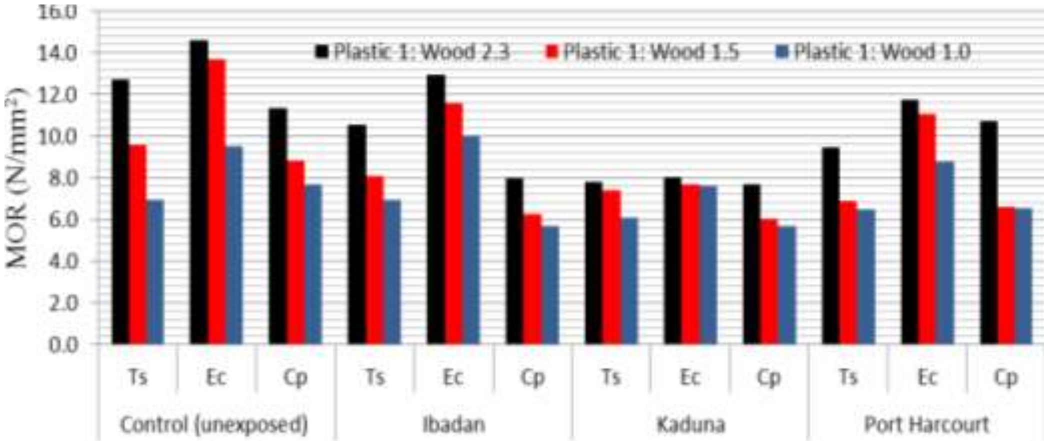

Figure 2: Percentage reduction in modulus of rupture of WPCs after 12 months of outdoor exposure to different ecological locations (TS reps *Triplochiton scleroxylon*, EC reps *Entandrophragma cylindricum* and CP reps *Ceiba pentandra*)

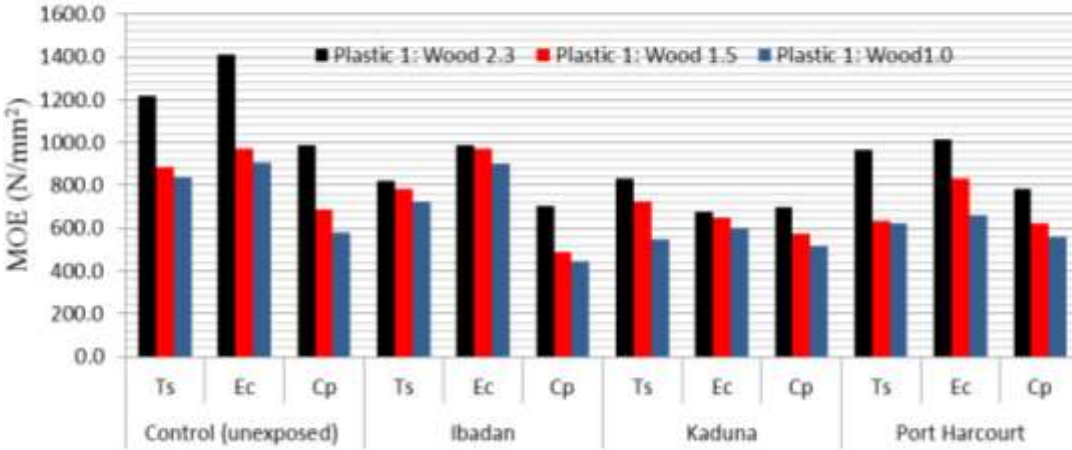

Figure 3: Percentage reduction in modulus of elasticity of WPCs after 12 months of outdoor exposure to different ecological locations (TS reps *Triplochiton scleroxylon*, EC reps *Entandrophragma cylindricum*, and CP reps *Ceiba pentandra*)

TABLE 2: Result of analysis of variance for modulus of rupture of the WPCs after exposure to weather conditions

Source of variation	df	3 months		6 months		9 months		12 months	
		F	Sig	F	Sig	F	Sig	F	Sig
Location	3	10.155	0.000*	32.616	0.000*	92.104	0.000*	104.199	0.000*
Wood species	2	315.214	0.000*	319.783	0.000*	291.675	0.000*	278.792	0.000*
Plastic/wood ratio	2	181.430	0.000*	198.142	0.000*	184.547	0.000*	182.798	0.000*
Location * wood species	6	4.561	0.000*	5.739	0.000*	9.813	0.000*	12.882	0.000*
Location * plastic/wood ratio	6	7.607	0.000*	12.817	0.000*	21.124	0.000*	23.551	0.000*
Wood species * plastic/wood ratio	4	28.331	0.000*	26.348	0.000*	24.006	0.000*	24.067	0.000*
Location * wood species * plastic/wood ratio	12	5.341	0.000*	7.234	0.000*	7.881	0.000*	7.996	0.000*
Error	144								
Total	179								

P≤0.05 mean significantly different at 5% level of probability, * represent significant while ^{ns} represent not significant

TABLE 3: Result of analysis of variance for modulus of elasticity of the WPCs after exposure to weather conditions

Source of variation	df	3 months		6 months		9 months		12 months	
		F	Sig.	F	Sig.	F	Sig.	F	Sig.
Location	3	60.386	0.000*	121.300	0.000*	182.129	0.000*	197.413	0.000*
Wood species	2	15.172	0.000*	367.096	0.000*	372.496	0.000*	332.312	0.000*
Plastic/wood ratio	2	40.682	0.000*	493.544	0.000*	357.430	0.000*	320.103	0.000*
Location * wood species	6	27.916	0.000*	33.257	0.000*	32.057	0.000*	40.509	0.000*
Location * plastic/wood ratio	6	13.815	0.000*	26.146	0.000*	40.060	0.000*	42.194	0.000*
Wood species * plastic/wood ratio	4	2.866	0.025*	5.689	0.000*	5.042	0.001*	6.548	0.000*
Location * wood species * plastic/wood ratio	12	12.308	0.000*	10.789	0.000*	8.872	0.000*	9.037	0.000*
Error	144								
Total	179								

P≤0.05 mean significantly different at 5% level of probability, * represent significant while ^{ns} represent not significant

TABLE 4: Result of DMRT for of WPCs exposed to outdoor conditions

Variables	Level	Modulus of rupture				Modulus of elasticity			
		Period of exposure (months)							
		3	6	9	12	3	6	9	12
Wood species	*Triplochiton scleroxylon*	9.10^{b}	8.83^{b}	8.50^{b}	8.50^{b}	852.43^{a}	831.83^{b}	806.97^{b}	806.97^{b}
	Entandrophragma cylindricum	12.50^{a}	11.74^{a}	11.05^{a}	10.94^{a}	972.21^{a}	926.06^{a}	901.43^{a}	881.13^{a}
	Ceiba pentandra	7.98^{c}	7.87^{c}	7.68^{c}	7.68^{c}	692.38^{c}	662.36^{c}	632.02^{c}	632.02^{c}
Plastic/wood ratio	1:1.0	8.12^{c}	8.05^{c}	7.85^{c}	7.84^{c}	721.88^{c}	713.16^{b}	700.59^{b}	700.37^{b}
	1:1.5	9.77^{b}	9.21^{b}	8.77^{b}	8.73^{b}	744.20^{b}	721.49^{b}	705.11^{b}	702.27^{b}
	1:2.3	11.69^{a}	11.19^{a}	10.60^{a}	10.54^{a}	1050.90^{a}	985.59^{a}	934.73^{a}	910.54^{a}
Ecological location	Unexposed	10.56^{a}	10.56^{a}	10.66^{a}	10.56^{a}	932.43^{a}	932.43^{a}	932.43^{a}	932.43^{a}
	Ibadan	9.66^{b}	9.21^{c}	9.00^{b}	9.00^{b}	849.82^{b}	802.98^{b}	770.21^{b}	770.21^{b}
	Kaduna	9.43^{b}	8.85^{c}	7.78^{c}	7.63^{c}	766.53^{d}	752.37^{d}	669.46^{c}	651.73^{c}
	Port-Harcourt	9.30^{b}	9.31^{b}	8.96^{b}	8.96^{b}	807.26^{c}	759.21^{c}	748.48^{b}	748.48^{b}

Means of the same source of variation with different alphabet are significantly different at ($P \leq 0.05$)

CONCLUSION

The findings from this study show that:

1. Factors such as wood species, plastic/wood ratio and exposure to weather conditions at different ecological locations will significantly influence the properties of WPCs.
2. There is variation in strength properties of WPC to different wood species. But as the wood content increases the strength also increases and as the polymer content increases, the strength also decreases.
3. WPC produced from *Entandrophragma cylindricum* at plastic/wood ratio of 1:2.3 was stiffer and stronger than the other two wood species and ratio used in this study.
4. Following exposure to weather condition at different ecological locations, strength properties of the WPC boards made from *Entandrophragma cylindricum* and at ratio of 1:2.3 decrease more than any other variables used in this study.
5. WPCs exposed at Kaduna decrease in strength properties more than any other two ecological locations.

RECOMMENDATIONS

Based on the research investigations carried out in this study for weathering effects on strength properties of WPCs, the following recommendations are made;

1. Variable factors such as wood species and plastic/wood ratio should be appropriately considered for WPCs production
2. Indigenous wood species like *Triplochiton scleroxylon*, *Ceiba pentandra* and *Entandrophragma cylindricum* could serve as potential raw materials for the production of WPCs.
3. Other indigenous wood species with other recycle plastic materials should be investigated for possible WPC production
4. Plastic pellets made from packaged water bags should be considered as potential raw material for WPC production and this will also serve as alternative to virgin plastic.
5. Further research on weathering of the WPCs at other ecological locations like Arid savannah, Sahel savannah and high altitude like Jos in Plateau State should be investigated
6. Weathering of WPCs should be extended to other part of Africa.

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Investigation of the Anatomy and Fibre Characteristics of Selected Tropical Timber Species

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Abstract

The use of tropical timber species is diverse, and their utilization is influenced by their anatomy and fibre characteristics. The anatomy and fibre characteristics of three tropical timber species (Terminalia superba, Triplochiton scleroxylon, and Nauclea diderrichii) were investigated with the aim to determine their alternative application other than their use for construction purposes. The study was carried out by selecting three trees for each species with clear boles at the plantation of the Forestry Research Institute of Nigeria (FRIN) Ibadan, Nigeria. The cores samples were collected at the diameter at breast height of the selected trees. Cores were collected and divided into the sapwood and heartwood zones. Slides were produced from the cores by using sliding microtome to produce micro sections of 10 -20µm both from the heartwood and sapwood zones. Part of these micro sections were macerated using a mixture of equal volume of ethanoic acid and hydrogen peroxide in ratio 1:1. Parameters that influences the use of fibrous materials for pulp and paper products, such as fibre length (FL), fibre diameter (FD), lumen width (LW) and cell wall thickness (CWT), were measured using ocular micrometer fitted into a light microscope. The derived values such as runkel ratio (RR), coefficient of flexibility (CoF) and relative fibre length (RFL) were calculated. Results showed that although the T. superba and T. scleroxylon species are already in use for construction purposes, they are also suitable for pulp and paper production due to their low cell wall thickness (3.63µm and 4.07 µm respectively). However, the cell wall thickness of N. diderrichii is much higher (5.72 µm), and is less suitable for pulp and paper production.

Keywords: *Nauclea diderrichii, Terminalia superba, Triplochiton scleroxylon,* fibre characteristics, morphological indices, wood anatomy

INTRODUCTION

The tropical part of the world is endowed with numerous hardwood species most of which serve mainly as timber, pulp, pole, etc. A large number of African trees are economic trees that are versatile and are suitable particularly for construction purposes. Timbers are wood of trees cut and prepared for use as building material (Dinwoodle, 2000). The properties of wood, anatomical properties, physical, chemical, mechanical properties, and natural durabilities are interrelated. Hence, wood is not only meant to meet the needs of the plant, but also as a natural material in diverse application. For this reason, it is crucial to note that although many indigenous species are popular in their use for construction purposes, but they may be applicable in other areas of wood utilization. The study of their anatomical and fibre properties can reveal details on about other possible areas of utilization, other than their present use for construction purposes. In addition, their microstructure can influence other properties such as treatability or absorption, retention and penetration of commercial preservatives or chemicals during wood modification. Wood is a variable material i.e. it is highly heterogeneous. There is variation in physical, strength properties and qualities within and between species and these variabilities are influenced by their anatomical properties. Knowing the anatomical properties of wood species will help to determine the suitability of the species for the intended purpose, reduction in overexploitation of endangered economic species when alternatives are discovered, and ensure sustainable use of forest resources.

Triplochiton scleroxylon is a species belonging to the family *Sterculiaceae* with the popular name Obeche and also known as Arere among the Yoruba speaking people in the southwestern Nigeria. It is an environmentally and economically important African tropical tree (Hall & Bada, 1979; Bosu & Krampah, 2005). *Terminalia superba* commonly known as Afara is a tropical tree species native to tropical western Africa (Gledhill, 1972). It belongs to the family Combretaceae. *Nauclea diderrichii* is a tree of genus Nauclea in the family Rubiaceae. The species *T. scleroxylon*, *N. diderrichii*, and *T. superba* are important hardwood species that are now depleted due to overexploitation. Some of these species, though popularly harvested for construction purposes are underutilized leading to a lot of residues, which may eventually become a waste or go into landfill. These wastes can be channeled to other applications such as pulp and papermaking if their properties are revealed through fibre characterization. The study therefore focused on the assessment of the anatomy and fibre characteristics of these tropical timber species used for construction purposes, in order to ascertain their morphological indices and suitability of other uses, especially for papermaking.

MATERIALS AND METHODS

Study Area

This study was carried out in July, 2019 at the Forestry Research Institute of Nigeria (FRIN). FRIN is located between Ibadan north-west and Ibadan south-west ranging from 7.397975°N, 3.863391667°E to 7.385619444°N, 3.855163889°E. The *T. scleroxylon and T. superba* samples used in this study were obtained from FRIN arboretum, while *N. diderrichii* were obtained at the Opepe plantation of FRIN.

Sample Collection

Samples for this study were collected with an increment borer. The samples were collected at the diameter at breast height (dbh) of 1.3 m above the buttress and the sharp edge of the increment borer was used to bore across the stem of the tree. The core samples were kept in a polystyrene bag which were labelled according to the species and tree number (ranging from one to three) from which they were collected. Core samples were collected from three sample trees each of the selected species, with cores extending from the sapwood to the heartwood zone of each tree. A total of nine core samples were collected (three cores per species) and used for the study.

Procedure for sample selection

The sapwood and heartwood zones of the collected core samples were separated by cutting at the start of a clear variation in the colours of the core samples. The cores collected show clear differences in each zone, the heartwood zone being darker in colour than the sapwood zone. This is however different for *T. scleroxylon*, which zones cannot be separated using colour differences as the species have the same colour in the sapwood and heartwood region with no difference. For this, core samples closest to the pith and extracted by the tip of the increment borer was selected.

Maceration

Sample preparation involved the use of sliding microtome to produce micro sections of 10-20 µm from the cores (different micro section both sapwood and heartwood section of the species) collected. Cores were placed inside a test tube containing a mixture of equal volume of ethanoic acid and hydrogen peroxide in ratio 1:1 as described in procedures by Oluwadare 1998; Oluwadare and Sotannde 2007. The test tubes were labelled according to the wood species from which the samples were obtained. Hydrogen peroxide in the mixture bleached the samples completely into white and ethanoic acid soften the fibres to enable the separation of the sample to an individual strand of fibres. The test tubes containing various wood samples were placed in the digital oven for 3 hours at a temperature of 100 - 105^{o}C. This allowed the dissolution of the lignin and hemicellulose components of the wood leaving only the cellulose fibres. The macerates produced were properly rinsed and placed in a Petri dish for measurement one after the other.

Wood Sectioning

Core samples that were collected from the field were divided in similar fashion explained in the procedure for sample selection. A small portion of the core extending to 2 cm was cut out of both zones (sapwood and heartwood) each from a core of the different species. The transverse plane was determined by observing the cube under a hand lens and spotting out the top openings of the vessels that would have shown from the early cuttings. The surface was moistened a bit for clearer and better observation. The tangential and radial plane was determined by using the grain direction as it was noticed that the grains were parallel to the growth ring for the tangential plane and perpendicular for the growth ring for the radial plane. Thin sections of 20µm were prepared from the three well-oriented planes viz, transverse section (T.S), radial longitudinal section (R.L.S) and the tangential longitudinal section (T.L.S) respectively using a microtome according to procedures by Gills and Onuga (1984).

The slices produced were placed in petri dishes containing methylated spirit for moistening (this was particularly helpful when producing the sections of *N. diderrichii*). Staining was done by adding drops of safranin solution (organic dyes) to the sections and left for a minimum of five minutes. Excess safranin was washed off using water and was then followed by dehydration using 95% ethanol. Clove oil was added to remove ethanol. This is referred to as cleaning. The sections were individually placed on a glass slide, while qualitative a filter paper was used to mop up excess clove oil. Canada balsam was added to the sections on glass slide and covered with the slide cover. Thereafter, heat was applied to the prepared slide to remove air bubbles and to improve the spread of Canada balsam.

Microscopy and Image Analyses

Three sections transverse, radial, and tangential obtained from the wood sectioning of the three species in this study were prepared and placed on slides. Microscopic observation of each slide was made and captured using light microscope (Reichert) with trace reflector at 10x magnification. Ocular microscope (Olympus) was used in measuring fibre dimensions. The description of anatomical features observed used terminologies and procedures from IAWA Hardwood List (IAWA, 1989).

Fibre morphological indices

The morphological indices which include; runkel ratio, coefficient flexibility, and slenderness ratio (Saikia *et al*., 1997; Amoo, *et al*., 2016) were derived using the fibre dimensions collected. The following equations showed the morphological indices measured:

Runkel Ratio = $\frac{2\times Cell\ Wall\ Thickness}{Lumen\ Width}$ (1)

Coefficient of Flexibility = $\frac{Lumen\ Width}{Fibre\ Diameter} \times 100$ (2)

Relative fibre length or Slenderness ratio (S.R) = $\frac{Fibre\ Length}{Fibre\ Diameter}$ (3)

RESULTS AND DISCUSSION

Anatomical characteristics

The details of the anatomical properties of *N. diderrichii* (Opepe), *T. scleroxylon* (Obeche) and *T. superba* (Afara) are described in Table 1. Exclusively solitary diffusely porous grouped vessels can be seen across the three species according to (IAWA, 1989). There is no evidence of any occlusions or formation of tylose in the vessels. The absence of any occlusion or tylose in the vessels signify that little or difficulty will be encountered in the impregnation of these species either with commercial preservatives or in penetration of reagents into the matrix of the cell wall (Olaniran *et al*. 2010, Sangumbe *et al*. 2018) N. *diderrichii* vessels are arranged diagonally to radial section. *T. scleroxylon* and *N. diderrichii* possesses apotracheal parenchyma cells with *N. diderrichii* being scanty, and *T. scleroxylon* being diffuse in aggregate, while *T. superba* possess unilateral paratracheal parenchyma cells. Rays are exclusively uniseriate rays in *T. superba*, while *T. scleroxylon* and *N. diderichii* have ray width of one to three cells wide, and a multiseriate rays respectively. The ray cells are storied in *T. superba* while the Opepe and Obeche have non-storied ray cells.

Anatomical Characteristics

Table 6: Anatomical characteristics of N. diderrichii, T. scleroxylon and T. superba

Features	Nauclea diderrichii	Triplochiton scleroxylon	Terminalia superba
Growth ring boundary	Boundaries indistinct or absent	Boundary marked by thick-walled latewood fibres and marginal parenchyma band	Boundary marked by thick-walled latewood fibres and marginal parenchyma band
Porosity	Diffuse porous	Diffuse porous	Diffuse porous
Vessel grouping	Exclusively solitary	Exclusively solitary	Exclusively solitary
Vessel arrangement	Diagonal to radial pattern	Very large pores no specific arrangement	Diagonal pattern
Axial parenchyma	Apotracheal scanty parenchyma cells	Apotracheal diffuse-in-aggregate cells present	Unilateral paratracheal parenchyma cells
Rays width	With multiseriate portion(s) as wide as uniseriate portions	1-3 cells wide	Exclusively uniseriate
Rays storied	No	Yes (low rays storied, high rays nonstoried	No
Rays contain sheath cells	No	Yes	No

Fibre Characteristics

The mean fibre characteristics of the three species are presented in Table 2. There are significant differences ($p \leq 0.05$) in the effect of the species on the fibre length, fibre diameter, lumen width, and cell wall thickness as shown in Table 3. The result by Table 3 also revealed that there was no significant difference in the fibre characteristics between the sapwood and the heartwood. The non-significant difference in the fibre characteristics of both sapwood and heartwood is contrary to previous reports where a significant difference was observed in other species such as *Brachystegia spiciformis* and *Pericopsis angolensis*, where indices such as fibre width, cell wall thickness and lumen width vary from sapwood to heartwood (Sangumbe *et al.*, 2018). Bajpai (2018) stated however, that since the heartwood were once sapwood, there is generally a minor difference in their strength.

Table 7: Mean fibre values of species

Species	FL (mm)	FD (µm)	LW (µm)	CWT (µm)	RR (µm)	CoF (µm)	SR
Obeche	1.66	21.80	13.66	4.07	0.60	62.70	76.09
Afara	1.59	24.72	17.46	3.63	0.42	70.64	64.17
Opepe	2.19	31.51	20.06	5.72	0.57	63.64	69.47

Table 8: Analysis of variance of the fibre dimensions

Variable	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
FL (mm)	Corrected Model	.436^{a}	3	.145	95.791	.010
	Intercept	19.693	1	19.693	12984.275	.000
	Species	.435	2	.218	143.418	.007*
	Zone	.001	1	.001	.538	.539^{ns}
	Error	.003	2	.002		
	Total	20.132	6			
	Corrected Total	.439	5			
FD (µm)	Corrected Model	99.362^{a}	3	33.121	24.262	.040
	Intercept	4059.641	1	4059.641	2973.842	.000
	Species	99.192	2	49.596	36.331	.027*
	Zone	.170	1	.170	.125	.758^{ns}
	Error	2.730	2	1.365		
	Total	4161.733	6			
	Corrected Total	102.092	5			
LW (µm)	Corrected Model	42.389^{a}	3	14.130	30.301	.032
	Intercept	1746.262	1	1746.262	3744.798	.000
	Species	41.364	2	20.682	44.352	.022*
	Zone	1.025	1	1.025	2.198	.276^{ns}
	Error	.933	2	.466		
	Total	1789.583	6			
	Corrected Total	43.322	5			
CWT (µm)	Corrected Model	4.975^{a}	3	1.658	27.432	.035
	Intercept	120.154	1	120.154	1987.655	.001
	Species	4.881	2	2.441	40.373	.024*
	Zone	.094	1	.094	1.551	.339^{ns}
	Error	.121	2	.060		
	Total	125.250	6			
	Corrected Total	5.096	5			

*Species sig. diff at $p \leq 0.05$ * Zone not sig. diff at $p \geq 0.05$ | ^{ns} no significant difference

Fibre Length

The species with the highest fibre length is Opepe with 2.19mm, then Obeche with 1.66mm then Afara with 1.59mm. The values from this study agrees with findings of Ricther & Dallwitz (2000) for Opepe which findings were ranging from 1.1mm – 2.5mm. Results of fibre length for Obeche in this study agrees with Jayeola, *et al.*, (2009) as Afara for this study also agrees with Okoh (2014). The fibre lengths obtained in this study are not within the range of softwood species of 2.7-4.6 mm. Only *N. diderrichii* is closest to this range with a value of 2.19mm. Fibre length is one of the major attributes that determines the suitability of any wood species for pulp and paper production. Although softwood fibres are more preferred due to their longer fibre length, and depending of the paper grade to be produced, this result obtained for Opepe showed that its fibre length is closer to the range for softwood species. This may increase its potential as a suitable pulpwood.

Fibre Diameter

The highest fibre diameter was observed from Opepe, followed by Afara, and lastly Obeche as shown in Table 2. Fibre diameter obtained for Opepe for this study is in accordance with Adeniyi, *et al.*, 2013, while findings for Afara and Obeche of this study both contradicts the findings of Adeniyi, *et al.*, 2013. It is imperative not to ignore the point that fiber is the major contributor to wood strength (Brown, *et al.*, 1949). The fibre diameter of *N. diderrichii* of 31.51µm ± 3.575 is the only diameter within the range for fibre diameter of softwoods which is approximately 32-43µm (H'ng, et al., 2016).

Lumen Width

Lumen width is the diameter of the internal cavity, it influences beating if pulp and is largely determined by the age of trees (Ogunjobi, *et al.*, 2018). Large lumen width is characteristics of species for good pulp production (Olorunfemi, *et al.*, 2016). Lumen width observed in this study was highest in Opepe compared to other species as shown in Table 2. The values obtained from this study for Opepe and Obeche disagrees with the findings of Adeniyi, *et al.*, 2013. Afara is the only species in agreement with the findings from Adeniyi, *et al.*, 2013. The values obtained from this study for the three species fall within the class of fibre with large LW. Large LW enhances the beating of pulp as it improves the penetration of pulping liquor into the intracellular spaces of the fibers (Olorunfemi, *et al.*, 2016; Bektas, *et al.*, 1999; Young, 1981).

Cell Wall Thickness

The thickness of the cell wall is largely influenced by the age of the tree as previously reported by Ogunjobi, *et al.*, (2018). CWT contributes more to wood density (Kretschmann, 2010; H'ng, et al., 2016). As observed from Table 2, Opepe has the highest CWT, with correspondingly high density compared to other species with lower cell wall thickness and a corresponding low density as reported in previous studies (Olufemi and Malami 2011; Falemara *et al*, 2012). The density of wood will largely contribute to its mechanical properties. However, for pulp and paper production, species with high cell wall thickness are undesirable.

Morphological Indices (Derived values)

Runkel ratio and slenderness ratio are higher in *T. scleroxylon* with values of 0.60 µm and 76.09 respectively, while the coefficient of flexibility of *T. superba* with 70.64 µm is higher compared to *T. scleroxylon* and *N. diderichii* as shown in Table 2. There is no significant difference ($p \geq 0.05$) in the effect of zones (i.e. sapwood and heartwood) across the derived values as shown in Table 4. Furthermore, there is a significant difference in the effect of the species on RR and CF but no significant difference in the effect of species on SR.

Runkel Ratio

Runkel ratio is an important indicator of the suitability of fibre for paper-making (Ogunjobi, *et al.*, 2018). It relates to pulp yield, fibre density and paper conformability (Ogunjobi, *et al.*, 2014: Ogunjobi, *et al.*, 2018). Fibres with a RR less than 1 are good for paper making because the fibres are more flexible, collapse easily and form papers with large bonded areas while those above one are considered thick-walled and stiffer and form bulky paper sheet of lower bonded area (Dutt, *et al.*, 2004; Ogunjobi, *et al.*, 2018). The result of this study showed that even though the species examined have RR values below 1, the RR for Afara is lowest compared to the other species and may be adjudged more suitable for papermaking.

Coefficient of Flexibilty

The coefficient of flexibility of the three species are 62.70%±1.83, 70.64%±1.83 and 63.64%±1.83 for Obeche, Afara, and Opepe respectively. These are higher than the values of obtained for the flexibility ratio for *Leucaena leucocephala* by (Oluwadare & Sotannde, 2007; Ogunjobi, *et al.*, 2018). According to Oluwadare (1998), the values of coefficient of flexibility obtained in this study are of acceptable range for hardwood species used in papermaking. Samariha, *et al.*, (2011) gave four groups of fibers: (i) High elastic fibres having elastic coefficient greater than 75: (ii) Elastic fibres having a ratio between 50-75: (iii) Rigid fibres having a ratio between 30-50: (iv) Highly rigid fibers having elasticity ratio less than 30. According to these classifications, the fibres of the species under study are elastic, and within the acceptable range.

Slenderness Ratio

The average slenderness ratio of the three species are 76.09µm±11.26, 64.17µm±11.26, 69.47µm±11.26 for Obeche, Afara, and Opepe respectively. The values of this study are higher, compared to those obtained for fibres obtained from various paper products by (Amoo, *et al.*, 2016), the values for *Ricinodendron heudelotii* by (Ogunleye, *et al.*, 2017) and also for *leucaena leucocephala* by (Ogunjobi, *et al.*, 2018). The SR of a cellulosic material greater than 33 is considered to be a good material for pulp and paper production (Amoo, *et al.*, 2016; Xu, *et al.*, 2006; H'ng, et al., 2016). According to Hng et al, 2016, a high value of SR provides better forming and well bonded paper. From this, the species best for pulp for paper making taking the SR as the parameter of interest, amongst the three species is Obeche with a slenderness ratio of 76.09 ± 11.26, then Opepe with a SR of 69.47 ± 11.26, and Afara with a SR of 64.17.

Table 9: Analysis of variance of the derived values

Variable	Source	Type III sum of Squares	Df	Mean Square	F	Sig.
RR	Corrected Model	.043[a]	3	.014	128.413	.008
	Intercept	1.672	1	1.672	15062.452	.000
	Species	.038	2	.019	170.637	.006*
	Zone	.005	1	.005	43.966	.022[ns]
	Error	.000	2	.000		
	Total	1.715	6			
	Corrected Total	.043	5			
CoF	Corrected Model	84.694[a]	3	28.231	77.999	.013
	Intercept	25865.532	1	25865.532	71462.552	.000
	Species	75.382	2	37.691	104.135	.010*
	Zone	9.312	1	9.312	25.726	.037[ns]
	Error	.724	2	.362		
	Total	25950.949	6			
	Corrected Total	85.418	5			
SR	Corrected Model	143.593[a]	3	47.864	3.495	.230
	Intercept	29322.754	1	29322.754	2141.221	.000
	Species	142.690	2	71.345	5.210	.161[ns]
	Zone	.903	1	.903	.066	.821[ns]
	Error	27.389	2	13.694		
	Total	29493.736	6			
	Corrected Total	170.981	5			

*Species sig. diff at $p \leq 0.05$ * Zone not sig. diff at $p \geq 0.05$ | [ns] no significant difference

CONCLUSION

Fibre characteristics are indispensable factors for the determination of suitability of any raw material for pulp and paper production. However, fibre characteristics should not be limited only to pulp and paper production; it is an important factor that affects the strength property of any wood species and therefore their general mechanical properties. Two species, *T. superba* and *T. scleroxylon* used in this study out of the three species are well suited for pulp and paper production, even though they are presently used only for construction purposes. However, it should not be forgotten that they can only produce short fibres, so their application can be limited in papermaking. *N. diderrichii* however, is considered as a very good timber species that can be used for construction or applied where load carrying capacity is required. This is due to the species having the highest cell wall thickness, which contributes immensely to its density. The high cell wall thickness value of Opepe has made it less suitable for paper production, although having other very good characteristics such as long fibres than the other species.

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Susceptibility of Wood Cement Composites to Microbial Attack

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Abstract

There is an emerging need for production of wood-cement composites because of the degradation of ordinary wood by microbes and insects. Hence, this study was investigated to determine susceptibility of wood cement composites to microbial attack. Sawdust from two indigenous wood species namely Triplochiton scleroxylon ('Obeche') (T) and Terminalia superba ('Afara') (A) and one exotic species, Gmelina arborea (G) were collected from a sawmill industry in Akure, Ondo State. The dusts were sieved and pretreated at 80^0C and then blended with cement particles in different compositions (1.0, 2.0, 2.5 and 3.0) and densities (800, 900 and 1000 kg/m^3) to form varying wood cement composites (WCC-1.0., WCC-2.0, WCC-2.5 and WCC-3.0 per density). Each WCC formed (e.g. 800, 900 and 1000T/ WCC-1.0., 800, 900 and 1000A/ WCC-2.0 etc) was later subjected to microbial analysis before and after field exposure for 12 weeks. Pour-plate technique was used for counting and isolation of microorganisms present in each WCC. Results showed that the bacterial counts ($x10^1$cfu/ml) in each WCC and the control before exposure were 0.00±0.00 and thus implied absence of bacteria growths in each WCC regardless of compositions and densities. However, there were varying bacterial counts that were also non composition and density dependent, after 12 weeks of field exposure in each WCC and were significantly different ($P \geq 0.05$) from the control. The bacteria counts ranged from 1.00±0.01 in T900 to 27.67±0.70 in G800 (WCC-1.0); 2.05±0.05 in A1000 to 33.67±0.37 in G900 (WCC-2.0); 0.00±0.00 in T900 to 18.00±0.80 in G900 (WCC-2.5) and 3.33±0.03 in T900 to 14.33±0.73 in G800 (WCC-3.0). Likewise before exposure, the fungi counts ($x10^1$ sfu/ml) in each WCC and the control were 0.00±0.00 which implied absence of fungi growth regardless of compositions and densities. Nevertheless, there were aslo different fungi counts after 12 weeks of field exposure. The fungi counts ranged from 0.33±0.03 in G800 to 4.33±0.33 in A800 (WCC-1.0); 0.00±0.00 in G900 to 5.67±0.55 in A800 (WCC-2.0), 0.00±0.00 in T900 to 6.33±0.36 in A800 (WCC-2.5) and 0.00±0.00 in G900 to 5.33±0.35 in A800 (WCC-3.0). Meanwhile, the bacterial isolates identified after field exposure were Lactobacillus and Bacillus species while Colletotrichum gloeosporioides was the only fungi isolate. Absence of microbial growth before exposure showed that the experimental WCC samples were not susceptible to microbial attack and remarkably, the highest microbial count after exposure did not exceed the acceptable limit (1 x 10^2cfu/ml) for microbial decay. More so, none of the isolates identified after exposure is a wood decaying pathogen and consequently cannot cause wood decay, perhaps have come in contact with the WCC on field through air or soil.

Keywords: *Gmelina arborea*, *Terminalia superba*, *Triplochiton scleroxylon*, Portland cement, composites, decay

INTRODUCTION

Production of wood-cement composites (WCC) which are basically formed by wood particles, cement (Portland) and water may serve as a good substitute and can be used in construction industries for various purposes (thermal and acoustic insulation, fire resistant cladding, better performance against weathering, fire, fungi and insect attacks) due to their low densities and maintenance costs and environmental performance together with non-toxic characteristics when compared with solid wood treated with chemicals (Matoski and Iwakiri, 2007). Nevertheless, wood is naturally affected by moulds and decay fungi as biodegradation agent (H'ng *et al*., 2011) and research relating to decay of WCC in industry and academia has been very limited and controversial. In fact, data on microbial decay comparing laboratory test results with field performance for these composites are also lacking (Ibach *et al*., 2004). This study therefore investigated before and after field exposure, microbial deterioration of wood cement composites produced from wood sawdusts obtained from three different wood species, *Gmelina arborea*, *Terminalia superba*, and *Triplochiton scleroxylon*.

MATERIALS AND METHODS

Source and collection of samples

Sawdust from two indigenous wood species namely *Triplochiton scleroxylon (*'Obeche') (T) and *Terminalia superba (*'Afara') (A) and one exotic species, *Gmelina arborea* (G) were collected from Ibitoye sawmill industry in Akure (7.25°N, 5.19°E). The dusts were sieved with 2mm sieve to obtain a uniform particle size and then oven-dried at 80^0C to remove traces of inhibitory chemical substances which may hinder the binding of the cement (Ajayi, 2000; Olorunnisola, 2009). The pretreated dusts were then blended with the Portland cement particles in different compositions (1.0, 2.0, 2.5 and 3.0) at density 800, 900 and 1000 kg/m^3 to form wood cement composites (WCC-1.0., WCC-2.0, WCC-2.5 and WCC-3.0 per density). Each WCC formed (e.g. 800, 900 and 1000T/ WCC-1.0., 800, 900 and 1000A/ WCC-2.0 etc) was later subjected to microbial analysis before and after field exposure for 12 weeks. The whole experimental set up was from April to September, 2018.

Counting and isolation of microorganisms

Pour-plate technique was used for counting and isolation of microorganisms present in each of the WCC samples before field exposure. One gram of each WCC samples was serially diluted with sterile distilled water to obtain primary dilution ($\times 10^1$). One milliliter of the primary dilution was then pipetted into a sterilized Petri-dish aseptically. This was followed by pouring separately, already prepared sterilized molten nutrient agar medium for bacteria count and already prepared sterilized molten malt extract agar (MEA) medium for fungi count. The Petri dish was later swirled gently to allow the contents to mix together, then allowed to solidify and incubated at 28±2°C for 24 and 72 hours, for bacteria and fungi counts respectively. Petri dish containing only molten medium without any composite sample served as control. Each set up was in three replicates. After 24 hours, bacteria count was carried out with a colony counter (Gallenkamp model) while after 72 hours, fungi count was also done with a colony counter. Sub culturing of any observable isolate was done several times until a pure culture was obtained. The experimented was repeated for all the composites samples after 12 weeks of field exposure in an open field. The bacteria were identified based on their colonial morphology, cellular morphology and their biochemical characteristics. Each isolate was identified using Buchanan and Gibbons (1974) while the fungal isolate was identified using PCR (polymerase chain reaction) analysis under the conditions suggested by Freeman *et al*. (2000) and Afanador-Kafuri *et al*. (2003).

Statistical analysis

Data obtained for both bacteria and fungi counts were analyzed using one –way ANOVA and means were separated by Tukey posthoc test, with the significant difference level of $p = 0.05$ (software SPSS version 11.5).

RESULTS AND DISCUSSION

Microbial counts of wood cement composites (wcc) before and after field exposure

Results showed that the bacterial counts ($x10^1$cfu/ml) in each WCC and the control before exposure were 0.00±0.00 and thus implied absence of bacteria growths in each WCC regardless of compositions and densities. However, there were varying bacterial counts that were also non composition and density dependent, after 12 weeks of field exposure in each WCC and were significantly different ($P \geq 0.05$) from the control. The bacteria counts ranged from 1.00±0.01 in T900 to 27.67±0.70 in G800 (WCC-1.0); 2.05±0.05 in A1000 to 33.67±0.37 in G900 (WCC-2.0); 0.00±0.00 in T900 to 18.00±0.80 in G900 (WCC-2.5) and 3.33±0.03 in T900 to 14.33±0.73 in G800 (WCC-3.0). Likewise before exposure, the fungi counts ($x10^1$ sfu/ml) in each WCC and the control were 0.00±0.00 which implied absence of fungi growth regardless of compositions and densities. Nevertheless, there were aslo different fungi counts after 12 weeks of field exposure. The fungi counts ranged from 0.33±0.03 in G800 to 4.33±0.33 in A800 (WCC-1.0); 0.00±0.00 in G900 to 5.67±0.55 in A800 (WCC-2.0), 0.00±0.00 in T900 to 6.33±0.36 in A800 (WCC-2.5) and 0.00±0.00 in G900 to 5.33±0.35 in A800 (WCC-3.0). The conidia of the fungal isolate observed were cylindrical with round apex and base (Figure 2). The PCR analysis (Figure 2) confirmed the isolate to be *Colletotrichum gloeosporioides*.

Table 1. Bacterial Counts of Wood-Cement Composites Before Field Exposure

Species	Density (kg/m^3)	Wood cement compositions: Bacteria counts ($x10^1$cfu/ml) 1.0	2.0	2.5	3.0
`	800	0.00±0.00a	0.00±0.00a	0.00±0.00a	0. 00±0.00a
T. superba (A)	900	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
	1000	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
	800	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
G. arborea (G)	900	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
	1000	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
	800	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
T. scleroxylon (T)	900	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
	1000	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
Control		0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a

Values are means of 3 replicates. Means followed by the same letters are not significantly different (P≤ 0.05) from on from one another within the same column using Tukey posthoc test. **Cfu-** c Cfu- colony forming unit

Table 2. Bacterial Counts of Wood-Cement Composites After Field Exposure

Species	Density (kg/m^3)	Wood cement compositions: Bacteria counts ($x10^1$cfu/ml) 1.0	2.0	2.5	3.0
	800	10.10±0.10c	3.03±0.03b	4.67±0.40c	6.33±0.03a
T. superba (A)	900	2.05±0.05b	6.06±0.06c	5.03±0.05c	4.40±0.14b
	1000	9.20±0.09c	2.05±0.05b	5.30±0.03c	5.05±0.60b
	800	27.67±0.70e	15.33±0.15d	2.33±0.20b	14.33±0.73d
G. arborea (G)	900	13.33±0.13d	33.67±0.37e	18.00±0.80e	9.33±0.93c
	1000	7.07±70.07c	14.33±0.03d	9.67±0.09d	4.33±0.30b
	800	3.67±0.07b	7.07±0.07c	8.67±0.70d	5.33±0.03b
T. scleroxylon (T)	900	1.00±0.01b	9.00±0.30c	0.00±0.00a	3.33±0.03b
	1000	6.03±0.03c	6.67±0.70c	9.67±0.09d	5.67±0.07b
Control		0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a

Values are means of 3replicates. Means followed by the same letters are not significantly different (P≤0.05) from one another within the same column using Tukey posthoc test.
Cfu – Colony forming unit

Table 3. Fungi Counts of Wood-Cement Composites Before Field Exposure

		Wood cement compositions			
		Fungi counts ($x10^1$sfu/ml)			
Species	Density (kg/m^3)	1.0	2.0	2.5	3.0
`	800	0.00±0.00a	0.00±0.00a	0.00±0.00a	0. 00±0.00a
T. superba (A)	900	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
	1000	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
	800	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
G. arborea (G)	900	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
	1000	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
	800	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
T. scleroxylon (T)	900	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
	1000	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
Control		0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a

Values are means of 3replicates. Means followed by the same letters are not significantly different (P≤ 0.05) from one another within the same column using Tukey posthoc test. Sfu – Spore forming unit

Table 4. Fungi Counts of Wood Cement Composites After Field Exposure

		Wood cement compositions			
		Fungi counts ($x10^1$sfu/ml)			
Species	**Density (kg/m^3)**	**1.0**	**2.0**	**2.5**	**3.0**
	800	4.33±0.33c	5.67±0.55c	6.33±0.36d	5.33±0.35d
***T. superba* (A)**	**900**	4.30±0.03c	4.33±0.33c	4.33±0.33c	3.33±0.39c
	1000	4.30±0.03c	0.67±0.71a	1.33±0.13b	1.33±0.13b
	800	0.33±0.03a	2.02±0.20b	0.33±0.03a	0.67±0.71a
***G. arborea* (G)**	**900**	0.67±0.07a	0.00±0.00a	1.00±0.00b	0.00±0.00a
	1000	0.33±0.03a	1.67±0.76b	0.33±0.03a	0.67±0.71a
	800	0.67±0.07a	0.33±0.03a	0.67±0.71a	1.33±0.13b
***T. scleroxylon* (T)**	**900**	3.67±0.60b	2.33±0.30b	0.00±0.00a	3.33±0.39c
	1000	2.30±0.30b	2.33±0.30b	2.33±0.30b	1.67±0.76b
Control		0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a

Values are means of 3replicates. Means followed by the same letters are not significantly different (P≤ 0.05) from one another within the same column using Tukey posthoc test.

Sfu – Spore forming unit

Figure 1. Cylindrical and rounded end conidia of *Colletotrichum* isolate

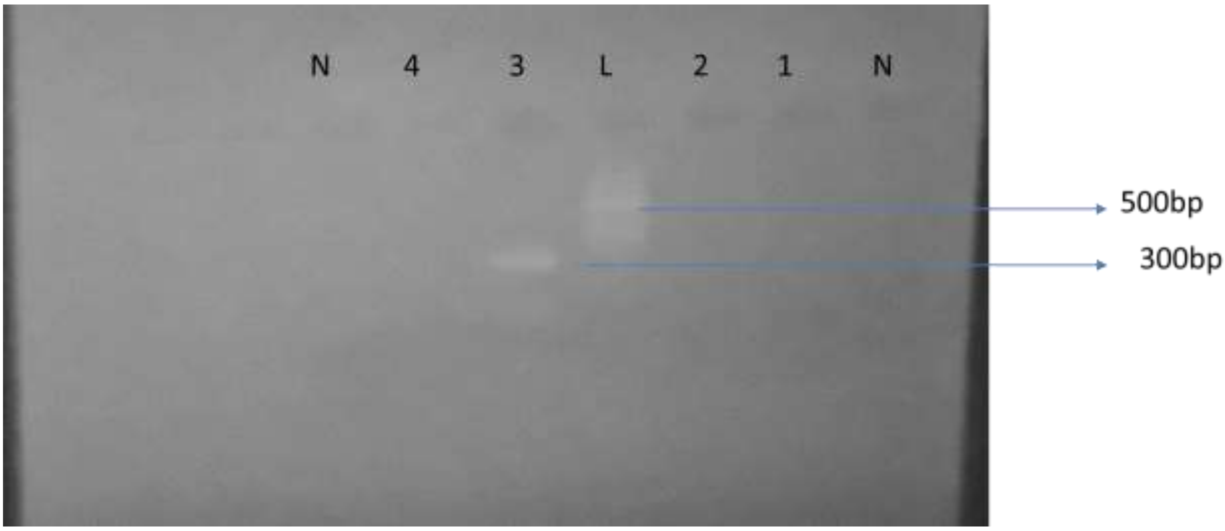

Figure 2. A gel electrophoresis picture showing DNA sample in lane 3 Positive for *Collectotrichum gloesporiodes* with the Cgint primer. **Note:** N – Negative control (no DNA)

Discussion

From the results, no bacterial and fungi isolate occurred on all the WCC samples before field exposure and this could but be connected with the fact that the wood cements composites did not support microbial growth. Therefore, blending the wood sawdust with cement particles could offered better performance against weathering fungi attacks when compared to ordinary wood. However, there were varying microbial counts after field exposure that was non composition and density dependent because the isolates observed are not wood pathogens. Meanwhile, the presence of *Bacillus* and *Lactobacillus* species in the composite samples after field exposure suggests possible contamination by spores in the air. The light spores of these organisms might be present in surrounding air where the samples were exposed since their spores are common air contaminants (Arotupin *et al*., 2003). Besides, these isolates are widely distributed in nature probably (dusts and soils) and possess ability to exploit and utilize available nutrients in these habitats. Though *C. gloeosporioides* was not detected in the composite sample before field exposure, it was present after field exposure. The presence of *Colletotrichum* after field exposure suggests soil contamination from the field. This is because the isolate is a soil fungus and must have found itself on the sample through soil particles.

Conclusion

Findings from this work showed that the experimental samples were not susceptible to microbial attack before field exposure. This could have been influenced by the blending of the wood dusts with Portland cement particles. Nevertheless, there were varying microbial counts after field exposure as a result of contamination from the environment (air, soil) where the samples were exposed. Interestingly, none of these isolates can cause wood decay because they are not wood decaying pathogens but must have probably come in contact with the WCC on field through air or soil.

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Conflict of Interest:

The authors declare no conflict of interest.

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Bamboo Resources: Uses and Development in Nigeria

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Abstract

Bamboo has a long history of traditional use in Nigeria but is considerably less utilized in comparison to Asian countries. In Nigeria, bamboo is largely used in the handicraft industry and in the housing and construction sector. Bamboo is also often cultivated for soil stabilization, used as support in the farm for yams, beans and vegetables. Two species, Oxytenanthera abyssinica and Bambusa vulgaris, are used almost exclusively for these purposes. Attention is drawn in this paper to the urgent need to intensify the use of the bamboo resources in Nigeria to meet up with the industrial development as seen in the Asian countries. Forestry Research institute of Nigeria (FRIN) the Institute with mandate on bamboo research will need to step up research in bamboo production and utilization especially on technology transfer to assist the small scale bamboo entrepreneurs. Government should support research projects on bamboo development and utilization in Nigeria to further motivate creative inventions.

Keywords: Bamboo, Resources, Development, Utilization, Industry

INTRODUCTION

The Bamboo belongs to the grass family and is one of the fastest growing plants in the world as some species are reported to have a growth rate of about 1m per day (Scurlock *et al*., 2000; Igbokwe *et al*., 2016). It is a plant of enormous importance to the rural people in several parts of the world and has been dubbed 'poor man's timber'. Its excellent growth, mechanical and engineering properties makes it a fine alternative to tropical timber.

Bamboo is a renewable plant and grows abundantly in the tropics, subtropics and temperate regions within latitude 40^0 S and 40^0 N and average annual temperature of 15 - 20^0 C and precipitation of 1000 – 1500mm (Scurlock *et al*., 2000; Ogedengbe 2010). Nigeria falls into the above described location hence the presence of bamboo in the country (ladapo *et al*., 2017)

In rural arrears, bamboo is extensively used in making fence, planted around ponds as water sheds to reduce evaporation, carbon sequestration, making of wood gong, used as staking materials for yams, decking of storey buildings, support for banana and plantain as well as support for thatched houses (Nwaihu, *et al*., 2015)

In Asian countries, bamboo has been used for household utilities such as containers, chopsticks, woven mats, fishing poles, cricket boxes, handicrafts, chairs, etc. It has also been widely used in building applications, such as flooring, ceiling, walls, windows, doors, fences, housing roofs, trusses, rafters and purlins. It is also used as structural materials for bridges, water transportation facilities and skyscraper scaffoldings (Adejoba and Ojo, 2013). The level of bamboo utilization in Nigeria is still low. RMRDC (2004) reported that the range of uses to which bamboo is put in Nigeria is still very narrow when compared to what obtains in other bamboo producing countries like china, India and other Asian countries.

BAMBOO RESOURCES DISTRIBUTION IN NIGERIA

Bamboo is widely distributed in the tropical, subtropical and mild temperate zones of the world, with the tropical belt having the largest number of species. Worldwide, approximately 87 genera and over 1500 species of bamboo exist. There are about five species of Bamboo in Nigeria namely: *Bambusa vulgaris; Bambusa arundinacea; Bambusa tulda; Dendrocalamus gigantes and Oxytenanthera abyssinica* and only two species namely, B*ambusa vulgaris* and *Oxytenanthera abyssinica* are commonly propagated (RMRDC, 2006). *Bambusa vulgaris* grows commonly in the southern parts of Nigeria, while *Oxytenanthera abyssinica* occurs in the savanna zones of the country. (RMRDC 2004)

In Nigeria, there is presently lack of published works on the occurrence and distribution of bamboos, both the indigenous as well as those introducedinto the country. A study published by RMRDC (2004) revealed that the bamboo species occurring and distributed across Nigeria have similar morphological characteristics. The report however named the dominant bamboo occurring in Nigeria as India bamboo according to its trade name in many parts of the country.

The nationwide survey of bamboo availability in Nigeria by RMRDC (2004) also showed that bamboo is widely distributed with concentration in the south and middle belt areas of the country. The distribution was found to be related to the ecological conditions with the rainforest areas having the most abundant distribution. According to the report, four levels of classification of abundance were used; abundant for states where 10% of the natural vegetation is dominated by bamboo (Ogun, Oyo, Osun, Ondo, Edo, Delta, Rivers, Akwa Ibom, Cross River, Abia Eboyi, Enugu, Ananbra and Imo states); Frequent for states with 6.0-9.9% of the natural vegetation dominated by bamboo (Lagos, Ekiti, Bayelsa, Kogi, Kwara, Benue and Nasarawa); occasional for states with 3.0-5.9% of the natural vegetation occupied by bamboo (Niger, Taraba, Plateau and the federal Capital Territory); and rare for states with less than 3% of vegetation dominated by bamboo (Adamawa, Bauchi, Borno, Gombe, Kano, Kaduna, Katsina, Kebbi, Sokoto, Jigawa, Yobe and Zamfara)

In Nigeria very little is known about bamboo propagation and utilization. Eleojo, (2008) reported that in Nigeria, the potentials of bamboo is greatly untapped due to lack of awareness. The country has a suitable land for bamboo propagation, since bamboo strive very well and in abundance in our natural forest, most especially in the southern part of Nigeria. We underutilize bamboo by subjecting them to use such as television antenna, yam tending, building construction, musical instruments, fish traps and other various domestic uses depending on the community, while the potentials remain greatly untapped due to lack of awareness.

BAMBOO UTILIZATION IN NIGERIA

The present level of bamboo utilization in Nigeria is still low, according to the survey reported by RMRDC (2004) there was a clear indication that the range of uses to which bamboo is put in Nigeria is still very narrow when compared to what obtains in other bamboo producing countries like china, India and other Asian countries. The major areas of bamboo application presently in Nigeria are still restricted to six areas namely: Building construction, yam stakes by farmers, environmental control, handicrafts, fuel wood and fencing. This is grossly underutilization considering the over a thousand and one uses for which bamboo material have been put in other countries of use.

Bamboo use as building material in Nigeria cut across the country and this occurs in different forms. In the construction of multi-storey buildings, bamboo culms are employed either as pillars to provide temporary support for decks floors or as scaffold materials during construction activities. In some rural areas, bamboo culms are used for construction of mud houses. When used in this manner, the bamboo serves as the reinforced skeleton, which is later plastered with mud. Houses built with this method usually have very straight walls, very solid and much stronger than the houses built without bamboo (RMRDC, 2004). Similarly, bamboos are being employed as roof trusses as well as columns for buildings in some rural areas where bamboo is abundant

ADVANCED UTILIZATION IN BAMBOO

Globally bamboo has been used widely for household products and extended to industrial applications due to advances in processing technology and increased market demand. In Asian countries, bamboo has been used for household utilities such as containers, chopsticks, woven mats, fishing poles, cricket boxes, handicrafts, chairs, etc. It is also been widely used for structural applications such as in bridge construction, water transportation facilities and skyscraper scaffoldings and building parts such as flooring, ceiling, walls, windows, doors, fences, housing roofs, trusses, rafters and purlins. Bamboo fiber is longer than wood fiber which gives bamboo some technological advantage. It is used for composite materials such as veneer, strip boards, mat boards, fiber boards, particle boards, medium density boards and so on (Jamatia, 2012). The current industrial bamboo composite materials, panels and boards and veneers are manufactured by utilizing synthetic resins to glue the particles. Novel developments in the bamboo composites are reported with renewable polyesters, polyesters, polyamides or bio-based polynylene (Wageningen, Food and Bio-based Research, 2015).

Countries such as China and India use bamboo for Pulp and paper production. Paper made from bamboo has the same quality with paper made from wood. Its brightness and optical properties remain stable while those made from wood may deteriorate over time. The morphological characteristics of bamboo fibers give paper made from bamboo a high tear index (Zing and Cheng, 2012). Bamboo has a high cellulose (40 – 60%) and low hemicelluloses content, and the fibres are strong, long (2.0 – 3.0mm), have a high length to width ratio and thick walls which are beneficial for paper making. Generally bamboo culms are excellent raw materials for pulp and paper production. (INBAR, 2006). Bamboo is processed into charcoal as a substitute for wood charcoal or mineral coal. Activated bamboo charcoal can be used for purification the environment, absorbing excess moisture (Jamatia, 2012). Bamboo charcoal and briquette production is a simple technology that is used in China and promoted in African countries such as Ethiopia, Kenya and Ghana (INBAR, 2016). FAO and INBAR (2006) reported that, Bamboo viscose fiber is marketed in China as a very versatile textile raw material that competes with synthetic textile yarns and natural fibers like cotton, wool, linen and silk. Table 1 shows the various bamboo industries products

Table 1: Bamboo Industries and Corresponding Products

Industries	Products
Wood products	Ply bamboo, laminated bamboo board (planed), mat ply bamboo, curtains ply bamboo, laminated wood strips, mat curtains ply bamboo, bamboo chipboard, floor tiles and composites
Houses	Prefabricated houses made of engineered bamboo
Pulp and Paper production	Paper products
Bamboo chemicals and Pharmaceuticals	Vitamins, amino acids, flavine, phenolic acids, polysaccharide, trace elements and steroids, beverage and beer, bamboo ethanol, and butanol, activated carbon
Energy generation	Biofuels, charcoal, briquettes, biomass feedstock,
Textiles	Fabrics, Yarns, Clothes, Socks
Utensils	Spoons, plates, cup and serving tray, tooth pick
Miscellaneous uses in the Industrial sector	Used extensively in the electrical, electronics and communications, industries for production of wrist watches, chains, fan blades,
Farming	Irrigation and drainage pipes, bamboo leaves incorporated into livestock feeds,

Sources: Ogunwusi and Onwualu (2013); Okwori and Chado (2013)

IMPEDIMENTS TO EFFECTIVE UTILIZATION OF BAMBOO IN WOOD INDUSTRIES IN NIGERIA

Jamatia, (2012) pointed out that bamboo is the second China's forest products. Bamboo plants grow quickly and have the ability to propagate easily. It has been observed that Asia countries and some developed countries make use of bamboo very well which contributes to the economic development of their countries while opposite is the case with Nigeria. This paper identifies impediments to effective utilization of bamboo in wood industries in Nigeria. These impediments include lack of public awareness in the use of bamboo in modern buildings and furniture, lack of bamboo research institute, unavailability of technical experts for processing bamboo for use, lack of facilities for processing bamboo for domestic and industrial work and government attitude towards the use of bamboo in Nigeria.

Lack of Public Awareness in the use of Bamboo in Modern Buildings and Furniture.

It is not an over statement to say that many carpenters and cabinet makers in Nigeria do not know that bamboo is used for roof structural members such as kingpost, purlin, rafters, tie beam in modern buildings and also furniture of different kinds after processing and lamination. Many woodworkers are only acquainted with the traditional method of using bamboo in buildings and furniture (Okwori and Chado, 2013). Thus, there is need for serious enlightenment programmes to promote government interest in bamboo development in Nigeria (Ogunwusi, 2013).

Lack of Bamboo Research Institute:

There is a bamboo research institute in China, India and other countries because of the importance placed on the plants. However, this is not so in Nigeria. Bamboo research institute will promotes the use of bamboo by carrying out researches relating to bamboo and also for training technical and non-technical staff in the area of bamboo.

Unavailability of Technical Experts for Processing Bamboo.

It is a fact that due to lack of bamboo research institute in Nigeria and nonchalant attitude of government towards the use of bamboo, the technical experts for processing bamboo for use in modern buildings and furniture are lacking. Most sawmills and wood industries in Nigeria do not have the technical staff for processing bamboo. Also there is limited capacity building for the crafts men whose skill is limited to a number of simple items that cannot compete in the global market (RMRDC, 2004).

Lack of Facilities for Processing Bamboo for use.

In Asia and other countries that bamboo is greatly used for construction work, the required facilities for processing are available. In Nigeria, most sawmills and wood industries do not have facilities for processing bamboo due to its non-usage for furniture and other construction work. Even, wood technology students who are interested in carrying out researches on bamboo hardly have access to facilities for their studies.

Government Attitude Towards Bamboo as a Forest Product.
The Nigerian government has not fully recognized the importance of bamboo and its role as a substitute to wood in major applications . No concerted effort has been made to grab the large potential which has been successfully demonstrated by the Chinese bamboo industry. Presently bamboo is found in abundance in Nigeria but underutilized. Hence, it has been impossible to develop bamboo to the level where it can contribute in any reasonable measure to raw materials supply or as a foreign exchange earner through export of bamboo produ cts (Ogunwusi and Onwualu, 2013).
The government seems to have nonchalant attitude towards bamboo as a forest product when compared to wood while some countries like China rely much on bamboo which has boosted their economy very well due to revenue generated yearly from it. It was revealed that Nigeria is a member of International Network for Bamboo and Rattan but has never exported bamboo nor used it effectively. The reason why Nigeria is not among the countries exporting bamboo is because of government's nonchalant attitude towards bamboo as a forest product. It is not surprising because Nigeria has no bamboo research institute and there is no bamboo plantation. It is also good to embrace bamboo instead of relying completely on wood. When bamboo is embraced it will serve as complementary for wood since wood is used for everything in Nigeria. For instance, building construction, furniture, charcoal and so on. This will boost the Nigerian economy as seen with Chineese.

RECOMMENDATIONS FOR DEVELOPING BAMBOO RESOURCES AND INDUSTRY IN NIGERIA
According to Ogunwusi (2013), Nigeria's bamboo sector is wrought with problems among which are unplanned harvesting, lack of large organized bamboo industries, prevalence of low cost added bamboo products, and lack of research and inventory data for bamboo lands. As bamboo utilization has been tested over time, it will be appropriate for policy makers to promote industrial utilization of bamboo in the country. For this to be feasible, the following recommendations have to be attended to:

1. There should be bamboo development policy to give focused thrust to develop the sector with an integrated approach for commercialization of bamboo. Hence the need for a national bamboo policy. The policy should spell out the objectives of bamboo development and provide detailed guidelines for implementation. The bamboo policy framework should encourage and promote establishment of cottage, small and medium industries. The current incentives such as pioneer industries, 100% capital repatriation etc shall fully apply to pioneer industries in the sector. Emphases should be laid on adoption of proven technology (Ogunwusi, 2013)
2. Introduction of exotic bamboo species with high industrial potentials, high biomass and fast growth rate.
3. Nigeria needs a bamboo inventory. It is necessary to determine the quantity and quality of bamboo that currently exists in Nigeria, their distribution, types of species and quality of stocks available. Many studies show the lack of reliable data on Nigeria's bamboo. This information gap needs to be filled before the country can develop a plan for bamboo development. This study can be carried out by the National Space Research and Development Agency in collaboration with the Federal Ministry of Environment.
4. Bamboo development is currently a mandate of Forestry Research Institute of Nigeria, Ibadan. However, paucity of funds coupled with low level of interest in industrial bamboo utilization locally has frustrated bamboo development programmes initiated by the institute. To promote industrial development of bamboo locally, it may be necessary to release special fund to the institute mainly for bamboo development.
5. Plantation establishment should be encouraged and promoted due to their high value, productivity, uniformity of crop and choice of species as linked to people and industrial needs. Private bamboo plantation should not be left out.
6. Awareness on the utilization of bamboo is expedient to promote public acceptance and the simple skill needed for adopting bamboo as supplementary to wood

CONCLUSION AND RECOMMENDATION
It is quite apparent that bamboo resource in Nigeria can play an important role in the development of the country's economy considering the various importance of Bamboo especially in the wood industries. This will contribute significantly to the rural economy by generating entrepreneurship and employment; the main thrust of the present government's poverty alleviation programmes
Developments in the utilization of bamboo in the Asian countries, such as China may be acquired in the utilization of Nigeria bamboo as suitable raw material to complement for the wood industry. Indeed bamboo can substitute for wood in many of wood traditional uses such as paper fibreboard, glue-laminated structural material, furniture, panels and flooring for the full actualization of bamboo potentials. Forestry Research institute of Nigeria (FRIN) will need to step up research in bamboo production and utilization especially on technology transfer to assist the small scale bamboo entrepreneurs. Government should support research projects on bamboo development and utilization in Nigeria and in FRIN to further motivate creative inventions.

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Adhesive penetration and adhesive bonding strength in wood composite application: a review

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Abstract

Adhesives play an indispensable role in the manufacture of many modern engineered wood products such as plywood, oriented strandboard, laminated veneer lumber, and cross-laminated timbers. However, for the development of a new adhesive or an improvement in pre-existing wood adhesives, it is important to effectively evaluate their prospects for wood composite application and understand the adhesive/wood interaction. This helps to gain scientific insights to guide the adhesive development and application in terms of the mechanical strength and adhesive penetration. In this review, the important adhesive penetration behavior in the wood and the techniques available for characterizing the adhesive penetration as well as the common mechanical tests of the bonded wood composite are discussed.

Keywords: **Adhesive bonding, mechanical strength, adhesive penetration, wood composite**

Introduction

Wood-based composites represent a broad class of materials which are critically important to residential construction, timber engineering and furniture manufacturing industries. The performance of all adhesively-bonded materials, including wood products, depends on the ability for the adhesive to transfer mechanical stresses across the joint interface. Strength tests are one of the most important means of determining many different characteristics of adhesives, from chemical composition to their use in structural applications. While adhesives may be represented by a number of measurable chemical and physical properties such as viscosity, pH, particle size, solid content, polarity, and rate of hardening, the ability to form bond of prescribed strength.

Wood Adhesive Bonding Strength Evaluation

Bond-forming properties are normally checked by the use of standard test specimens in various tests such as shear strength (tensile or horizontal shear), pull-off strength, and delamination tests (Heon Kwon *et al*, 2015; Ozdemir, 2015). Bending strength test (Gaff and Gasparik 2015) are mainly used to evaluate the bonding strength of wood adhesives and the mechanical properties of wood composites. There are several standards to measure the shear strength of the adhesive bonded wood composites such as the ASTM (American Standard Standards for Testing Materials) test method for strength properties of adhesive bonds in shear by compression loading (D 905, D 4262 and D 2559; Mckinley *et al*, 2016; Song *et al*, 2016). The European Standard EN 205; as demonstrated by Heon Kwon *et al* 2015 and Adamopoulos *et al*, 2012. As described in these standards, one end of each wood chip is glued by adhesives and the other end is inserted into the clamps, while the shear test is done in tension (Figure 1a) at a certain speed until the failure of the bond line is achieved. According to the ASTM-D 4541 (1995) standard, Figure 1b illustrates the setup of the pull-off test. A thin layer of wood adhesive is coated onto the wood surface and the larger head of the aluminum stud is pressed and attached onto the wood adhesive. The tail of the stud is then inserted into the clamp, and moved up slowly at a constant speed until failure occur on the wood/adhesive interface. The maximum force is the tensile strength of the aluminum stud separated from the wood surface. The bonding strength is calculated as shown in Equation (1) from Örs, *et al*, 2004.

$$\text{Bonding strength } (\sigma) = \frac{f_{max}}{s} \qquad (1)$$

in which $\sigma_{bonding\text{-}strength}$ is the bonding strength, f_{max} is the maximum force, and S is the contact area.
According to the standard ISO 3133 (1975) used by Gaff (2012), the bending strength of wood composites is tested by three-point test method in a standard tensile-pressing machine (Figure 1c). The bending strength can be calculated by Equation (2:

$$\sigma_b A = 32 f b h_{max} 2l \qquad (2)$$

Where σ_b is the bending strength (MPa), f_{max}), is the breaking force of the sample, l is the space between each supporting pin (mm), b is the width of the sample (mm), and h is the thickness of the sample (mm).
In this method, wood composite is placed onto two supporting points after that the probe is brought into contact with the wood chip; the preload increases slowly at a constant rate until the wood composite breaks. The maximum force f_{max} is recorded and used to calculate the bonding strength of the wood adhesive.

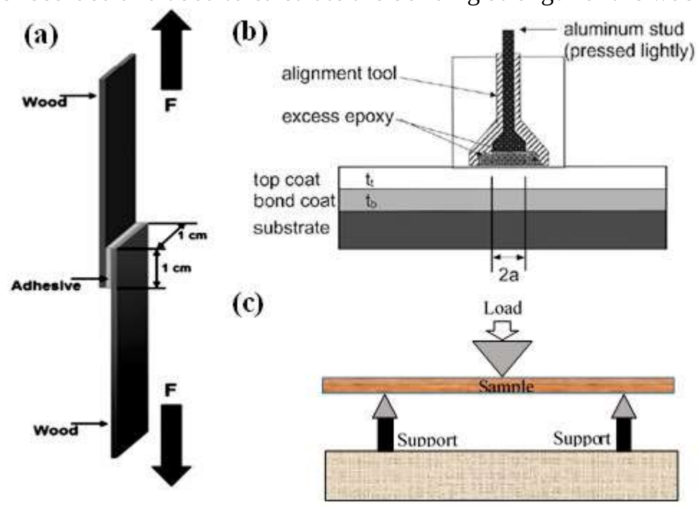

Figure 1. Schematic of wood adhesive (**a**) shear strength test Song *et al* 2016, (**b**) pull-off strength test Kohl *et al* 1999, and (**c**) three-point bending strength test.

To interpret the measured bonding strength of wood adhesives, it is essential to know where the failure or separation occurred in the mechanical tests. There are four main types of failure modes for the adhesive bonded wood composites: (a) cohesive failure of the adhesive; (b) adhesive failure at the interface; (c) mixed failure , that is a combination of (a) and (b) and (d) wood cohesive failure or wood failure (Desai *et al* 2003; Davalos, *et al* 2000; Frangi, *et al*, 2004). In cohesive failure of the adhesive, the failure is observed in the adhesive layers. In adhesive failure, the adhesive was detached from the wood at the interface. In the mixed failure mode, both the cohesive failure of the adhesive and adhesive failures at the interfaces are observed. In wood cohesive failure, an entire layer of wood fibers is pulled off from the wood substrate and thus failure occurs in the wood. The percent material failure is often used to describe failure of wood composites, indicating how much of the adhesive or wood substrate is pulled off from the whole contact area under a certain condition. In the proposed four types of failure mode, the cohesion failure of adhesive indicates the weak bonding which is not acceptable in structural applications. The adhesive failure between adhesive and wood implies the better bonding performances of wood adhesives while the mixed failure indicates a better interactions between adhesive and wood substrate resulting in a stronger bonding. When the adhesive penetrates into the wood substrate deep enough so as to form mechanical interlocks and other interactions with the wood, a layer of wood would be taken off from the bonded surface. Thus the mixed and wood failure are preferred in wood fabrication to obtain a well-bonded and high performance wood composites (Desai *et al* 2003; Davalos, *et al* 2000; Frangi, *et al* 2004).

Wood Adhesive Penetration
As wood is a porous material, the nature of its surface is highly variable depending on the porous structure of the wood species. The cellular nature of wood allows for rapid flow of adhesives into the large earlywood lumens in softwood and vessel elements in hardwoods hence, liquid adhesives can flow and penetrate the porous structure during bonding.

A wide variety of wood adhesives have been developed and extensively utilized in industrial processes to manufacture advanced structural wood-based products (Adamopoulos *et al*, 2012). The main function of wood adhesives is to bond wood panels and small wood pieces together, and form wood composites with the desired dimensions, mechanical properties, and without the natural wood anisotropy (Mendoza *et al* 2010). The bonding interactions between the adhesive and wood are principal factors affecting the performance of wood composites (Wang 2011; Follrich et al, 2010; Gardner 2005). Therefore, it is essential to characterize the interactions of wood and adhesive to reveal the bonding mechanism (Stelte; *et al*, 2011). Wood surface has high porosity, high surface energy, and good wettability Kamke, 2007; Shi and Gardner (2001); Singh *et al*, 2002 Thus, polar liquids are able to wet the wood surface and flow into the porous structure (e.g., vessels and lumens) of wood (Kamke (2007). This phenomenon is defined as adhesive penetration, which has a profound influence on bonding interactions and bonding strengths. As illustrated in Figure 2a, the adhesive penetration was quantitatively described by four parameters. These include numbers of filled fibers (NFF), represented by circles filled with red color), numbers of filled vessels (NFV), The ray fibers were filled with adhesive, parallel to the bond line denoted by 1), maximum penetration depth in fibers is denoted by (MPD_f, the furthest circle filled with red perpendicular in direction to the bond line denoted by 5), and the maximum penetration depth in rays is denoted by (MPD_r, parallel to the direction bond line, there four rays of circles are filled with red color) Edalat; *et al*, 2014.

In most cases, adhesive penetration in wood is not uniform and involves different depths as shown in Figure 2b to include fully filled vessels and partially filled vessels (Gavrilovic-Grmusa; *et al*, 2008). The movement of adhesives in the longitudinal direction of wood is more significant than in the lateral direction due to the particular arrangements of vessels/lumens in the longitudinal direction and having end-to-end connection (Kamke. 2007). Penetration depth has a close relationship with the ultimate performance of wood composites. An excessive penetration causes an increase in manufacturing cost and starved bondline. In contrast, insufficient penetration leads to a reduction in bonding strength due to limited contact areas for formation of chemical/mechanical bonding (Edalat *et al*, 2014; Paris and Kamke 2015).
Adhesive penetration can be divided into two categories: (1) gross penetration at the microscale (Gavrilovic-Grmusa., *et al*, 2008) and (2) cell-wall penetration at the nanoscale (Konnerth, 2008). In gross penetration, the liquid adhesives wet and spread on the wood fibers, flowing into micro-sized pores and fully or partially filling the lumens, vessels and encapsulating fractures (Kamke 2007; Gavrilovic-Grmusa *et al*, 2008). There are two driving forces for gross penetration: hydrodynamic flow and capillary action (Kamke 2007; Paris and Kampe, 2015). In cell-wall penetration, liquid adhesives diffuse from outside to cell walls and micro-cracks, swelling and plasticizing the cell wall (Kamke, 2007; Paris and Kamke, 2015). In addition to the penetration phenomena, the formation of adhesive bonds has been described by various interaction mechanisms such as mechanical interlock, chemical covalent bonding, electrostatic induced interaction, wetting induced interaction, diffusion induced interaction and van der Waals or hydrogen bonding interactions (Gardner, 2005). Among those interactions, mechanical interlock is the primary interaction between wood and adhesive which controls the properties of bond line and affects the performance of wood composites.

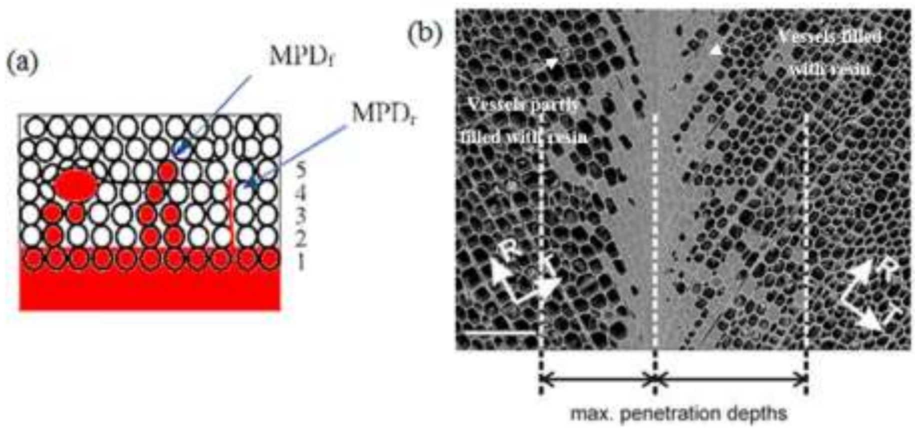

Figure 2. (**a**) Illustration of numbers of filled fibers (NFF), numbers of filled vessels (NFV), maximum penetration depth in fibers (MPD_f), and maximum penetration depth in rays (MPD_r) (**b**) states of adhesives filled in vessels

Factors Affecting Wood Adhesive Penetration
Adhesive penetration includes both flow of adhesives into wood micron-scale voids and infiltration into the polymer components of the wood cell wall layers. Adhesives penetration is affected by wood properties of both softwood and hardwood because of their differences in surface roughness Wang *et al*, (2015); pore size Imam *et al*, (2010); growth ring orientation Li., (2005) and wettability. Adhesive property: molecular weight, viscosity, and solid fillers effect, and processing conditions (temperature, pressure, and moisture) are all influenced by adhesive properties (Johnson and Kamke, 1992; Laborie *et al*, 2006). Wang *et al*, (2015) investigated the influence of two types of wood, i.e., softwood (Douglas-fir) and hardwood (hybrid polar), on adhesive penetration. It was found that the penetration of adhesive is much faster in softwood than in hardwood. The fast penetration in softwood could be associated with its highly ordered and well-aligned tracheid, as well as its relatively uniform pore size. In contrast, hardwood has randomly distributed vessels with a wide size distribution, resulting in a random penetration of adhesives (Li *et al*, 2015).

Surface roughness also affects the bonding performance since it is directly related to the contact area between adhesive and wood. Follrich, *et al*, (2010) studied the effect of five wood fibers with different roughness on the bonding strength. The outcome showed that the highest tensile strength was achieved for the wood fiber-based sample with the greater surface roughness. Wang and Yan (2005) used two types of wood fibers (birch and aspen) to evaluate the effect of pore size on the bonding with phenol formaldehyde resin without any application pressure. The results showed that phenol-formaldehyde resin readily penetrated into pores larger than 40 µm, partially penetrated into pores ranging from 1 to 40 µm, and barely penetrated into pores smaller than 1 µm.

The nature of the growth orientation of wood also influences the adhesive penetration as well as the bonding strength as reported by Follrich *et al*, (2010), who showed that shear strength decreased with increasing grain angle. Surface wettability of wood can control the flow and motion of liquid adhesives on the wood surface and lead to different degrees of penetration. Wei *et al*., 2012 changed the wettability of birch by using different dyes. It was found that a deeper penetration occurred on a sample with a better wettability (or a smaller contact angle with water). Although wood surface and structures have considerable effects on adhesive penetration, factors related to the adhesive properties should also be considered, including the adhesive viscosity, molecular weight, and fillers. Johnson and Kamke (1992) demonstrated that adhesive with a larger molecular weight (≥10,000 g/mol) had a limited penetration while the adhesive with a smaller molecular weight (≤10,000 g/mol) had a significant penetration into wood fibers. In another study, Laborie *et al*, (2006) showed that a lower molecular weight PF had better penetration than a high molecular weight PF. It could be related to the higher mobility of low molecular weight PF and the formation of better nanoscale interactions. Cellulose nanofibril (CNF) was used as a filler in urea-formaldehyde (UF) adhesive; the added CNF increased the viscosity of UF resulting in a thicker bond line and a smaller penetration (Veigel *et al*, 2011). Additionally, the application processes have apparent effects on adhesive penetration. For example, a proper processing pressure is required to form a desired penetration. Cheng and Sun (2006) found that either high or low pressure was not good for penetration. Extra high pressure might destroy the interlayers leading to a poor penetration while at low pressure, there is insufficient contact between the adhesives and wood resulting in a poor penetration.

To predict the penetration of liquid adhesives in the porous wood, Darcy's law has been used to describe the flow of liquid adhesive into wood fiber under ideal conditions (Kucˇerová *et al*, 2012).

$$\varrho = K.\Delta P \frac{A1}{L\eta} \qquad (3)$$

Where, Q, K, A, L, η, and ΔP are the liquid volume flow rate ($m^3 \cdot s^{-1}$), specific permeability of wood (m^2), area perpendicular to the liquid flow (m^2), sample length in the direction of flow (m), dynamic viscosity of the liquid (Pa·s) and the pressure drop (Pa), respectively. This equation illustrates that adhesive penetration is determined by the factors of the processing pressure ΔP, liquid viscosity η and the wood permeability to liquid K supporting the characterization of wood adhesive penetration at the theoretical level. Furthermore, the distribution of adhesives in wood was evaluated by using a non-destructive transmission visualization technique and described by the Lambert-Beer Law (Kucˇerová *et al*, 2012).

$$I = I_0 e^{-\mu d} \qquad (4)$$

$$\mu = \mu 0_p \qquad (5)$$

Where, I, I_0, µ, µ', and d, are the radiation intensity that passes through the bonded wood ($cm^{-2} \cdot s^{-1} \cdot A^{-1}$), the radiation intensity before adhesive penetration ($cm^{-2} \cdot s^{-1} \cdot A^{-1}$), the attenuation coefficient (cm^{-1}), mass density of liquid adhesive ($kg \cdot m^{-3}$), mass attenuation coefficient of wood ($cm^2 \cdot g^{-1}$) and penetration depth (cm). These equations highlight that the adhesive penetration is the result of the synergetic effects of multiple factors such as the intrinsic property of wood and the property of adhesive.

Characterization Techniques of Wood Adhesive Penetration

The penetration of adhesives into wood fibers likely cause changes in the wood properties such as the morphology of interlayer, elastic modulus difference, composition changes, polymerization etc. (Modzel *et al*, 2011; Hass *et al*, 2012; Mendoza *et al*, 2010). Both quantitative and qualitative techniques have been developed to observe adhesive penetration at the micro- and nanoscales. These techniques include optical microscopy techniques (Kamke and Lee 2007), electron microscopy techniques (Kamke and Lee 2007), spectroscopy techniques (Ren and Frazier 2012) and tomography techniques (Bastani *et al*, 2016). Many optical microscopy techniques have been used for examining adhesive penetration. These include fluorescent microscopy scanning thermal microscopy (SThM) (Konnerth *et al*, 2008) and confocal laser scanning microscopy (CLSM) (Cyr *et al*, 2008). For the electron microscopy method, the widely used methods include scanning electron microscopy (SEM) (Bolton *et al* 1988), transmission electron microscopy (TEM), energy-dispersive X-ray analysis (EDX) (Egerton, 2006), electron energy loss spectroscopy (EELS) (Egerton, 2006), and X-ray tomographic microscopy (SRXTM). The common spectroscopy techniques to characterize adhesive penetration are infrared spectroscopy (FTIR) (Ren and Frazier 2012), nuclear magnetic resonance spectroscopy (NMR), Raman spectroscopy (Wang and Spencer

2002), X-ray microtomography (XMT) (Modzel *et al*, 2011), and micro X-ray computed tomography (XmCT) (Bastani *et al*, 2016) which are all considered as tomography techniques. The comparison of these techniques is listed in Table 1 in terms of their applications, advantages, and disadvantages.

Conclusions and Perspective

This paper reviews the recent development in adhesive bonding strength as it relates to penetration and methods used in evaluating it. It was found that the adhesion bonding strength is significantly affected by the penetration of adhesives into wood fiber. Therefore, the mechanism of penetration, the factors affecting the penetration, and various techniques for measuring the penetration should be examined in parallel to the global mechanical strength evaluations. There is no detailed published work on penetration of bio-adhesives into wood fiber. As mentioned above, the adhesive penetration has a significant influence on bonding interactions and bonding strengths of wood composites. So, it is necessary to conduct more studies on the penetration of bio-adhesive to determine the optimum adhesive properties and the best preparation conditions to reach the bio-based wood composite with the greatest performance.

Table 1. The comparison of common techniques used in adhesive penetration characterization.

Technique	Application	Advantages	Disadvantages	Reference
Scanning probe microscopy (SPM)/nanoindentation	Cell-wall penetration	Adhesives penetration map	Modulus difference required, two techniques combination	Konnerth et al, 2007
Fluorescent infrared spectroscopy (FTIR)	Gross-penetration	Chemical bonding	No penetration depth and bond line information	Ren and Frazier, 2012
X-ray photoelectron spectroscopy (XPS)	Cell-wall penetration	Penetration to single fiber, quantification measurement	No penetration depth and bond line information, limitation in large scale	Gavrilovic´*et al* 2016
Scanning electron microscopy (SEM)/energy-dispersive X-ray analysis (EDAX)	Gross-penetration Cell-wall penetration	Adhesive distribution, penetration, bond line morphology	Gray image, poor contrast, quantitative measurement difficult, large excitation volume	Mendoza *et al* 2010
Transmission electron microscopy (TEM)	Cell-wall penetration	Adhesive penetration, bond line morphology, morphology of diffusion in cell wall	Gray image, poor contrast, quantitative measurement difficult, slow	Bolton *et al* 1988
Scanning thermal microscopy (SThM)	Cell-wall penetration	Distribution at bond line area, high spatial resolution, simple specimen preparation, specimen preparation is simple	Rely on thermal conductivity difference, assisted by AFM, resolution depend on surface height variation, smaller image size	Konnerth, *et al* 2008
13C CP/MAS NMR	Gross-penetration Cell-wall penetration	Nanoscale observation, cell-wall penetration, relationship of molecular weight and penetration	Lack of morphology analysis, distribution and penetration depth	Kim, 1999
X-ray micro-tomography (XMT)	Gross-penetration Cell-wall penetration	3D view, pattern of adhesive	Gray image, poor contrast	Modzel and Kamke, 2011

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Layered Structure and Properties of Wood-Cement Composites Produced from Flakes and Sawdust of *Gmelina arborea*

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Abstract

This study was carried out to examine the physical and mechanical properties of composite boards made from cement and wood particles in the forms of sawdust and flakes from Gmelina arborea wood. Single layered boards made of sawdust alone and three-layered boards with surface layers made of sawdust and core made of flakes were produced at four ratio of 1:1, 2:1, 2.5:1 and 3:1 for both the single layered and three-layered wood cement composite boards. The boards produced were assessed for physical and mechanical properties which include board actual density, water absorption, thickness swelling, modulus of rupture and modulus of elasticity. The actual densities for single layered board ranged from 664.08 to 1200 kg/m^3 while the values for three layered board ranged from 490.38 to 1097.98 kg/m^3. Water absorption and thickness swelling for single layered and three-layered board ranged from 0.55 to 6.86 % and 0.63 to 4.51 %, respectively. The mean values of Modulus of Elasticity ranged from 638.17 to 5772.11 (N/mm^2) and 417.16 to 2281.34 (N/mm^2) for single layered and three layered boards, respectively. The mean values of Modulus of Rupture varied from 1.69 to 7.40 (N/mm^2) and 1.18 to 4.28 (N/mm^2), respectively, for single layered and three-layered boards. The results of this study indicate that all the properties examined improved with increase in cement–wood ratio from 1:1 to 3:1. Board produced at highest mixing ratio of 3:1 and with nominal board density from 800 to 1000 kg/m^3 for both the single layered and three layered wood cement composite boards. Single layered wood cement composite boards produced with sawdust alone had higher mechanical properties than three layer boards made with sawdust as the face layers and flakes as the core.

Keywords: Wood-Cement, Composite, *Gemelina arborea*, Nominal density, Thickness swelling

INTRODUCTION:

A wood-cement composite material is made by combining two or more materials. Often-ones that have very different properties. The two materials work together to give the composite unique properties. Wood-cement composite is a wood-based product made from lignocellulosic particles that are pressed in a mat under pressure band adhesive. Wood-cement composite is used in many areas of applications including furniture, doors, paneling, flooring and table top. However, multilayer or 3 layered particleboard is commonly produced than single layered board. Three layered board made sandwiching a core layer of coarse particles with fine particles of surface layers and higher resin content at both faces than the core layer to reduce the total resin without reducing the overall strength. The main idea behind the production of particleboard is to reduce and utilize excessive waist at the sawmill into usable product rather than being born. The urgent need to have effective replacement for wood in wood based industry in Nigeria can not be overemphasized. This become highly relevant in view of recent trends in deforestation. Nigeria was reported to have the highest rate of deforestation in the World (Mohammed, 2014). The increased in demand for wood and wood based panel products in Nigeria has placed a significant pressure on current forest resources, which has consequently led to an increase in price of wood. This demand has led to the need to find alternative raw materials for production of board and panels.

The volume of sawdust from different sawmills in Nigeria continued to increase with an increase in lumber production and utilization of less efficient machines (Fuwape, et al 2007). It was reported that about 753,000 m3 of sawdust was generated in 1993 alone from 2700 operational sawmills in Nigeria. Badejo (1989) stated that substantial proportion of the wood residue could be used in particleboard production. The development of engineered wood products also provides from various grades of wood is possible because of the introduction of new technologies (Fabiyi et al 2010) This development also provides an effective way of using low grade wood species and any wood residue generated in wood processing industry. An example of such engineered wood product is cement bonded composites produced from wood, cement and other chemical additives. Over the last five decades, concerted effort have been on the use of lignocellulosic material (e.g. wood, grass, shrub e.t.c.) in the production of cement bonded composites to replace asbestos. There are problems of large quantity of wood waste generation in primary wood industry in Nigeria. During logging operation, wood wastes such as branches, oversized logs, off cuts, pieces of wood at the gantry and clear felled trees are usually very common. Wood wastes are also generated in wood industries during log conversion into sawn timbers. These wastes include off-cut, sawdust, edgings, slabs, trimming, shavings, that are generated continuously in the sawmill industry dominated by French made horizontal series which account for 95% of the total sawmill in Nigeria (Badejo, 1989). The bulk of the volume of wood wastes generated in Nigeria was estimated to be about 1.72million m^3 in 1985 (GWV, 1994) and 2.32 million m^3 in 1990 (Badejo, 2011).

The use of wastes for cement flake board production is a vital and profitable line of reducing wastes. Much more importantly, is the fact that the new product intended to be fabricated will significantly increase the potentials for the use of wood wastes. Despite the fact of high utilization of meal and plastic as substitute materials for wood, the forest industry in Nigeria has been on a gradual decline in terms of capacity utilization because of dwindling timber resources (Ogunwusi, 2011). Therefore, this research evaluate the physical and mechanical properties of composite boards made from cement and wood particles from *Gmelina arborea* sawdust and flakes.

Procurement of raw materials

The wood material used in this study was *Gmelina arborea* in the forms of sawdust and flakes. The sawdust was collected from a sawmill in Owena while the conversion of wood to flakes was done in wood workshop of the Department of Forestry and Wood Technology, Federal University of Technology Akure Ondo State. Ordinary Portland cement was purchased from local cement dealer while the chemical additive (calcium chloride) was purchased from Scientific Chemical Laboratory in Akure. Distilled water was obtained from the Department Forestry laboratory. Other materials and equipment that were used include caul plates, press, mould of 350 mm x 350 mm, weighing balance, veneer caliper, freezer and oven.

Experimental Design and Layout

The experimental design for the study was 2 x 3 x 4 factorial experiment in Completely Randomized Design (CRD), the combination of which gives twenty four (24) treatments. Factor A was the board structure which are single-layer board and three-layer board, Factor B was three (3) densities (800, 900 and 1000 kgm^3) and Factor C was four (4) cement wood ratios (1:1, 2:1, 2.5:1 and 3:1). Board made from each study variable combination was replicated three times.

Preparation of wood materials

The sawdust and flakes were pre-treated by boiling in hot water for 30 minutes at temperature of 90°C to remove inhibitory substances that may negatively affect cement hydration and setting. After the pretreatment, the particles were air dried for 14 days in the laboratory to attain moisture content of approximately 12 % prior to use. A wooden mould with inner dimensions of 350 mm in length 350 mm in width and 150 mm high was constructed which served as the framework for the mat formation of the single-layer and three-layer boards.

Board Formation

The required quantities of the pre-treated flake and sawdust, cement and chemical additive were weighed separately and stored in sealed polythene bags prior use. The required amount of chemical additive was three percentage of the cement weight for forming each board. The additive was dissolved in the required quantity of water. The flakes and the sawdust for the production of three layered boards were mixed with the required amount of cement and water containing the chemical additive separately. After thorough mixing to obtain cement-sawdust mix for the face layers and wood flake-cement mix for the core, half of the quantity of the cement-sawdust mix was felted on a metal caul plate which has been covered with polythene sheet to prevent sticking of the board on the plate. Thereafter, the cement-flake mix was added to form the core layer, and then the remaining half of the cement-sawdust mix was added to form the second face layer. The three-layered mattress formed was transferred to the cold press where it was pressed to 8 mm thickness with the aid of stops. The board was left under pressure for 24 hours. The same production process was used for the single layered board but the difference is that it was only made up of cement-sawdust mix to form homogeneous board.

After 24 hour press time, the boards were removed from the press and put in sealed polythene bags for five days to allow for further curing of the cement. Thereafter the experimental boards were removed from the polythene bag and conditioned for 28 days prior testing. The boards produced were trimmed to sizes and later cut into sample sizes for laboratory analysis. Two different boards were produced; a single-layer board composed entirely of saw dust and cement mix and a three-layered boards with flake and cement mix for the core layer and sawdust and cement mix for the faces. Figure 1 shows the flow chart of the experimental wood cement composite board production.

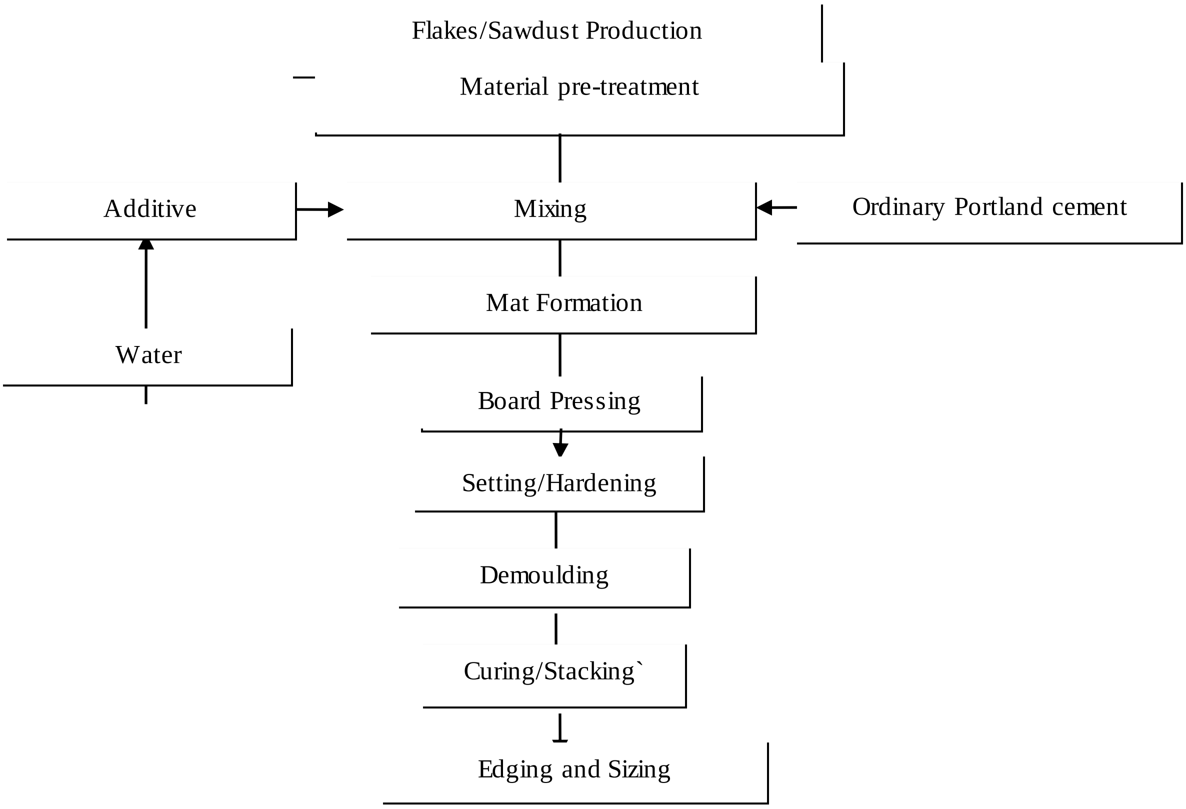

Figure 1: Production flow chart for wood cement composite board

Physical Properties test

The physical properties which include: Density, Water absorption (WA) and Thickness swelling (TS) tests were conducted according to ASTM D570-98 2005.

Determination of Density

Three test specimens, 50 mm x 50 mm were taken from each board and were oven-dried at 105 °C for 24 hrs. After cooling in a desiccator, the specimens were weighed using electronic weighing balance of 0.01g precision. The volume of the specimen was calculated from the sample dimension: length × breadth × thickness. The oven-dry density of each specimen was then calculated using the formula below:

$$Density = \frac{M}{V}$$

(kg/m^3)

Where M = Ovendry weight of the test specimen

V = Ovendry volume of test specimen

Water absorption

This is the percentage increase in weight of the board following water absorption over the initial weight. Sample size of 50 x 50 x 8 mm for both the single layer- and three layer- wood cement composite boards were cut, weighed and then later soaked in water for 24 hrs. Samples were removed and mopped with clean cloth to remove excess surface water before weighing and taking the measurement. Water absorption was calculated using the formula:

$$WA = \frac{W_2 - W_1}{W_1} X 100$$

Where:

WA= Water absorption (%)

W_1= Initial weight of the specimen (g)
W_2= Final weight of the specimen (g)

Thickness swelling
This is the percentage increase in thickness of the board following water absorption over the original thickness. The size of test specimens for this test was same as the water absorption test. The procedure was similar to WA test, only that the thickness of each specimen at a pre-determined spot was taken at the end after 24 hours of immersion in distilled water. Thickness swelling was expressed as:

$$TS\% = \frac{T_2 - T_1}{T_1} X 100$$

Where:
TS= Thickness swelling (%)
T_1= Initial thickness of the specimen (mm)
T_2= Final thickness of the specimen (mm)

Mechanical Test
Modulus of rupture (MOR),
The strength properties analysis of the wood composite board were determined using a Universal Testing Machine Model: WDW-20 and capacity 25 KN according to ASTM D. 1037-06a (2006). The specimen dimension was 195 mm x 50 mm x 8 mm. The samples were mounted one by one on the machine and load was applied at the center with the aid of an electro-mechanical motor till the point when failure occurred. The records of the ultimate load (P) were recorded and copied directly from computer system embedded with machine.

$$MOR = \frac{3PL}{2BD^2} (N/mm^2)$$

$$MOE = \frac{PL^3}{4BD^3 \Delta S} (N/mm^2)$$

Statistical Analysis
The data obtained from the experiment were analyzed using Microsoft excel spreadsheet and Statistical Package for Social Science (SPSS). The analysis carried out includes:

1. Descriptive statistics
2. Graphical representation
3. Analysis of variance (ANOVA)

The descriptive statistics gave the summaries of the raw data which are represented in tabular forms while the graphs plotted show the variables over different levels of the factors. The ANOVA indicates whether or not significant difference existed and Duncan Multiple Range Test (DMRT) shows the level of significance between the levels of each of the factors. It also indicates whether significant interactions existed among the factors.

Results

Physical Properties

Density

The mean values for the actual density obtained for the different study variable combinations employed in the production of wood cement composite boards are presented in Table 1, 2 and Figure 2. The mean actual density values ranged from 490.38 kg/m^3 for board produced at nominal density 800 kg/m^3 at the cement wood rand Figure tio of 1:1 for the three layered board to 1200.74 kg/m^3 for board produced at nominal density of 1000 kg/m^3 at the cement wood ratio of 3:1 for single layered board. The nominal density of each board varied significantly from the observed actual density. The mean actual density for both the single layered and three layered boards increased with decrease in cement wood ratio. The single - layered boards generally had higher mean actual density when compared with three layered boards. Analysis of variance (Table 3) for the actual density shows that the nominal density, cement wood ratio, layering structure and interactions had significant effect on the mean actual density of the board produced. Duncan Multiple Range Tests (Tables 4, 5 and 6) showed that the effects of cement–wood ratios of 2:1 and 3:1 on mean actual density were not significantly different while the effects of the different levels of nominal density and those of layering structure were all significantly different.

Table 1: Mean Values for Water absorption, Thickness swelling, Modulus of Rupture and Modulus of Elasticity for a single layer board

Nominal Density (kg/m^3)	Cement Wood Ratio (CWR)	Actual Density (kg/m^3)	Water Absorption (WA %)	Thickness Swelling (TS %)	Modulus of Elasticity (MOE N/mm^2)	Modulus of Rupture (MOR N/mm^2)
1000	1:1	720.35±1.23	28.90±1.88	3.75±0.63	1626.21±1.34	3.00±0.35
	2:1	982.11±1.14	16.79±1.39	1.74±0.70	3049.10±1.53	3.13±0.29
	2.5:1	1199.14±1.59	9.46±0.69	0.98±0.53	3754.25±1.85	3.85±0.36
	3:1	1200.74±1.09	8.94±0.99	0.55±0.32	5772.11±1.68	7.40±0.69
900	1:1	716.09±1.67	30.85±1.28	5.88±1.73	731.64±0.73	2.09±1.05
	2:1	945.49±1.11	23.79±0.81	2.96±0.39	1618.76±1.36	3.11±0.70
	2.5:1	1068.56±1.01	20.03±0.54	1.30±0.72	2640.29±0.88	3.11±1.48
	3:1	1189.47±1.11	9.25±0.83	0.66±0.23	3501.41±1.21	3.84±1.77
800	1:1	664.08±1.80	38.49±1.04	6.86±1.96	638.17±1.99	1.69±0.29
	2:1	910.77±1.29	29.19±1.01	3.31±1.87	1616.76±1.36	2.39±0.81
	2.5:1	939.86±1.53	25.75±1.81	2.78±1.22	2447.04±0.88	2.80±0.89
	3:1	1065.69±2.54	23.52±1.81	1.54±0.36	3299.75±0.06	3.52±0.99

Table 2: Mean Values for Water Absorption, Thickness Swelling, Modulus of Elasticity and Modulus of Rupture of the 3-layer board

Nominal Density (kg/m^3)	Cement Wood Ratio (CWR)	Actual Density (kg/m^3)	Water Absorption (WA %)	Thickness Swelling (TS %)	Modulus of Elasticity (MOE N/mm^2)	Modulus of Rupture (MOR N/mm^2)
1000	1:1	956.20±2.29	18.16±4.34	1.87±1.38	1537.51±1.02	2.98±0.59
	2:1	962.03±2.51	17.40±7.13	1.26±0.38	2044.87±1.83	3.57±1.39
	2.5:1	996.21±5.58	13.71±5.28	0.79±0.31	2178.54±1.49	3.92±1.90
	3:1	1097.98±1.10	11.28±2.20	0.63±0.64	2281.34±1.93	4.28±1.36
900	1:1	685.33±2.69	25.60±16.78	3.99±0.61	759.75±1.91	2.01±0.42
	2:1	805.88±1.54	22.66±6.77	2.40±0.99	1081.19±1.50	2.42±0.64
	2.5:1	842.88±2.69	15.45±3.16	1.54±1.17	1722.68±2.51	3.20±1.11
	3:1	1037..53±5.15	13.83±3.72	0.63±0.50	1796.05±1.56	3.61±0.41
800	1:1	490.38±1.75	37.65±10.77	4.51±0.55	417.16±1.43	1.18±0.62
	2:1	545.35±1.75	36.18±3.71	3.06±1.88	642.08±1.65	1.49±0.35
	2.5:1	599.08±1.05	21.54±3.72	2.30±1.54	745.24±1.95	1.84±0.62
	3:1	729.64±1.60	16.42±2.19	2.08±1.84	990.16±1.75	2.31±0.57

Table 3: Analysis of variance for density of the wood-cement composite boards

Source	*Sum of Squares*	*Df*	*Mean Square*	*F*
Nominal Density	532419.76	2	266209.88	39.80*
Cement Wood Ratio	1309597.20	3	436532.40	65.28*
Layering Structure	855172.91	1	855172.91	127.84*
ND*CWR	478715.17	6	79785.86	11.93*
ND*LS	1502869.02	2	751434.51	112.33*
CWR*LS	843712.14	3	281237.38	42.04*
ND*CWR*LS	373027.50	6	62171.25	
Error	802730.21	120	6689.42	
Total	6731442.00	143		

*significant ($p < 0.05$)

ND*CWR denotes interaction between nominal density and cement wood ratio

ND*LS denotes interaction between nominal density and layering structure

CWR*LS denotes interaction between cement wood ratio and layering structure

ND*CWR*LS denotes interaction between nominal density, cement wood ratio and layering structure

Table 4. Duncan Multiple Range test (DMRT) for Density of the wood-cement composite boards

Density (Kg/m^3)	Actual Density (Kg/m^3)	Water Absorption (WA %)	Thickness Swelling (TS %)	Modulus of Elasticity (MOE N/mm^2)	Modulus of Rupture (MOR N/mm^2)
1000	957.63^a	22.19^a	3.44^a	2757.81^a	3.89^a
900	894.79^b	21.52^a	2.56^{ab}	1670.18^b	2.70^b
800	814.81^c	20.30^a	1.65^b	1393.40^b	2.43^b

Values with the same letter along the column are not significantly different while values with different letter along the column are significantly different.

Table 5. Duncan Multiple Range test (DMRT) for cement-wood ratio of the wood-cement composites

Density (Kg/m^3)	Actual Density (Kg/m^3)	Water Absorption (WA %)	Thickness Swelling (TS %)	Modulus of Elasticity (MOE N/mm^2)	Modulus of Rupture (MOR N/mm^2)
3:1	1000.07^a	29.55^a	3.60^a	2501.85^a	3.54^a
2.5:1	925.83^b	20.57^b	2.31^b	2455.12^a	3.38^{ab}
2:1	895.49^b	17.63^b	2.16^b	1862.55^{ab}	2.97^{ab}
1:1	739.36^c	17.54^b	2.07^b	957.72^b	2.17^b

Values with the same letter along the column are not significantly different while values with different letter along the column are significantly different.

Table 6. Duncan Multiple Range test (DMRT) for the board layering structure

Density (Kg/m^3)	Actual Density (Kg/m^3)	Water Absorption (WA %)	Thickness Swelling (TS %)	Modulus of Elasticity (MOE N/mm^2)	Modulus of Rupture (MOR N/mm^2)
Single Layer	966.80^a	21.99^a	3.02^a	2556.13^a	3.28^a
Three Layer	813.57^b	20.64^a	2.06^b	1332.49^b	2.75^a

Values with the same letter along the column are not significantly different while values with different letter along the column are significantly different.

Water Absorption

The results of the tests conducted on water absorption of wood cement composite board for single-layer and three-layer boards after soaking for 24 hours are shown in Tables 1 and 2. The mean values of water absorption ranged from 8.94 % for board produced at nominal density of 1000 kg/m^3 at the cement wood ratio of 3:1 for the single layer-board to 38.49% for board produced at nominal density of 800 kg/m^3 at the cement wood ratio of 1:1 for board for single layer-board. At each level of nominal density, the mean values of water absorption for both the single layer- and three layer-boards decreased with increase in cement wood ratio. The result of the Analysis of variance presented in Table 7 for water absorption shows that the main effects of cement wood ratio and the interactions effect of the factors were significant while the main effects of density and layering structure were not significant. Duncan Multiple Range Test in Table 5 shows that the mean value of water absorption for board produced at cement–wood ratio of 3:1 was significantly higher than other three levels; while other three levels are not significantly different from each other.

Table 7: Analysis of variance for water absorption of the wood-cement composite boards

Source	*Sum of Squares*	*Df*	*Mean Square*	*F*
Nominal Density	144.78	2	72.39	0.10^{ns}
Cement Wood Ratio	3650.08	3	1216.69	15.28*
Layering Structure	51.13	1	51.13	0.64ns
ND*CWR	1590.62	6	265.10	3.33*
ND*LS	3077.41	2	1538.71	19.33*
CWR*LS	948.18	3	316.06	3.97*
ND*CWR*LS	1284.81	6	214.14	2.69*
Error	9552.61	120	79.61	
Total	20137.72	143		

*significant ($p< 0.05$)
ND*CWR denotes interaction between nominal density and cement wood ratio
ND*LS denotes interaction between nominal density and layering structure
CWR*LS denotes interaction between cement wood ratio and layering structure
ND*CWR*LS denotes interaction between nominal density, cement wood ratio and layering structure

Thickness swelling

The results of the tests carried out on thickness swelling of the wood cement composite board for single-layer and three-layer boards after soaking for 24 hours are shown in Tables 1 and 2. The mean thickness swelling ranged from 0.55 % for board produced at 1000 kg/m^3 nominal density and at 3:1 cement-wood ratio for the single-layer board to 6.86 % for board produced at nominal density of 800 kg/m^3 at cement wood ratio of 1:1 for board for single layered board. The mean values of thickness swelling for both the single layer- and three layer- boards at each nominal density level decreased with increase in cement wood ratio. The result of the Analysis of variance presented in Table 8 shows that board density, cement wood ratio and layering structure had significant effect on the thickness swelling of the board produced. All the interaction of the three variables also had significant effect on the thickness swelling properties of the board. Duncan Multiple Range Test in (Table 4, 5, and 6) shows that no significant difference existed between 2.5:1 and 2:1.

Table 8: Analysis of variance for thickness swelling of the wood-cement composite boards

Source	*Sum of Squares*	*Df*	*Mean Square*	*F*
Nominal Density	78.25	2	39.12	5.41*
Cement Wood Ratio	53.69	3	17.90	2.48*
Layering Structure	31.63	1	31.63	4.38*
ND*CWR	154.97	6	25.83	3.57*
ND*LS	49.81	2	24.90	3.45*
CWR*LS	165.31	3	55.10	7.63*
ND*CWR*LS	158.85	6	26.48	3.66*
Error	867.08	120	7.23	
Total				

*significant ($p< 0.05$)

ND*CWR denotes interaction between nominal density and cement wood ratio

ND*LS denotes interaction between nominal density and layering structure

CWR*LS denotes interaction between cement wood ratio and layering structure

ND*CWR*LS denotes interaction between nominal density, cement wood ratio and layering structure

Mechanical Properties

Modulus of elasticity (MOE)

The mean modulus of elasticity obtained for the wood-cement composite boards are presented in Tables 1 and 2. The MOE values ranged from 471.16 N/mm2 for boards produced at nominal density of 800 kg/m3 at the cement-wood ratio of 1:1 for the three layer board to 5772.11 N/mm2 for board at nominal density of 1000 kg/m3 at the cement-wood ratio of 3:1 for single layer board. At each level of nomnal density, the mean MOE for the single layered and three layered boards increased with an increase in cement-wood ratio. The single layered board generally had higher MOE values than the three layered board. Analysis of variance is presented in Table 9. The results showed that all the factors; density, mixing ratios and board layering structure had significant effects on the MOE. The effect of the interaction between layering structure and wood-cement ratio and MOE was significant, while the effects of all other interactions were not significant. Duncan Multiple Range tests in Tables 4, 5 and 6 show that cement-wood ratio had significant effect on MOE.

Table 9: Analysis of variance for Modulus of elasticity of the wood-cement composite boards

Source	*Sum of Squares*	*Df*	*Mean Square*	*F*
Nominal Density	50120909.81	2	25060454.91	5.97*
Cement Wood Ratio	55806101.32	3	18602033.77	4.43*
Layering Structure	54109184.45	1	54109184.45	12.90*
ND*CWR	10922071.11	6	1820345.19	4.34^{ns}
ND*LS	4443018.43	2	2221509.21	0.53^{ns}
CWR*LS	33464472.33	3	11154824.11	2.66*
ND*CWR*LS	11787166.17	6	1964527.70	0.47^{ns}
Error	503514612.2	120	4195955.10	
Total	725118973.9	143		

*significant ($p< 0.05$)

ND*CWR denotes interaction between nominal density and cement wood ratio

ND*LS denotes interaction between nominal density and layering structure

CWR*LS denotes interaction between cement wood ratio and layering structure

ND*CWR*LS denotes interaction between nominal density, cement wood ratio and layering structure

Modulus of Rupture

The mean values of Modulus of Rupture (MOR) for the experimental cement wood composite boards in this study are presented in Tables 1 and 2. The mean MOR values at each level of the study variables are also graphically shown in Figure 1. The mean MOR values ranged from 1.18 N/mm^2 for board produced at nominal density 800 kg/m^3 at the cement wood ratio of 1:1 for the three-layer board to 7.40 N/mm^2 for board produced at nominal density 1000 kg/m^3 at the cement wood ratio of 3:1 for board for single-layer board. At each level of nominal density, the mean MOR for both the single layered and three layer-boards increased with increase in cement wood ratio. Generally, the single layered boards had higher mean MOR values than the three layer-boards. The result of the Analysis of variance is presented in Table 10. The results indicate that density and cement–wood ratio had significant effects on MOR, while layering structure had no significant effect. The effects of the two-way and three-way interactions of the factors on MOR were also not significant. The Duncan Multiple Range Test (Tables 4, 5 and 6) indicates that significant difference exists among the three density levels and among the four cement wood ratio levels, while no significant difference existed between the single- and three-layer board.

Table 10: Analysis of variance for Modulus of rupture of the wood-cement composite boards

Source	*Sum of Squares*	*Df*	*Mean Square*	*F*
Nominal Density	58.28	2	29.14	4.47*
Cement Wood Ratio	40.90	3	13.63	2.09*
Layering Structure	10.40	1	10.40	1.59^{ns}
ND*CWR	8.83	6	1.47	0.23^{ns}
ND*LS	14.75	2	7.38	1.13^{ns}
CWR*LS	48.70	3	16.23	2.49^{ns}
ND*CWR*LS	34.34	6	5.72	0.88^{ns}
Error	783.28	120	6.53	
Total	999.86	143		

*significant ($p< 0.05$)
ND*CWR denotes interaction between nominal density and cement wood ratio
ND*LS denotes interaction between nominal density and layering structure
CWR*LS denotes interaction between cement wood ratio and layering structure
ND*CWR*LS denotes interaction between nominal density, cement wood ratio and layering structure

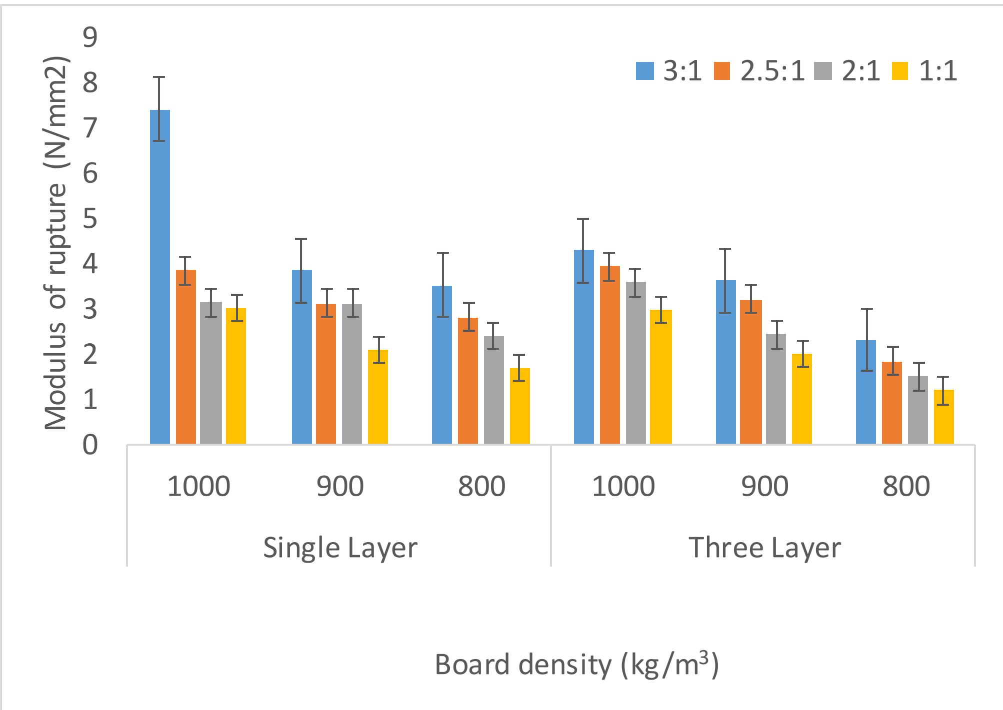

Figure 1: Effects of nominal board density, cement wood ratio and board structure on Modulus of rupture of cement wood composite board

DISCUSSION

The actual (observed) density of the experimental boards varied significantly from the nominal density. The term 'nominal density' as used here is the sum of the oven dry weight of wood particles and dry cement employed for fabricating a board divided by the intended volume of board. The observed difference between the nominal densities and the actual density can be associated with error in manual felting and increase in board thickness which resulted from the reversal of part of the compressive stress imposed on the wood components of the board during pressing following release of the pressure. This in turn, resulted in thickness spring back in the thickness direction of the board (Oyagade, 1992). It may also be associated in part to shrinkage of the cement paste following drying and to variation in weight of the cement during hydration. In the process of hydration, water amounting to about 23 % mass of dry weight of cement chemically combines with the dry cement (Murduck and Blackiedge, 1968). Oyagade (1990) observed that thickness springback increased with increase in nominal density and with decrease in cement wood ratio and that the significance of the effect of the cement wood ratio decreases with increase in cement wood ratio.

The values of water absorption of the experimental wood cement composite boards in this study compared favourably with those reported by Oyagade and Fabiyi (2003). The result from this study clearly shows that at each nominal density level, the amount of water absorbed by the single- and three- layer boards was strongly related to cement wood ratio and board density, with water absorption decreasing with increase in both factors. The reduction in water absorption of the composite boards at high cement wood ratio and board density agrees with previous findings (Oyagade 1992, Vital *et. al*., 1994). This relationship was explained by decrease in void volume present in the board for water occupation as density increased (Oyagade 1992). For each nominal density, there was a decrease in thickness swelling with increase in cement wood ratio and actual density. This observation agrees with other on cement–wood composite boards from various wood species (Oyagade 1992, Oyagade and Fabiyi 2003). As noted by Oyagade (1992), when increase in board density is achieved by increasing cement wood ratio, the amount of cement coating restraining the individual particles from swelling will increase as density is increased and consequently, a decrease in thickness swelling of board with increase in cement wood ratio and board density. The single- and three- layer wood cement composite boards produced from Gmelina awdust and flakes gave values of thickness swelling which satisfy the requirement of cement particleboard that has the moderate to high level of performance in the presence of water (BS 5669: Part 4, 1989)

At each nominal density level for both single- and three- layer board, the two mechanical properties (MOE and MOR) were improved with increase in cement wood ratio and board density. Fuwape (1995), Oyagade and Fabiyi (2003) observed similar pattern of variations. This observation may be explained by the fact that when cement wood ratio and density levels are increased, boards will have better inter-particle contact with improved bonding between the particles, better densification of individual particles and more materials to distribute stresses within the board result (Oyagade 1990).

CONCLUSION

The findings from this work has shown that:

1. Cement wood composite boards have the tendency to springback in the thickness direction; the magnitude of spring back depends on both cement wood ratio and nominal density. As a result of springback, the nominal density varied widely from the actual density
2. Thickness swelling following 24-hour water soak decreased with increase cement wood ratio and increased with increase in both nominal and actual density
3. Water absorption also decreased with increase in both nominal and actual density
4. Wood cement composite boards which were sufficiently stable in thickness swelling and minimum water absorption were produced at 2.5:1 and 3.0:1 cement–wood ratio. Both the nominal and actual densities were positively related to the bending stiffness (modulus of elasticity) and bending strength (modulus of rupture) of the composite boards when cement wood ratio was held constant
5. Wood cement composite boards made with sawdust alone to form homogenous structure were generally less stable in terms of thickness swelling when compared with three layer board having wood flakes as the core and saw dust as the face layers
6. The effect of board structure was more pronounced on stiffness (MOE) than bending strength (MOR)
7. Wood cement composite board which had sufficient bending properties were produced from Gmelina arborea wood particles at cement wood ratio of 3.0 : 1and 2.5 : 1
8. Composite board can be successfully prepared using wood wastes of *Gmelina arborea* from sawmills.

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Characterization of Lignins Isolated from Bamboo (*Bambusa vulgaris*) Organosolv and Kraft Black Liqour

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Abstract

Bamboo biomass were pulped using organosolv methods: Acetic acid and formic acid; hydrogen peroxide and formic acid; ethanol and water and kraft process with varying concentrations of the cooking chemicals. The properties of the isolated lignin were influenced by the black liqour pH as well as the pulping method. Highest pH (12.8) was recorded for kraft at 70:30 liqour concentration while lowest pH of 2.5 was recorded for both Aceticformic (70:30) and Ethanol/water (70:30 & 60:40). There were obvious differences in the characteristic colours, shapes and sizes of the lignin samples. Bamboo kraft lignin samples formed large pieces much easier than that of Organosolv. Aceticformic (70:30) had the best filteration properties (FC) while Ethanol/water had the poorest. Generally, kraft recorded the highest lignin yield while all the organosolv processes recorded reduced yield. Highest yield (119.25g/l) was gotten from kraft (50:50) while Peroxyformic (60:40) had the lowest yield of 8.20 g/l. The results showed that higher liqour pH favours total dissolved solid as well as lignin precipitation. As the pH increases, total dissolved solid, yield, Klason and low molecular weight (LMW) lignin content increases while FC decreases. The klason and LMW lignin content increased with incresing lignin yield.

Keywords: Bamboo, Total Dissolve Solid, Filteration capacity, Guaiacyl, Syringyl units

Introduction

After cellulose, lignin is not only the second most abundant polymeric organic substance on the planet but also the most abundant aromatic renewable material (Gellerstedt and Henriksson, 2008). Due to its robust and amorphous structure, the valorisation of lignin is quite difficult. However, lignin can be changed over to numerous products (Xu et al., 2013). Invariably, lignin is usually considered as a low-value residue and in most cases disposed-off as wastes during pulping of biomass (Cherubini et al., 2010) with only a small fraction incinerated to produce process steam and energy and only a very small part used for the production of value-added products (Rastogi and Dwivedi, 2008). Pulping spent liquors contain organic and inorganic materials (Saeed and Fatehi, 2011). Although, lignin has been used in polymeric applications as stabilizers (Sasaki et al., 2013), surfactants (Thakur et al., 2014), epoxy resins (Kadla et al., 2002) and superabsorbent hydro-gels (El-Mansouri and Salvadó, 2006).

However, lignin needs to be isolated from pulping spent liquors to allow the production of more high value-added products. Presently, Kraft process is the dominant alkaline pulping process and most used pulping process for wood and non-wood such as bamboo (Kamthai, 2005). Kraft process is a cheap conventional way of extracting lignin, however with negative health effects (Krief et al., 2008). Although, Kraft liquor yield are encouraging, but environmental concern on the pulping process are discouraging. The organosolv process on the other hand has the advantage of using substances which are less harmful to human health and the environment compared to conventional processes (Kraft and Sulfite) that cause major problems of pollution (Ruiz, 2011).

Organosolv pulping is a clean chemical process that uses organic solvents to aid in the removal of lignin and hemicellulose from lignocellulosic raw materials. The process involves the cooking of lignocellulosic biomass in a mixture of water and an organic solvent that leads to the deconstruction of both lignin and hemicellulose and its dissolution in the cooking liquor (Sannigrahi and Ragauskas, 2013). The lignin is typically retrieved as a precipitate by dilution of the liquor with water. The process provides facility for solvent recovery after pulping (Ruiz, 2011). The process has been successfully used as a pretreatment and fractionation process in a variety of lignocellulosic materials, such as agricultural, hardwoods and softwoods (Galbe and Zacchi, 2002).

Recovered lignin has some commercial applications, such as additives in cement and concrete industry, animal feed, polymers industry and painting sector (Stewart, 2008). Other applications are as binders and adhesives to replace phenolic resins and the production of particulate panels and as dispersants in pesticide industry, petroleum production sludge, in leather tanning and dye industry among others (Stewart, 2008). Studies on yield and other properties of lignin have been more on Kraft process. There is need to evaluate the concentration and pulping type that favours the best lignin in terms of yield and functionality from kraft and organosolv pulping processes using *Bambusa vulgaris* as biomass source. In Nigeria, bamboo is underutilized, lignin can be extracted from these bamboos for high value-added use.

Materials and methods

Biomass Collection and Preparation

Bamboo biomass wastes were collected during industrial bamboo processing at Forest Product Development Unit of the Forestry Research Institute of Nigeria (FRIN), Ibadan, Oyo State. The bamboo wastes were dried to constant weight and there after screened with 40 mesh sieve to obtain homogenous particle size. All reagents used such as NaOH, Na_2S, H_2O_2, CH_2O_2, H_2SO_4, C_2H_5OH, were analytical grade.

Organosolv Pulping of Bamboo wastess used

Three organosolv pulping types were employed which were based on the type of reagents used Acetic-formic acid (PFA) treatment In the acetic-formic treatment, the volume ratio of acetic acid to formic acid were varied. The ratios were 50:50, 60:40, and 70:30 respectively. The biomass was delignified in a laboratory size digester at 90^oC for 90 minutes. Thereafter, the spent liquor was filtered from the delignified cellulosic residues with the aid of bucner funnel.

Ethanol/water (EW) treatment

Delignification procedures followed the procedures suggested by Zhao et al. (2009). In Ethanol/water process, the volume of ethanol to water was varied as 50:50, 60:40, and 70:30 respectively as was done for acetic-formic process. The reaction was catalysed by the addition of 40ml H_2SO_4 at 90^oC for 90 minutes as reported in literatures.

Peroxyformic acid (PFA) treatment

Bamboo biomass was delignified by treating with a mixture of hyrdrogen peroxide and Formic acid of varying proportions as recommended by Watkins et al. (2014). The volume of H_2O_2 to Formic acid were 50:50, 60:40, and 70:30 respectively. After delignification, the spent liquor was filtered from the delignified fibre. Lignin precipitation was done as applicable to the two processes above.

Kraft Pulping

The cooking liquor (white liquor) comprises of sodium hydroxide (NaOH) and sodium sulphide (Na_2S). The concentration of NaOH to Na_2S were varied as done for organosolv process; 50:50, 60:40, and 70:30 respectively. Delignification was carried out at 120^{0}C for 2 h. Thereafter, black liquor were filtered from the delignified fibre.

Lignin Isolation

For the organosolv spent liquor, the black liqours were concentrated at 40°C, the lignin in the black liquor were then precipitated by addition of water, five times the volume of the black liquor for 1 hour with constant agitation. The filter cake recovered after filtration, were then subsequently washed three times with 200ml of the corresponding organic solvent-water (50/50, v/v) and finally washed severally with 300 ml of distilled water. Acid (60% H_2SO_4) was used to precipitate lignin from kraft liquor. The precipitated lignin was filtered, washed with acidified water followed by de-ionised water. The filter cake was thereafter air dried and then further dried in an oven at 30°C to constant weight.

Characterisation of the lignin

The total dry solids (TDS) content of the black liquor was determined according to the Tappi T650 om-09 method: 10 ml each of the black liquor samples was put in a ceramic cup and put in an oven with a temperature of 105°C overnight. After constant weight was obtained, the total dissolved solid was determined gravimetrically and the pH of the black liquor was measured with a digital pH meter. Ease of filtering (filteration property) which is the quantity of precipitated lignin that can be filtered per unit time was done by taking note of the time it took to filters 150ml of mixture of the black liquor and precipitating agent. Yield was determined gravimetrically by measuring the quantity of lignin that was recovered from a certain quantity of spent liquor and thereafter estimated in g/litre. The Klason lignin content was determined following Tappi T222 cm-00 method. The filtrate was analysed for residual lignin (low molecular weight lignin) using Atomic Absorption Spectrometry (AAS) method at 270 nm. Briefly, the filtrate from Klason lignin was diluted to 100 mL in a volumetric flask. A solution that was 50 (for precipitated lignin) or 100 (for black liquor filtrate) times weaker was prepared for UV measurement. The concentration of acid-soluble lignin was measured based on the absorbance value determined by UV at a wavelength of 270 nm in a Specord 205, Analytik Jena.

Table 1: Delignification variables for the Organosolv and Kraft process

Pulping type	Liqour Conc. (%)	Process Designation	Biomas (g)	Temperature (°C)	Pulping Time (mins)
$CH_3COOH:CH_2O_2$	70:30	Aceticformic 70:30 = AF1	125	80	60
$CH_3COOH:CH_2O_2$	60:40	Aceticformic 60:40 = AF2	125	80	60
$CH_3COOH:CH_2O_2$	50:50	Aceticformic 50:50 = AF3	125	80	60
$C_2H_5OH:H_2O$	70:30	Ethanol/water 70:30 = EW1	125	80	60
$C_2H_5OH:H_2O$	60:40	Ethanol/water 60:40 = EW2	125	80	60
$C_2H_5OH:H_2O$	50:50	Ethanol/water 50:50 = EW3	125	80	60
$CH_2O_2 : H_2O_2$	70:30	Peroxyformic 70:30 = PF1	125	80	60
$CH_2O_2 : H_2O_2$	60:40	Peroxyformic 60:40 = PF2	125	80	60
$CH_2O_2 : H_2O_2$	50:50	Peroxyformic 50:50 = PF3	125	80	60
$NaOH : Na_2S$	70:30	Kraft 70:30 = KL1	125	120	90
$NaOH : Na_2S$	60:40	Kraft 60:40 = KL2	125	120	90
$NaOH : Na_2S$	50:50	Kraft 50:50 = KL3	125	120	90

Analysis of the Functional Groups

Fourier transform infrared spectroscopy (FTIR) was used to identify and determine the lignin content, the functional group and bond linkage contained in the lignin samples. The spectra were recorded on a Nicolet iS5 FT-IR Spectrometer. Isolated lignin sample was vacuum dried at room temperature for 24 h. The dried lignin sample (2 mg) was powdered and mixed with 300 mg of anhydrous KBr. The mixture was pressed under vacuum to obtain the pellets, and the spectrum between 4000 and 500 cm-1 was measured. The background spectrum of air was subtracted from the spectra of the samples. The Organosolv and Kraft lignin samples were investigated using this technique.

Statistical Analysis

The experiment was two factors experiment in a Completely Randomised Design (CRD) with five replications. Factor A: Pulping type (4 levels: Ethanol, Peroxyformic, Acetylformic and Kraft); Factor B: Liquor concentration (3 levels: 50:50, 60:40 and 70:30). Data were analysed by one-way analysis of variance (ANOVA). Significant difference among means were determined. Means were separated using Duncan Multiple Range test.

Results

Influence of Liqour concentration and cooking type on the Properties of Black liqour and Precipitated lignin The properties of the black liqour and isolated lignin from both Organosolv and Kraft lignin with varying cooking and liqour concentrations are shown on Tables 1 & 2 as well as figures 1 to 3. The properties of the isolated lignin were influenced by the black liqour pH as well as the pulping methods. The ANOVA results (Table 2) showed significant statistical differences in the pH, TDS, FC, yield, klason contant, LMW and HMW lignin content. The influence of liquor concentration, cooking type and the interraction of liqour concentration and cooking type were highly significant at 95% level of significance. However, HMW lignin concentration were not influenced by liquor concentration (Table 2).

The mean value for the properties of lignin from Organosolv and Kraft process are presented in Table 3 and 4. Highest pH (12.8) was recorded for kraft at 70:30 liqour concentration which was closely followed by 60:40 with pH value 12.4. Lowest pH of 2.5 was recorded for both AF (70:30) and EW (70:30 & 60:40). This indicates that kraft process is alkaline while all the Organosolv processes were acidic in nature. Also, the result further shows that Kraft (50:50) had the highest TDS of 394% followed by kraft (60:40) with value of 288% while AF (50:50 & 70:30) had the lowest 23% (Fig. 2 & 3).

The pulping processes and liqour concentration with the best filtration property was Aceticformic (70:30) which was filtered within 39. This was closely followed by Kraft (70:30) with filtration time of 60 seconds. All the Ethanol/water (EW) lignin had the poorest filtration (Fig. 2 & 3). Highest lignin yield (119.25g/l) was gotten from kraft (50:50) closely followed by kraft (70:30) while Peroxyformic (PF) (60:40) had the lowest yield of 8.20 g/l. The result showed that higher liqour pH favours TDS as well as lignin precipitation.

Table 2: Analysis of Variance for the influence of Liquor concentration and Pulping type on the pH, Total dissolved solid, Filtration capacity, Yield, Klason lignin, HMW and LMW Lignin.

Source of variation	Black liqour		FC (ml/sec)	Yield (g/l)	Klason (%)	Lignin Conc (*nm*).	
	pH	TDS				HMW	LMW
Liquor Conc.	7.877**	63.683**	7.189**	167.693**	229.099**	0.955ns	117.499**
Pulping Type	3.818E3**	702.896**	51.295**	1.712E4**	1.128E3**	45.233**	125.413**
Liqour Conc.* Pulping type	3.375**	63.101**	2.079**	133.579**	362.295**	15.081**	187.922**

** = Significant at ($p \leq 0.05$) probability level; ns = Not significant

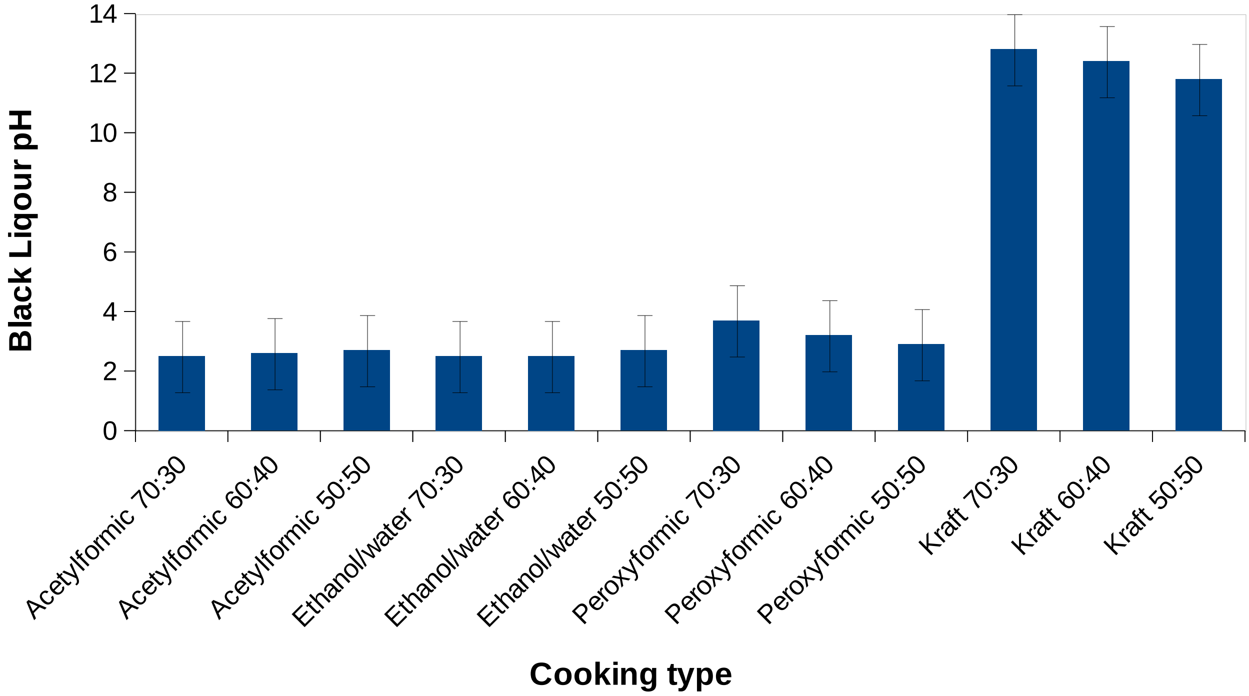

Figure 1: Influence of pulping method on the Black liqour pH

Generally, kraft process recorded the highest lignin yield while all the organosolv processes recorded reduced lignin yield. The reason for the low yield of organosolv lignin might be as a result of the volatility of the organic solvents compared to the inorganic chemicals which resulted in low delignification at low temperature. This result was in agreement with the study of Vazquez-Torres et al. (1992). Also, it can be seen that the higher the black liqour pH, the higher the lignin yield. This indicates that the lignin in the bamboo biomass was more solubilized at low pH than high pH. However, low pH favours lignin precipitation from Bamboo kraft Black liqour. This is because the lignin was more soluble at high pH than low pH, and therefore more low-molecular fragments of lignin were dissolved at higher pH such as 11.8, 12.4 and 12.8 than at low pH (Gellerstedt et al. 1994).

Klason lignin is the solid residual material that is obtained after a sample of BL has been subjected to hydrolysis treatment with 72% H2SO4. Klason lignin content of kraft (50:50) was highest with value of 49% followed by kraft (70:30) while lowest (11.20%) was ecorded for AF at 50:50 liqour concentration. The content of acid-soluble lignin, the purity and the components of isolated lignin, was determined using UV spectroscopy. The absorbance of lignin was recorded at wavelength of 270*nm*. The concentration of the High Molecular Weight (HMW) and Low Molecular Weight (LMW) lignin showed EW (60:40) and kraft (70:30) to be highest with values of 0.164*nm* and 0.229*nm* respectively while the lowest of 0.003*nm* and 0.024*nm* were recorded for HMW and LMW lignin respectively (Fig 3).

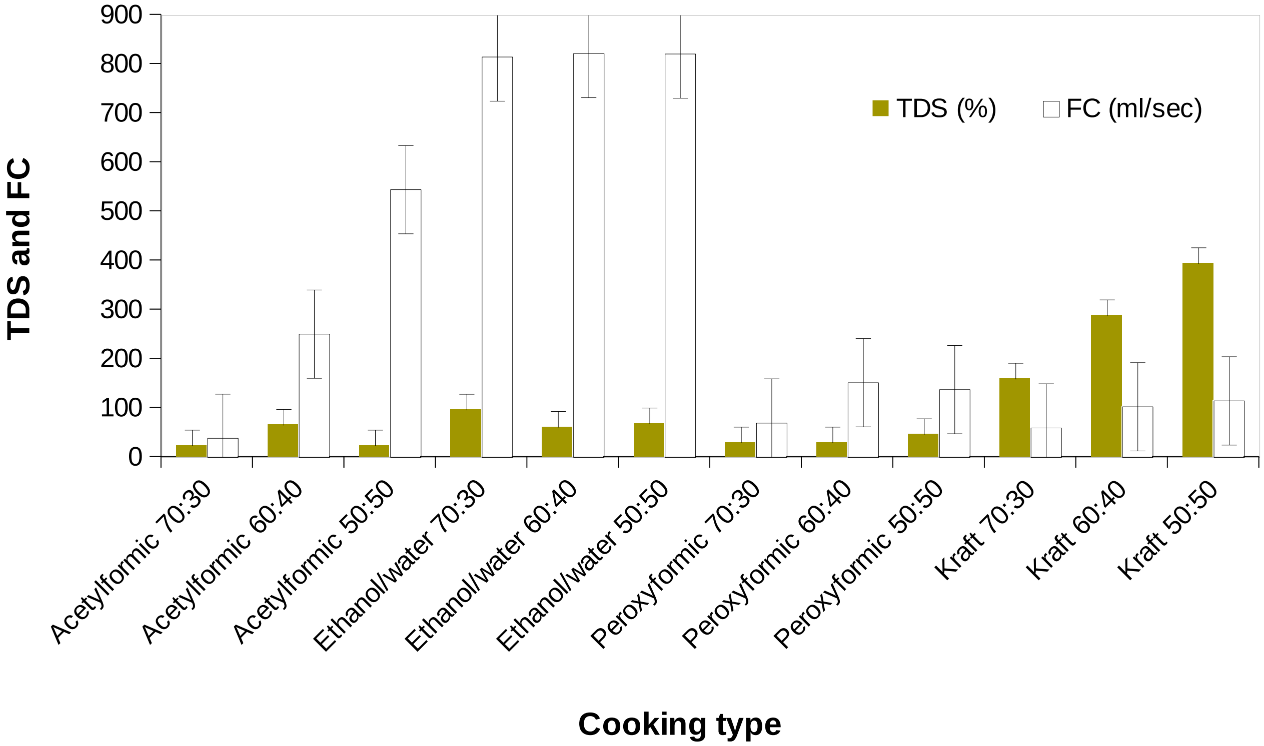

Figure 2: Influence of pulping method on the Total dissolve solid and fiteration properties of the isolated lignin

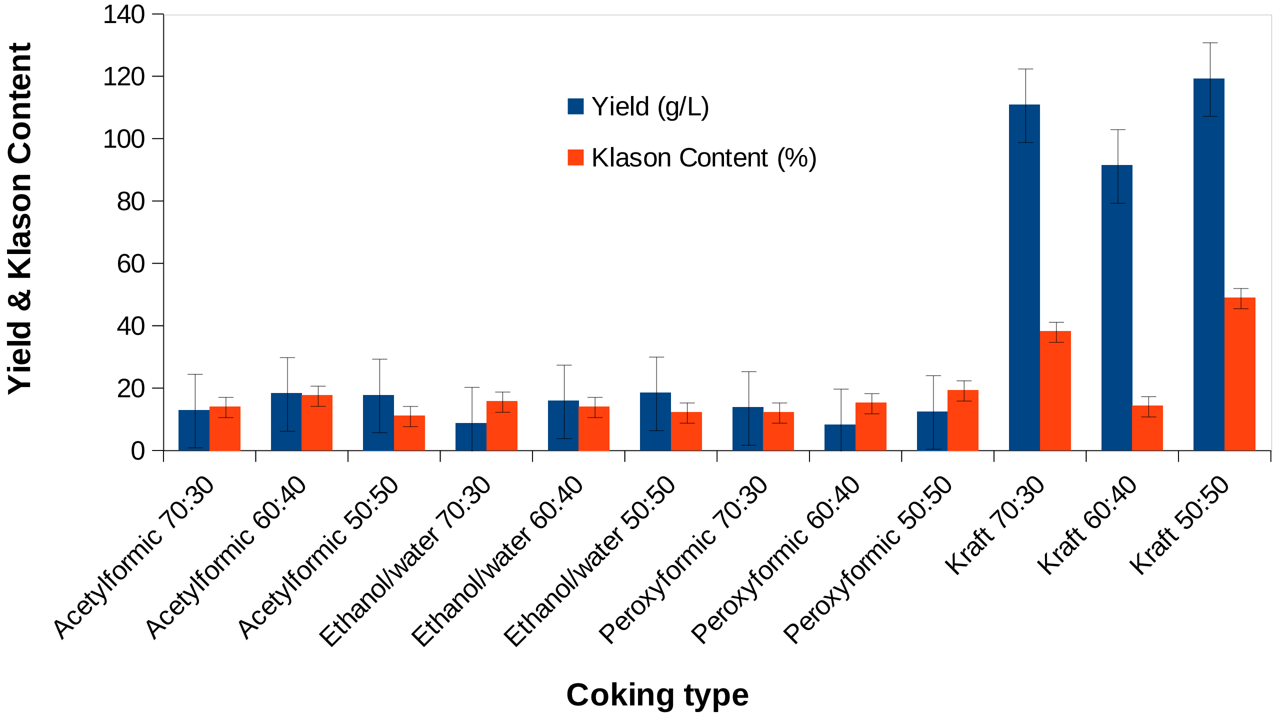

Figure 3: Influence of pulping method on the yield and klason content of the isolated lignin

Higher liqour pH favours LMW lignin. Although, HMW lignin was not influeced by liqour pH but seemed that concentration of HMW lignin were higher for Organosolv than Kraft process. Although there were statistical variations in the properties of the black liquor and the precipitated lignin based on the liquor concentration and pulping type. However, the pH of Aceticformic and Ethanol as well as TDS of Aceticformic and Peroxyformic were statistically similar (Table 3). The klason lignin content of Aceticformic and Ethanol/water were similar as well as LMW lignin concentration of Ethanol/water and Peroxyformic lignin (Table 4).

Table 3: influence of cooking type and liqour concentration on the ph, total dissolved solid, filtration property and yield of technical lignin.

Source of variation	Levels	pH	TDS (%)	FC (ml/sec)	Yield (g/l)
Cooking type	Aceticformic	2.60^{a}	37.22^{a}	278.22^{b}	16.35^{c}
	Ethanol/water	2.66^{a}	70.00^{b}	745.20^{c}	14.26^{b}
	Peroxyformic	3.24^{b}	34.50^{a}	126.38^{a}	11.23^{a}
	Kraft	12.33^{c}	271.22^{c}	92.78^{a}	106.64^{d}
Liquor Concentration	70:30	5.04^{a}	128.75^{a}	405.17^{a}	41.46^{a}
	60:40	5.35^{b}	74.33^{b}	246.67^{b}	33.60^{b}
	50:50	5.18^{ab}	109.58^{c}	331.58^{c}	36.55^{c}

Values in the same column with the same superscript are not significantly different

Table 4: Influence of cooking type and liqour concentration on the klason, high molecular weight lignin and low molecular weight lignin of technical lignin.

Source of variation	Levels	Klason content (%)	HMW (cm^{-1})	LMW (cm^{-1})
Cooking type	Aceticformic	14.47^{a}	0.08^{a}	0.14^{c}
	Ethanol/water	13.87^{a}	0.11^{b}	0.07^{a}
	Peroxyformic	16.09^{b}	0.18^{c}	0.07^{a}
	Kraft	33.66^{c}	0.31^{a}	0.08^{b}
Liquor Concentration	70:30	22.88^{a}	1002.00^{a}	0.075^{a}
	60:40	20.04^{b}	1128.00^{b}	0.081^{b}
	50:50	15.46^{c}	1156.00^{c}	0.123^{c}

Values in the same column with the same superscript are not significantly different

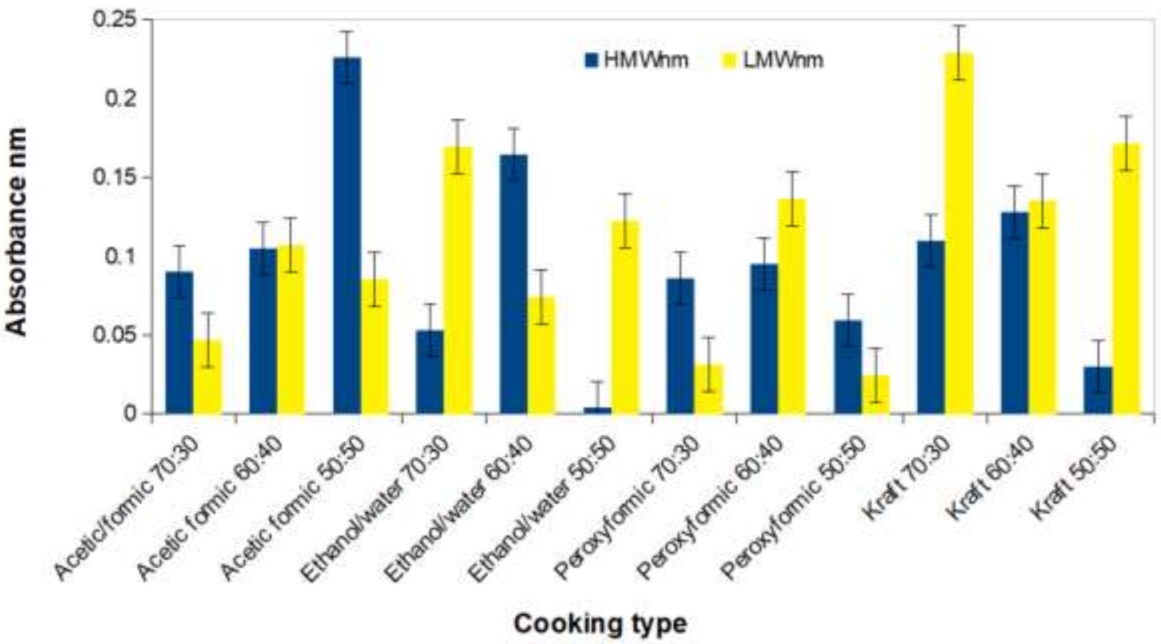

Figure 4: Influence of pulping method on the Concentration of HMW and LMW lignin

According to the intrinsic structure of lignin, several absorptions attributed to different purity level were observed, as shown in Table 6. Based on the Lambert-Beer's Law, UV spectroscopy can be used for the semi-quantitative determination of the purity of lignin and its degradation product (Prozil et al. 2014). Because of the cross-linking structures of lignin with carbohydrates, cellulose, and hemicelluloses, the isolation of lignin is extremely difficult. The absorbtion values for the HMW lignins are arranged in desreasing order, indicating that the lignin purity increases with decreasing absorption value. Acetylformic (50:50) had the highest purity with absorbance of 0.226nm followed by Ethanol/Water (60:40) while Ethanol/water (50:50) had the least purity with absorbance value of 0.004nm (Table 5).

Table 5: Lignin purity based on the UV absorbance of HMW Lignin

Lignin type	UV absorbance (nm)	
	Yield (g/L)	Lignin purity
Acetic formic 50:50	17.80	0.226
Ethanol/water 60:40	15.90	0.164
Kraft 60:40	91.40	0.128
Kraft 70:30	110.85	0.11
Acetic formic 60:40	18.30	0.105
Peroxyformic 60:40	8.20	0.095
Acetic/formic 70:30	12.95	0.09
Peroxyformic 70:30	13.80	0.086
Peroxyformic 50:50	12.50	0.059
Ethanol/water 70:30	8.75	0.053
Ethanol/water 50:50	18.45	0.004
Kraft 50:50	119.25	0.003

Due to different pH value, the colour of the isolated lignin varies significantly from cream to light brown and dark brown. The colour changes from cream to dark brown with decreasing pH. In addition, there were obvious differences in the shape and size of lignin. Kraft lignin colour also varied from brown to dark brow with decreasing pH. In general, the precipitation yield of Organosolv and Kraft lignin depended on several factors, for instance, the pH value of liquor and the cooking method. The comparison of Organosolv and Kraft lignins according to different pH values are shown in Figure 2. As can be seen, for a certain type of process e.g. Peroxyformic, due to different pH value, the colour of the lignin varied from light brown to dark brown with pH value decreasing. In addition, there were obvious differences in the shape and size of the lignins. Kraft lignin colour too varied from brown to dark brow with decreasing pH. Kraft lignin sample of bamboo formed large pieces much easier than that of Organosolv, and the process also filtered relatively faster than that of Organosolv during the precipitation process. This was related to the work of (Li et al. 2012) when he compared different Kraft lignins based on hardwood and softwood.

Figure 5: A = AF1 (70:30); B = AF2 (60:40); C = AF3 (50:50); D = EW1 (70:30); E = EW2 (60:40); F = EW3 (50:50); G = PFI (70:30); H = PF2 (60:40); I = PF3 (50:50); J = KL1 (70:30); K = KL2 (60:40); L = KL3 (50:50)

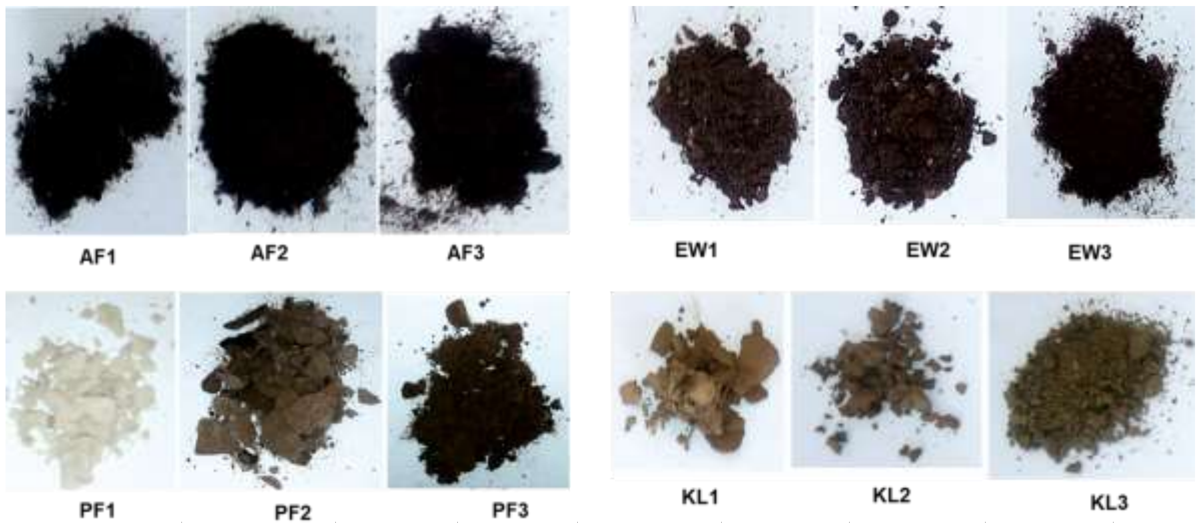

Figure 6: Samples of the Isolated Lignins

Correlation Analysis

The correlation between the liquor concentration and lignin parameters were presented in Table 7. There were strong positive correlation between pH and TDS, yield, Klason and low molecular weight lignin content. Only FC had strong negative correlation with pH. TDS had strong positive correlation with yield, klason and Low molecular weight lignin. Yield had significant positive correlation with klason and Low molecular weight lignin content. Likewise, Klason lignin content showed significant positive and negative correlations with Low molecular and High molecular weight lignin content respectively (Table 6). This indicates that as the pH increases, the TDS, yield, Klason and low molecular weight lignin content increases while FC decreases and vice versa. Also, klason and Low molecular weight lignin content increased with incresing lignin yield. In addition, the Klason lignin content had a considerable influence on the absorbance values of the HMW lignin. This was in agreement with the work of (Kallavus et al. 2015), who reported that the type and structure of lignin, solvent, and pH of the solution have a considerable influence on the UV spectra values.

Table 6: Correlation matrix of the liquor concentration and lignin properties

Properties	Liquor conc.	pH	TDS (%)	FC (ml/sec)	Yield (g/l)	Klason (%)	HMW (cm^{-1})	LMW (cm^{-1})
Liquor Conc.	1							
pH	-0.030	1						
TDS (%)	0.204	0.854**	1					
FC (ml/sec)	0.208	-0.477**	-0.250	1				
Yield (g/l)	0.049	0.980**	0.883**	-0.413*	1			
Klason (%)	0.105	0.728**	0.726**	-0.375*	0.815**	1		
HMW (cm^{-1})	-0.046	-0.079	-0.275	0.074	-0.109	-0.335*	1	
LMW (cm^{-1})	-0.107	0.671**	0.577**	0.016	0.692**	0.618**	-0.133	1

** = Highly significant correlation; * = Significant correlation

Fourier Transform Infrared Spectroscopy (FTIR) Analysis of the Lignin.

The FTIR spectra of the lignin isolated from the *B. vulgaris* contained most of the characteristic absorption bands for the different chemical structures. The lignin samples were analyzed based on the chemical structures and the peaks were identified by comparing their wavenumbers with literature data. The FTIR spectra obtained for both processes are shown in Fig 4. The characteristic bands between 3500-3000cm^{-1} indicate the existence of alcohol and carboxylic group in the samples. It was observed that Ethanol/Water, Peroxyformic, and Kraft lignin resonates at this wavelength. Which means Acetylformic did not provide information about the secondary structure of this functional group. The appearance of the band in the range of 1120-1270cm^{-1} and 1330-1375cm^{-1} shows the existence of P-hydroxyl (H), guaiacyl (G) & Syringyl (S) Unit in the bamboo lignin which are the basic precursor for lignins (Table 8). Apparently, this characteristics band were found to be present in all the lignin type. C-H stretching in Alkanes and Alkyls group is reflected in the band of 2901cm^{-1}. All the lignin types exhibited this functional groups. Band at 1600-2500cm^{-1} were attributed to Alkenes and Carbonyls group which are the characteristic bands found in the infrared spectra of Peroxyformic lignin (Table 7). The absorption band associated with all the lignin type at 1600-1680cm^{-1} are attributed to stretching vibrations of the C=H bond of the Alkenes. Absorption associated with the Amides R-C(O)-NH-R band at wave number between 1500-1550cm^{-1} leads primarily to bending vibrations of the N-H bond. Furthermore, C-Br stretching in Alkyl halides groups is reflected in the band of 1019-400cm^{-1} for Ethanol/Water, Peroxyformic and Kraft lignin.

Table 7: Band assignment for the isolated Lignin FTIR spectra

S/N	Class of Compounds	Wave no cm^{-1}	Intensity	Functional groups	AF	EW	PF	KL
1.	Alcohol & Carboxylic Acids	3500-3000	s	O-H stretch		4.	5.	6.
2.	Alkanes and Alkyls	2985-2900	s	C=H stretch	9.	10.	11.	12.
3.	Carbonyls	1700-2500	m-s	C=O stretch			✓	
4.	Alkenes	1600-1680	m-s	C-H bend	✓	✓	✓	✓
5.	Amides R-C(O)-NH-R	1500-1550	s	N-H bend	✓	✓		✓
6.	Nitro Compounds	1300-1400	s	N-O symmetric				✓
7.	P-hydroxyl (H), guaiacyl (G) & Syringyl (S) Unit	1200-1295	s	C-O-C stretch	✓	✓	✓	✓
8.	Alkyl halides	1019-400	m-s	C-Br stretch		✓	✓	✓

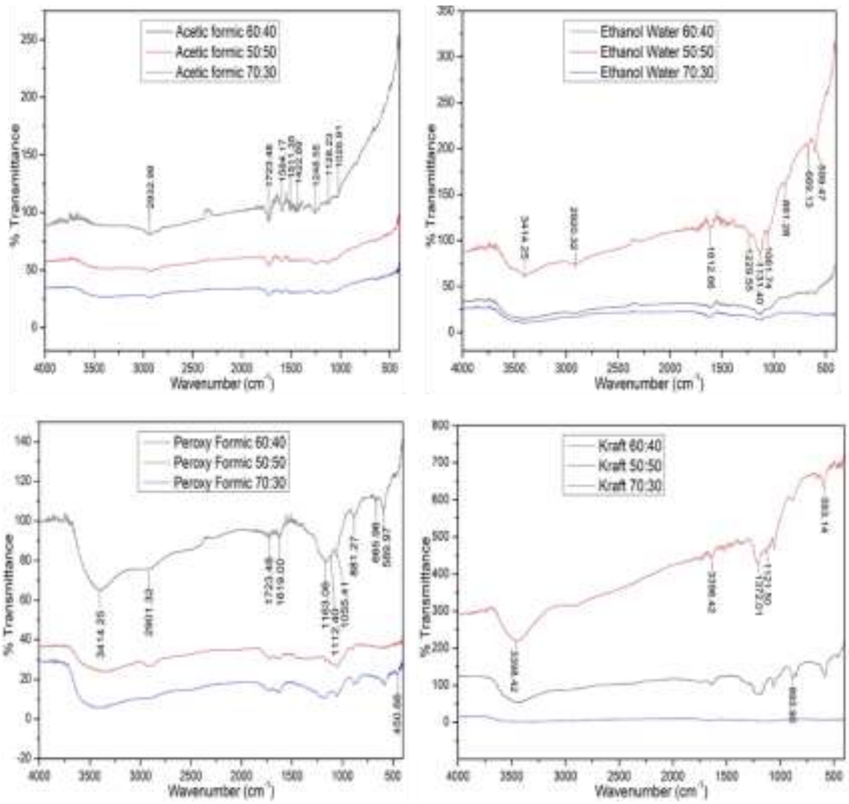

Figure 7: FTIR Spectra of the Isolated Lignins

CONCLUSION

The highest lignin precipitated (119.25 g/l) was recorded for Kraft at 50:50 liquor concentration while the lowest (8.20 g/l) was recorded for Peroxyformic at 60:40 liquor concentration. Acetylformic (70:30) was the easiest to filter which was filtered within the shortest period of 39 seconds compared to Ethanol/water (60:40) that took 822 secs before the filter cakes could be filtered off the residual filtrate. Generally, the precipitation yield of lignin decreased with increasing pH value. Ethanol/Water at 60:40 liquor concentration was found to have the highest purity judging from the UV spectrometric analysis. The cooking type and liquor concentrations have considerable influence on the concentration of the lignin. Functionality of Organosolv and Kraft lignin showed that Alcohol and Carboxylic Acids, Alkanes and Alkyls, Carbonyls, Alkenes, Amide, and Alkyl halides are functional groups present in the isolated lignin.

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Comparative Analysis of the Physical Properties of Wood Plastic Composites (WPC) Produced from Sawdust of *Ceiba pentandra* and *Cola gigantia* Wood

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Abstract

Sawdust (SD) of Ceiba pentandra, Cola gigantia, were each mixed with Polyethylene Terephthalate (PET) using percentage weight based ratios SD/PET of 40:60, 30:70 and 20:80. The research was based on Binary Blend Mixture Experimental Design. The SD was sieved to size 2.00 mm and air dried to a moisture content of 12 %. The PET was sorted, cleaned and shredded to size 1.57 mm^2. PET chips were melted inside the melting unit of the extruder at 190^{o}C temperature before adding SD. This was fed under gravity into the Extruder at 200^{o}C temperature and powered by 3 kW Electric Motor. WPC produced was collected into a rectangular mould of 125 mm x 15 mm x 3.2 mm dimension and compressed at 1.12 N/mm^2 pressure to ASTM D 695 International Standard for physical properties of WPC which include Water Absorption, Thickness Swelling, and Linear Expansion. The result of the test showed WPC from Ceiba pentandra with SD/PET mix ratio 20:80 having the lowest Water Absorption of 4.44 %, Thickness Swelling of 3.85 % and Linear Expansion of 0.42 % when compared to Cola gigantia of 5.76 %, 4.76 % and 0.40 % respectively at the same ratios. Analysis of Variance carried out at 0.05% probability level revealed that the mix ratio, type of wood and time specimen spent inside water were significant to their physical properties. It was concluded that WPC from Ceiba pentandra is more durable to use as Farm Structure cladding when compared to that of Cola gigantia.

Keywords: Wood, Plastic, Composites, Waste, Extruder

INTRODUCTION

Wood wastes are the tiny sized and powdery product of wood shavings from machining and sawing of wood in sawmills and other wood-processing factories (Maharani *et al.*, 2010). They are poorly disposed in our environment today through open burning and emission of its toxic and non-toxic particulates into the air during wood processing causing air pollution (Akinfiresoye *et al.*, 2017; Kehinde *et al.*, 2014; Edith and Edmund, 2012). Similarly used plastic water bottles are either discharged into streams, canals and rivers indiscriminately or used for land filling and in some cases incinerated (Ugoamadi *et. al.*, 2011). Adhikary *et al.* (2008) in Akinfiresoye, *et al.* (2018), reported that plastic waste being a non-biodegradable materials has several negative impacts on the health of ecosystems and aquatic animals (Oluwatosin *et al.*, 2014).

In Nigeria, studies have shown the role of occupational exposure to environmental pollutants such as wood dust in the incidence of respiratory diseases (Oppliger *et al.*, 2005; Ige and Onadeko, 2000). Oppliger *et al. (*2005) observed a high prevalence of respiratory symptoms, increased nose and eye irritations, skin symptoms, and high prevalence of allergy/sensitivity symptoms among workers exposed to wood dust compared to those unexposed. Researchers have worked on converting wood waste to composites using nylon as the binders. This they do by mixing the sawdust of specific wood and nylon threads under specific heat and pressure (Aina *et al.*, 2016; Aina *et al.*, 2014; Oluyege *et al.*, 2017; Oladejo and Omoniyi, 2017). Not much composite work has been done on *Cola gigantia*, a common hard wood now been used in the South Western part of Nigeria for building structures using waste plastic water bottle as the binder (Akinfiresoye *et al.*, 2018). This research produced and compared the physical properties of WPC made from the mixture of Polyethylene Terephthalate (PET) and sawdust of *Ceiba pentandra*, popularly called “Araba Tree” among Yoruba tribe of Nigeria and *Cola gigantia*, also called “Oporoporo tree” by the same tribe. The study eliminates potential risk of environmental pollution, which adversely affects our climate. It also utilized wood and plastic waste by converting them to clad useful for farm structures to provide protection against mould, and decay in areas prone to intense rainfall and high moisture regime.

METHODOLOGY

Sawdust (SD) of *Ceiba pentandra* and *Cola gigantia* were collected from Olukayode sawmill along Onyearugbulem road in Akure, Ondo State Nigeria, while the Polyethylene Terephthalate, (PET) plastic water bottles were collected from Ade Super Hotel, along Ilesha Road, Akure. The research was carried out in the workshop and laboratory of the Department of Agricultural Engineering of the Federal University of Technology, Akure, Ondo State, Nigeria. Locally fabricated plastic shredder, WPC extruder and hydraulic press were used in the production of the WPC (Akinfiresoye *et al*., 2016; Akinfiresoye *et al*., 2017; Akinfiresoye *et al*., 2018). PET collected were sorted, cleaned, dried and shredded into 1.89 mm^2 average size with the plastic shredder. SD collected were sieved to 2.00 mm size using standard wire mesh screen and air dried to a moisture content of 12 % by means of hygrometer to measure the moisture reduction. Weight based in grams of three mixing ratios of SD and PET were chosen after the trial test forming three batches in one group. For the first batch, SD was weighed to 210 g using electronic digital weighing balance while the PET was weighed to 84 g, 63 g and 42 g representing 40 %, 30 % and 20 % of the SD. The second batch has SD weighed to 195 g and PET was weighed to 78 g, 59 g and 39 g. The third batch has SD weighed to 180 g and PET was weighed to 72 g, 54 g and 36 g to form the SD/PET of mixing ratios 40:60, 30:70 and 20:80 respectively.

For the first batch, PET of 84 g was allowed to melt at 190°c without degradation inside the melting chamber of preheated WPC Extruder. Thereafter, 210 g of SD was added, mixed together to slurry form and fed into the extruding chamber of the Extruder already preheated and maintained at temperature 190°c from 4.8 kW heat band. The extruder kneaded the composites thoroughly at speed 277 rpm and the extruded (WPC) was collected at the exit end of the extruder into a mould of dimension 125 mm x 15 mm x 3.2 mm. This was hot pressed at 120°c and 1.12N/mm^2 force to a thickness of 12.7 mm using infrared thermometer and calibrated Hydraulic Press respectively. The WPC produced was allowed to cool down before removal and trimmed to dimension 125 mm x 12.7 mm x 3.2 mm based on ASTM D 695 International Standard for physical properties of WPC. This procedure was repeated for the second and third batch of the SD/PET. Three specimens were produced for each of the batches, making nine specimens for each group and twenty seven specimens for the three groups under investigation. The physical properties of the products from *Ceiba pentandra* and *Cola gigantia* were investigated and compared to ascertain the best product suitable for farm structure cladding.

PHYSICAL TEST OF WPC SPECIMEN

The physical properties investigated were water absorption, thickness swelling and linear expansion. The thickness (mm), weight (g) and length (m) of the samples were taken prior to immersion in water as initial parameters while the final measurement was taken after immersion in water at 20°C for 24 hours. The thickness, weight and length of the WPC was taken at 2 hours interval. Electronic weighing balance, digital caliper, micrometer screw gauge and meter rule were used to measure the water absorption through the weight of the samples, thickness swelling, and linear expansion respectively. The different parameters were calculated using equations 1, 2 and 3 as expressed by Aina *et al*. (2014).

Water Absorption (WA)

$$WA = \frac{m_2 - m_1}{m_1} \times 100 \qquad (1)$$

Where, WA (%) is water absorption, m_2 is weight (g) of WPC after soaking and m_1 is weight (g) of WPC before the soaking.

Thickness Swelling (TS)

$$TS = \frac{T_2 - T_1}{T_1} \times 100 \qquad (2)$$

Where, TS (%) is thickness swelling, T_1 is thickness of WPC before soaking (mm) and T_2 is thickness after soaking (mm)

Linear Expansion (LE)

$$LE = \frac{L_2 - L_1}{L_1} \times 100 \qquad (3)$$

Where, LE (%) is linear expansion, L_1 is the final length of WPC before soaking (m) and L_2 is the final length after soaking (m).

RESULTS AND DISCUSSION

The results of the physical properties of WPC produced from the mixture of SD of *Ceiba pentandra, Cola gigantia* and PET is as discussed.

Water Absorption

The line charts of Figures 1 and 2 shows the results of Water Absorption of WPC produced from SD of *Ceiba pentandra* and *Cola gigantia* when immersed in water for 24 hours. *Cola gigantia* absorbed water much more than *Ceiba pentandra* for all the mix ratios of SD and PET. While the former absorbed water by 3.23 %, 2.01 % and 1.64 % for SD/PET mixing ratio 40:60, 30:70 and 20:80 respectively at the end of the first 2 h of water immersion; the latter percentage of absorption were just 2.33, 1.52 and 1.10 at the same mix ratio. This trend was maintained all through the 2 h interval measurement taken up until the 24th hour. The least water absorbed at the end of the 24 hours showed *Cola gigantia* absorbing 5.76 % of water while that of *Ceiba pentandra* was 4.26 % for SD/PET of 20:80 mixing ratio. It was observed that the higher the content in percentage of SD in the sample, the higher the water absorbed. This corroborates the works of Aina *et al.* (2016) and Oluyege *et al.* (2017) who observed that the WPC with higher SD content absorb more water than the lesser ones.

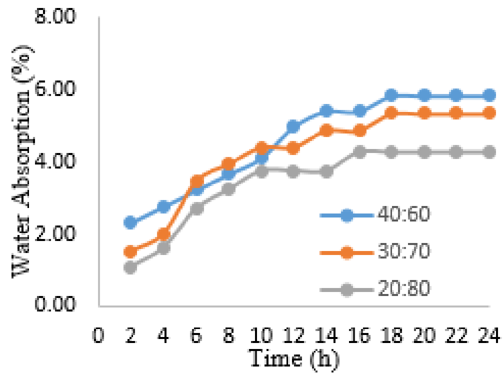

Fig. 1. Water absorption for *Ceiba pentandra*

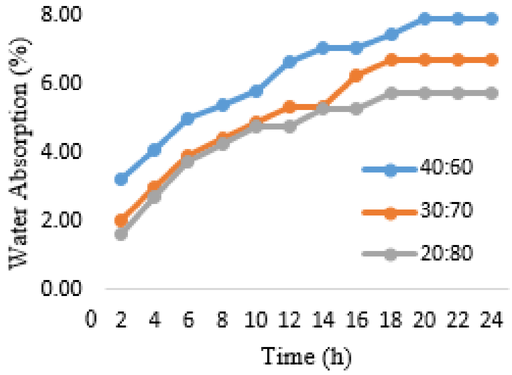

Fig. 2. Water absorption for *Cola gigantia*

Thickness Swelling

The results of thickness swelling of WPC produced from SD of *Ceiba pentandra* and *Cola gigantia* when immersed in water for 24 hours is as represented in the line charts of Figures 3 and 4 respectively. It was generally noticed that the samples swells at different rates, from 0.76 % to 8.45 % for the three mix ratios. While *Ceiba pentandra* swells between 0.76 % and 6.68 %, that of *Cola gigantia* swells between 1.52 % and 8.45 %. After the first 2 hours of water immersion, the SD/PET mix ratio 20:80, 30:70 and 40:60 for *Ceiba pentandra* swells by 0.76 %, 1.52 %, and 3.7 % respectively. This is lower to that of *Cola gigantia* of 1.52 %, 3.70 %, and 5.11 % for same mixing ratio respectively. This was the trend up to 24 hours of water immersion with *Cola gigantia* swelling the most at 4.76 % compared to 3.70 % of *Ceiba pentandra* for SD/PET mix ratio of 20:80. It was observed generally that the higher the PET content in the sample, the lesser is the thickness swelling which is also directly proportional to water absorbed by the sample. This is in agreement with the work of Izekor and Mordi, (2014) on Dimensional stability and strength properties of wood plastic composites produced from sawdust of *Cordia alliodora* (Ruiz and Pav.)

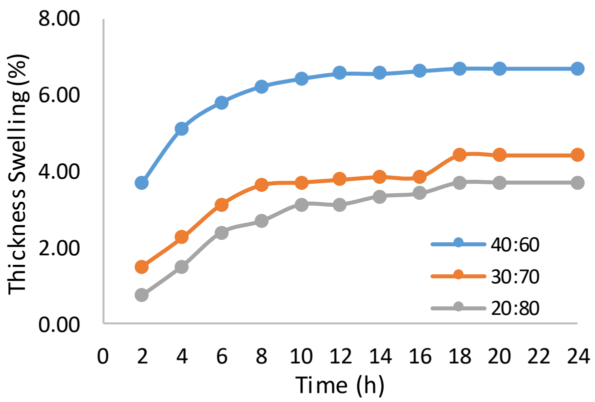

Fig. 3. Thickness Swelling for *Ceiba pentandra*

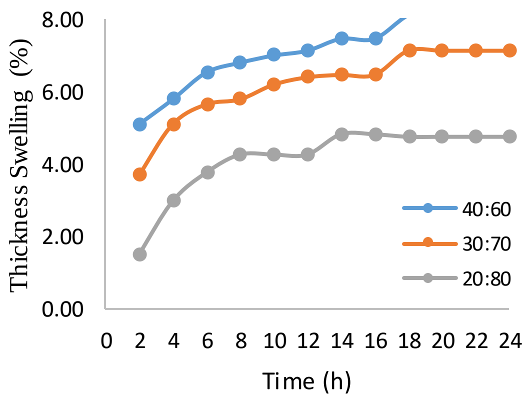

Fig. 4. Thickness Swelling for *Cola gigantia*

Linear Expansion

The linear expansion of the WPC produced from *Ceiba pentandra* and *Cola gigantia* is presented in Figures 5 and 6 after 24 hours of water immersion. *Ceiba pentandra* expanded linearly by 0.35 % and 0.07 % respectively after 2 hours of water immersion, whereas *Cola gigantia* expanded by 0.56 % and 0.31 % for SD/PET mix ratio 40:60 and 20:80 respectively. This shows that the linear expansion of *Ceiba pentandra* was low when compared to that of *Cola gigantia* and this was the trend up to the 24th hour of water immersion. *Ceiba pentandra* ended up expanding by 0.69 %, 0.63 % and 0.42 % while *Cola gigantia* expanded by 1.15 %, 0.70 %, and 0.40 % for SD/PET mix ratios 40:60, 30:70 and 20:80 respectively. It was generally observed for the two types of wood that the higher the SD content, the lower the linear expansion. This was the same observation made by Aina *et al.* (2014); Oluyege *et al.* (2017) and Izekor Mordi (2014)

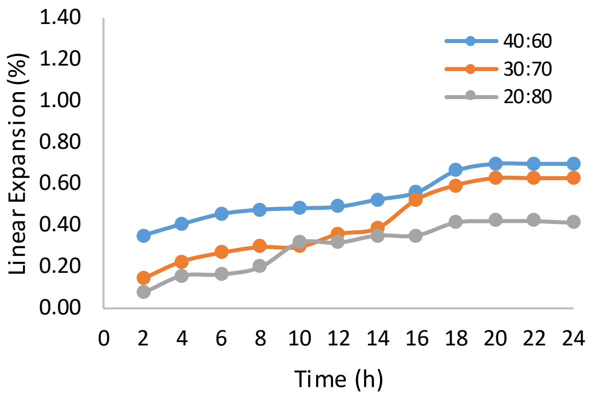

Fig. 4. Linear expansion for *Ceiba pentandra*

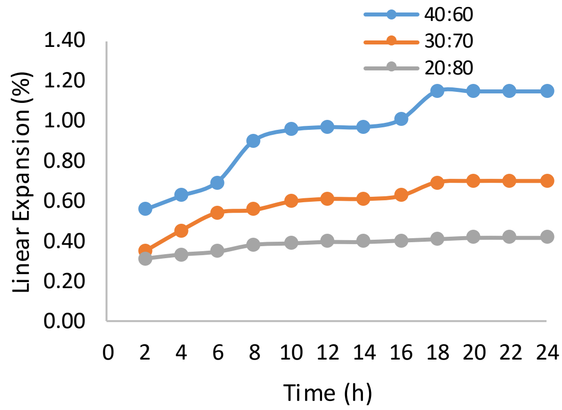

Fig. 5. Linear expansion for *Cola gigantia*

ANALYSIS OF VARIANCE (ANOVA)

Analysis of variance (ANOVA) at $\alpha \leq 0.05$ was carried out to check the significance of the type of wood, the mixing ratio and time taken during water immersion on the physical properties of WPC samples and the following observations were made:

Water Absorption

ANOVA of the means of the water absorbed by *Ceiba pentandra* and *Cola gigantia* showed that the water absorbed has significant impact on the type of wood, the mix ratio and the time spent inside the water since *P-value* < 0.05 as shown in Tables 1 and 2 respectively

Table 1: Anova: *Ceiba pentandra* WPC water absorption

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Type of Wood	386.3972	3	128.7991	21.4019	2.65E-07*	2.960351
Mix Ratio	210.0372	9	23.33747	3.877872	0.00295*	2.250131
Time (h)	102.655	1	269.6957	9.898532	0.004689*	4.30095
Error	162.489	27	6.018113			
Total	861.5785	40				

*significant at (P<0.05) probability level; ns not significant at (P<0.05) probability level

Table 2: Anova: *Cola gigantia* WPC water absorption

Source	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Type of Wood	276.6596	3	92.21986	17.04538	2.07E-06*	2.960351
Mix Ratio	243.4348	9	27.04831	4.999452	0.000527*	2.250131
Time (h)	102.655	1	269.6957	9.898532	0.004689*	4.30095
Error	146.0769	27	5.410254			
Total	768.8262	40				

*significant at (P<0.05) probability level; ns not significant at (P<0.05) probability level

Thickness Swelling

ANOVA of the means of the thickness swelling by *Ceiba pentandra* and *Cola gigantia* showed that the type of wood, the mix ratio and the time WPC spent inside water were significant to the thickness swelling of the WPC as presented in Tables 3 and 4.

Table 3: Anova: *Ceiba pentandra* WPC thickness swelling

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Type of Wood	417.1731	3	139.0577	20.26393	4.39E-07*	2.960351
Mix Ratio	169.0323	9	18.78136	2.736879	0.020669*	2.250131
Time (h)	102.655	1	269.6957	9.898532	0.004689*	4.30095
Error	185.2829	27	6.862328			
Total	874.1433	40				

*significant at (P<0.05) probability level; ns not significant at (P<0.05) probability level

Table 4: ANOVA-*Cola gigantia* WPC thickness swelling

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Type of Wood	258.1185	3	86.03949	12.99652	1.93E-05*	2.960351
Mix Ratio	179.8692	9	19.98546	3.018862	0.01255*	2.250131
Time (h)	102.655	1	269.6957	9.898532	0.004689*	4.30095
Error	178.7453	27	6.620197			
Total	719.3879	40				

*significant at (P<0.05) probability level; ns not significant at (P<0.05) probability level

Linear Expansion

ANOVA of the means of the linear expansion obtained from WPC produced from *Ceiba pentandra* and *Cola gigantia* showed that the type of wood and the time spent inside water were significant to the linear expansion of the WPC whereas the mix ratio did not have significant effect on the thickness swelling as seen in Tables 5 and 6.

Table 5: ANOVA-*Ceiba petandra* WPC Linear Expansion

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Type of Wood	809.0563	3	269.6854	30.42884	8.25E-09*	2.960351
Mix Ratio	91.2075	9	10.13417	1.143447	0.368215^{ns}	2.250131
Time (h)	102.655	1	269.6957	9.898532	0.004689*	4.30095
Error	239.2963	27	8.862824			
Total	1242.215	40				

*significant at (P<0.05) probability level; ns not significant at (P<0.05) probability level

Table 6: ANOVA-*Cola gigantia* WPC Linear Expansion

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Type of Wood	845.6267	3	281.8756	32.05735	4.8E-09*	2.960351
Mix Ratio	93.05895	9	10.33988	1.175942	0.348835^{ns}	2.250131
Time (h)	102.655	1	269.6957	9.898532	0.004689*	4.30095
Error	237.407	27	8.792852			
Total	1278.748	40				

*significant at (P<0.05) probability level; ns not significant at (P<0.05) probability level

CONCLUSION

Wood Plastic Composite were produced from the mixture of sawdust of *Ceiba pentandra* and *Cola gigantia* each mixed with Polyethylene Terephthalate chips as the binder. Their physical properties were investigated and compared to ascertain the best out of the two wood species, which can be used for farm structure cladding in waterlogged environment. It is concluded from the research findings and Analysis of Variance carried out at 95 % probability level that the wood type, the mix ratio and the time these samples spent inside water have significant effects on Water Absorption and Thickness Swelling, whereas, the mix ratio did not have much significance on the linear expansion of the WPC. *Ceiba pentandra* has low water absorption, thickness swelling and linear expansion when compared to that of *Cola gigantia*.

RECOMMENDATION

WPC made from *Ceiba petandra* at SD/PET mix ratio of 20:80 is recommended as cladding or water-proof protector for farm structures in areas prone to water. It is also recommended for livestock water trough, farm landscaping, railings, decking, irrigation and drainage paths, etc.

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Evaluation of Banana Stalk and Oil Palm Empty Fruit Bunch Fibers for Paper Production

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Abstract

Morphological and chemical characteristics of banana stalk fiber (BSF) and oil palm empty fruit bunch fiber (OPEFBF) were evaluated in order to determine their suitability for paper production. Macerated fibers from the two fiber source were prepared to determine to determine the fiber dimensional characteristics (fiber length, width, and diameter, wall thickness, felting rate, elastic coefficient, and rigidity coefficient and ronkel ratio). Chemical analysis was also carried out to determine the content of ash, cellulose, and lignin. Each of the two fibrous materials was subjected to pulping using four pulping treatments of soda (NaOH) concentrations and temperatures viz; 7% at 110^{o}C, 7% at 120^{o}C, 9% at 110^{o}C and 9% at 120^{o}C, in order to determine their effects on pulp yield. Analysis of variance using was conducted for the pulp yield for significant difference in the pulping treatments. The mean fiber length, diameter, lumen width and cell wall thickness of banana stalk and oil palm fruit bunch is 2.14±0.85, 24.44±11.52, 15.51±9.05 and 4.47±1.97 respectively for banana stalk and 1.02±0.35, 19.59±4.54, 12.32±4.29, and 3.99±1.28 respectively for oil palm bunch. The mean derived fiber characteristics (felting rate, elastic coefficient, and rigidity coefficient and ronkel ratio) of banana stalk and oil palm bunch is of banana stalk and oil palm bunch is 0.11±0.08, 60.60±11.52, 19.71±5.48 and 0.70±0.32 respectively for banana stalk and 0.05±0.01 62.78±15.81, 20.37±5.07 and 0.71±0.29 respectively for oil palm bunch. The result of the chemical analysis of banana stalk and oil palm bunch is 44.31% cellulose, 11.05% lignin and 12.46% ash for banana stalk while oil palm bunch fiber is made up of 35.25% cellulose, 15.84% lignin and 8.00 % ash. The study shows that BSF belongs to long fiber group while OPEFBF belongs to short fiber group. Their derived fiber morphology shows that paper produced from them could have acceptable tensile and burst strength due to high elasticity coefficient (>50) and low ronkel ratio (<1). The two materials have high cellulose and low lignin indicating easy pulping. Pulp yield was higher at lower soda concentration than at higher soda concentration. It is an indication that a mild soda pulping would suitable for them. From this study, banana stalk and oil palm empty fruit bunch fibers proved to be suitable fibrous materials for pulp and paper production.

Keywords: Banana stalk, Oil palm bunch, fibre morphology, pulp, paper production

INTRODUCTION

As the world population is increasing every day, the need to improve the literacy level and quality of life also increases. The importance of using pulp and paper and their products to improve the quality of life cannot be over emphasized. It has been anticipated by the Organization of Economic Control and Development (OECD) in 2001, that the global paper production will increase by 77% between 1995 and 2020. Consequently, it is obvious that the demand for pulp fiber resources will definitely increase. Since paper is identified with trees in the forest, the increased demand for pulp fiber will undoubtedly increase exploitation pressure on the world diminishing forest biodiversity, thereby raising the threat of environmental degradation. Recently, people have placed a high emphasis on forest preservation and rational use of forest and agriculture residues (Shi yu Fu Li *et al.* 2010). Consequence upon shortage of conventional raw materials coupled with the increasing world demand for paper and paper products, there has been a renewed interest in the use of non-wood fibers as alternative fiber sources for paper industries. The chemical composition and morphology of fiber are important determinants of its suitability for paper making. Fiber characteristics vary across and within species. The method of pulping employed in converting any fibrous material into paper also determines the quality of the paper obtained. Pulping conditions such as temperature and liquor concentration play important role in paper quality. The specific physical and chemical characteristic is also important in the technical aspects of pulping which has a direct correlation with the economic, environmental and ethical contexts of the paper industry (Rousu *et al*., 2002). Hence, this study examined the chemical and morphological characteristics of the plant resources under study. It also evaluated the effects of varying temperature and soda concentration on pulp yield and paper quality. This is aimed at determining the potentials of banana stalk and oil palm empty fruit bunch as alternative sources of paper making.

METHODOLOGY

This study was carried out at Federal Institute of Industrial Research Oshodi, Lagos State and Forestry Research Institute of Nigeria. Banana stalks and oil palm empty fruit bunches were collected from their dump ground in Ore and cleaned to remove sands. Strands of the test materials were collected and macerated in equal volume of acetic acid and hydrogen peroxide in order to determine the fiber dimensional characteristics (fiber length, width, and diameter, wall thickness, felting rate, elastic coefficient, rigidity coefficient and Ronkel ratio). The remaining materials were chipped into particle size of 2 inch and air dried. The moisture content of the air dried test samples was determined by drying in oven at 103±2^{o}C until a constant weight was obtained. The oven dried material was powdered with the help of powder making machine of size 0.04mm according to standard TAPPI test method 267-om85. Sample of extractive free material was prepared and of the extractive free sample was weighed each for chemical analysis to determine the percentage α-cellulose, lignin and ash content of the raw materials. Four pulping treatments were carried out with 7% soda at 110^{o}C, 7% soda at 120^{o}C, 9% soda at 110^{o}C and 9% soda at 120^{o}Cwith constant mixing ratio of 1:30 raw material to pulping soda. Each pulping treatment was applied in triplicates (3-replicates). After the pulping, the pulp was washed, screened, oven dried and the percentage pulp yield was determined and the average pulp yield was determined. The pulp was thereafter refined by electric blender. Handmade paper was produced from each refined pulp treatment. The results obtained were recorded and represented in tables and graph. Analysis of variance was conducted for the pulp yield for significant difference in the pulping treatments.

RESULTS

Fiber Morphological Characteristics

The mean and standard deviation of the fiber length, diameter, lumen width and cell wall thickness of banana stalk and oil palm fruit bunch is presented in Table 1 as 2.14±0.85, 24.44±11.52, 15.51±9.05 and 4.47±1.97 respectively for banana stalk and 1.02±0.35, 19.59±4.54, 12.32±4.29, 3.99±1.28 respectively for oil palm bunch

Table 1: Fiber dimensional characteristics of banana stalk and oil palm bunch

	Fibre Dimensional Characteristics			
	Fiber length (mm)	**f- dimeter**	**lumen width**	**cellwall thickness**
Fibre sources				
banana stalk	2.14±0.85	24.44±11.52	15.51±9.05	4.47±1.97
Oil palm bunch	1.02±0.35	19.59±4.54	12.32±4.29	3.99±1.28

Derived fiber Characteristics

The mean derived fiber characteristics of banana stalk and oil palm bunch is presented in Table 2. It shows that the mean and standard deviation of derived fiber characteristics (felting rate, elastic coefficient, and rigidity coefficient and ronkel ratio) of banana stalk and oil palm bunch is 0.11±0.08, 60.60±11.52, 19.71±5.48 and 0.70±0.32 respectively for banana stalk and 0.05±0.01 62.78±15.81, 20.37±5.07 and 0.71±0.29 respectively for oil palm bunch.

Table 2: Mean derived fiber characteristic as index for paper strength and quality

	Derived fibre Characteristics			
	Felting rate	Elastic coefficient (%)	Rigidity coefficient (%)	Runkel ratio
Standard	≥0.033	≥50%	≥30%	≤1
Fibre sources				
banana stalk	0.11±0.08	60.60±11.52	19.71±5.48	0.70±0.32
Oil palm bunch	0.05±0.01	62.78±15.81	20.37±5.07	0.71±0.29

Chemical Composition

The result of the chemical analysis of banana stalk and oil palm bunch is presented in Table 3. Banana stalk fiber is made up of 44.31% cellulose, 11.05% lignin and 12.46% ash while oil palm bunch fiber is made up of 35.25% cellulose, 15.84% lignin and 8.00 % ash

Table 3: Chemical composition (%) of banana stalk and oil palm bunch fiber

Chemical composition	Banana stalk(%)	oil palm(%)
Cellulose	44.31	35.25
Lignin	11.05	15.8
Ash	12.46	8.03
Others	32.18	40.95

Pulp Yield

The mean pulp yield (%) from banana stalk and Oil palm bunch is presented in Table 4 and Figure 1. The result shows that banana stalk gives the highest pulp yield value of 68.78% when pulped with 7% NaOH at 110°C and lowest value of 46.25% when pulped with 9% at 110°C. Oil palm bunch produces the highest pulp yield value of 72.79% when pulped with 7% NaOH and lowest yield of 60.86% when pulped with 9% NaOH at 120°C.

Table 4: Mean percentage pulp yield (%)

	Pulp yield (%)	
	Banana stalk	Oil palm bunch
Pulping conditions (Concentration and temperature)		
7% at 110^{0}C	68.67±6.7	67.60±4.7
7% at 120^{0}C	53.86±2.1	72.79±3.8
9% at 110^{0}C	46.25±1.5	64.51±9.2
9% at 120^{0}C	47.87±3.3	60.86±9.2

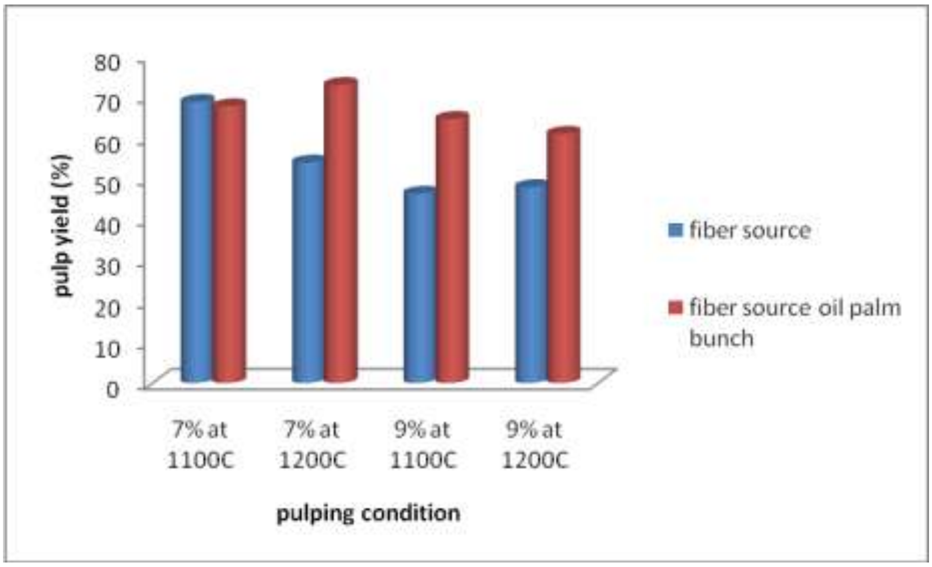

Figure 1: Variation of Pulp Yields (%) with Pulping Variables

Table 5: Analysis of Variance for Pulp Yield from Banana Stalk and oil palm bunch

Source of Variation	df	SS	MS	F	P-value	F crit
Banana pulp Pulping conditions	3	88.34	29.45	0.24	0.87	4.07NS
Error	8	992.97	124.12			
Total	11	1081.32				
Oil palm pulp Pulping conditions	3	229.40	76.46	2.32	0.15	4.07NS
Error	8	263.55	32.94			
Total	11	492.94				

Discussion

Fiber morphological characteristics of banana stalk and oil palm bunch

The result of fiber morphological characteristics of banana stalk and oil palm empty fruit bunch shows that banana stalk has a relatively long fiber length close to that of temperate zone coniferous wood 2.7-4.6mm, while oil palm bunch has a relatively short fiber length of 1.02 mm, which is similar to that of tropical hardwood 0.7-1.6mm (Atchison, 1989). Fiber length is a vital factor in determining bonding and stress distribution (Khalil *et al*. 2008). Different fiber lengths are desirable for different properties in paper. For example, longer fiber length is desirable for strength properties in paper, but they tend to bunch together and as a result do not provide good formation. Shorter fibers on the other hand provide excellent formation. Hence, oil palm empty fruit bunch fibers could be blended with any long fibrous material to keep pace with paper strength and formation. Moreover, blending the two raw materials will produce paper with improved properties of good formation derived from oil palm bunch fibers and strength derived from banana stalk fibers. The fiber length, diameter and cell wall thickness of oil palm empty bunch in this study is similar in values to that of (Law and Jiang 2001).

Effect of derived fiber characteristics on the strength of paper

Felting rate or Slenderness ratio.

According to Xu, *et al*., 2006, the acceptable felting rate of a fibrous material for pulp and paper production is 0.033 and above. This indicates that banana stalk and oil palm bunch could be suitable for papermaking since their slenderness ratios are above the minimum requirement. This results in satisfactory pulp tears indices and bursting strengths for printing and writing purposes (Cappelletto *et al*., 2000 and Law *et al*., 2001). According to Reddy and Yang (2005), lower aspect ratio reduces paper strength and modulus.

Elastic and rigidity coefficient

The elasticity coefficient of the banana stalk and oil palm bunch is 60.60% and 62.78% respectively (Table 10). According to Bektas, *et al*., (1999), the elastic coefficient are categorized into four group of fibers namely; highly elastic fibers, having elasticity coefficient greater than 75%, elastic fibers; having elasticity coefficient between 50-75%, rigid fibers having elasticity coefficient between 30-50% and highly rigid fibers; having elasticity coefficient less than 30%. Based on this classification, the elasticity coefficient of banana stalk and oil palm bunch falls into the elastic fiber group. This indicates that paper produced from the two fiber sources would have good tensile, tear and burst strength. Elastic fibers produce paper with good strength properties. On the other hand, rigid fibers do not have efficient elasticity, they are not suitable for paper production and they are used more on fiber plate and rigid cardboard production (Akgul and Tozluoglu, 2009). Also, the rigidity coefficients of banana stalk and oil palm bunch of 19.71 and 20.37 respectively are low and similar to that of softwood, *Pinus syvestries*; 19.97 (Akkayan, 1983. This implies that the fibers are easily collapsible during chemical pulping.

Runkel ratio

The Runkel ratio of banana stalk and oil palm bunch in this study is 0.70 and 0.71 respectively. According to Eroglu, (1980), when Runkel ratio is greater than 1, it is assessed as fiber having thick wall and cellulose obtained from this type of fibers is least suitable for paper production. When Runkel ratio is equal to one (1), cell wall has medium thickness and cellulose obtained from this type of fiber is suitable for paper production. When the rate is less than 1, cell wall is thin and cellulose obtained from these fibers is most suitable for paper making. According to du Plooy (1980), tensile strength and tear strength are differently correlatedwith fiber morphology. While tensile strength is negatively correlated with cell wall thickness, tear correlates positively. This shows that pulp beatability (response to beating) is a function of the strength of pulp as shown in the thickness of walls of individual fibers. The thicker walled fiber tends to produce an open and bulky sheet with low burst/tensile strength with high tearing resistance (Mishra *et al*. 2004). Runkel ratio of banana stalk and oil palm bunch is less than one (1) and this implies that their fibers have thin wall and can be easily felted into paper. Moreover, the two fiber materials will require mild pulping chemical since they have flexible wall.

In general, the derived fiber morphological characteristics values of banana stalk and oil palm bunch obtained from this study are acceptable for good quality paper production.

Chemical Composition of Banana Stalk and Oil Palm Bunch

The result of the chemical analysis of banana stalk and oil palm bunch shows that banana stalk fiber is made up of 44.31% of cellulose, 11.05% lignin and 12.46% ash. Oil palm bunch fiber is made up of 35.25% cellulose, 15.84% lignin and 8.003% ash. The result showed that banana stalk fiber contains high cellulose and less lignin. This should give banana stalk fiber a greater advantage in pulp and paper production. The lignin content of wood is 26 - 30% (Moore, 1996), both banana stalk and oil palm bunch fibers are low in lignin compared to wood indicating that both of them should be easier to pulp than wood. According to Manish (2011), banana stem is made up of 43.6% cellulose and 11% lignin.Hussain and Tarar, (2014) also reported 39.12 % and 11.34% of cellulose and lignin respectively. These results shows that banana stem cellulose is lower to that of its stalk while both have similar lignin content to the one obtained from this study. This indicates that the cellulose content of both banana stem and banana stalk varied and similar in lignin content. However, a further research would be necessary for validation of variation in chemical composition along the parts of banana and oil palm plants. Sreekala *et al*.,(2004) and John *et al*., (2008) reported that high cellulose content and high toughness value of oil palm bunch fibers makes it suitable for application in polymer composites. However, the cellulose content of oil palm bunch obtained in this study was low compared to 43% obtained by Khoo and Lee(1991), 48% by Hill and Abdul Khalil (2000), 50% by Khalil *et al*.,(2008) and 65% by Sreekala *et al*.(1997) and Law *et al*. (2007). It was only similar to 36% by Minowa *et al*., (1998). The differences in the cellulose and lignin content of oil palm bunch fiber could be as a result of the fact that the chemical compositions of a ligno cellulosic fiber vary according to the species, growing conditions, method of fiber preparations and many other factors (Bledzki and Gassan 1999). Chew and Bhatia (2008) also reported that chemical constituents of oil palm biomass significantly vary due to their diverse origins and types. According to Maria and Jurad(2011), the cellulose content of fibrous material correlates positively with pulp yield and fiber strength, whereas increase in lignin content correlates negatively with pulp yield and fiber strength. It was also reported that generally, the tensile strength and Young's modulus of plant fiber increases with increasing cellulose content of the fibers (Aji *et al*., 2009). The cellulose and lignin content of banana stalk and oil palm bunch obtained from this study shows that both materials will have appreciable pulp yield and fiber strength.

Effects of pulping variables on pulp yield

It was discovered from the result that the pulp yield increases with decrease in the concentration of NaOH at the same temperature. It is conceivable that the high pulp yield from both fiber sources is attributed to low lignin content and high alkali solubility. However, the result of the analysis of variance for pulp yield from banana stalk and oil palm bunch shows that at probability level (α =0.05), table 5 showed that there is no significant difference in the pulp yields between the pulping conditions

Conclusion

The results of this study have shown that the stalk of banana and the empty fruit bunch of oil palm are quality raw materials for pulp and papermaking. The fiber characteristics of the two raw materials compared well with commercial long and short fiber pulp wood. The stalk of banana fiber falls within long fiber category, while oil palm empty fruit bunch fiber falls within short fiber category. The two fibrous materials possess high slenderness ratio, and elasticity coefficient, low rigidity coefficient and low ronkel ratio. Consequence upon this, paper produced from them would have high tensile and burst strength. Banana stalk and oil palm empty fruit bunch fibers are characterized by high cellulose, low lignin and relatively high ash content resulting in high pulp yield, good paper strength, economy of pulping and bleaching. Pulp yield increases with decrease in the concentration of NaOH at constant temperature.

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Volumetric Shrinkage and Moisture Content Relationsof *Pterocarpus santilinoides*' Wood in Parts of Rivers State

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Abstract

This study evaluated volumetric shrinkage and moisture content relationship of Pterocarpus santilinoides' woods in Tai, Eleme and Rivers State University Campus, Port Harcourt, Nigeria. Data were collected from samples of this species of diameter classes of 10-30cm, 31-40cm and 41-50cm at 25%, 50%, and 75% of merchantable height, radially across rings and axially along the tree height. Soil samples were also collected at trees' sites and analysed for mineral content and moisture content of wood samples were measured. The results showed that there was no significant difference in the volumetric shrinkage (P> 0.05) amongst top, middle and bottom of all the diameter classes (DC) at all locations. The mean radial shrinkage (MRS) of 0.6% and mean tangential shrinkage (MTS) of 0.89 in the 10-30cm DC in Tai, 0.6 and 0.9 in the 31-40cm DC while in the 41-50cm DC MRS and MTS were 0.76 and 1.03 respectively. In Eleme LGA MRS and MTS were 0.8 and 1.16 in 10-30cm DC, 0.6 and 0.87 in the 31-40cm DC and 0.5 and 0.73 in 41-50cm DC: MRS and MTS decreased with increased DC: 0.8>0.6>0.5 (MRS), 1.16>0.87>0.73. In RSU campus, MRS was 0.7, 0.7 and 0.73 within the 10-30cm, 31-40cm and 41-50cm DCs respectively while the MTS was 0.97, 1.01 and 0.97 within the 10-30cm, 31-40cm and 41-50cm DCs respectively. The results of the correlation of moisture regimes and shrinkage of wood samples showed no significant difference (P>0.01): negative values of r^2 shows that the higher the MC, the lower the shrinkage. There exists an inverse relationship between shrinkage and soil elements like Potassium, Manganese, Zinc, and Phosphorus showed negative correlation coefficient (r^2) except others. The wood of the species is dimensionally stable, and therefore, it should be used in services in consideration of moisture changes since shrinkage was affected by of MC regimes particularly on dry basis. Strength properties of species should be studied.

Key Words: Shrinkage, Radial, Tangential and Diameter class

INTRODUCTION

Physical properties of wood are very basic to the general behaviour of wood; all the physical properties of wood are determined by the factors inherent in its structural organization. Panshin and Dezeeuw (1980) reported that physical characteristics of wood is expressed in terms of the amount of (a) cell wall substances present in a given volume of wood, (b) the amount of water present in the cell wall, (c) the proportional composition of the quantity and nature of extraneous substances present, (d) the arrangement and orientation of micro fibril (angle of the micro fibril of the S_2 layer) in the cell wall, and (e) the types, size, proportion and arrangement of the cells making up the woody tissue. Essentially, physical properties of wood are commonly observed in its specific gravity or density, moisture content, and shrinkage and swelling, among others. Shrinkage in wood is a measure of its dimensional instability leading to reduction in dimensions of wood along its principal directions (longitudinal, radial or tangential). Anisotropic shrinkage or dimensional changes occur when change in dimension is different along the different directional axes of wood leading to swelling or shrinkage (Brown, 2012). Shrinkage is unequal in the three axial directions: along the grain (longitudinal), and perpendicular to the grain (radial and tangential). In normal wood longitudinal shrinkage is quite small (less than 0.4%) but radial and tangential shrinkage is appreciable (on average 4% and 8% respectively) Jozsa and Middleton (1995). Wood shrinks and swells only with changes in the bound water content, i.e. below the FSP (Brown, 2012). Free water content has no effect on wood dimensions since it is mere vapour found in natural air spaces in the wood. Direct implications like defects (checks, warp, cup and crevices) caused by shrinkage of wood affect end use potentials especially in structural applications have been documented by Panshin and Dezeeuw (1980) and Ogunsanwo and Onilude (2000).

Wood is hydrophilic depending on the ambient temperature, fibre saturation status and in symbiotic relationship with water. Water absorption by wood frequently assumes great importance, especially in the structural uses of wood (Baronas*et al*., 2001). The periodic water absorption has a negative effect (Khazaei, 2008) and also has positive effect on wood quality depending on the end use and drying time (David, 2013). Consequently, in residential buildings, and in some industrial applications, some components are often made from wood or wood-based composites (Candanedo and Derome, 2005). The woody components of appliances like doors, window frames, crates etc. exposed to water or exposed to dryness: imbibing and desorbing water respectively thus acclimatizing to the prevailing environment is often described as air conditioner. Thus, wood is always undergoing changes in moisture content depending on the vapour pressure of its immediate environment. Understanding water absorption by wood during soaking and water desorption during drying are of practical importance, since it affects the stability and mechanical properties of the wood product. The effects of moisture content on the mechanical properties of wood have been the subject of an intense investigation worldwide (Gerhards, 1998; Obataya*et al*., 1998; Severa*et al*., 2003). All strength properties decrease as wood adsorbs moisture in the hygroscopic range below the fibre saturation point (FSP): wood swells and shrinks while above FSP, wood remains unchanged in shape and size. Important properties such as modulus of rupture and compressive strength parallel to grain may decrease up to 4 and 6 percent, respectively, for each percent increase in moisture content (Bendtsen, 1966). This study therefore evaluated volumetric shrinkage-moisture content relationship of *Pterocarpus santilinoides*' woods in parts of Rivers State.

MATERIALS AND METHODS

Wood samples for this study were collected from two locations each in Eleme, Tai and Rivers State University in Obio Akpor Local Government Areas. Tai Local Government Area (TALGA) is on latitude 4^{o}46'N and longitude 7^{o}13'E East of Port Harcourt (David-Sarogoro & Emerhi, 2016), and 15.4 miles (18.48km) away from Port Harcourt (State capital). Eleme is on Lat. 4.51^{o}N and Longitude 7.01^{o}E (Tariah, *et al*., 1991), and Rivers State University, Port Harcourt in Obio-Akpor on Latitude 6^{o}44'N and 7^{o}33N and Longitude 4^{o}38'E and 5^{o}5'E (David-Sarogoro, 2016) Local Government Areas all in Rivers State. Three standing trees were selected and cut from each diameter classes of 10-30cm, 31-40cm and 41-50cm with a diameter tape at strategic positions of 25%, 50%, and 75% of merchantable height (Akachukwu, 1984; Mitchell and Dane, 1997; Akpofure, 1992).

Radial Variation: Wood samples were collected from three positions across the rings-near pith.

Axial: Along the Bole Variation- Wood samples were collected from 3 discs-top, middle and base.

Volumetric Shrinkage Procedure

Wood samples of 20 x 20 x 40 mm were prepared and aligned to represent planes of wood i.e. radial, tangential and longitudinal and dried samples were soaked in water for 48 hours in order to get them conditioned to moisture above fibre saturation point (FSP). They were removed one after the other and their dimensions were measured in wet condition to their nearest millilitre and oven dried to constant weight and measures the dimension again.

Volumetric shrinkage was determined using the formula:$V = SR + ST$ Ogunsanwo and Omole, 2010)

Where: VS=Volumetric Shrinkage, SR=Radial Shrinkage, ST=Tangential Shrinkage

Moisture Content (Wet and Dry basis) and Absorption Percentage

Samples (wood cubes-20 x 20 x 40 mm) were measured before (wet) taken in a crucible and kept in an oven maintained at 105^o C for 48 hours till the weight stabilized and reweighed (Wo). The weight loss was measured and the moisture content of the sample was estimated as follows.

Moisture Content (Wet basis) = $\frac{Wwt - Wo\ X\ 100}{Www}$

Moisture Content (dry basis) = $\frac{Wwt - Wo\ X\ 100}{Wwd}$

Where: Wwt = Total weight of wet samples

Wo = Oven dry weight of samples, Www = Total weight of wet samples, Wwd = Total weight of dry samples.

Soil Analysis

Soil samples were collected with soil auger at various sites of study from the various Local Government Areas sampled. The mineral compositions of the soil samples were composited and ashed at 550° C for 48 hours; the ash from each was digested with 10ml of 10% HCL in a beaker. The mixture was filtered and 50 ml of the filtrate placed in the flask with deionised water, which was used to standardize the solution. The minerals were determined using Atomic Absorption Spectrophotometer (AAS) at University of Port Harcourt. The following minerals were assessed: - Sodium (Na), Potassium (K), Magnesium (Mg), Calcium (Ca), Iron (Fe), and Zinc (Zn), Lead (Pb), Copper (Cu) and Manganese (Mn).

Experimental Design/ Data Analysis

Randomized Complete Block Design (RCBD) was adopted for the study and treatments replicated thrice. Descriptive statistics were used where necessary; data were analysed using two-way analysis of variance (ANOVA) at probability level of 5%. Pearson correlation analysis was used to compare effects of soil properties on shrinkage characteristics and between moisture content and shrinkage of wood.

RESULTS

Shrinkage of the wood species

The results presented in Table 1 showed that there was no significant difference in the volumetric shrinkage (P>0.05) amongst top, middle and bottom of all the diameter classes (DC) at all the various locations. Within Tai, mean VS ranged from top to bottom 1.45, 1.50 and 1.80 within of the10-30cm, 31-40cm and 41-50cm respectively. Similarly, mean tangential/radial ratio ranged from 1.46, 1.52 and 1.34 In Eleme LGA, mean VS were 1.96, 1.46 and1.23 and average T/R ratio were 1.45, 1.38 and 1.48 within the10-30cm, 31-40cm and 41-50cm respectively, while within RSU campus, the trees had within the 10-30cm DC at top, middle and bottom, VS of 1.80, 1.60 and 1.60 and T/R ratio of 1.57, 1.28 and 1.28 respectively, and within the 31-40cm DC, VS was 1.80 at top, 1.50 at middle and 2.00 at bottom while T/R ratio was 1.57, 1.50 and 1.50 at top, middle and bottom respectively. The 41-50cm DC had VS of 1.60 at top and middle and 1.90 at bottom and T/R ratio of 1.00, 1.28 and 1.71: top, middle and bottom respectively (Table 1). *Pterocarpus santalinoides* had a mean radial shrinkage (MRS) of 0.6% and mean tangential shrinkage (MTS) of 0.89 in the10-30cm DC in Tai, 0.6 and 0.9 in the 31-40cm DC while in the 41-50cm DC MRS and MTS were 0.76 and 1.03 respectively. Similarly, in Eleme LGA MRS and MTS were 0.8 and 1.16 in 10-30cm DC, 0.6 and 0.87 in the 31-40cm DC and 0.5 and 0.73 in 41-50cm DC: MRS and MTS decreased with increased DC: 0.8>0.6>0.5 (MRS), 1.16>0.87>0.73 (Table 1). In RSU campus, MRS was 0.7, 0.7 and 0.73 within the 10-30cm, 31-40cm and41-50cm DCs respectively while the MTS was 0.97, 1.01 and 0.97 within the 10-30cm, 31-40cm and 41-50cm DCs respectively (Table 1).

Table 1: Volumetric Shrinkage of Wood of *Pterocarpussantalinoides*

			Radial	**Tangential**	**VS**	**T/R**
Tai	10-30cm	Top	0.7	0.9	1.6	1.28
		Middle	0.5	0.8	1.3	1.60
		Bottom	0.6	0.9	1.5	1.50
		Mean	**0.6**	**0.89**	**1.45**	**1.46**
	31-40cm	Top	0.6	0.8	1.4	1.33
		Middle	0.5	0.9	1.4	1.80
		Bottom	0.7	1	1.7	1.42
		Mean	**0.6**	**0.9**	**1.5**	**1.52**
	41-50cm	Top	0.8	1	1.8	1.25
		Middle	0.7	0.9	1.6	1.28
		Bottom	0.8	1.2	2	1.50
		Mean	**0.76**	**1.03**	**1.8**	**1.34**
Eleme	10-30cm	Top	0.8	1.2	2	1.50
		Middle	0.7	1	1.7	1.42
		Bottom	0.9	1.3	2.2	1.44
		Mean	**0.8**	**1.16**	**1.96**	**1.45**
	31-40cm	Top	0.6	0.9	1.5	1.28
		Middle	0.5	0.8	1.3	1.60
		Bottom	0.7	0.9	1.6	1.28
		Mean	**0.6**	**0.87**	**1.46**	**1.38**

	41-50cm	Top	0.6	0.7	1.3	1.16
		Middle	0.4	0.6	1	1.50
		Bottom	0.5	0.9	1.4	1.80
		Mean	**0.5**	**0.73**	**1.23**	**1.48**
UST	10-30cm	Top	0.7	1.1	1.8	1.57
		Middle	0.7	0.9	1.6	1.28
		Bottom	0.7	0.9	1.6	1.28
		Mean	**0.7**	**0.97**	**1.67**	**1.37**
	31-40cm	Top	0.7	1.1	1.8	1.57
		Middle	0.6	0.9	1.5	1.50
		Bottom	0.8	1.2	2	1.50
		Mean	**0.7**	**1.01**	**1.71**	**1.52**
	41-50cm	Top	0.8	0.8	1.6	1.00
		Middle	0.7	0.9	1.6	1.28
		Bottom	0.7	1.2	1.9	1.71
		Mean	**0.73**	**0.97**	**1.7**	**1.33**

Moisture Content on Location and Radial-Tangent of the species

The results of the correlation of moisture regimes and shrinkage of wood samples (Table 2) showed that in Tai, Eleme and RSU, the radial shrinkage was not significant (P>0.01) with *P-value*s 0.786, 0.433 and 0.446 and correlation coefficients (r^2) are -0.069 (6.9%), -0.193 (19.3%) and -0.192(19.2%) respectively. The negative values of r^2 shows that the higher the MC, the lower the shrinkage.

Table 2: Correlations Table of Moisture Content and shrinkage on Location and Radial-Tangent of the species

Planes	**Tai-MC** n=18	**Eleme-MC** n=18	**RSU-MC** n=18
Radial	-0.069^{ns}(0.786)	-0.193^{ns}(0.433)	-0.192^{ns}(0.446)
Tangential	0.931^{**}(0.442)	0.342**(0.965)	0.630**(0.943)

** Correlation is significant at 0.01 level (2-tailed) at P<0.05, ns=not significant P>0.05: *P-values* in bracket

The result of correlation of shrinkage and the soil minerals from Table 3 showed that the following minerals were significant (P<0.01) Potassium, Calcium, Manganese, Zinc, Iron, Copper and Sodium while the other mineral elements were not significant (P>0.05). Potassium, Manganese Zinc and Phosphorus showed negative correlation coefficient (r^2) except others. This shows that the higher the element, the lower the shrinkage or vice versa, while r^2 positive in Calcium Lead Manganese Iron Copper and Sodium indicates that the higher the element, the higher the shrinkage.

Table 3: Effects of Soil Minerals on Shrinkage the species

Soil Minerals	**Significance %**	***P-value***	**Remark**
pH	18.3	0.468	ns
Potassium	-90.0	0.000	**
Magnesium	-19.0	0.451	ns
Calcium	89.7	0.000	**
Lead	13.6	0.591	ns
Manganese	90.8	0.000	**
Zinc	-61.8	0.006	**
Iron	62.5	0.006	**
Copper	60.3	0.008	**
Sodium	68.1	0.002	**
Phosphorus	-32.1	0.189	ns

*** Correlation is significant at 0.01 level (2-tailed) at P<0.05, ns=not significant P>0.05: P-values*

DISCUSSION

The findings that low volumetric shrinkage (1.61%) and the T/R (0.95%) ratios of *Pterocarcarpus santalinoides* agrees with Jozsa and Middleton (1995) that observed that when lumber is dried below the fibre saturation point, it will shrink in width or thickness about 1% for each 4% reduction in MC. The low T/R ratios observed in the study shows that the *Pterocarcarpus santalinoides'* wood is suitable for some end-users, which agrees with Ogunsanwo and Omole (2010) that low value of T/R is synonymous with high suitability of wood for end use. This result disagrees with Samuel and Samuel (2012) that observed volumetric shrinkage (5.8%), tangential shrinkage (4.4%) and radial shrinkage (2.6%) of redwood species. The findings that low volumetric shrinkage and the T/R ratios of *Pterocarcarpus santalinoides* may be due to evenly response of wood cells within its surface area of wood-water interphase as hydrophilic nature of the wood resulting in creation of new bond with forced minimum disordered causing the shrinkage affected their dimensions. This agrees with David (2013) that observed no end checks (facial defects) on the woods of *Pterocarpus santalinoides* at moisture content 18% (dry basis) but various surface checks was exhibited by *Anthocleista djalonensis* at the same moisture content. This implies that on oven drying the *Pterocarpus santalinoides* wood, its shrinkage observed was an indication of loss of inherent moisture from interstice of individual wood cells (David, 2013).This refers to chemically bound water, which is locked onto OH groups of cellulose, hemicellulose and lignin molecules within its cell wall (Jozsa and Middleton, 1995).According to Jozsa and Middleton (1995), shrinkage occurs when water molecules vacate the microfibrillar spaces reaching maximum levels in the oven-dry (moisture free) condition.

Jozsa and Middleton (1995) adduced reasons for the shrinkage (anisotropic) to the various wood planes-structure and orientation of the cellulosic micro-fibril of the cell walls as well as the elongated shape of the individual fibres, infrequent pitting on the tangential surfaces, numerous pitting on the radial surfaces and reinforcing effect of rays on radial planes. Dimensional stability influences construction efficiency and structural serviceability and depends on anatomical and chemical properties of the wood (Jozsa and Middleton, 1995) and site factors especially edaphic like mineral elements potassium, calcium, manganese, zinc, iron, nitrogen, sodium which showed significant impact on shrinkage. This supports Aguilar-Rodriguez *et al*., (2006) as reviewed by Zobel and Van Buijtenen (1989) that reported the effects of chemical or physical soil characteristics on wood quality like density, specific gravity and strength properties of teak. Similarly, Kokutse *et al*., (2004) found that the heartwood percentage, wood density, the dynamic elastic modulus and moisture content depended on mineral elements of the soil (site location). Dünisch and Bauch (1994) reported on the effect of water content and mineral nutrients of soil on the size of growth rings for *Picea abies*. Rigatto *et al*. (2002) found soil chemical properties affected wood quality and physical properties affected the production of cellulose in *Pinus tadea*, evidenced by the low wood density, short fiber wide cellular wall, high contents of extractives and lignin, and low contents of cellulose. Yáñez *et al*., (2004) found that soil texture and water salinity were highly correlated with anatomical characteristics of four species in a mangrove forest community in Mexico. Classification of wood species based on the lower dimensional shrinkage, *Pterocarpus santalinoides* could be placed in Millwork/European Joinery Grades (National Lumber Grades Authority) (Jozsa and Middleton, 1995). This class is material can be used or be remanufactured into components for items such as windows, doors, furniture, and cabinets where appearance and dimensional stability are important (Jozsa and Middleton, 1995).

CONCLUSION

The study has established that the wood of *Pterocarpus santalinoides* has low shrinkage on the various planes irrespective of the parts of tree used. Moisture content had inverse relation with shrinkage of the species, though; some soil minerals had effect on shrinkage indicating edaphic effect. The findings of this study presupposes that the species could be used or be remanufactured into components for items such as windows, doors, furniture, and cabinets and even high pressure parts of tools like working tool handles without splitting in general in construction especially in timber industry. The wood of the species is dimensionally stable and therefore, it should be used in services in consideration of moisture changes consideration since shrinkage was affected by of MC regimes particularly on dry basis. However, soil chemical composition had effect on shrinkage. The wood of the species from different locations with different soil chemical constituents varied in difference in shrinkage. The strength properties of species should be studied to know its applicability for structural purposes.

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SUB-THEME 8

Sustainable Production, Harvest and Replenishment of Non-Timber Forest Products (NTFPs) in Nigeria

Emerging Potentials of Mushroom as a Non – Timber Forest Product in Nigeria- A Review

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Abstract

Mushrooms are non-timber forest products (NTFP) which grow on both terrestrial and ligneous habitats and are widely distributed in Nigeria. They are macro-fungi with large fruiting bodies which are produced above ground or on suitable surfaces, mainly agricultural waste. They belong to two subdivisions of fungi; Basidiomycetes and Ascomycetes, about 140,000 species exist in the world and only about 10% are known. Mushrooms are reported to possess high nutritional properties and are rich in protein, vitamins, dietary fibre and minerals with about 2000 species of mushrooms safe for consumption. Studies have documented that certain mushrooms exhibit medicinal properties due to presence of some bioactive compounds and anti-oxidants such as ascorbic acid, carotenoid, flavonoids, phenolics and terpenoids. These characteristics have made mushrooms to obtain wide applications in producing antibacterial agents, liquid biofertilizers and complementary food for infants. Hence, they are known for their economic, health, nutritional and aesthetic benefits. Mushrooms like Pleurotus ostreatus have been successfully used for bioremediation of soil contaminated by petroleum hydrocarbons. Despite this wide range of benefit, petroleum hydrocarbon, pesticide application, deforestation and desertification have contributed to the reduction in the quantities of mushrooms growing in the wild in Nigeria. Improved propagation of mushrooms in Nigeria can develop rural economy, boost industrialization and earn the country foreign exchange. Consequently, sustainable production of mushroom is therefore required so as to harness the benefits, while further studies should be encouraged on determining optimal conditions for propagation of mushrooms in Nigeria.

Keywords: Potentials, Mushroom, Non – timber Forest Product, Nigeria

INTRODUCTION

Non – timber forest products (NTFPs) can be defined as biological resources other than timber, harvested from either natural or managed forests. NTFPs include fruits, mushrooms, wild games, firewood, nuts, seeds, oils, spices, resins, gums, medicinal plants and fibres. They are highly valued for their leaves, roots, bark and fruit which serves as source of food, income and medicinal materials (Adedayo, 2018; Chidiebere-Mark et al., 2016). other than woods . NTFPs are important part of forest and forest use in many parts of the world (Global Forest Atlas, 2018). In India over 50million people are dependent on NTFPs for their subsistence and cash income. In Zambia it contributes to rural household income and food security; while in developing countries, Nigeria inclusive, in forest based activities NTFPs accounts for up to 17 million full time jobs in the formal sector and 30 million in the informal sector (Suleiman *et al*., 2017; Olaniyi *et al*., 2013).

NTFPs also contribute to 13% – 35% of all rural non – farm employment in the developing countries. In Nigeria alone, rural households derived up to 80% of their incomes from the sales of NTFPs (Suleiman *et al*., 2017). They are important forest products that form alternative sources of livelihoods. NTFPs contribute to poverty alleviation by generating income, food, improved nutrition, medicine and foreign exchange earnings (Olaniyi *et al*., 2013). Due to these benefits, there is a growing awareness of NTFPs contributions to household economies, national economies and conservation of biodiversity. Nevertheless the role of NTFPs to rural households cannot be over emphasized; providing foods to supplement and complement the daily diet of the rural poor. In fact, many rural poor all over Africa would have been showing signs of malnutrition if not for the food provided by NTFPs in form of forest fruits and vegetables (Adedayo, 2018).

Mushrooms being a non – timber forest product can contribute to the livelihood of rural dwellers (Tijani, 2019). Mushrooms are also highly nutritious, rich in protein, vitamins, dietary fibre, minerals and all the nine essential amino acids required by human. Some also contain bioactive compounds such as ascorbic, alkaloids, carotenoids, flavonoids, folates, glycosides, lectins, phenolics, terpenoids, tocopherols. All these have implications to prevent or treat various types of diseases (Buba *et al*., 2018). They are used to prevent or treat diseases such as Parkinson, Alzheimer, tumor, cancer, hypertension and high risk of stroke. Some mushrooms serve as antimicrobial agents, enhances the immune system and lowers cholesterol level (Valverde *et al*., 2015). Due to their nutritional and medicinal values, mushrooms are regarded as an excellent source of nutrition to combat malnutrition in developing countries (Buba *et al*., 2018).

Edible mushrooms are usually collected from wild woodlands in developing countries, however their quantities are reducing due to degraded environment, deforestation and desertification; sustainable production of mushroom is therefore necessary. In Nigeria, farmers are being trained to produce mushrooms by using different substrates, especially agricultural wastes. The trainings are carried out by research institutes such as Forest Research Institute of Nigeria (FRIN), Institute of Agricultural Research and Training (IAR&T) and non – governmental organisations (Tijani, 2019). Mushrooms are fruiting bodies of macro - fungi that are produced above ground or on substrate and are large enough to be seen with the naked eye and to be picked up with bare hands Elenwa et al., 2019) They have been found growing on substrates such as dead woods, fallen trees, soil debris, wastes, termite nests, and palm trees, cassava peels in forest and bush areas, swamps, grassy places, cocoa plantations and burnt bushes.

In Nigeria, mushrooms grow throughout the year with the highest occurrence mostly in April to June. However, petroleum hydrocarbons, pesticide application, deforestation and desertification have contributed to the reduction in the quantities of mushroom growing in the wild in many developing countries (Adeniyi *et al*., 2018). Several researches on mushroom production and its benefits have been carried out in recent times. This review aims to compile information on the emerging potentials of mushrooms in Nigeria and to encourage sustainable production of mushrooms.

RECENT RESEARCHES ON MUSHROOM IN NIGERIA

The distribution of wild mushroom in a Nigerian forest reserve, Environmental Pollution Science and Technology (ENPOST), Ilesha, Southwestern, was studied by Adeniyi *et al.* (2018). Mushrooms were found to grow in two habitats; the ligneous (woody) and terrestrial habitats (land). The terrestrial habitat consists of soil heap, termite mound, soil debris, bank of fish pond while the ligneous habitat include root, stump, stem log, branch, leaves and twig of dead wood such as *Magnifera indica, Pseudospondias microcarpa, Gliricidia sepium, Musa paradisiaca* and *Pycnanthus angolensis*. The species of mushrooms that grew in the ligneous habitats were higher (54.31%) than those on the terrestrial habitat (45.03%). Examples of wild mushrooms found at ENPOSTare shown in figure1 below.

A B C D

Fig 1: Examples of wild mushrooms found at ENPOST Ilesha, Southwestern, Nigeria. A. *Auricularia auricularia* – judae; B. *Daldina concentric*; C. *Lycoperdon spadiceum*; D. *Peziza aurantia*.

In a study carried out in the savannah ecological zone of Bauchi State in 2016 and 2017 from the onset of rain till the end of the rainy season; 31 different edible mushrooms species were found and they largely belong to the families of Agaricaceae, Lyophyllaceae and Polyporaceae (Table 1). These species were found in 18 different microhabitats such as arable lands which is now under cultivation, fallow lands, and soils around dead tree stumps, decaying woods and 14 different living tree species. Out of the 31 species, 21 species were found in 2016 while 24 species were found in 2017 and only 13 species were found both in 2016 and 2017 even though the difference in number of species between 2016 and 2017 was not statistically significant (p value – 0.961) (Buba *et al*., 2018).

Table 1 : Some edible mushrooms found in the savannah ecologicalzone of Bauchi State, Nigeria

Family	Species
Agaricaceae	*Agaricus augustus*
	Agaricus bitorquis
	Agaricus impudicus
	Agaricus subrufescens
	Bovista colorata
	Bovista plumbea
	Bovista sp
	Calvati cyathiformis
	Chlorophyllum brunneum
	Chlorophyllum rachodes
Lyophyllaceae	*Termitomyces eurrhizus*
	Termitomyces microcarpus
	Termitomyces reticulatus
	Termitomyces robustus
Polyporaceae	*Lentinus concavus*
	Lentinus trigrinus
	Pycnoporus cinnabarinus

Source: Buba *et al*. (2018)

The research by Adejo and Ademu (2018) revealed that the people of Dekina Local Government Area of Kogi State, Nigeria consume more of Oru – olih (*Auricula auricularia*) mushroom species followed by Trimela fungi formis (Oru – Elikpo) and Red stropharia (Oru – Akpetina). They are consumed for their medicinal, palatability and nutritional purposes as well as being a close substitute to meat or fish. It was also revealed that mushroom can be consumed in roasted, dried, fried and parboiled forms. The factors affecting mushroom consumption include seasonality of production (76.32%) which is the most common factor identified followed by problems of identifying edible species (48.1%), then allergy in consumption (34.4%), knowledge of preservation (40.0%), problems of shelf life (25.6%) and market proximity (39.4%).

In the study done by Okigbo and Okigbo (2018), a newly discovered mushroom, *Cantharellus spp*. was found to be edible and it is so valued in the locality such that it is used in preparing soups on special occasions such as marriage and burial ceremonies. It is also used to welcome special visitors into their home. *Cantharellus spp* is also preserved and sent to family members living abroad and freshly harvested ones can stay up to two weeks without spoiling. Another mushroom *Termitomyces* spp is regarded as bringing good omen. When found in the bush, it's an indication that the gods want to bless you and as soon as it is seen there are words to recite so that anybody passing through the route will not see it except you. *Termitomyces sp* is very expensive and tastes like chicken and very rare to come by. The rule is that when found in the wild, the hunter should share with neighbours and upon receipt a gift will be presented to the hunter in return along with verbal offerings of blessings.

Chukunda and Nnandi (2018) identified and evaluated the nutrient compositions of two wild edible mushrooms in Oduoha – Emohua Forest, Rivers State. The two mushrooms are *Pleurotus citrinopileatus* and *Pleurotus tuber-regium* whose occurrence had been reported by several researchers. The result of proximate composition revealed that the two mushrooms were rich in carbohydrate, moisture, crude proteins, lipid and total ash which is an indication that they are good mushrooms and can be used as supplementary nutrition in the diet of man.

Adebiyi and Yakubu (2016) carried out a survey of mushrooms in two Local Government Areas of Ekiti State, Nigeria. 109 samples were collected and 19 species were discovered out of which 11 are edible and 8 species are inedible (Table 2). The morphological studies was carried out and the mushrooms were distributed among 13 different families which includes Schizophyllaceae, Lycophyllaceae, Pleurotaceae, Agaricaceae, Coprinaceae, Russulaceae, Hymenochaefaceae, Polyporaceae, Auriculaceae, Ganodermataceae, Nidulariaceae, Geasteraceae and Stereaceae. The rich diversity of mushrooms in Ekiti State has socio – economic advantage.

Table 2. Edible and Inedible mushrooms in two Local Governments in Ekiti State.

S/N	Scientific name	Local name	family	Substrate	Status
1	*Schizophyllum commune*	Ese adiye	Schizophyllaceae	Leaf litters	Edible
2	*Termitomyces mammiformis*	Osun rooro	Lycophyllaceae	Soil	Edible
3	*Lentinus tuber regium*	Osun Owu	Pleurotaceae	Ploughed land	Edible
4	*Lentinus squarrosulus.*	Osun awo	Polyporaceae	Dead wood	Edible
5	*Agaricus campestris*	Osun tractor	Agaricaceae	Ploughed land	Edible
6	*Psathyrella candolleana*	Osun wowo	Psathyrellaceae	Dead wood	Edible
7	*Termitomyces robustus*	Osun ogogo	Lycophyllaceae	Soil	Edible
8	*Lactinus piperatus*	Osun ata	Russulaceae	Dead tree	Edible
9	*Hydnochaete* spp.	Atipa – tipa	Hymenochaetacea	Mango tree	Edible
10	*Lentinus sajo-caju*	Owu oyibo	Polyporaceae	Cultivated soil	Edible
11	*Polyporus* spp.	Eleuruju	Polyporaceae	Wood	Edible
12	*Auricularia* spp.	Unknown	Auriculariaceae	Dead tree	Inedible
13	*Chlorophyllum* spp.	Unknown	Agaricaceae	Trees	Inedible
14	*Trichaptum biforme*	Unknown	Polyporaceae	Hardwood	Inedible
15	*Ganoderma applanatum*	Unknown	Ganodermataceae	Dead wood	Inedible
16	*Coprinus nivenus*	Unknown	Agaricaceae	Palm frond	Inedible
17	*Cyathus* spp.	Unknown	Nidulariaceae	Wood	Inedible
18	*Geastrum* spp.	Unknown	Geastraceae	Rotten leaves	Inedible
19	*Stereum* spp.	Unknown	Stereaceae	Tree bark	Inedible

Source: Adebiyi and Yakubu, (2016)

EMERGING POTENTIALS OF MUSHROOM IN NIGERIA

Restoring the aesthetic beauty of our ecosystem: Agricultural waste is of primary concern in our world today, especially its disposal without pretreatment can result in environmental pollution. However, cultivation of mushrooms with agro-wastes serves as an eco-friendly method to reduce the nutrient level in these wastes to acceptable level to be used as manure. In the study carried out by Peter *et al*. (2019) *Pleurotus ostreatus* (oyster mushroom) has been found to convert lignocellulosic waste materials into human food. The waste include cassava peel, banana leaves, saw dust, yam peel and groundnut shell. Osunde *et al*. (2016) also cultivated mushroom on wastes (corncob, sawdust and waste paper) and the proximate composition of the mushroom was analysed.

As an antibacterial agent: according to Ikon *et al*. (2019) Pleurotus ostreatus was screened for antibacterial activity and it showed its ability to inhibit pathogenic microorganisms in the order of the diameter of zones of inhibition, 27.50mm > 25.30mm > 24.40mm for Staphylococcus aureus, Proteus sp and Escherichia coli respectively in ethanol extract. Moreover, there are documented evidences on the effectiveness of oyster mushrooms against drug resistant *Escherichia coli* and Staphylococcal infections. Drugs made from macro fungi have been shown to be readily available, effective, less expensive with minimal or no side effects.

Production of liquid biofertilizer: In recent times, liquid biofertilizer has been found to have advantages over solid biofertilizer such as no contamination, better survival on seeds, longer shelf-life, less dosage and easy to use. The study carried out by Okolie *et al*. (2018) revealed that liquid biofertilizer can be produced from cassava peel and spent mushroom substrates(i.e substrates that mushroom had grown in it and has been harvested). The biofertilizer produced was found to be biodegradable because the carbon Nitrogen ratio of the biofertilizer is 0.396, less than 20 which researchers had stated that it is easily degraded. The shelf-life was also found to support the entire crop cycle.

Production of complementary food for infants: In the research carried out by Ikujenola and Ogunba (2018), complementary food was produced from quality protein maize supplemented with sesame and mushroom (*oudemansiella radicata*). The results of the proximate composition of the mixture revealed that the protein content has a better chance to sustain infants. The protein content however was improved by the addition of sesame and mushroom. Also, the fat content of the mixture was found to be 2.41 – 4.67% and appropriate for infant growth according to Protein Advisory Group (PAG) which states that fat in food meant for infant should be less than 10%.

Health Benefits: researchers have stated that mushrooms have bioactivities, anti-inflammatory, anti – tumor, anti – oxidant and antiviral functions. Mushrooms are also beneficial for treating breast cancer, prostrate, diabetes, high cholesterol levels and cardiovascular diseases (Acham et al., 2018). The study conducted on Igala land in North Central Nigeria revealed that some edible mushrooms are consumed for medicinal reasons (Table 3).

Table 3. Mushrooms useful for medicinal purpose by the Igala people of Nigeria.

Mushroom	Local name	Ailment used to treat	Mode of preparation	Mode of administration
Polyporus officinalis	Oru akpayi	Hernia, cough and catarrh	Boil together with other herbs	Drink it hot
Sclerotia of pleurotus tuberregium	Oru owo or oru akpaya	Hypertension, fever, diabetes	Boil in wrapped banana leaves and spices	Eat when boiled
Termitomyces robustus	Oru obe or oru okiti	Malaria fever	Make into pepper soup	Eat and drink the soup
Termitomyces letestui	Oru aberedodolo or oru ogbagbajele	Malaria, fever, stomach upset	Dry and grind into powder	Eat and drink the soup
Unidentified	Oru okpoli	fever	Cook with soup	Eat and drink the soup
Unidentified	Oru okpoli	fever	Cook with soup	Eat and drink the soup

Source: Acham et al., (2018)

Nutritional benefits: the nutritional benefits of edible mushrooms is due to their beneficial components such as dietary fibre, protein, vitamins, mineral, low levels of calories, low levels of fat and toxic metals. They also contain vitamin D, iron and selenium. Selenium was observed can help in losing weight of the body (Acham *et al*., 2018).
Bioremediation: Contamination of soil by petroleum hydrocarbon has been a major problem in most countries including Nigeria. Spent mushroom (*Pleurotus ostreatus*) substrate, a composited organic material remains after mushroom has been harvested was used to treat soil contaminated by crude oil. It is used due to its ability to catabolize pollutant thereby decreasing pollutants in contaminated soil. The treated soil supported the growth of maize by 60% (Chukwumati *et al*., 2019).

Development of rural economy: Qualitative research carried out across households in Ihiagwa, a rural community in Owerri South East, Nigeria revealed that 161 households in the area can gather about 370kg of mushroom annually which can provide an estimated value of 855,081 NGN per annum to household income (Onyema *et al*., 2019).

PROPAGATION AND MARKETABILITY OF MUSHROOM IN NIGERIA

In developing countries, mushrooms are usually harvested from wild woodlands. However, mushrooms are reducing in quantity from degraded environment and nature resources. Due to this, farmers are being trained to produce mushrooms from agricultural wastes and other substrates for sustainable production of mushrooms (Tijani, 2019). Several researchers have grown mushrooms using agricultural wastes (Peter et al., 2019; Osunde et al., 2016; Ajayi et al., 2015). Mushrooms are sold in local markets in Nigeria and other countries (Onyema et al., 2019; Elenwa et al., 2019; Doaa et al., 2020) as a source of livelihood. Mushrooms can be considered by industries to be used for the production of infant food due to their nutritional benefits; sold in cans as canned foods as it obtains in Egypt and also for the production of liquid biofertilizers (Doaa et al., 2020; Ikujenola and Ogunba, 2018; Okolie et al., 2018

Conclusion

Mushrooms are valuable non-timber forest products (NTFP) which possess huge domestic, nutritional, health, industrial and economic potentials in Nigerian economy. However, mushrooms are reducing in quantity in the wild in developing countries. Controlled and concerted propagation of edible mushrooms must be encouraged at the rural communities to ensure its availability all year round for consumption and industrial purposes. This can be done through public enlightenment on the beneficial uses of mushrooms and training of local farmers on mushroom production by various research institutes and non-governmental organizations. Studies should be conducted into the optimal conditions required for growth of mushrooms.

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Decomposition Rate of *Albizia zygia* (DC.) J. F. Macbr and *Albizia adanthifolia* Leaves (Schum.) W. Wight on Soil Properties

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Abstract

This study was carried out to investigate the effects of decomposition rate and soil physical properties of Albizia zygia and Albizia adanthifolia leaves on soil properties. Fresh leaves of agroforestry tree species were collected and applied as mulch on demarcated 12 micro-plots of 2m by 2m. These fresh tree species leaves were replicated three times. Soil samples from the mulched plots were collected from depth 0 to 15 cm after eight weeks and nutrient elements such as soil nitrogen and phosphorus were analyzed. Also soil moisture and temperature were measured to assess the rate of decomposition by the physical properties. The analysis showed that application of the mulch materials tend to reduce the temperature and increase the moisture content of the soil. The nutrient contents (N and P) tends to increased moderately on each plot except on the control plot compared with the initial analyses taken. The lowest soil temperature of 28.4^{0}C was observed under the mixture of Albizia zygia and Albizia adanthifolia and least soil moisture 7.8% on the plots of Albizia zygia for the eight weeks period. Hence, there is need for proper selection of mulch materials which can bring about direct and indirect influence on the soil necessary for basic plant nutrition.

Keywords: Soil fertility, *Albizia zygia, Albizia adanthifolia*,soilmoisture, temperature and mulching

INTRODUCTION

Many farmers in sub Saharan part of the Africa especially Nigeria practiced for a very long time using certain substances (such as cow dung, poultry manure and wood ash), on the soil to improve soil fertility and production, commonly called fertilizers that is loss due to deficiency of some nutrient element (Ayeni, 2011). According to Banyong *et al*., (2014), crop productivity can be improved through addition of chemical fertilizers and the use of organic fertilizers such as compost or farmyard manure and recycling of crop and organic residues in production systems. However, lack of availability of organic fertilizers in sufficient quantities, cost of chemical fertilizers which make it generally out of reach for many poor farmers and the high cost of transporting the bulky materials of both fertilizers are major constraints (Batiaono, 2001; Ayeni, 2011)

Soil quality and soil fertility management is of fundamental importance for agricultural production in Nigeria, which has increasingly becoming a debate in decision making on food security, poverty alleviation and environmental sustainability and human health (white et al., 2012;) In the past years, soil nutrition declined rapidly during cultivation due to factors such as erosion, leaching, nutrient uptake by cultivated crops, uncontrolled burning and reduced decomposition of litter to the soil which affects the rate of humus in the soil as well role of soil pH in plant nutrition which in due cause affect the biological processes in the soil, nutrient imbalance, increase in soil bulk density and low infiltration rate (Tilman 1998; Gyaneshwar *et al*., 2002; Kennedy *et al*., 2004). The persistence of these problems may be due to inefficiency use of fertilizers applied to plants externally and also due to its long termand excessive application (Barlog and Grzebisz, 2004). Also, as reported by Batiano and Mokunye, 1991, removal of soil nutrients due to continuous cropping reduces the soil organic matter, cause acidification and yield reduction of crops. Even though high crop yield are obtained with the application of inorganic fertilizers and enhanced crop yields obtained alternatively for improving soil fertility and productivity, integrated to this effect is that it is economically and environmentally implicated (Batiano and Mokunye, 1991; Batiano *et al*., 2004). This necessitated the search for alternative sources of maintaining the fertility of the soil.

Integrating leguminous trees as well as its leaf biomass into farmland help maintain soil fertility by adding humus to the soil, improving soil physical, chemical and biological properties of soils and crop performance status in which their roots absorb nutrients from beneath the soil (Osunde, 1995; FAO, 2005; Kareem, 2014) . Such crops have aided in the recovery of marginal lands for agricultural development due to their ability to fix nitrogen, control erosion, and act as a refuge for other species, in addition to their capacity to improve soil mineral composition and microbial biodiversity (Castro *et al.*, 2017).

Also, it contributes to improving soil structure and aggregation as well as decrease soil bulk densities and increased the percentages of pore spaces and activities of soil organism which therefore result in increased infiltration of soil water and water holding capacity (Olojugba and Oke, 2015). According to Banyong *et al.*, 2014, it is necessary to integrate tree species especially those that improves soil fertility into soil and farmland in order to enhance sustainability in the long run. Some of these leguminous trees are known to biologically fixing atmospheric nitrogen (N) in symbiosis with *Rhizobium* bacteria which can at least partly reduce the nitrogen fertilizer requirement of the main field crop in rotation. Thus, commonly available and affordable source of nitrogen to many poor farmers even though they cannot totally replenish loss soil fertility. It is important to know that several leguminous trees such as *Gliricidia sepium, Albizia lebbeck, Albizia zygia, Albizia adanthifolia, Leucaena leucocephala* and *Azadirachta indica* are used to improve the fertility of soil which have solved enough soil problems as compared to inorganic fertilizer and animal source of organic fertilizer that are usually insufficient and unavailable quantities on most farms and as well as application that is labour intensive (Jama *et al.*, 2000; Damian *et al.*, 2015). Although high crop yield are noted to be obtained with the application of inorganic fertilizers, but both have economic and environmental implications (Ugwu *et al.*, 2017; Damian *et al.*, 2015). Asserted by many researchers, *Albizia zygia* and *A. adanthifolia* can help to replenish soil organic matter and nutrient status by protecting the soil against soil erosion, enhancing humus and nutrient accumulation in the soil through litter fall and mineralization and by recycling nutrients leached into the sub-soil back to top soil (Sylvia *et al.*, 1999; Harris,2002).

This work is aimed at investigating and examining the soil fertility effects of *Abizia zygia* and *Albizia adanthifolia* leaf biomass in soil productivity on soil temperature, and moisture. Thus, a special emphasis is placed on the use of these two legumes species to improve fertility and increase crop productivity.

MATERIALS AND METHODS

Study Area

The experiment was conducted at the Agroforestry Site of the Department of Forestry and Wood Technology, Federal University of Technology Akure, Nigeria. The site was on latitude 7° 17′ N, longitude 5° 10′ E, and falls into 350 m above sea level in the humid tropical rainforest zone of Nigeria. It has an annual average rainfall of between 1500-1800mm and the elevation is about 65m with gently undulating land form. Relative humidity ranges between 85% and 100% during the raining season and less than 60% during the dry period from November to April and a mean annual temperature of 26^0 C.

Experimental Procedures

Complete Randomized Design (CRD) was used for the experimental layout. The mulch materials constituted the treatments. A land area of 8m x 8m was demarcated as the experimental plot. This was later partitioned into 12 micro-plots of 2m x 2m in dimension. Adjacent micro-plots were separated from each other by a buffer 0.5 m wide. Each treatment including a control (without mulch) was replicated three times and treatments were randomly allocated to the micro-plots. The micro-plots were selected for the application of mulch which was applied to each sample plot at the rate of 5kg per micro-plots. A mixture of fresh mulch materials from the two species (treatment 1:1 w/w) was randomly applied to selected micro-plots. Each treatment was replicated three times.

Selection and Collection of Mulch Materials

Two agroforestry species which include *Albizia zygia* and *Albizia adanthifolia* were selected for this study. These species differ from one another in shape, size, chemical composition and texture. Mature leaves of these two agroforestry species were collected from their stand at the agroforestry plot of the Department of Forestry and Wood Technology, Federal University of Technology, Akure, Nigeria. The fresh mulch materials were collected weighed and applied at the rate of 1 kg per micro-plot.

Soil Sampling

Samples were collected before and after the application of mulch materials at 0 – 15cm depths using soil auger taken from the experimental sites. The samples were bulked (to make a composite sample), the soil were air dried and sieved using a 2mm sieve and analyzed for particle size, soil organic matter, pH, total nitrogen and phosphorus. Particle size analysis determined using the hydrometer method (Bouyoucos, 1962).

Measurement of Soil Temperature and Moisture Contents

Soil temperatures were measured at each micro sample plots. A liquid crystal display (LCD) thermoprobe was used to measure the soil temperature and moisture meter was placed in the soil to determine the moisture content of the soil at each micro mini plots and it was set at 15cm depth.

Soil Nutrients Analysis

Soil samples were collected from each micro plot at the end of eight weeks of application of mulch to the soil. The soil samples collected were dried, sieved and labeled accordingly. Samples for total nitrogen determination were digested using semi-micro-kjeldahl method with selenium catalyst. The digested sample was distilled after the addition of Sulphuric acid and ammonium thus released was determined by simple acid-base titration. Phosphorus in the sample was determined by the molybdenum blue method. The soil pH was determined using an electronic pH meter. The pH of the soil was determined by immersing the glass electrode of the pH meter into a partly settled suspension of soil collected. This method was chosen because of its sensitivity, which makes it suitable for soil samples of low temperature contents.

Statistical analysis

Graphs were plotted to summarize the data for the soil temperature and soil moisture determinations. The data obtained from nutrient analysis were subjected to analysis of variance to determine the significance of treatments. Mean separation was done using Duncan New Multiple Range Test.

RESULTS AND DISCUSSION

Results

Effect of Mulch Types on Soil Moisture and Temperature

The result of analyses of soil moisture properties and soil temperature under the various mulches are shown in figure 1 below. The graphic below shows the effect of the mulches at the end of 8 weeks after the application of the mulch on the soil temperature and soil moisture. The least soil temperature (28.4^{0}C) was recorded under the plots of *Albizia adanthifolia* and *Albizia zygia*(mixture) mulch and the highest temperature (37.5^{0}C) was recorded on control plots while the highest moisture content were recorded on the plots of *Albizia zygia* plots (14.6%).

The graphical illustrations of changes in soil temperature are presented in Fig 1 while those of moisture are in Fig 2. During the 8 weeks period of this study, soil temperature showed fluctuation over time. For all the mulched plots, the soil temperature at the initial stage (before mulch application) was high. Temperature decreased (below 30^{0}C) with time after the third week of mulch application for all treatment, the temperature rose again for all the plots afterwards with the highest temperature observed on the control plot (38.5^{0}C).During the eighth week of mulch application there was disappearance of mulch materials.

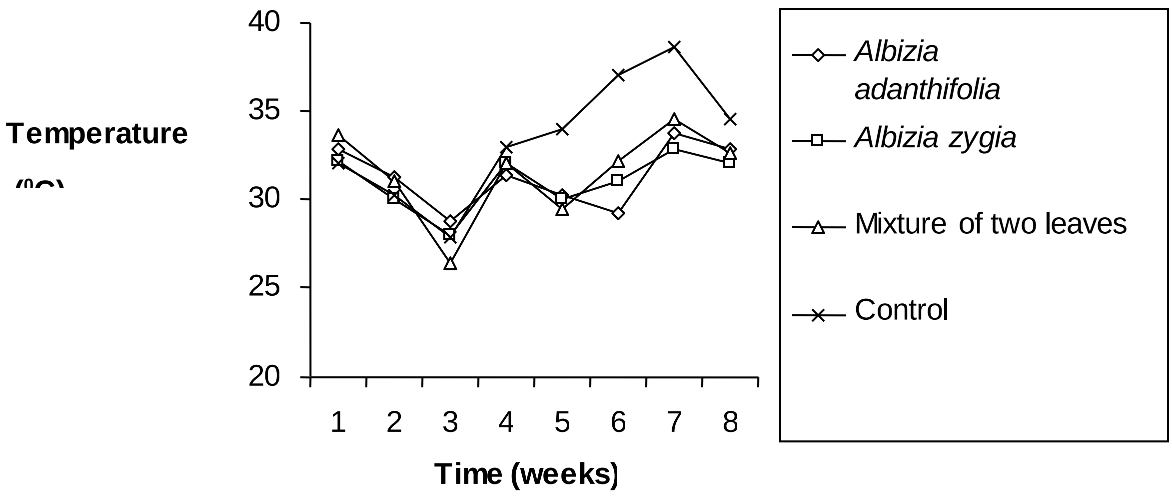

Fig. 1: Effects of mulching with leaves of the agroforestry species on soil temperature

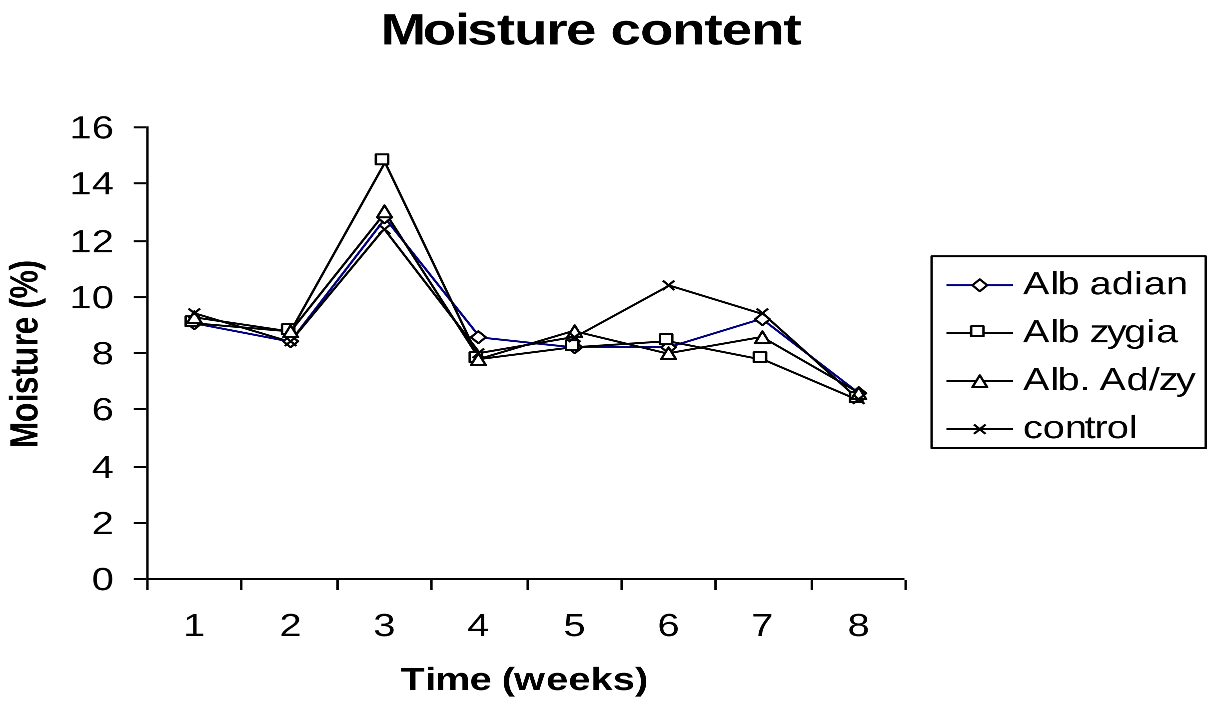

Fig. 2: Effects of mulching with leaves of the agroforestry species on soil moisture content

Effect of Mulch Types on Soil Chemical Properties

The result of chemical analyses showed that the nutrient level of the soil were not that affected by the application of mulch materials. The nutrients were not significantly increased after 8 weeks of mulch application. Initially, *Albizia zygia* and *Albizia adanthifolia* (mixture) has the highest nitrogen level on the sample plot followed by *Albizia zygia* while the control have the lowest even though they all showed no significant after their analyses with a little bit different from the initial analyses before mulching as shown in Table 1 below.

Effect of mulch type on Nitrogen content of the soil

The composition of soil nitrogen was nearly similar in all the plots before application of mulch. After the 8 weeks of mulch application to the soil, there is an increases in nitrogen content of the soil and is varied with the types of mulch. Table 2 shows that *Albizia adanthifolia* had the highest and the greatest contribution to the nitrogen pool of the soil after mulching. However, it was observed that the treatment did not have any significant effect on the soil nitrogen when compared to each other. However there is variation with the mulch type. The value of nitrogen after 8 weeks of application varied from 1.8%, 0.18%, 0.16%, 0.14%, for *Albizia adanthifolia*, mixture of both, *Albizia zygia* and for the control respectively.

Table 1. ANOVA test of significant for comparing the initial and final soil properties of the species.

	Source	Sum of squares	Df	Ms	F-cal	Sig. value
Initial Nitrogen	Treatment	0.507	3	0.169	0.196	4.07
	error	6.880	8	0.860		
	Total	7.386	11			
Final Nitrogen	Treatment	0.113	3	0.038	1.145	4.07
	error	0.263	8	0.033		
	Total	0.376	11			
Initial Phosphorus	Treatment	37.393	3	12.464	0.651	4.07
	error	153.133	8	19.142		
	Total	190.527	11			
Final Phophorus	Treatment	28.984	3	9.661	1.066	4.07
	error	72.528	8	9.066		
	Total	101.512	11			

Since F-calculated is less than F-tabulated, the null-hypothesis is accepted. This implies that there is no significant different no significant variability in the soil nitrogen and the phosphorus of the mulch material with the different agroforestry leaves species had no significant different in the agroforestry leaves species. Since the Since F-calculated is less than F-tabulated, the null-hypothesis is accepted. It is therefore concluded that there is no significant different in the soil phosphorus among the agroforestry leaves species.

Effect of Mulch Type on Soil Phosphorus

The level of phosphorus content varied in the sample plots before the application of mulch. Changes in phosphorus content were observed after the 8 weeks application of mulch. These changes varied from mulch type to the other (Table 4). The analyses obtained from the soil initially before mulch application shows that control had the highest phosphorus followed by soil under *Albizia adanthifolia* while *Albizia zygia* and *Albizia adanthifolia* (mixture) had the least phosphorus content with little different in nutrient content in all. In the final analyses of phosphorus obtained, control have the least phosphorus content while *Albizia zygia* and *Albizia adanthifolia* (mixture), *Albizia zygia* and *Albizia adanthifolia* had the highest respectively. The level of phosphorus increased slowly for all the selected species.

DISCUSSION

During the 8 weeks period of this study, the entire measured variable (soil moisture, soil temperature and soil nutrient) shows fluctuation with climatic condition over time. This is due to certain condition such as rainfall, solar radiation, humidity, soil organism. The highest moisture content obtained was observed in soil under *Albizia zygia* mulch. This may be due to the broad, thick and the slow decomposition rate of *Albizia zygia* leaves which might have resulted in reduced evaporation of water from the soil surface. The soil temperatures observed in the soil under control have the highest heat with the soil. Soil temperature may vary appreciably with depth below the surface and surface temperature may undergo a wide range of fluctuation at different time of the year which alter the rate of soil organism activities, organic matter decomposion and mineralization of different organic materials due to the effect of climate change, radiant energy, energy change and vegetation on soil condition (Balisky and Burton 1993; Nwankwo and Ogugurue 2012; Onwuka and Mang, 2018) .

The application of mulch can increase soil organic matter and also alter soil temperature and water regime improving soil structure, thus, variation in temperature could amount to radiant energy reaching the surface and the thermal properties of the soil and during the Sunny day may be considerably difference for a bare soil as compared to one with a vegetative cover, this may affect the activities of soil organism (Lal, 2000). In this study, mulch application had no significant difference when compare with the initial treatment probably due to the rate of decomposition.The decomposition rate of mulch of *Albizia zygia* and *Albizia adanthifolia* (mixture) plot was slow and that of the *Albizia adanthifolia* and *Albizia zygia* plots was moderately disintegrated. Some remnants of the leaves were still retained on the plot. However, there were little decomposed mulch on the plots of *Albizia zygia* and *Albizia adanthifolia* (mixture) and the release of nutrients from organic residues and also maybe due to accumulated nutrients in the leaves at the young stages which were not translocate prior to harvesting which is very crucial for the transfer of maximum benefits to the soil from green manuring (Young 1997). Juo *et al*., (1995) suggested that plant fallow system should include several contrasting species in other to combine the beneficial attribute of rapid ground coverage, effective biological nitrogen fixation and cycling of sub-soil nutrients.

This studies suggest that nutrient content increases gradually than that of the initial analysis, this may be associated with some biological cycling and distribution of nutrient in the soil. In contrast, leaves legume with slower decomposition tends to maintain soil cover, control growth of weed, reduces evaporation of soil moisture, helps maintain uniform soil temperature, and reduces soil erosion. Also, incorporation of different mix legume species will marked difference in level of macro and micronutrient in litters used in mulching, such that there is better mix in term of nutrient content (Jobb´agy and Jackson 2001; Bergo *et al*., 2006).

CONCLUSION AND RECOMMENDATION

This study has investigated the effect of soil fertility of *Albizia zygia* and *Albizia adanthifolia* leaves. These results did not support the hypothesis that the *Albizia zygia* and *Albizia adanthifolia* leaves have significant influence on soil physical and chemical properties. Since the use of organic mulch affect soil temperature, which influences soil chemical, physical and biological processes and also reduce soil temperature amplitude at certain depth. In the study, mixture of the agroforestry leaves have proven increased phosphorus content which readily release nutrient to the soil and *Albizia zygia* tends to release nitrogen content to the soil more readily than the other agroforestry species. Hence, there is need for proper selection of mulch materials which can bring about direct and indirect influence on the soil. It is recommended that selection should be rich in nutrients necessary for basic plant nutrition, including nitrogen, phosphorus and potassium. Physical, chemical and biological properties should be of choice so as to obtain an optimum soil fertility which will enhance sustainability and productivity which is an important step in creating a sustainable agriculture.

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Households' Cooking Energy Use and Incidence of Common Ailments: Secondary Data Analysis of 2018/19 Nigerian General Household Survey

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Abstract

The type of cooking energy used is a standard factor determining human and environmental health. However, consequences of cooking energy use and incidence of common ailments using macro-data is seemingly non-existent. This study was therefore undertaken to examine the influence of cooking energy use and incidence of cold/cough/catarrh and headaches. Secondary data bothering on the proportion of Nigerian households using wood, charcoal, kerosene and gas for cooking as well as the incidence of cough/cold/cata rrh and headache in Nigeria were extracted from the 2018/19 Nigerian General Household Survey (2018/19 GHS). They were subjected to Spearman rank correlational analysis. Results indicate that wood, charcoal, kerosene and gas were used in 66.5%, 4.7%, 21.3% and 10.2% of Nigerian households respectively. Among respondents who reported that they encountered any health problem in the 4 weeks before the 2018/19 GHS, 25.0% and 12.5% suffered from common cold/catarrh/cough and headache respectively. There is significantly positive relationship between use of wood and incidence of cold/catarrh/cough ($r = 0.783, p < 0.05$) and headache ($r = 0.787, p < 0.05$). The use of charcoal is insignificantly related with the incidence of cold/catarrh/cough ($r = 0.633, p > 0.05$) and headache ($r = 0.126, p > 0.05$). Using kerosene for cooking is inversely and significantly related with the incidence of cold/catarrh/cough ($r = -0.783, p < 0.05$). However, using kerosene has inverse but insignificant influence on the incidence of headache ($r = -0.586, p > 0.05$). Finally, the use of domestic cooking gas is inversely and significantly related with the incidence of cold/catarrh/cough ($r = -.667, p < 0.05$) and headache ($r = -.0912, p < 0.05$). The use of wood makes individuals significantly vulnerable to developing cold/catarrh/cough and headache while using gas significantly protects them against developing same. Gas use for household cooking is sine qua non in promoting human health, and should therefore be rigorously promoted in Nigeria.

Keywords: Wood, charcoal, kerosene, gas, common cold/catarrh/cough, headache

INTRODUCTION

The implication of using solid as opposed to non-solid energy/fuel for especially household cooking is huge, multifaceted and challenging to the developing world and beyond. Solid fuels are solid materials burnt to produce heat or light for man use. These include traditional biomass— wood, charcoal, agricultural wastes and processed biomass such as briquettes. On the other hand, non-solid fuels are liquid or gaseous materials used in energy production, including kerosene, ethanol and natural gas. The more solid the state of fuel, the greater the threat it poses to sustainable development. No wonder solid and non-solid energy are otherwise known as dirty versus clean energy respectively (Rahut, Ali & Behera, 2016; Rosenthal *et al*., 2018), though kerosene has been found to be a polluting fuel whose use is now discouraged by the World Health Organization (WHO, 2016).

Woodfuel harvesting enable people to generate income and diversify their livelihood. Angelsen *et al*. (2014) asserted that 35% of forest income is through harvesting of woodfuels in 25 developing countries. Firewood and charcoal accrued from forests are used by about 3 to 4 billion persons for cooking in developing countries (Das De Groote & Behera, 2014; WHO 2016). In sub-Saharan Africa, about 80% of rural households count on these solid fuels for their energy needs (Akintana, Jewittb & Clifford, 2018). In addition, urban and peri-urban resource poor individuals also partake in fetching and using solid fuels (Ibid). The use of solid fuel stands against human and environmental health, women empowerment and sustainability. Invariably, "access to clean household energy for cooking, heating and lighting is key to achieving a range of global priorities, such as improving health, gender equality, equitable economic development and environmental protection" (WHO, 2016).

The use of solid fuel for cooking affords a great source of household air pollution (HAP), which threatens life and is actually responsible for losing lives (Liu *et al*., 2018; Chafe *et al*., 2013; Lacey *et al*., 2017, Smith *et al*. 2014; Oguntoke, Adebulehin, & Annegarn 2013; Oluwole *et al*., 2013). In low- and middle-income countries (LMICs), being exposed to HAP as a result of burning biomass fuel was recorded as the thirteenth biggest risk factor for global burden of disease (Forouzanfar *et al*. 2015). This pollution caused the loss of 2.6 million lives in 2016 (Health Effects Institute, 2018). Being exposed to HAP on the account of using solid fuel for cooking cause 4.3 million undue deaths every year, 3.8 million of which are caused by non-communicable diseases (WHO, 2016). In LMICs, 2012 estimates show that 25% of all deaths on account of stroke, 15% of deaths accruing from ischaemic heart disease, 17% of deaths due to lung cancer, and over 33% of deaths resulting from chronic obstructive pulmonary disease were caused by HAP (Ibid). Being exposed to HAP accounts for about 25% of the burden of disease from cataract, and it is the foremost cause of blindness in LMICs (Ibid). Physical efforts devoted to fetching woodfuel makes people develop spinal conditions and chronic headaches (Rahut, Ali & Behera, 2016; WHO, 2016).

Globally, about 30% of wood harvest is unsustainable (Bailis *et al*., 2015). In LMICs, use of biomass fuel was the second-biggest risk factor for environmental protection (Forouzanfar *et al*., 2015). Worldwide, HAP is the most significant of all environmental risk factor (WHO, 2016). HAP is associated with deforestation and climate change owing to carbon emissions (Sesan, 2014). Moreover, gathering woodfuel for household use costs time and energy which is typically borne by women and girls including children (Chafe *et al*., 2013; Akintana, Jewittb & Clifford, 2018; Lacey *et al*., 2017). The study of Adeyemi & Ibe (2014) in Owerri, south-eastern Nigeria also shows that women dominated the sample of firewood exploiters. This thwarts the time and energy available for playing and schooling, thereby jeopardizing the opportunity for greater education among girls (Oluwafemi, *et al*. 2012). Further, gathering woodfuel makes women and girls susceptible to being injured, being attacked by animals and being exposed to physical and sexual violence (WHO, 2016). Women and children have higher risk of contracting diseases out of being exposed to HAP, making them to suffer 60% of all undue deaths credited to HAP (Ibid).

On the other hand, use of clean fuels like liquid petroleum gas (LPG), electricity, biogas, or ethanol is strongly associated with improved health outcomes (Rosenthal *et al*., 2018). It is also associated with improved life quality, sustainable economic development as well as environmental sustainability (Onoja & Idoko, 2012; Spalding-Fecher, 2005; Rahut, Ali & Behera, 2016). For example, the study of Alexander *et al*., (2017) indicated significantly lowered blood pressure among pregnant women in Nigeria upon the introduction of clean fuel, ethanol.

Indeed, type of energy used by individuals and households is a subject of monumental importance. Wilkinson *et al*. (2007) asserted that "the harnessing of energy sources in the service of human needs—fuel for cooking and space heating; electricity; … enhances and protects human health in many ways. Indeed, one reason why low-income groups are generally less healthy than high-income groups is due to a *lack of access to these benefits*". As much as there is a wide range of data specifying the effects of fuel use on varying health conditions, there is a seeming dearth of information concerning this use and the incidence of common ailments like headaches and cold/cough/catarrh. Most available information were not country but regionally-specific. Therefore, this study was designed to examine relationship between cooking energy use and incidence of common ailments, using information obtained from the 2018/19 Nigerian General Household Survey. The following research questions were framed and answered:

1. What is the extent to which Nigerian households use wood, charcoal, kerosene and gas for cooking?

2. What is the incidence of cough/cold/catarrh and headache in Nigeria?

3. What kind of relationship exists between the use of wood, charcoal, kerosene, gas and the incidence of cough/cold/catarrh as well as headache in Nigeria?

METHODOLOGY

The study area is Nigeria, a country in Africa, south of the Sahara. Nigeria is a West African country having a total land area of about 923,773 km^2. This represents about 14% of West Africa's total land area. Nigeria is made up of 36 states and the Federal Capital Territory (FCT) which are clustered into 6 geo-political zones. Nigeria is the most populous country in Africa with a total population of 201 million (United Nations Population Fund, 2019). It is also Africa's biggest economy (Peng & Poudineh, 2019; Oludaisi, Kayode & Ayodeji, 2017). As a country, it is influential among its neigbouring countries and beyond, thereby having leadership status especially in the West African sub-region (Wright & Okolo, 2018). Incidentally, Nigeria is a country experiencing a high level of energy poverty despites its huge energy resources (Emodi *et al*., 2017).

This study is an analysis of secondary data amassed from the 2018/19 Nigeria General Household Survey (2018/19 GHS) from the National Bureau of Statistics, 2019. The survey was designed to draw nationally representative sample, and to aim at producing apt information about features and situations of households including dynamics of agricultural activities in Nigeria. The survey was accomplished in a collaborative effort among national and international bodies. They include the National Bureau of Statistics, the Federal Ministry of Agriculture and Rural Development, the National Food Reserve Agency, the Bill and Melinda Gates Foundation and the World Bank. The 2018/19 GHS is the fourth to be conducted. The preceding ones were accomplished in 2010/11, 2012/13, and 2015/16. Approximately 5,000 (specifically, 4,976) persons across households in Nigeria's six geo-political zones were interviewed. The character of the relationships existing between pairs of variables were determined using Spearman rank correlation coefficient. Statistical Package for the Social Sciences (SPSS) version 23.0 was used to analyze data.

RESULTS AND DISCUSSION

Types of Fuel Used in Nigerian Households

Use of wood for cooking in Nigerian households

This study shows that wood was the source of fuel in 66.5% of Nigerian households. This is similar to findings reported in the 2018 Nigeria Demographic and Health Survey (NDHS), where wood was said to be used for cooking in 61.1% of Nigerian households (National Population Commission, 2019). Woodfuel was also the source of 70% of Kenya's household energy use (Ngui *et al*., 2011). The predominant use of woodfuel in Nigeria is associated with its cost and availability. Anozie *et al*. (2007) reported that woodfuel was found to be least costly while LPG was the costliest. The study of Bamiro & Ogunjobi (2015) among 150 respondents in Ogun State, south-western Nigeria revealed that one of the determinants of using solid fuel is its price. Current findings also show that in rural Nigeria, 82.3% of households rely on wood for fuel while 31.7% of urban households do same. Indeed, the use of woodfuel is predominant in Nigeria, especially in rural areas where more than 8 of 10 households use wood to cook. Rural areas are typically reported to be far greater user of wood fuel (Anozie *et al*., 2007).

Using wood for cooking was highest in the North-east where about 19 of 20 households (95.7%) use it for cooking. The situation is similar in the North-west region where up to 9 of 10 households (89.2%) use wood to cook. In the North-central, about 15 of 20 households (74.6%) relied on wood to cook. The situations in the South-east and the South-south regions were such that roughly 11 of 20 (55.8%) and 10 of 20 (50.8%) households respectively use wood to cook.

The use of wood for cooking is lowest in the South-west region where about 7 of 20 households (35.9%) relied on wood for cooking. The use of woodfuel was the most predominant type of fuel used in cooking in Nigeria, especially in the Northern region. Invariably, Nigerians and especially the people of this region were generally vulnerable to the dangers accruable to using woodfuel for cooking. This finding is consistent with the report of Audu (2013), who asserted that woodfuel is nearly absolutely used in the Northern Nigeria, the most desert-prone region of the country thereby worsening vulnerability to desertification in the region. The distribution of the use of woodfuel is shown on Table 1.

Use of charcoal/coal/coal briquette for cooking in Nigerian households

Table 1 also shows that charcoal/coal/coal briquette were used in only 4.7% of Nigerian households. This proportion is close to the proportion reported in the 2018 NDHS, where charcoal was found to be used for cooking in 5.8% of Nigerian households (National Population Commission, 2019). This use was common in urban (9.1%) as opposed to rural areas (2.6%). Across the zones, the use of charcoal was most common in the North-east (11.6%), and then the North-central (9.0%), followed by the North-west (6.0%). Charcoal use was peripheral in the South-west where roughly 3 of 100 households cook with same. However, the study of Ogunniyi, Adepoju & Olapade-Ogunwole (2012) among 200 households in the urban community of Ogbomoso, southwestern Nigeria shows that, charcoal was second most popular, and was used for cooking in 69.5% of households. This proportion is outrageously higher than current findings. Charcoal was also second most popular and was used in 30.6% of the households in Lagos, Southwestern Nigeria (Ozoh *et al*., 2018). Current findings show that the use of charcoal is even more marginal in the South-east and the South-south where just about 8 in 1000 (0.8%) and 1 in 1000 (0.1%) households respectively make use of same for cooking.

Use of kerosene as cooking fuel in Nigerian households

Kerosene was used in approximately 1 of every 5 households (21.3%) in Nigeria. It was however reported in the 2018 NDHS that kerosene was used for cooking in 15.0% of Nigerian households (National Population Commission, 2019). The use of kerosene for cooking is more predominant in urban areas where more than 4 of 10 (41.7%) households use it for cooking. On the contrary, just over 1 in 10 (12.0%) households use kerosene to cook in rural communities. Kerosene use is relatively comparable in the South-east (37.9%); the South-west (35.6%) and the South-south (31.6%). In these three regions, more than three and up to four households use kerosene to cook. Ogunniyi, Adepoju & Olapade-Ogunwole (2012) reported that all (100%) households sampled in their study used kerosene for cooking, making kerosene the principal type of energy used for cooking in the urban community of Ogbomoso, Southwestern Nigeria. The study of Ozoh *et al*. (2018) in 519 households of Lagos, Southwestern Nigeria also showed that kerosene was most popular and was used in 91.5% of households. The use of kerosene is popular in the southwest. Nigeria.

The use of kerosene for cooking was lowest in the region where the use of wood was highest: the North-east and the North-west. Kerosene was used in only 1.3% and 5.6% of households in the North-east and the North-west, respectively. The use of kerosene for cooking was also poor but noticeable in the North-central, where 14.0% of households use same. The popular use of kerosene in urban Nigerian can be attributed to various reasons. Desired gaseous fuels like LPG and biogas are often inaccessible or high-priced. Moreover, kerosene has been promoted in the past as clean energy alternative (Lam *et al*., 2012). Even scholarly researches confuse the categorization of kerosene. While some classified it as clean, others classified it as dirty energy (Lam *et al*., 2012). Kerosene is regularly viewed as a "step up the energy ladder" from biomass fuels (Smith *et al*. 1994), making it to become popular as societies develop and urbanize. In their survey of 519 households in Lagos, Southwestern Nigeria, Ozoh *et al*. (2018) reported that 89.6% of their respondents knew at least one detrimental health effect of using biomass for cooking. However, just 26.6% of them knew at least one detrimental health effect of using kerosene for cooking. The distribution of the use of kerosene for cooking is also shown on Table 1.

Use of LPG/gas as cooking fuel in Nigerian households

Table 1 indicates that only 1 in 10 (10.2%) of Nigerian households use gas to cook. Meanwhile, 14.0% of Nigerian households were reported to have used gas to cook in the report of 2018 NDHS (National Population Commission, 2019). This extent of use of gas for cooking is very low in Nigeria. Yet, gas is the cleanest form of energy with the highest thermal efficiency and the smallest polycyclic aromatic hydrocarbon (PAH) emissions (Shen *et al*., 2017). Yet again, a vast amount of gas is flared in Nigeria which could have been tapped for domestic use (Agboola *et al*., 2011).

The use of gas for cooking is more common in urban areas where almost a quarter, i.e. 25 of 100 (23.6%) households do so. In contrast, 4 in 100 households use gas in rural areas. The use of gas is highest in the South-west region (25.7%), followed by the South-south region (17.9%). The extent of gas use was low in the North-central (6.7%) and the South-east (6.0%) regions where less than 1 in 10 households use same. Like the use of kerosene for cooking, the use of gas was most marginal in the regions where the use of wood was most pronounced in the North-east and the North-west. In these regions about 3 in 1,000 (0.3%) and 24 in 1,000 (2.4%) households respectively use gas for cooking. Ozoh *et al*. (2018) reported that increased education and higher income were associated with the use of LPG in Lagos, Southwestern Nigeria. The distribution of the use of gas for cooking is presented in Table 1.

Table 1: Distributions of types of fuel used in Nigeria

	Region	Use of wood (%)	Use of charcoal/coal/coal briquette (%)	Use of kerosene (%)	Use of LPG/cooking gas (%)
1	North Central	74.6	9.0	14.0	6.7
2	North East	95.7	11.6	1.3	0.3
3	North West	89.2	6.0	5.6	2.4
4	South East	55.8	0.8	37.9	6.0
5	South South	50.8	0.1	31.6	17.9
6	South West	35.9	2.7	35.6	25.7
7	Urban	31.7	9.1	41.7	23.6
8	Rural	82.3	2.6	12.0	4.1
9	Nigeria	66.5	4.7	21.3	10.2

Source: Extracted from the report of the 2018/19 GHS (National Bureau of Statistics, 2019).

Common Ailments in Nigeria

Incidence of cough/cold/catarrh in Nigeria

In the 2018/19 GHS, 22.6% of male and 24.5% of female respondents reported that they encountered any health problem in the 4 weeks before the survey (National Bureau of Statistics, 2019). Of these individuals, 25.0% declared that they suffered from common cold/catarrh/cough. This imply that 1 in 4 Nigerians reporting any illness suffered from cold/catarrh/cough. This incidence is huge. It is a considerable health burden in the light that cold/catarrh/cough impairs concentration and it is very discomforting. The incidence of cold/catarrh/cough in Nigeria is comparable to its incidence in urban and rural areas, where approximately 1 in 4 persons reporting any illness suffers from cold/catarrh/cough.

Among persons reporting any illness, the incidence of cold/catarrh/cough across the South-south (21.9%), South-east (21.5%) and South-west (19.4%) is comparable, where 2 or a little above 2 persons out of 10 suffer from the ailment. This incidence is also similar in the North-east (28.1%) and the North-west (26.0%) regions where less than 3 of 10 suffer from cold/catarrh/cough. The people of the North-central are the greatest sufferers of cold/catarrh/cough. Among individuals reporting any illness, the proportion of persons reporting the ailment in this region is 34.7%, implying that

7 out of 20 persons are affected. The distribution of persons reporting that they had cold/catarrh/cough in the four weeks before the 2018/19 GHS is presented in Table 2.

Incidence of headache in Nigeria

Table 2 further indicates that among persons reporting any illness, 12.5% had headache in the four weeks preceding the 2018/19 GHS. Invariably, 1 of 8 of these persons suffered from headache during the period under review. Headache is more common in rural (13.8%) as opposed to urban areas (9.0%). There are no great divergencies in the incidence of headache among individuals reporting any illness across regions, except that it is considerably lower in the South-west (5.8%) where far less than I of 10 had headache. This is followed by the South-south region (11.0%) where a little more than 1 in 10 had headache. Among persons reporting any illness, 13.4%, 14.7%, 13.4% and 14.2% reported they had headache from the North-central, the North-east, the North-west and the South-east respectively. Hence, far less than 2 in 10 persons reporting any illness had headache in these regions. The distribution of persons reporting that they had headache among people reporting any illness in the four weeks before the 2018/19 GHS is also shown in Table 2.

Table 2: Incidence of cough/cold/catarrh and headache in among Nigerians

	Region	Cold/catarrh/ cough (%)	Headache (%)
1	North Central	34.7	13.4
2	North East	28.1	14.7
3	North West	26.0	13.4
4	South East	21.5	14.2
5	South South	21.9	11.0
6	South West	19.4	5.8
7	Urban	24.5	9.0
8	Rural	25.1	13.8
9	Nigeria	25.0	12.5

Source: Extracted from the report of the 2018/19 GHS (National Bureau of Statistics, 2019).

Relationships between types of fuel used in Nigerian households and incidence of common ailments in Nigeria

The Spearman's *r* in Table 3 presents varying degrees of correlations between types and extent of fuel used for cooking and incidence of common ailments in Nigeria. The use of wood is positively, strongly and significantly related with the incidence of cold/catarrh/cough (r = 0.783, p < 0.05). Hence, the more people use wood to cook, the more it is to be expected that people will suffer from cold/catarrh/cough. The use of charcoal is also positively and strongly related with the incidence of cold/catarrh/cough but this not significant (r = 0.633, p > 0.05). The strength and direction of this correlation still indicates that using charcoal for cooking is important in people's development of cold/catarrh/cough. Further, using kerosene for cooking is inversely, strongly and significantly related with the incidence of cold/catarrh/cough (r = -0.783, p < 0.05). In addition, the use of gas for cooking is also inversely, strongly and significantly related with the incidence of cold/catarrh/cough (r = -.667, p < 0.05). These are very interesting findings revealing that increased use of kerosene and gas for cooking yields strong and significantly reduced incidence of cold/catarrh/cough. Although subsequent reclassification has shown that kerosene is no longer considered as clean energy (WHO, 2016), current findings have indicated that kerosene is the most strongly and negatively correlate of having cold/catarrh/cough.

Table 3 further reveals that the use of wood is positively, strongly and significantly related with the incidence of headache (r = 0.787, p < 0.05). The use of charcoal is also positively but weakly and insignificantly related with the incidence of headache (r = 0.126, p > 0.05). These positive correlation coefficients indicate that increased use of wood and charcoal similarly increases the incidence of headache in the population. However, the use of wood is significant and strong in this regard. Using kerosene (r = -0.586, p > 0.05) and gas (r = -.0912, p < 0.05) are inversely related to developing headaches. This implies that the more kerosene and gas are used to cook, the less the incidence of headache. However, the use of gas is the only significant and inverse correlate of the incidence of headache.

The use of gas for cooking require utmost promotion in Nigeria. This can be achieved through making gas more available and affordable. Availability can be ensured by being more stringent in enforcing regulations against gas flaring in Nigeria. Agboola *et al*. (2011) asserted that 71 million m^3 of gas is flared during oil exploration on a good day in Nigeria, making the country to lose about \$2.5 billion yearly. Agboola *et al.* (2011) propounded that LPG could be derived and translated for domestic use in Nigerian households. Safety measures preventing gas explosions should also be strengthened. Ozoh *et al*. (2018) reported that an overwhelming proportion (90%) of their respondents who were non-users of LPG indicated fear of safety and high cost as limiting their use of LPG. On the other hand, this study has further demonstrated the need to vehemently discourage the use of wood for cooking. The regulation of population growth is fundamental in this regard. Audu (2013) asserted that unrestrained population explosion and its associated scuffle for survival in developing countries like Nigeria is the fundamental reason why forest resources are depleted.

Table 3: Relationship between types of fuel used in Nigerian households and incidence of common ailments

Cooking energy use		Incidence of cold/catarrh/ cough	Cooking energy use		Incidence of headache
Use of wood	Spearman's *r*	.783*	Use of wood	Spearman's *r*	.787*
	p value	.013		*p* value	.012
Use of charcoal	Spearman's *r*	.633	Use of charcoal	Spearman's *r*	.126
	p value	.067		*p* value	.748
Use of kerosene	Spearman's *r*	-.783*	Use of kerosene	Spearman's *r*	-.586
	p value	.013		*p* value	.097
Use of gas	Spearman's *r*	-.667*	Use of gas	Spearman's *r*	-.912*
	p value	.050		*p* value	.001

*Significant Correlations
Source: Computed from data extracted from the report of 2018/19 GHS (National Bureau of Statistics, 2019).

CONCLUSION

The greater the use of wood for cooking, the greater the incidence of cold/catarrh/cough. However, the greater the use of kerosene, the lesser is the incidence of cold/catarrh/cough. Similarly, the greater the use of gas for cooking, the lesser is the incidence of cold/catarrh/cough. The use of wood is significantly predisposing to the development of cold/catarrh/cough while the use of kerosene and gas are significantly protective against developing cold/catarrh/cough. The use of charcoal is not a significant factor affecting the incidence of cold/catarrh/cough in Nigerian households.

The greater the use of wood for cooking, the greater is the incidence of headache. However, the greater the use of gas for cooking, the lesser is incidence of headaches. The use of wood is also significantly predisposing to the development of headache while the use of gas is significantly protective against developing headache. The use of charcoal and kerosene are not significant factors affecting the incidence of headache in Nigeria.

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Evaluation of Honey Bee (*Apis melifera*) Pollen: Implications for Honey Production Sustainability

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Abstract

This study was carried out to identify the sources of the pollen collected by honey bees in order to prioritize bee floral plants for beekeeping. This was in view of recent increase in honey demand coupled with degraded vegetation which has led to scarcity of honey. The honey samples used for Palynological analysis were obtained from nine apiaries purposively selected in Ekiti State. The Palynological analysis of the honey for quantitative and qualitative pollen analyses was carried out under a light microscope in the Palynological Laboratory of the Department of Archaeology, University of Ibadan, Oyo-State, Nigeria. The result revealed pollen grains from 30 plant species belonging to 22 families. The most abundant pollen grains were Aspilia africana, Mimusops sp. and Elaeis guineensis which ranked 1st, 2nd, and 3rd with % occurrence of 24.4, 15.9 and 12.0 respectively. Tree species constituted 66.6 % of the pollen types, 20.0% were shrubs while 13.3% were herbs. For the families, Fabaceae consists of four species, Anacardiaceae and Rubiaceae consist of three species each, Asteraceae consists of 2 species while the remaining 18 families which are Euphorbiaceae, Meliaceae, Combretaceae, Arecaceae, Phyllanthaceae, Irvingiaceae, Sapotaceae, Moracea. Chrysobalanaceae, Legminosae, Bombacaceae, Papilionaceae, Malvaceae, Compositae, Acanthaceae, Sapindaceae, Moringaceae and Myrtaceae consist of one species each. The 30 bee plants identified in this study could serve as a baseline for cultivating and conserving necessary flora plants for beekeeping. This will guarantee year-round availability of nectar with pollen and thus efficiency of honey bees in honey production.

Keywords: Honey bee, Pollen, Honey, Sustainability

INTRODUCTION

Honey contains pollen grains which are collected by honeybees while foraging the flowers for pollen and nectar. The bees visit plants to obtain nectar, which is the source of sugar in honey, fatty substances, minerals and vitamins as well as pollen as major source of protein and antioxidant (Escriche *et al*., 2014; Can *et al*., 2015) In order to survive and be productive, honey bee needs both nectar and pollen in adequate quantities. However, not all plant species are good for beekeeping. Some supply both nectar and pollen abundantly when in bloom, and these are often called honey plants, because they are best suited for honey production. Plants producing nectar but little or no pollen are also considered to be honey plants. Other plants, however, may yield pollen but little or no nectar. These pollen plants are also important in beekeeping, especially at the time of colony build-up, when the bees need large amounts of protein contained in pollen for their brood-rearing (Paterson, 2006).

Flowering plants that produce fruits are associated with higher numbers of visits by honey bees (Gingras *et al*., 1999; Pernal and Currie, 2004). A honey bee can fly for up to 10 kilometres and as fast as 24 kilometres per hour while visiting 50 to 100 plants during a collection trip. No honey produced by bees flying free is entirely unifloral, unless the bees were reared in apiaries and exposed to a particular species of bees pollinated plant (Terrab *et al*., 2002; Devillers *et al*., 2004). As honey bees forage and visit many plants, the substances and the mineral collected vary and it is a characteristic of the plant species foraged which varies with environmental conditions (Bertoncel *et al*., 2007; Can *et al*., 2015).

With the current growth in domestic consumption of honey in Nigeria due to consumer's awareness of its high values in maintaining good health and in treatment of various diseases, there has been a large gap in the supply - demand of quality honey available for consumption (Arowosoge, 2018). However, the plants foraged by bees for honey production are shrinking. The shrinkage is as a result of **degraded vegetation from** over-exploitation, deforestation and encroachment or conversion of forest estates to other forms of land use (FAO, 2013).

To produce large quantity of honey, a good beekeeping area with abundant nectar and pollen plants and long blooming season is needed. There is therefore the need to accord necessary priority to plants foraged by honey bees. This is because the knowledge of plants visited by bees is essential in guiding prospective beekeepers in the choice of suitable sites for locating apiaries.

In developed countries, Melitopalynology which is the study of pollen in honey has been carried out extensively to provide a catalogue of bee-friendly plants utilized for setting up apiaries (Pernal and Currie, 2004; Diez *et al.*, 2004). However, Melitopalynology study is still at low ebb in Nigeria. This reason underscores the relevance of the present study aimed at identifying and quantifying the pollen grains in honey produced by *Apis melifera* honey bee in order to determine plants foraged. This information would serve as a baseline for cultivating and conserving bee-friendly plants for beekeeping as it will increase the efficiency of honey bees in honey production.

MATERIALS AND METHOD

Sources of honey samples

The honey samples used for palynology analysis were obtained from three apiaries each from Ado-Ekiti, Ikere Ekiti and Ikole Ekiti Local Government areas. These made a total of nine samples. The apiaries locations were: Ekiti State University (EKSU), Federal Polytechnic and Odo for Ado-Ekiti; for Ikere Ekiti: College of Education, Ise road and Iju road and for Ikole Ekiti: Federal University, Oye (FUOYE), Odo Oro and Ara road. The researchers had access to the nine apiaries. Hence these apiaries were purposively selected in order to obtain non adulterated honey.

The honey were harvested and processed by the researchers. The samples were collected in well labelled clean white plastic containers which were labelled according to locations of apiaries where the honey was obtained.

Palynological Analysis of Honey

The Palynological analysis of the honey for quantitative and qualitative pollen analyses was carried out at the Palynological Laboratory of the Department of Archaeology, University of Ibadan, Oyo-State, Nigeria. Samples were prepared using standard acetolysis method (Ohe, *et al.*, 2004).

Approximately 10g of honey was weighed into a glass centrifuge tube of 100 ml capacity. The honey was dissolved with 20 ml of hot distilled water of temperature that was not above 40^{o}C. The solution was centrifuged for 10 minutes at a revolution of 2500 per minute and the supernatant liquid was decanted. In order to completely dissolve the remaining honey sugar crystals, 10 ml of hot (not above 40^{o}C) distilled water was added and centrifuged for 5 min at a revolution of 2500 per minute. The supernatant liquid was decanted to the last drop into calibrated centrifuge tubes of 100 ml. For acetolysis, 5ml of glacial acetic acid was added and centrifuged.

The mixture was washed three times and at the final washing the mixture was sieved with fine mesh sieve of 200µm (microns) and the residue was centrifuged. 0.5ml of glycerine was added to the residue and mix thoroughly with electric mixer. At the end of the chemical procedure, the liquid residue containing the pollen was 1ml. After mixing, a pipette was used to drop 10µm of the mixture on a marked area (20mm x 20mm) of slide and spread with a micro spatula. Three replicates of each mixture of honey were made and examined under microscope. The examination was carried out and photographs taken at the magnification of x400. The pollen of the plant per ml was determined to know the total pollen while the pollen grains types in each samples, were identified based on photomicrograph albums in the Palynological Laboratory of the Department of Archaeology, University of Ibadan as well as the following literature: Sowumi (1973, 1976, 1995) and Oriejemie (2017).

Data Analysis

Data collected were collated, classified and analyzed using descriptive statistics such as frequency distribution and percentages. Data were presented in tables and plates.

Data Analytical Tools

Determination of the number of plant pollen per millimetre =

$$Number\ of\ plant\ pollen\ in\ \frac{10\mu m}{10\mu m} X\ 1 Millimetre$$

Where 1ml =1000µm

Prioritization of Pollen in Honey Samples

The percentage of pollen occurrence was used to prioritize the pollen. This was determined by expressing the frequency of each pollen type in the samples as percentage of the total pollen.

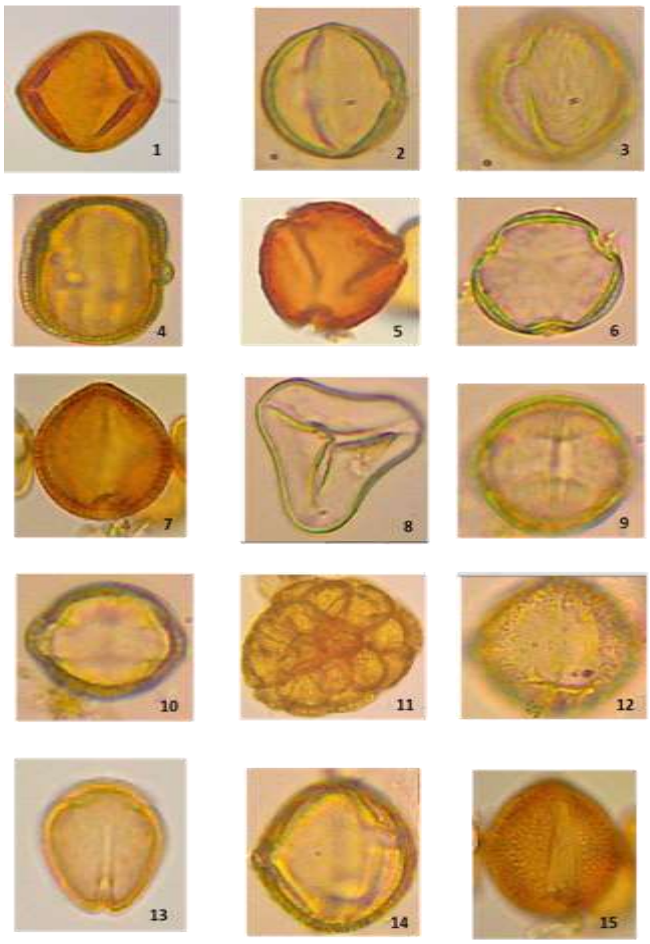
% of pollen occurrence $= \frac{Number\ of\ times\ a\ particular\ pollen\ occured}{Total\ numbers\ of\ pollen\ identified} X100$ …………Equation 1

RESULTS AND DISCUSSION

Pollen Plants Identification from Honey

Thirty (30) plant species were identified from the pollen grains obtained from honey samples used. The photomicrographs of the pollen grains obtained in the analysed honey samples are presented in Plate 1. The 30 plant species were compiled and presented alphabetically in their botanical names, common/vernacular names, families and vegetation strata as shown in Table 1. The botanical and common/vernacular names followed Keay, (1989) and Sowumi (1973, 1976, 1995). The 30 plants species belong to 22 families. Family Fabaceae consist of four species; Anacardiaceae and Rubiaceae consist of three species each; Asteraceae consists of 2 species while the remaining 18 families which are Euphorbiaceae, Meliaceae, Combretaceae, Arecaceae, Phyllanthaceae, Irvingiaceae, Sapotaceae, Moracea. Chrysobalanaceae, Legminosae, Bombacaceae, Papilionaceae, Malvaceae, Compositae, Acanthaceae, Sapindaceae, Moringaceae and Myrtaceae consist of one species each.

The results of this study showed that the honey samples were multifloral as the pollen types identified were from 30 plant species which belong to 21 families. This revealed the abundant and diversified pollen composition of the honey samples examined. This study confirms the finding of Terrab *et al*., (2002) that no honey produced by bees flying free is entirely unifloral, unless the bees were reared in apiaries and exposed to a particular species of bees pollinated plant. This finding further revealed that honeybees forage many plants in order to collect enough pollen which is the only protein food in the beehive (Peterson, 2006; Can *et al*.,2015). Pollen plays an important role in feeding the colony. Specifically pollen is used for feeding the larvae and the young bees. It is a determining factor in the development and the functionality of certain organs such as the ovaries and hypopharingeal glands of honey bees (Oyerinde *et al.,* 2017).



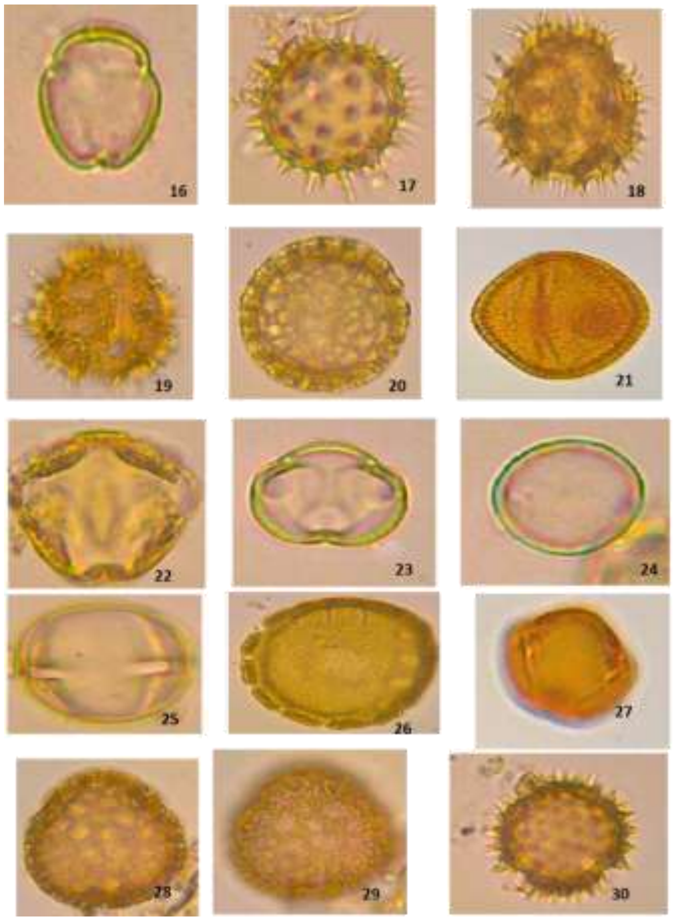


Plate 1: Photomicrograph of pollens obtained in the analysed honey samples

Key

1. *Alchornea cordifolia* (Euphorbiaceae)
2. *Aspilia africana* (Asteraceae)
3. *Asystasia sp*. (*Acanthaceae*)
4. *Azadirachta indica* (Meliaceae)
5. *Baphia pubescen* (Papilionaceae)
6. *Blighia sapida* (*Sapindaceae*)
7. *Bombax costatum* (Bombacaceae)
8. *Borerria scabra* (Rubiaceae)
9. *Elaeis guineensis* (Arecaceae)
10. *Eucalyptus spp* (Myrtaceae)
11. *Gliricida sepium* (Fabaceae)
12. *Hymenocardia acida* (Phyllanthaceae)
13. *Irvingia gabonensis* (Irvingiaceae)
14. *Lannea sp*.(Anacardiaceae)
15. *Mangifera indica* (Anacardiaceae)
16. *Mimusops sp*.(Sapotaceae)
17. *Moringa oleifera* (Moringaceae)
18. *Nauclea diederichii* (Rubiaceae)
19. *Parinari sp* .(Chrysobalanaceae)
20. *Parkia biglobosa* (Fabaceae)
21. *Pavetta sp* .(Rubiaceae)
22. *Peltophorum pterocarpum* (Fabaceae)
23. *Piptadenia africanum*(Leguminosae)
24. *Spondias mombin* (Anacardiaceae)
25. *Termilina spp* (Combretaceae)

26. *Tetrapleura tetraptera* (Fabaceae)
27. *Treculia africana* (Moracea)
28. *Tridax procumbens* (Asteraceae)
29. *Triumfetta sp*.(Malvaceae)
30. *Vernonia amygdalina* (Compositae)

Table 1. Plants identification from honey

S/N	Botanical Names	Common Names/Yoruba Names	Families	Vegetation Strata
1.	*Alchornea cordifolia*	Christmas bush/ Ipa	Euphorbiaceae	Shrub
2.	*Aspilia africana*	Wildsun flower/ Yunriyun	Asteraceae	Herb
3.	*Asystasia sp.*	Ewe didu	Acanthaceae	Shrub
4.	*Azadirachta indica*	Neem tree/Dongoyaro	Meliaceae	Tree
5.	*Baphia pubescen*	Awewi	Papilionaceae	Shrub
6.	*Blighia sapida*	Ackee apple/Isin	Sapindaceae	Tree
7.	*Bombax costatum*	Silk/cotton tree/Olokododo	Bombacaceae	Tree
8.	*Borerria scabra*	Isakoro/Ewe ifo	Rubiaceae	Herb
9	*Elaeis guineensis*	Palm kernel/Ope	Arecaceae	Tree
10	*Eucalyptus spp*	Gum tree	Myrtaceae	Tree
11	*Gliricida sepium*	Agunmaniye	Fabaceae	Tree
12	*Hymenocardia acida*	Fertility tree/Orupa	Phyllanthaceae	Tree
13	*Irvingia gabonensis*	African bush mango/Oro	Irvingiaceae	Tree
14	*Lannea sp.*	Okitiripo	Anacardiaceae	Tree
15	*Mangifera indica*	Mango tree/Igi mango	Anacardiaceae	Tree
16	*Mimusops sp.*	Emido	Sapotaceae	Tree
17	*Moringa oleifera*	Ewe igbale	Moringaceae	Tree
18	*Nauclea diederichii*	Yellow wood/Opepe	Rubiacea	Tree
19	*Parinari sp.*	Sand apple/Awewe	Chrysobalanaceae	Shrub
20	*Parkia biglobosa*	African locust beans/Irugba	Fabaceae	Tree
21	*Pavetta sp.*	Bride bush/Idofunigbo	Rubiaceae	Shrub
22	*Peltophorum pterocarpum*	Yellow flame/Igigbigbe	Fabaceae	Tree
23	*Piptadenia africanum*	African green heart/Agbonyin	Legminosae	Tree
24	*Spondias mombin*	Iyeye/Okikan	Anacardiaceae	Tree
25	*Termilina spp*	Afara/Idigbo	Combretaceae	Tree
26	*Tetrapleura tetraptera*	Fluted fruit tree/Aridan	Fabaceae	Tree
27	*Treculia africana*	African bread fruit/Afon	Moracea	Tree
28	*Tridax procumbens*	Igbalode/Muwagun	Asteraceae	Herb
29	*Triumfetta sp.*	Boko pupa/Esua	Malvaceae	Shrub
30	*Vernonia amygdalina*	Bitter leaf/Ewuro	Compositae	Herb

Prioritization of Pollen Grains Occurrence (%) in Honey

The pollen grains from the 30 plant species identified were prioritized and ranked as presented in Table 2. The pollen count ranged from 2 to 31,294 for *Tetrapleura tetraptera* and *Aspilia africana* respectively. The total pollen grain count of 128,370 were identified from the honey samples collected. The top three rated pollen grains are from *Aspilia africana, Mimusops sp*., and *Elaeis guineensis*. *Aspilia africana* had the highest pollen occurrence of 24.38% and ranked first, followed by *Mimusops sp* which ranked second with 15.94% while *Elaeis guineensis* had 12.04% and ranked third. *Tetrapleura tetraptera* had the least rated pollen occurrence of 0.0%.

Honeybees prefer to visit nectars of plants with good nutritional values and high pollen content (Smith, 1999; Ige and Apo, 2007). The findings of this study showed that *Aspilia africana* was most foraged by the honey bees since it ranked 1st with pollen occurrence of 24.38%. It could therefore be deduced that *Aspilia africana* contains nectars of high pollen contents and good nutritional values since it was the most foraged plant of the 30 plant species identified. The order of ranking as shown in Table 1 therefore showed how important the forage plants were to honey bees.

Table 2: Prioritization of Pollen Occurrence (%) in the Honey Sampled

S/N	Bee forage plants	Total number of pollen	% Occurrence	Rank
1.	*Alchornea cordifolia*	1,279	1.00	13^{th}
2.	*Aspilia africana*	31,294	24.38	1^{st}
3.	*Asystasia sp.*	131	0.10	21^{st}
4.	*Azadirachta indica*	1,468	1.14	12^{th}
5.	*Baphia pubescen*	21	0.02	24^{th}
6.	*Blighia sapida*	9,303	7.25	6^{th}
7.	*Bombax costatum*	30	0.02	24^{th}
8.	*Borerria scabra*	15	0.01	28^{th}
9	*Elaeis guineensis*	15,455	12.04	3^{rd}
10.	*Eucalyptus spp*	6,007	4.68	7^{th}
11.	*Gliricida sepium*	2,225	1.73	10^{th}
12.	*Hymenocardia acida*	3,849	3.00	8^{th}
13.	*Irvingia gabonensis*	1,288	1.00	13^{th}
14.	*Lannea sp.*	14,019	10.92	5^{th}
15.	*Mangifera indica*	1,884	1.47	11^{th}
16.	*Mimusops sp.*	20,468	15.94	2^{nd}
17.	*Moringa oleifera*	731	0.57	15^{th}
18.	*Nauclea diederichii*	2,983	2.32	9^{th}
19.	*Parinari sp..*	28	0.02	24^{th}
20.	*Parkia biglobosa*	384	0.30	16^{th}
21.	*Pavetta sp.*	14,221	11.08	4^{th}
22.	*Peltophorum pterocarpum*	63	0.05	23^{rd}
23.	*Piptadenia africanum*	127	0.10	21^{st}
24.	*Spondias mombin*	333	0.26	17^{th}
25.	*Termilina spp*	20	0.02	24^{th}
26.	*Tetrapleura tetraptera*	2	0.00	30^{th}
27.	*Treculia africana*	144	0.11	20^{th}
28.	*Tridax procumbens*	126	0.10	21^{st}
29.	*Triumfetta sp.*	239	0.19	18^{th}
30.	*Vernonia amygdalina*	233	0.18	19^{th}
	Total	**12,8370**	**100**	

CONCLUSION

This study has shown that 30 plant species were foraged by honey bees in the study area. The 30 plant species belong to 22 families. Family Fabaceae consist of four species. Anacardiaceae and Rubiaceae consist of three species each, Asteraceae consists of 2 species while the remaining 18 families which are Euphorbiaceae, Meliaceae, Combretaceae, Arecaceae, Phyllanthaceae, Irvingiaceae, Sapotaceae, Moracea. Chrysobalanaceae, Legminosae, Bombacaceae, Papilionaceae, Malvaceae, Compositae, Acanthaceae, Sapindaceae, Moringaceae and Myrtaceae consist of one species each. The most abundant pollen grains were *Aspilia africana*, *Mimusops sp.* and *Elaeis guineensis* which ranked 1^{st}, 2^{nd}, and 3^{rd} respectively with % occurrence of 24.38, 15.94 and 12.04 respectively. *Tetrapleura tetraptera* ranked the least (30^{th}) with occurrence of 0.00%.

RECOMMENDATIONS

Based on the findings of this study the following recommendations are made

i. The 30 plant species foraged by honey bees in this study should be listed according to their priority in a catalogue as bee-friendly plants by policy makers. This will help in guiding prospective beekeepers in setting up apiaries and in the choice of suitable sites for locating apiaries.

ii. Beekeepers in Nigeria should be encouraged through the Beekeepers Association of Nigeria (BAN) to cultivate and conserve the 30 bee plants identified in this study in their apiaries while giving priority to the top ten rated plant species. These will guarantee year-round availability of nectar with pollen and thus efficiency of honey bees in honey production.

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Effects of Periods of Organo-Priming and Hydro-Priming on the Germination Of *Vitex Doniana* and *Canarium schweinfurthii* Seeds

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Abstract

There is need to determine the appropriate periods of organo-priming and hydro-priming on germination of Vitex doniana and Canarium schweinfurthii seeds to avoid under and over priming of seeds. In this light, investigations were conducted on organo-priming which is the use of organic materials in priming in order to break the dormancy of Vitex doniana and Canarium schweinfurthii seeds, at the screen house of Federal College of Forestry Mechanization, Afaka, Kaduna State, Nigeria during 2018 dry season. The solution of the leaves of nitrogen fixing trees, Jacaranda mimosifolia is the source of organic materials used in organo-priming. Effects of periods (0, 6, 12, 18 and 24 hrs) of organo-priming and hydro-priming on the germination of V. doniana seeds were laid down in Completely Randomised Design with five replicates. Effects of periods (0, 6, 12, 18 and 24 hrs) of organo-priming on the germination of C. schweinfurthii seeds was laid down in Completely Randomised Design with five replicates. A significant germination percentage value of 63.33% was recorded in V. doniana seeds organo-primed for 18hours. Highest germination percentage value of 40 % was recorded in V. doniana seeds hydro-primed for 24 hours. Germination percentage of V. doniana seeds increased with the increasing periods of hydro-priming. The least mean germination time of 13.33 days was recorded in V. doniana seeds hydro-primed for 12 hours. Highest germination percentage of 40 % was recorded in C. schweinfurthii seeds organo-primed for 6 and 12 hours. Organo-priming and hydro-priming significantly (P<0.05) enhanced the germination percentage of the seeds. Organo-priming of V.doniana seeds for 18hours, hydro-priming of V. doniana seeds for 24hours, organo-priming of C. schweinfurthii seeds for 6 and 12 hours are recommended for mass production of their seedlings, having enhanced their germination percentages.

Keywords: Soaked, Primed, Dormancy, Natural and Germination, Organo-priming, Hydro-priming

INTRODUCTION

The developing nations including Nigeria are endowed with many indigenous fruits that are of great importance to the rural communities (Okunlola and Akinyele, 2017). Fruits are referred to as juicy seed bearing structure of flowering plant that may be eaten as food. According to Okafor (2010), the contributions of wild fruits, nuts, seeds, vegetables and other classes of edible forest products and their potential in overcoming or ameliorating prevailing food problems are enormous. According to Pye-Smith (2010), there are around 3000 species of wild fruits in Africa representing enormous important and largely untapped natural resources. *Vitex doniana* and *Canarium schweinfurthii* are examples of indigenous fruit tree species of immense potentials. *Vitex doniana* is called Black plum; Dinya; Ucha koro and Oori-nla in English, Hausa, Igbo and Yoruba respectively (Orwa *et al*., 2009). It belongs to the family Labiatae. The blackish pulp of the matured fruits is sweet and edible, and is eaten fresh. This pulp also serves in jam preparation. A beverage is made from the fruit juice, whereas boiled fruits are the basis for an alcoholic liquor and wine (Ky, 2008). The *V. doniana* is an important indigenous fruit or leafy vegetable in Africa (Burkill, 2000; Maundu *et al*., 2009) for food, medicine and other purposes (Dadjo *et al*., 2012). Hounkpèvi *et al*. (2018) stated that its leaves are used as fodder for livestock and the young leaves as leafy vegetables in sauces preparation.

Canarium schweinfurthii is indigenous to tropical Africa in rain forest, gallery forest and transitional forest of Senegal to west Cameroon, Ethiopia, Tanzania, Angola (Orwa *et al*., 2009). It is also found in Nigeria, Mali, Cameroon, Senegal, Ghana, Guinea-Bissau, Liberia and Sierra Leone (Okpala, 2016) and native to Sudan, Togo, Uganda and Zambia (Orwa *et al*., 2009; Maduelosi and Angaye, 2015). It belongs to the Burseraceae family

(Orwa *et al.,* 2009). It is called African elemi or bush candle tree in English. In Nigeria, it is also known by quite a number of local names which include; Berom (Pwat), Hausa (Atile or Atilis), Igbo (Ube agba) and Yoruba (Origbo, Elemi or Agbabubu) (Dawang *et al.,* 2016). The fruit pulp of *C. schweinfurthii* contains approximately 30-50% oil (Koudon *et al.,* 2005, Ehiem *et al.,* 2016). It also contains anti sickling phytomarkers such as phenolic and triterpenoic acids and merit more attention for a bio-prospecting program (Koto-te-Nyiwa *et al.,* 2015). Its fruits are cooked, and in Nigeria, sometimes prepared into a vegetable butter and eaten as a substitute for shea-butter (Orwa *et al.,* 2009; Ayoade *et al.,* 2017).

The *C. schweinfurthii* tree makes a good fuel wood, igniting readily and burning with a lot of heat. The resin burns readily and is used as a bush candle (Orwa *et al.,* 2009; Maduelosi and Angaye, 2015; Okpala, 2016). Locally, the wood is used for mortars, planks, canoes, boats and furniture (Orwa *et al.,* 2009; Okpala, 2016). In spite of enormous potentials of *Vitex doniana* and *C. schweinfurthii*, there are dearths of information on domestication and ex-situ conservation of them. To abate total loss or extinction of some of the important forest tree species, they should be cultivated more intensively through improved propagation either by seed or stem cuttings (Dolor, 2013). Seeds are still important starting materials for propagation of many vital tree species (Mng'omba *et al.,* 2007) and they are the easiest and cheapest, and the most common means for propagating many agro-forestry and timber tree species (Akinnifesi *et al.,* 2007). *V. doniana* and *C. schweinfurthii* have hard seed coat which prevents their germination in the presence of favourable condition necessary for germination and therefore they are dormant.

To overcome challenges of danger, high cost, unavailability and adoptability problems of other methods of pre-sowing, planters need to embrace natural sources of nutrients from the leaves of trees to break dormancy of seeds of agro-forestry tree species. Most of the methods of pre-sowing treatment such as physical, chemical and mechanical scarification only degrade the seed coat for germination (Aliero, 2004; Abubakar and Muhammad, 2013); without, always, rapidly and uniformly influencing the physiology of the seeds (Dewir *et al.,* 2011) and seedlings (Gehlot and Kasera, 2012) as well as not overcoming physiological dormancy of seeds (Habib *et al.,* 2015). To avoid wastage of time, money and energy, planters need to use appropriate periods of organo-priming and hydro-priming to overcome the dormancy of seeds of agro-forestry tree species. In light of this, these experiments were conducted to assess the effect of periods of organo-priming on the germination of *V. doniana* and *C. schweinfurthii* seeds. Nutrient in organic materials dissolve during watering and available to seeds to enhance the physiology of the embryo as well as relieving seeds from dormancy for germination to take place (Adelani *et al.,* 2018a). Relieving seeds of physiological (Adelani *et al.,* 2014a; Adelani and Bello, 2016) physical and mechanical dormancy encourage mass production of seedlings for agro-forestry systems (Adelani *et al.,* 2018a).

MATERIALS AND METHOD

Experimental Site

The research was conducted in the screen house of the Federal College of Forestry Mechanization, Afaka, Kaduna. The college is located in the Northern Guinea Savannah ecological zones of Nigeria. It is situated in Chikun Local Government Area of Kaduna state, Nigeria. It lies between Latitude 10° 35' and 10° 34' and Longitude 7° 21' and 7° 20' (Adelani, 2015). The mean annual rainfall is approximately 1000 mm. The vegetation is open woodland with tall broad leave trees (Otegbeye *et al.,* 2001).

Fruit Collection and Seed Extraction

The fruits of *V. doniana* were sourced from the mother tree in Buruku Forest Reserve, Kaduna State of Nigeria. The fruits of *C. schweinfurthii* were sourced from the mother tree in Pankshin, Plateau State of Nigeria. The seeds were extracted from the fruits and air dried for thirty minutes. Three hundred seeds were extracted from their fruits. The viability of the randomly selected *V. doniana and C. schweinfurthii* seeds samples were assessed using the cutting method (Schmidt, 2000).The river sand used for the experiment was collected from the floor of the college dam and made to pass through 2 mm sieve (Adelani and Bello, 2016) and then sterilized in the laboratory oven at 160 °C for 24 hours (Adelani and Joseph, 2014; Adelani and Maisamari, 2016). The polythene pots used was 20 x 10 x 10 cm^3 in dimension and filled with the sterilized river sand and arranged in the screen house.

Experimental design

The investigations on the effects of periods of organo-priming and hydro-priming on the germination of *V. doniana* seeds were laid down in completely randomized designs with five replicates. *S*eeds were soaked for periods (0, 6, 12, 18 and 24 hrs) in the solution of the leaves of nitrogen fixing trees, *Jacaranda mimosifolia* and water respectively. The initial moisture content of the samples of the seeds were determined by weighing the seeds on Mettler Top Loading Weighing Balance (Model-Mettler PM 11-K) before and after drying to constant weight. Twelve seeds represented a replicate. Three hundred (300) seeds were soaked in 0.5 % concentration of solution of the leaves of nitrogen fixing trees, *J. mimosifolia* and water for different periods (0, 6, 12, 18 and 24 hrs).
Stirring or bubbling was done to ensure uniform treatment and aeration. After each treatment, the seeds were removed, washed, air dried for 30 minutes and treated with fungicide (Vinclozolin). The seeds were also dried back to the initial moisture content. Treated seeds were planted in 4 cm depth of the sterilized sand and 200 ml of water per pot was

applied regularly at two days interval for twelve weeks (Adelani *et al*., 2014b). Seeds that were not soaked in the 0.5 % concentration of solution of leaves of nitrogen fixing tree, *J. mimosifolia* and water served as control.

The investigation on the effect of periods of organo-priming on the germination of *C. schweinfurthii* seeds was laid down in completely randomized designs with five replicates. Seeds were soaked for periods (0, 6, 12, 18 and 24 hrs) in the solution of the leaves of nitrogen fixing trees, *Jacaranda mimosifolia* respectively. The initial moisture content of the samples of the seeds were determined by weighing the seeds on Mettler Top Loading Weighing Balance (Model-Mettler PM 11-K) before and after drying to constant weight. Twelve seeds represented a replicate. Three hundred (300) seeds were soaked in 0.5 % concentration of solution of the leaves of nitrogen fixing trees, *J. mimosifolia* for different periods (0, 6, 12, 18 and 24 hrs).
Stirring or bubbling was done to ensure uniform treatment and aeration. After each treatment, the seeds were removed, washed, air dried for 30 minutes and treated with fungicide (Vinclozolin). The seeds were also dried back to the initial moisture content. Treated seeds were planted in 4 cm depth of the sterilized sand and 200 ml of water per pot was applied regularly at two days interval for twelve weeks (Adelani *et al*., 2014b). Seeds that were not soaked in the 0.5 % concentration of solution of leaves of nitrogen fixing tree, *J. mimosifolia* served as control.

A seed was considered to have germinated when the radicle was able to break open the seed coat and at the sight of plumule emergence. For these experiments, germination percentage and mean germination time were calculated using the following formula (1 and 2) suggested by Schelin *et al*. (2003)

Germination percentage (%)

Germination percentage was computed using the formula:

$$\text{Germination Percentage} = \frac{Total seed germinated}{Total seed sown} \text{x } 100 \quad (1)$$

Germination count was recorded every two (2) days interval for 12 weeks when no more germination was recorded. Mean germination time is a measure of the rate and time spread of germination (Soltani *et al*., 2015). It is denoted as MGT. The unit of mean germination time can be hours, days or other time unit (Ranal and Santana, 2006).

$$\text{MGT} = \frac{\Sigma(f_x)}{\Sigma X} \qquad \text{Schelin } et\ al. \text{ (2003)} \qquad (2)$$

Where: x is the number of newly germinated seeds on each day; f is the numbers of days after seeds were set to germinate; X is the Total number of seeds that germinated at the end of the experiment. Germination percentage and mean germination time were recorded at two days interval for 12 weeks.

Data Analysis
Data were collected for seed germination and subjected to analysis of variance (ANOVA) using SAS (2003) software. Mean separations at 5 % significant level of probability were carried out with use of Least Significant Difference (LSD).

RESULTS AND DISCUSSION
A significant germination percentage value of 63.33% was recorded in *V. doniana* seeds organo-primed for 18hours. The least mean germination time of 13.33 days was recorded in *V. doniana* seeds organo-primed for 12 hours (Table 1).

Table 1: Effect of periods of organo-priming on the germination of *V. doniana* seeds

Periods (hrs)	Percentage (%)	MGT (days)
0	43.33^{ab}	14.67^{b}
6	43.33^{ab}	20.67^{ab}
12	30.00^{ab}	13.33^{b}
18	63.33^{a}	24.00^{a}
24	26.67^{b}	14.00^{b}
SE±	13.51	8.96

*Means on the same column having different superscript are significantly different (P<0.05) vertically

Key: P-Periods, % germ- Percentage germination, MGT-Mean

Effect of periods of hydro-priming on the germination of *V. doniana* seeds

Highest germination percentage value of 40 % was recorded in seeds hydro-primed for 24 hours (Table 2). Akinola *et al*. (2000) reported that higher duration of exposure to seed treatment resulted in higher cumulative germination in wild sunflower. Positive effect of seed priming on seed invigoration depends on priming duration (Ashraf and Foolad, 2005). It can be inferred that germination percentage increased with increasing periods of soaking of *V. doniana* seeds in water. Similar observation has been reported by Adelani (2015) and Adelani *et al*. (2018b) (Table 2). There was no germination in seeds not hydro-primed (control) compared to seeds hydro-primed for different hours. Hydro-priming enhances germination of *V. doniana* seeds. This result is in consonance with the report of Kaya *et al*. (2006) working on germination of sunflower under drought and salt stress who stated that hydro-priming improved both rate of germination and mean germination time both under salt and drought stress conditions.

Table 2: Effect of periods of hydro-priming on the germination of *V. doniana* seeds

P.H.P (hrs)	P. G (%)	MGT (Days)
0	0.00^{b}	0.00^{c}
6	7.00^{ab}	13.01^{c}
12	7.01^{ab}	13.00^{c}
18	33.00^{ab}	82.00^{b}
24	40.00^{a}	117.00^{a}
SE±	15.91	10.8

*Means on the same column having different superscripts are significantly different (P<0.05)

Key: P.H.P-Periods of hydro-priming, P.G-Percentage germination, M.G.T-Mean germination time.

Effect of periods of organo-priming on the germination of *C. schweinfurthii* seeds

Germination percentages of *C. schweinfurthii* seeds soaked for 0, 6, 12, 18 and 24 hours ranged between 11.67-40 %. Highest germination percentage of 40 % was recorded in seeds soaked for 6 and 12 hours. The least mean germination time value of 67.4 days was recorded in seeds treated for 24 hours (Table 3). Untreated seeds did not germinate. Soaking of the seeds in the 0.5 % solution of *J. mimosifolia* for 12 hours enhanced mean germination time (13.00day). Mean germination time of primed seeds varied with organo-priming periods. The ability of primed seeds to germinate earlier compared to inability of untreated seeds to germinate showed that priming reduces the mean germination time of seeds. Similar observation has been made by Demir and Mavi. (2004) who stated that prime seeds of water melon emerged 4 days earlier more than those of unprimed ones.

Table 3: Effect of periods of organo-priming on the germination of *C. schweinfurthii* seeds

P.H.O (Hrs)	P.G (%)	MGT (days)
0	0.00^{d}	0.00^{b}
6	40.00^{a}	69.60^{a}
12	40.00^{a}	74.11^{a}
18	11.67^{c}	71.20^{a}
24	25.00^{b}	67.40^{a}
SE±	5.71	4.90

*Means on the same column having different superscripts are significantly different (P<0.05)

Key: P.H.O-Periods of Organo-priming, P.G-Percentage Germination, M.G.T-Mean Germination Time.

CONCLUSION

Investigation conducted into periods of organo-priming and hydro-priming revealed that organo-priming of *V.doniana* seeds for 18hours, hydro-priming of *V. doniana* for 24 hours and organo-priming of *C. schweinfurthii* for 6 and 12 hours enhanced the germination percentages of their seeds. Appropriate periods of priming methods prevents under and over priming of seeds of agro-forestry tree species.

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Early Growth Performance of *Pentaclethra Macrophylla* (Benth) as influenced by Pretreatments

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Abstract

The effect of pretreatment on seed germination and early growth of Pentaclethra macrophylla (Benth) at nursery stage were investigated. Pentaclethra macrophylla seeds were pretreated by soaking in dilute tetraoxosulphate (vi) acid (diluted H_2SO_4) for different time intervals i.e. 5, 10and 15minutes ($T_1 – T_3$) and then washed with water. Some were soaked in cold water for 24hours (T_4) while the mechanical scarification was done by gently cracked seeds with hammer and then planted in the planting trays and controls were sown without pretreatment. The treated seeds were sown in the planting trays containing sterilized river sand and watered daily. Observation was recorded daily for emergence. The seedlings from these treatments were transplanted into polythene pots containing 2kg of top soil, and watering was done once a day. The experiment was laid out in Completely Randomized Design (CRD) and replicated 10 times. Assessment of growth parameters was done weekly. Growth variables assessed were plant height (cm), stem diameter (mm), leaf production and biomass. The result of analysis of variance (ANOVA) showed that, there were no significant differences in height and stem diameter but there were significant differences in number of leaves as well as the biomass component parts of the seedlings (leaf, stem and root) at 5% level of probability. The seedlings whose seeds were pretreated with mechanical scarification had the highest mean seedling height (18.38cm), number of leaves (12.60), highest mean leaf dry weight (4.60g) and root dry weight (6.12g) respectively. Based on the results obtained from the experiment, it is recommended that Pentaclethra macrophylla seeds should be soaked in cold water for24 hours for proper seedlings emergence in plantation establishment because it can be readily available to the farmers, it does not require much technicality.

Keywords: Pretreatment, Early growth, *Pentaclethra macrophylla,* seed germination

Introduction

Forest represents an important natural resource that can help developing countries improve their economic well-being. More than 1.6billion people worldwide depend on forest for their livelihood (USAID, 2007). Forest provides a wealth of important wood and non-timber forest products (such as edible nuts and fruits, medicinal plants, fibres, rattan, gum arabic and tannins) that people in the developed and developing world rely on, the value of wood and non-timber products provided by forest is immeasurable. One of the edible nuts and fruits that are of great importance found in the forest is *Pentaclethra macrophylla* (Benth) (Agbogidi, 2010.

Pentaclethra macrophylla (Benth) occurs in the forest zone of West and Central Africa, from Senegal to South-eastern Sudan and to Angola. It belongs to the family Mimosaceae and the common name is African oil bean tree. *P. macrophylla* is planted or retained along the edges of home gardens and farms mainly for its seed from which edible oil can be extracted (Onyeike *et al*., 2002). Throughout the forest zone of West Africa the seeds are eaten boiled or roasted *(Oyeleke et al., 2014)*. They are also fermented to yield a snack or condiment with a meaty taste, very popular in Eastern Nigeria where it is called "ugba" (Oboh *et al*., 2004). The empty dry pods are used as fuel for cooking. According to (Emebiriand Anyim, 1997), the medium-sized to fairly large *P. macrophylla* tree is up to 35m tall; bole up to 100cm in diameter, often crooked and low branching with irregular, thick buttresses up to 3m high or without buttresses; outer bark grayish to reddish brown, thin flaking irregular, inner bark fibrous, yellow to orange twigs brown stellate –hairy *(Ladipo and Boland, 1995)*.

Pentaclethra comprises of three different species; two in Africa and one in South America. The other species which is *Pentaclethra eetveldeana* (De Wild and T. Durand) can be distinguished by its smaller leaflets and simple hairs (Ladipo and Boland, 1995). The American *Pentaclethra macroloba* (Wild) yields timber traded as 'gavilan' and is an important medicinal plant. (Akindahunsi, 2004). *P. macrophylla* is common in primary forest and secondary forest and coastal savanna, often in the vicinity of creeks and rivers. It is most common in altitudes up to 500m, although growth can be good at higher elevation where rainfall is adequate and temperatures are never cooler than 18^0C (Oxford Forestry Institute, 2004).Farmers protect *P. macrophylla* species on farms because its open crown does not severely affect crop growth and because some trees are leafless during the growing season. The leaves also contribute to soil fertility (Latham, 2004), thus it can be used in agroforestry system.

P. macrophylla wood called 'mubala' or 'ovala' is suitable as fuel wood and for charcoal making. As few trees develop straight trunk of harvestable size, timber of larger sizes is only occasionally available. The wood is hard and difficult to work, but suitable for poles, railway sleepers and general carpentry (Banks and Schoemen, 1999). Traditionally, pestles and mortars have been made from it; ash from its wood or pods is used as a mordant in the dyeing industry. Development of medicinal and aromatic plants such as Africa oil bean seed (*P. macrophylla*), Marjoram, Grindelia, Robusta Mustard, Nutmeg etc needs more attention due to its important role in the improvement of people's health. Hamann, (1991) reported that 75% - 90%of the world's population depends on traditional herbal medicine for their primary health care which *P. macrophylla* is a constituent ingredient.

Forest resources and their roles in livelihood are in many forms which include food supply, income earning, employment, education, medicine and energy where *P. macrophylla* have been found to be useful. African oil bean seed (*P. macrophylla*) are being used for upgrading protein content of body food. *P. macrophylla*is used in Africa in traditional human and veterinary medicine. The ripe fruits are applied externally to heal wounds. Extracts of the leaf, stem bark, seed and fruit pulp have anti-inflammatory and anthelmintic activity and are used to treat gonorrhea and convulsions, and also used as analgesic (Akindahunsi, 2004). Despite this enormous importance of *P. macrophylla*, there is paucity of information on the silvicultural requirement of the species for its proper plantation establishment. Therefore this study sought the effect of pretreatment on seed germination and early growth of *P. macrophylla* (Benth).

Materials and Method

The experiment was carried out at the Nursery of Federal College of Forestry, Jericho, Ibadan, Oyo State. The College is situated at Jericho Hill under Ibadan North-West Local Government areas of Oyo State, Nigeria. The area lies between latitude $7^0$23' N and longitude $3^0$51' E. The climate is tropically dominated by rainfall pattern ranging between 1400mm – 1500mm. The average temperature is about 26^0C, average relative humidity of about 65% with two distinct season of wet (April to October) and dry (November to March) (FRIN, Metrological Station 2013). The seeds of *P. macrophylla* were procured from Aleshinloye market in Ibadan. Seeds of *P. macrophylla* were soaked in each different treatment level of dilute tetraoxosulphate (vi) acid (dil H_2SO_4) at different time intervals i.e. 5minutes (T_1), 10minutes (T_2) and 15minutes (T_3) and then washed with water to remove traces of the acid after which it was air dried before sowing in germination trays. Treatment four (T_4) was seeds soaked in cold water for 24hours and air dried before sowing. Treatment five (T_5) was the mechanical scarification of seeds which was done by gently cracking seeds with hammer and then sown in germination trays. The control (T_0) was sown without pretreatment. The germination trays contained sterilized river sand and watered daily.

Observation was recorded daily for emergence until no germination was noticed. The germinated seedlings from these treatments were pricked into polythene pots containing 2kg of top soil, a week after germination and watering were done once a day. The experiment was laid out in Completely Randomized Design (CRD) and replicated 5 times. This was allowed to stabilize for a week before the commencement of growth parameters. Data collection was carried out weekly. Growth parameters under assessment included: Plant height (cm) and this was done with the help of meter rule, Stem diameter (mm)using digital vernier caliper, Leaf production usually by counting, leaf area according to Cliffton-Brown (1997) and Biomass accumulation (g) by weighing the wet weight, oven dry the plants using oven dry machine (GallenKamp), then weighing them to determine the dry weight and subtract the dry weight from wet weight of the component parts (leaves, stems and roots) in the laboratory using sensitive weighing scale.Data collected were subjected to descriptive statistics and Analysis of Variance (ANOVA) while significant means were separated using Least Significant Difference (LSD).

Results and Discussion

The result below showed that T_4 (seeds soaked in cold water for 24hours) and T_5 (seeds cracked with hammer) had the highest germination percentage of 90%. The result was followed by T_0 (control), T_1 (seeds soaked in diluted H_2SO_4 for 5min) and T_3 (seeds soaked in diluted H_2SO_4 for 15min) with 70% each. While T_2 (seeds soaked in diluted H_2SO_4 for 10min) have the least germination percentage of 50% respectively. A seed pre-treatment (mechanical scarification and soaking in water for 24hours) enhances the germination as reported by (Hong *et al*., 1996 and Alaje *et al*., 2018).

Table 1: Germination percentage (%) of pretreated *P.macrophylla* seeds.

Treatment	**Seeds Sown**	**Seed Germinated**	**Germination %**
T_0	50	35	70
T_1	50	35	70
T_2	50	25	50
T_3	50	35	70
T_4	50	45	90
T_5	50	45	90

Table 2: Mean seedling growth of *Pentaclethra macrophylla* from different seed germination pretreatments.

Treatment	Plant Height (cm)	Collar Diameter (mm)	Number of Leaf	Leaf Area (cm^2)
T_0	13.94c	1.71d	7.58c	30.94d
T_1	9.91d	1.69d	7.02d	29.20d
T_2	5.70e	1.04e	4.32e	28.36d
T_3	14.05c	1.87c	7.98b	31.00c
T_4	15.27b	2.02b	8.10b	31.72b
T_5	18.38a	2.45a	12.60a	33.34a

Note: Means with the same letter are not significantly different from each other.

Table 2 above shows that Treatment 5 had the highest plant height of 18.38cm, followed by treatment 4 which had 15.27cm. The least plant height was found in treatment 2 having 5.70cm. Analysis of variance shows there is no significant difference among the treatments in plant height (Table 4). In collar diameter, it followed same trend with plant height, treatment 5 had the highest diameter of 2.45mm, followed by treatment 4 (2.02mm) and the least was found in treatment 2 (1.04). Analysis of variance shows there is no significant difference among the treatments in collar diameter (Table 4). Number of leaf presented treatment 5 as the best in the production of leaf having 12.60 and least in treatment 2 with 4.32. Analysis of variance shows there is significant difference among the treatments in number of leaf (Table 6). The same trend also was recorded for leaf area. Treatment 5, 4 and 2 had 33.34, 31.72 and 28.36 cm^2 respectively. Analysis of variance shows there is significant difference among the treatments in leaf area (Table 6).

Table 3: Mean dry weights of component parts of *Pentaclethra macrophylla* seedlings.

Treatment	leaf	Stem	Root
T_0	4.52a	1.92abc	4.25ab
T_1	2.42bc	1.69bc	3.2bc
T_2	1.35c	0.84c	1.41c
T_3	3.00abc	1.89abc	3.10bc
T_4	3.86ab	3.13a	4.68ab
T_5	4.6a	2.95ab	6.12a
Grand mean	3.29	2.07	3.79
LSD	2.07	1.41	2.50
%CV	70.80	75.88	73.57

Note: Means with the same letter are not significantly different from each other but means with different letter are significantly different.

Biomass production in table 3 above shows that treatment 5 had the highest leaf, stem and root biomass as 4.6, 2.95 and 6.12 respectively and treatment 2 had the least leaf, stem and root biomass as 1.35, 0.84, 1.41respectively. Analysis of variance shows there is significant difference among the treatment in leaf, stem and root biomass (Tables 7, 8 and 9)

Table 4: ANOVA table for plant height (cm)

SV	**df**	**SS**	**MS**	**F**	**P-value**
Treatments	5	988.80	197.76	2.15	0.07ns
Error	54	4955.80	91.77		
Total	59	5944.60			

Note: there is no significance different among the treatment at 5% level of probability.

Table 5: ANOVA table for stem diameter (mm)

SV	df	SS	MS	F	P-value
Treatments	5	11.33	2.27	1.85	0.12ns
Error	54	65.99	1.22		
Total	59	77.32			

Note: there is no significance different among the treatment at 5% level of probability.

Table 6: ANOVA table for number of leaves

SV	df	SS	MS	F	P-value
Treatments	5	363.86	72.77	2.72	0.02*
Error	54	1443.43	26.73		
Total	59	1807.29			

Note: there is significance different among the treatment at 5% level of probability.

Table 7: ANOVA table for leaf dry weight

SV	df	SS	MS	F	P-value
Treatments	5	81.35	16.27	3.06	0.02*
Error	54	287.51	5.32		
Total	59	368.85			

Note: there is significance different among the treatment at 5% level of probability.

Table 8: ANOVA table for stem dry weights

SV	df	SS	MS	F	P-value
Treatments	5	86.07	7.21	2.93	0.02*
Error	54	133.06	2.46		
Total	59	169.13			

Note: there is significance different among the treatment at 5% level of probability.

Table 9: ANOVA table for root dry weights

SV	df	SS	MS	F	P-value
Treatments	5	129.59	25.92	3.33	0.01*
Error	54	420.53	7.79		
Total	59	550.12			

Note: there is significance different among the treatment at 5% level of probability.

DISCUSSION

Seed coats of many plant species are hard and have evolved to overcome difficult environmental conditions like heat by direct sunlight, digestive enzymes of animals, severe drought and mechanical damage (Meyer *et al*., 1991 and Silvertown, 1999).Seed dormancy has several advantages to plants (Tao, 2000) as it enriches the soil seed bank with hard seeds, provides germination over a period of time whenever environmental conditions are suitable for seedling growth and survival (Wang *et al*., 1998). These seed coats hardiness are important factor that affects the germination pattern of the species (Lodge and Whalley, 2002); without breaking this dormancy, it is difficult to obtain required quantities of seedlings to plant up hectares of land in plantation establishment. Therefore, breaking the seed dormancy will softening the seed testa and allows water inhibition which is crucial for any afforestation and deforestation programmes.

Analysis of Variance shows that there was no significant difference among the treatments in height and stem diameter but there was significant difference among the treatments in leaf count at 5% level of probability. Also there was significant difference among all the treatments at 5% level of probability in biomass production. However, treatment five (T_5) i.e. seeds pretreated through mechanical scarification has the highest mean value in plant height (18.38cm),collar diameter (2.45mm), number of leaves value (12.60) and (33.34cm^2) leaf area. It also shows the same performance in leaf dry weight mean value (4.60g) and root dry weight mean value (6.12g). T_4 i.e. seeds pretreated with cold water for 24hours performed next to T_5 in height mean value (15.27cm), (31.72cm^2) leaf area and number of leaves mean value (8.10). It has stem diameter mean value (2.02mm) and stem dry weight mean value (3.13g), T_5 in leaf and root dry weight has mean value of 3.86g and 4.68g.In all the variables assessed, T_2 i.e. seeds pretreated with dil. H_2SO_4 for 10minutes has the least performance.

The result above is in accordance with the assertion that a seed pre-treated with (mechanical scarification and soaking in cold water for 24hours) enhances seed germination (Hong *et al*., 1996). Alaje *et al*., (2018) also asserted that water treatments enhance germination percentage of *P. macrophylla* seeds and the seeds soaked in water for 6days recorded highest percentage germination. Lower germination percentage was recorded with Diluted H_2SO_4 could be as a result of acid burnt the seeds and thereby lost its germination ability.

Conclusion and Recommendation

This study indicated that *P. macrophylla* germinates readily and better when scarified with mechanical method and when soaked in cold water for 24hours.It is concluded that both mechanical scarification and soaking in cold water for 24hours pre-treatment influenced the production of healthy and vigorous *P. macrophylla* seedlings, because it has the highest value of seedling height, stem diameter and number of leaves production. It is recommended to crack *P. macrophylla* seeds or soak in cold water for 24 hours before sowing so as to enhance an encouraging germination percentage for sustainable production of *P. macrophylla*. This method can be easily carried out by the farmers and it does not require much technicality before they can practice it.

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Effect of Watering Regimes on the Early Growth of *Milicia excelsa* (Welw. C.C. Berg) Seedlings

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Abstract

The recent discovery and overexploitation of Milicia excelsa species has generated a lot of concern. The high rate of exploitation of this forest tree species and the large traffic flow of this wood timber across the state is a source of concern because of its likely consequence to the environment. An investigation was carried out to assess the effects of watering regime on the early growth ofMiliciaexcelsa seedlings. A randomized block experimental design with four replicates were used to investigate the effect of watering regimes namely:W1 (Watering once daily), W2 (Watering twice daily), W3 (Watering three times a week), W4 (Watering once a week). Data collected on morphological and physiological parameters were subjected to analysis of variance (ANOVA) while Least Significant Difference (LSD) test compared significant differences at 5% level of significance. The highest collar diameter (3.07cm) was observed in once a week watering regime (W4) to pot capacity and the least (2.43cm) in once daily watering regime (W1) to pot capacity. W1 had the highest plant height (26.05cm) to pot capacity and the least (20.66cm) was observed in W4 to pot capacity. Also, once daily watering regime (W1) had the highest leaf production (39.16) and the least (29.33) was observed in W3. The highest leaf area (28.95cm^2) was observed when wateredthree times a week (W3) to pot capacity and the least (27.04 cm^2) when watered two times daily (W2) to pot capacity. The highest leaf length (16.97cm) was observed in W3 and the least (15.34cm) was observed in W1. Once a week watering regime (W4) had the highest root length (25.35cm) and the least (11.13cm) was observed when watered in W2 to pot capacity. Results showed that watering regime once a week (W4) was significantly ($P \leq 0.05$)different on the chlorophyll content of Milicia excelsa seedlings. It was demonstrated that watering regime significantly affected some of the important morphological parameters such as collar diameter and root length as well as physiological parameters i.e. fresh weight, turgidity, dry weight and chlorophyll content in seedlings of Milicia excelsa seedlings. Milicia excels seedlings performed best when subjected to once a week watering regime (W4), which means Milicia excelsa seedlings can source for water and also survive during dry season because its roots penetrated deep into the soil, it had the highest chlorophyll content which is a vital component of photosynthesis. and the highest collar diameter which makes it valuable for timber.

Keywords: watering regime, *Milicia excelsa*, early growth, seedlings

INTRODUCTION

Forests are known as being essential to our efforts to improve and adapt to climate change (Friend of the Earth, 2008). There is a growing understanding of the importance of the natural ecology in urban forests. An urban forest is a collection of trees that grow within a city, town, or a suburb forest and in a wider sense it may include any kind of woody plant vegetation growing in and around human settlements (Wikipedia, 2012a). Importance of urban forest in ecology of human habitats are numerous: they filter air, water, sunlight; provide shelter to animals and recreational area for people; moderate local climate; slowing wind and stormwater; and shading homes and businesses to conserve energy (Wikipedia, 2012b).

On the other hand plant survival, development and growth are based on their significant environmental factors; sunlight, nutrients and water. Water is the most essential of all; it determines the extent of introduction of exotic species as well as the beginning of vital forest operations. Some minerals, such as calcium, are stored in water and the plant can only access these minerals by up taking water (Graham, 2006). Water is required by plants for the manufacture of carbohydrates and as a means for transportation of foods and mineral elements (Price *et al*., 1986).Adequate water is required for the sufficient development of crops to maximum final yield (Heinemann, 1994).

Water is a significant factor in dry land forestry and it is critical to tree growth and development in the tropics (Awodola and Nwoboshi 1993). According to (Kabir and Abubakar 2012), for each ton of vegetative growth, hundreds of tons of water may be consumed by the growing plant particularly in dry climates. Awodola 1984, observed that the reduction in relative water contents affects physiological processes and hence growth. Similarly, too much water, in excess of plant need may retard the physiological processes. Watering regime can be described as the quantity of water required for germination productivity of quality seedlings and satisfactory growth (Kozlowski and Pallardy, 2002). It has been observed that when water content of the soil is raised, the yield increase rapidly, then more slowly. It is important to note that the growth of root and shoot are not influenced equally by the factor and also chemical composition of some species is affected by variation of water availability.

Under irrigation gives poor soil salinity control which leads to increased soil salinity with consequent build-up of toxic salts on soil surface in areas with high evaporation. Over irrigation because of poor distribution uniformity or management wastes water chemicals, and may lead to water pollution (Wikipedia, 2010). According to Broner (2005), irrigation scheduling is the decision of when and how much water to apply to a field. Its purpose is to maximize irrigation efficiencies by applying the exact amount of water needed to replenish the soil moisture to the desired level. The purpose of irrigation scheduling is to determine the exact amount of water to apply to the field and the exact timing for application. The amount of water applied is determined by using a criterion to determine irrigation need and a strategy to prescribe how much water to apply in any situation (Broner, 2005). Many growers obtain much lower yield, primarily because of inadequate irrigation scheduling (Mermoud*et al.,* 2005).

Milicia excelsa is one of the most important timber trees in Nigeria. The heartwood is durable, workable and resistant to termites and marine borers. The gravity is about 0.55g1cm^3 (Dorthe, 2005). It is mainly used for outdoor construction work, furniture, boats, cabinet-work, panelling, frames and floors. The bark, its ashes, leaves and latex are used in local min edicine and the trees play a major role in many local cultures where they are considered sacred, or parts of the tree serve ceremonial purposes (Putheti and Okigbo, 2008). There has not been any successful plantation establishment of this species in Nigeria due to the problem of gall fly, Phytolymafusca that affect it in early growing stage (Cobbinah*et al*, 2000; Alebiosu and Oyeleye 2007). In addition, International Union for Conservation of Nature (IUCN, 2006) Red Data List of threatened species listed Iroko as one of the “near threatened” valuable timber species. A number of countries have formulated policies toward its protection. For instance, it is protected by legislation in Ghana, Ivory Coast and Mozambique, while in Kenya, a Presidential ban on logging of indigenous timber was implemented in 1986 (CBD, 2002). Populations of M. excelsa in the natural forests have been in decline over the years, resulting in the fact that only areas which still have considerable stands of*M. excelsa* are universities Forests, Strict nature reserves and cemeteries (Borokini *et al*., 2013).

The recent discovery and over exploitation of *Miliciaexcelsa* species has generated a lot of concern. The high rate of exploitation of this forest tree species and the large traffic flow of this wood timber across the state is a source of concern because of its likely consequence to the environment. As a result of this situation, there is an urgent need for the protection, conservation multiplication of our indigenous tree species of *Miliciaexcelsa* is one of them. The determination of the productivity requirements of these tree species for its effective germination and multiplication is needed.

This study aimed at determining the effect of watering regime on this economic species to help improve the quality and quantity of wood supply to wood based industries and ever increasing demand due population growth and rising standard of living.

MATERIALS AND METHODS

Study area and Plant materials

The experiment was carried out in the forest nursery of the department of forestry and wildlife management in the Federal University of Agriculture Abeokuta. This area falls within the latitude 70 N and 7°58 and longitude 3°20’E and 3°37’E. It has a gentle undulating landscape and mild slope. The soils are sand and clay with crystalline basement complex. It has annual rainfall of 1200mm with peaks in June and July; there is a dry season of two or three months. The relative humidity of the area is 82.5 4% and an average monthly temperature of 35.8°C.
The items used for this research include; *Miliciaexcelsa*seedlings, polypots, veneer calliper for the measurement of stem girth, water, ruler for the measurement of seedling height, weighing balance, watering can, petri dishesand oven to dry the plants.

Experimental Design

Miliciaexcelsa seedlings were raised in polypots using the nursery soil at FUNAAB nursery. A completely randomized design was laid to assess the effect of watering regimes There were four experimental treatments for the species thus the treatment were represented as SWR_1, SWR_2, SWR_3, SWR_4. The seedlings used were denoted as S for *Milicia excelsa* and the watering regimes was denoted as WR.

Table 1: A table showing the experimental layouts for *Milicia excelsa*

	Replicates			
Treatment	1	2	3	4
WR_1				
WR_2				
WR_3				
WR_4				

Watering regime l (WR1) — once daily watering
Watering regime 2 (WR2) — twice daily watering
Watering regime 3 (WR3) — three times a week
Watering regime 4 (WR4) — watering once a week

Data collection on morphological parameters

Parameters measured include; morphological parameters like collar diameter, plant height, leaf area, leaf lengthand physiological parameters like relative leaf turgidity, chlorophyll content, shoot to root ratio, net assimilation rate (NAR), relative assimilation rate (RAR), absolute assimilation rate (AGR). At the start of the experiment, number of nodes per seedling and number of fully unfolded leaves per seedling were determined by physical count and after every 2 weeks, until termination of the experiment. The plant height (cm) was measured vertically using a meter rule from the base to the tip of the seedling at the start of the experiment and after every 2 weeks until termination of the experiment.

Data collection on physiological parameters

Destructive analysis was carried out on seedlings to obtain the relative turgidity, chlorophyll content, shoot to root ratio, NARI (Net assimilation rate), RGR (Relative growth rate), AGR (Absolute growth rate).

$$\text{Relative Turgidity (RT)} = \frac{FreshWeight - DryWeight}{Turgidweight - DryWeight} \text{ X } 100$$

$$\text{Root to shoot ratio} = \frac{Root\ weight}{Shoot\ weight}$$

$$\text{NAR} = \frac{Final\ weight\ (W_2) - Initial\ weight\ (W_1)}{Change\ in\ time\ (T)\ X\ Leaf\ area}$$

$$\text{RGR} = \frac{W_2 - W_1 X\ 100}{T}$$

$$\text{AGR} = \frac{W_2 - W_1}{T}$$

Data Analysis

The data obtained were subjected to ANOVA, using statisticalanalysis system(SAS 9.1) and means were separated using Least Significant Difference (LSD) test at 5% levelof significance.

RESULTS AND DISCUSSION

Effects of treatment on collar diameter of *Miliciaexcelsa* seedlings (mm).

Highest collar diameter (3.07cm) occurred in *Miliciaexcelsa*seedlings when treated with once a week watering regime (W4) and the least (2.43cm) was observed when watered daily (W1) (Table 2). The result showed that there was no significant ($P \leq 0.05$)effect of watering regime on collar diameter of *Miliciaexcelsa* seedlings (Table 3).This correlates with the findings of Mohamed *et.al* (2013) that there was no significant($P \leq 0.05$) difference in collar diameter between different irrigation frequencies.

Effects of treatments on plant height of *Miliciaexcelsa* seedlings (cm).

Highest plant height (26.05cm) was obtained in *Miliciaexcelsa*seedlings treated with once daily watering regime (W1) and the least (20.66cm) was observed when treated with once a week watering regime (W4) (Table 2).This is contrary to the findings of Ogunrotimi and Joshua 2018 who reported that seedlings subjected to watering once a week had the highest plant height.The effect of watering regime on the height of *Miliciaexcelsa*seedlings.was not significantly ($P \leq 0.05$)different ($p<0.05$).This is similar to the findings of Oladeji *et al*. (2014) who reported that plant height of *Dialiumguineense* was not significantly ($P \leq 0.05$)affected by watering regime as well as the result of Mohamed *et al* (2013) where the height was not significantly affected by different irrigation frequencies.

Effects of treatments on leaf production of *Miliciaexcelsa* seedlings

The result showed that the highest leaf production (39.16) occurred in *Miliciaexcelsa* when treated with once daily watering regime (WI) and the least (29.33) was observed when treatedwith three times a week watering regime (W3) (Table 2). Similar observation was made by Adelani (2019), who stated that highest number of leaves of C. tangelo was recorded in seedlings watered daily and the least was observed when watered three times a week (W3). The effect of watering regime was not significantly ($P \leq 0.05$)different on the leaf production of *Miliciaexcelsa* seedlings (Table 3).This is in consonance with reports of Oboho and Igharo (2017) who stated that the rate of increase in leaf numberof *Pycnanthusangolensis*can be said to be directly proportional to the frequency of wateringregime as seedlings watered everyday produced thehighest number of leaves.

Effects of treatments on leaf area of *Miliciaexcelsa*seedlings (cm^2)

The result showed that highest leaf area (28.95cm^2) occurred in*Miliciaexcelsa* seedlings when treated with three times a week watering regime (W3) and the least (27.04 cm^2) when treated with twice daily watering regime (W2) (Table 2).There was no significant ($P \leq 0.05$)effect of watering regime on the leaf area of *Miliciaexcelsa*seedlings (Table 3),this is contrary to Dauda*et al*(2009) who reported that the leaf area of Myrobian seedlings was significantly($P \leq 0.05$) affected by watering frequency.Also, this is not in conformity with the findings Ogunrotimi and Kayode (2018) who stated that*Solanummacrocarpon*might require much water as seedlings watered everyday had the highest leafarea.

Effects of treatments on leaf length of *Miliciaexceisa* seedlings (cm)

From Table 2, the highest leaf length (16.97cm) was observed in *Miliciaexcelsa* when treated with three times a week watering regime (W3) and the least (15.34) was observed when treated with once daily watering regime (W1). Also,the effect of watering regime was not significant($P \leq 0.05$) on the leaf length of *Miliciaexcelsa s*eedlings(Table 3).

Effects of treatments on root length of *Miliciaexcelsa* seedlings (cm)

The result showed that highest root length (25.35) occurred *Miliciaexcelsa* seedlings when treated with once a week watering regime (W4) and the least was (11.125) was observed when treated with twice daily watering regime (W2) (Table 2).The effects of watering regime was significantly($P \leq 0.05$) different on the root length of *Miliciaexcelsa* seedlings (Table 3). This is contrary to the findings of Mohamed *et.al* (2013) where no effect was observed among the different watering frequencies with respect to root length.

Table 2: Means of some growth parameters of *Miliciaexcelsa*seedlings under different watering regimes

Treatments	Collar Diameter (mm)	Plant Height (cm)	Leaf Production	Leaf Area (cm^2)	Leaf Length (cm)	Root Length (cm)
Once daily watering (W1)	2.43	26.05	9.79	27.59	15.34	12
Twice daily watering (W2)	2.65	24.2	9.41	27.04	15.84	11
Thrice a week watering (W3)	2.88	22.95	7.34	28.95	16.97	21
Once a week watering (W4)	3.07	20.66	8.49	28.29	16.26	25

Table 3: Summary of analysis of variance for growth variablesof *Miliciaexcelsa*seedlings under differentwatering regimes

		Collar Diameter		Plant Height		Leaf Production		Leaf Area		Leaf Length		Root Length	
SV	Df	Ms	F	Ms	F	Ms	F	Ms	F	Ms	F	Ms	F
Treatment	3	0.30	5.30*	20.9	3.00^{ns}	4.8	2.30^{ns}	4.80	0.66^{ns}	1.9	1.21^{ns}	191.3	2.67*
Error	12	0.05		6.37		2.12		2.10		1.57		0.716	
Total	15												

*Significantly different ($P \leq 0.05$), Keys: SV- Source of variation; MS- Mean square; F- F value.

Effects of watering regime on the physiological parameters of*Miliciaexcelsa* seedlings

Watering regime was significantly ($P \leq 0.05$)different on the fresh weight, turgidity,shoot weight, dry weight and chlorophyll content of *Miliciaexcelsa* seedlings when treated with once a week watering regime(W4) (Table 4). Watering regime once a week (W4) was significantly different on the chlorophyll content of Miliciaexcelsa seedlings. The highest value of was observed when watered once a week (W4) and the least value occurred when watered once daily (W1).Similarly,Luvaha*et al*.,(2012), reported that, *Mangifera indica* seedlings under mild water deficit (watering once or twice in a week) promote growth rate as compared to well watered seedling (watering once or twice daily). The effect of watering regime once a week (W4) was significantly($P \leq 0.05$) different on the fresh weight, turgidity and the dry weight of *Miliciaexcelsa* seedlings.This result agreed with the findings of Sakio (2005) that flooding reduces the total dry weight increment in some plant species.

Watering regime had no significant ($P \leq 0.05$) effect on the shoot weight and root weight of *Miliciaexcelsa* seedling. This supports Mohmed*et.al* (2013) and Adelani (2019) who made an observation that there were no significant ($P \leq 0.05$) differences found among the four irrigation frequencies with respect to shoot fresh weight and shoot dry weight. It was also revealed that watering regime had no significant effect on the absolute growth rate, relative growth rate, net assimilation rate and relative water content of *Milicia excels* seedlings.

Table 4: Summary of analysis of variance for morphological parameters of *Miliciaexcelsa*seedlings under different watering regimes

Parameters	SV	Df	Ms	F
Fresh weight	Treatment	3	23.01	3.66*
	Error	12	6.28	
	Total	15		
Turgidity weight	Treatment	3	34.04	4.15*
	Error	12	8.20	
	Total	15		
Shoot weight	Treatment	3	11.46	2.79*
	Error	12	4.11	
	Total	15		
Dry weight	Treatment	3	2.48	3.75*
	Error	12	0.66	
	Total	15		
Chlorophyll content	Treatment	3	5.65	225*
	Error	12	0.03	
	Total	15		
Root weight	Treatment	3	2.51	2.2^{ns}
	Error	12	1.13	
	Total	15		
root Relative Growth Rate	Treatment	3	8.22	0.5^{ns}
	Error	12	15.8	
	Total	15		
Absolute Growth Rate (AGR)	Treatment	3	0.02	2.9^{ns}
	Error	12	0.01	
	Total	15		
Relative Water Content (RWC)	Treatment	3	128	0.3^{ns}
	Error	12	499	
	Total	15		
Net Assimilation Rate (NAR)	Treatment	3	1.76	1.3^{ns}
	Error	12	1.31	
	Total	15		

*Significantly different at $P \leq 0.05$, Keys: SV- Source of variation; MS- Mean square; F- F value.

CONCLUSION

It was demonstrated that watering regime significantly affected some of the important morphological and physiological parameters such as collar diameter, root length, fresh weight, turgidity, dry weight and chlorophyll content in seedlings of *Milicia excelsa* seedlings. *Milicia excelsa* seedlings performed best when subjected to once a week watering regime (W4), which means *Milicia excelsa* seedlings can source for water and also survive during dry season because its roots penetrated deep into the soil, it had the highest chlorophyll content which is a vital component of photosynthesis and the highest collar diameter which makes it valuable for timber. All these were observed during the experiment. It is better for a tree to have a deep root than a high shoot.

RECOMMENDATIONS

It was observed that once a week watering regime (W4) did better than other watering regime. Therefore, it is recommended that once a week watering regime (W4) should be adopted for the growth of *Milicia excelsa* in order to have optimum performance.

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Germination Studies in Seeds of Selected Semi-Arid Agroforestry Trees in Nigeria

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Abstract

Germination of seeds of some agroforestry species was evaluated to determine the most plausible nursery practices. Maturity of seeds (green, light brown, and brown seeds), ratio of seed-weight: hot water, and mechanical scarification were examined for their effects on germination. Storage of seeds in refrigerator (2^0C), screen house (31-42^0C) and laboratory (32 ± 4^0C) were also investigated for germination. Completely randomized design was employed and the data obtained were subjected to analysis of variance. Means were separated using Ducan Multiple Range Test (DMRT). Non-fully matured (light brown) seeds of Acacia nilotica recorded the highest (90%) germination, but the seeds of the rest five tree species required to be fully matured for good germination. The screen house stored-seeds showed the highest percentage germination: A. nilotica (42.3%), Zizyphus spina-christi (51.4%), Zizyphus mauritiana (39.7%), Diospyros mespiliformis (31.9%), Tamarindus indica (36.9%), while Balanites aegyptiaca seeds stored in the laboratory (29.2%) germinated the most except those of Z. spina-christi and D. mespiliformis that germinated highest after two months of storage. Higher seed-weight to hot water elicited better germination. Seeds of most tree species germinated best when matured. The screen house storage is the best for seed germination. The forest tree seeds germinated faster with scarification.

Keywords: germination, sacrification, maturity, agroforestry, screen-house

INTRODUCTION

The Sudan savanna ecological zone in Nigeria is threatened by the encroaching desert from the Sahara. Consequently, afforestation programmes particularly through shelterbelt establishment are being reinforced to combat desertification. *Zizyphus mauritiana* (Lam), *Diospyros mespiliformis* (Hochst), *Balanites aegyptiaca* (Linn), *Acacia nilotica* (L) and *Tamarindus indica* (Linn) are woody species with potentials as agroforestry tree species in the semi-arid and arid zones of Nigeria (Ola-Adams, 2009). One of the requirements for success in agroforestry systems is quick and early establishment of the tree component (Kings, 2017). This is largely a function of percentage seed germination.

To obtain prompt and where possible, increase total germination, seeds of tree species which show low or prolonged germination are often subjected to some pre-germination treatments such as light and temperature variation, soaking in water, mechanical and chemical treatments (Ibrahim and Nwoboshi,1990). Once the seed coat is made permeable to water, the inhibitory substances are leached out and germination occurs (ICRAF, 1992). Germination of most tree seeds can occur over a wide range of temperature and it has generally been found that the best germination occurs when temperature fluctuates than when constant (Shaw, 2015). Although, it is known that seed coats of most legumes are hard and impervious to water and gas, and that scarification with hot water or mechanical scarification is widely used to break seed coat dormancy, some of the current procedures are either not specific enough or too costly to give consistently high germination percentage. This investigation is designed to assess the effects of hot water treatment method, storage conditions, mechanical scarification and seed maturity on germination percentage in seeds of all the species used.

MATERIALS AND METHODS

Seeds of *Zizyphus spina-christi* (L.), *Zizyphus mauritiana* (L.), *Diospyros mespiliformis* (H), *Balanites aegyptiaca* (L.), *Acacia nilotica* (L.)and *Tamarindus indica* (L.) were investigated for germination. Fifty seeds were used in each case and in each trial 10 seeds represented a replicate.

Experiment I: Effect of seed maturity on germination:
The aim of this investigation was to assess the effect of different stages of seed maturity (green, light brown and brown seeds) on percentage germination of the six tree species. The experiment was carried out using a randomized complete block design with five replications of each species.

Experiment II: Effect of mode of storage on seed germination:
Ripe seeds of the six selected tree species were obtained from the plants and stored for various periods (1, 2 and 3 months) at a screen house (31-42^{0}C), laboratory (32±4^{0}C) and in refrigerator (2^{0}C). At the end of each storage, sample seeds were treated with 10% sulphuric acid and the rest (untreated) served as control. Percentage germination of the seeds was comparatively studied.

Experiment III: Effect of mechanical seed scarification on seed germination:
This experiment was carried out to assess the effect of mechanical seed scarification on percentage germination of the seeds. The seeds were scarified at three different sites, the micropylar region, the circumference and the distal end. The seeds were cut with a sharp knife. The scarified seeds were laid on moist cotton wool inside Petri dishes. The trial was carried out using completely randomized design with five replication of each species.

Experiment IV: Effect of hot water treatment on seed germination:
The seeds of six species were soaked in hot water of 70^{0}C for 30 minutes and tested for germination using split plot design with five replications. The volume of hot water (1 and 2 litres) made up the sub-plot treatment. The light seeds were tied up in muslin cloth together with a weight (small stone) that made it sink in the hot water (70^{0}C).

Data analysis.
The data obtained from all the variables were subjected to package for agricultural research (AGRES). Significant difference in the treatments was further subjected to Duncan Multiple Range Test (DMRT) for the separation of treatment means.

RESULTS
The results of all experiments in this investigation are as presented in Tables 1-3. Non-fully matured (light brown) seeds of *Acacia nilotica* recorded the highest (90%) germination, while the seeds of the rest five tree species required fully matured seeds for good germination. The screen house stored-seeds showed the highest percentage germination: *A. nilotica* (42.3%), *Z. spina-christi*(51.4%), *Z.mauritiana* (39.7%), *D.mespiliformis* (31.9%) *T. indica* (36.9%), while *B. aegyptiaca* seeds stored in the laboratory (29.2%) germinated the highest. Three months storage seed germinated the most except those of *Z. spina-christi* and *D. mespiliformis* that germinated the highest by two months in storage. Higher seed weight to hot water elicited better germination. Seeds of most tree species germinated best when matured. The seeds should be kept in the screen house for storage. They responded to scarification than the non-treated (Tables 1, 2 & 3). The seeds of *Z. spina-christi* and *D. mespiliformis* stored in the screen house for 3months recorded lesser percentage germination than those stored for two months. The seeds of *A. nilotica, Z. mauritiana*, *B. aegyptiaca* and *T. indica* had progressively higher percentage germination over the 3months of storage (Table 3).

The effect of seed-weight to volume of hot water on percentage germination showed that 50g:1litre and 100g:1litre seed weight to hot water ratios generally recorded higher germination percent than 10g:1litre. Similar results were obtained with 2litres hot water (Table 5). Rate of germination among the six tree species is fastest in *A. nilotica*, followed by *T. indica*, *Z. mauritiana*, Z. *spina-christi, D.mespiliformis* and *B. aegyptiaca* taking the longest days to germinate.
Mechanical seed site scarification influenced germination percentage of the species. The scarification of the seeds at the circumference enhanced the highest percentage germination than the other sites. The seeds of *A. nilotica* scarified at the circumference had the best germination percentage (60.3%), followed by *Z. spina-christi* (54.2%), *Z. mauritiana* (42.2%) *D. mespiliformis* (50.2%) and *T. indica* (40.7%), However, the seeds of *B. aegyptiaca* scarified at the micropylar end had best germination percentage (30.2%) compared with the other seed-sites tested for germination (Table 4).

Table 1. Effect of maturity on percentage seed germination.

Species	Green Seed	Light Brown	Brown
Acacia nilotica	14.9^b	90.0^e	23.8^c
Zizyphus spina-chirsti	8.6^a	28.6^c	31.7^d
Zizyphus mauritiana	6.7^a	27.4^c	33.3^d
Diospyros mespiliformis	8.6^a	24.9^c	28.3^c
Balanites aegyptiaca	3.6^a	26.0^c	29.0^c
Tamarindus indica	12.7^a	30.4^d	39.6^d

Means in a column followed by the same letter(s) are not significantly different (P<0.05) according to Duncan's New Multiple Range Test (DMRT).

Table 2. Germination of seeds stored in different conditions

Storage condition	*Acacia nilotica*	*Zizyphus spina-christi*	*Zizyphus mauritiana*	*Diospyros mesipiliformis*	*Balanites aegyptiaca*	*Tamarindus indica*
Refrigerator	0.8[a]	1.5[a]	1.5[a]	0.4[a]	0.3[a]	0.6[a]
Laboratory	27.4[d]	32.9[e]	16.3[c]	11.8[c]	29.2[d]	24.7[d]
Screen House	42.3[f]	51.4[f]	39.7[e]	31.9[e]	18.4[c]	36.9[e]
Untreated Seeds	16.9[c]	13.7[c]	11.4[c]	1.8[a]	1.3[a]	4.3[a]

Means with different letters are not significantly different (P<0.05) according to Duncan's New Multiple Range Test (DMRT).

Table 3. Percentage germination of the screen house seeds assessed over 3 months

Months	*Acacia nilotica*	*Zyziphus spina-christi*	*Zyziphus mauritiana*	*Diospyros mesipiliformis*	*Balanitis aegyptiaca*	*Tamarindus indica*
1	33.2[a]	21.5[d]	20.8[d]	12.7[c]	8.1[b]	12.4[c]
2	36.1[e]	48.8[f]	24.9[d]	13.2[c]	8.9[d]	13.1[c]
3	47.5[f]	26.9[d]	30.0[e]	12.9[c]	10.9[c]	16.7[c]
Untreated Seeds	16.9[c]	13.7[c]	11.4[c]	1.8[a]	1.3[a]	4.3[a]

Means with different letters are not significantly different (P<0.05) according to Duncan's New Multiple Range Test (DMRT).

Table 4. The mechanical seed scarification of percentage seed germination of tree species.

Species	Time of germination (Days)	Micropyle	Circumference	Distal end
Acacia nilotica	6[a]	10.6[a]	60.3[g]	22.8[c]
Zizyphus spina-christi	13[a]	19.9[b]	54.2[f]	23.4[c]
Zizyphus mauritiana	13[b]	19.7[b]	42.2[c]	19.5[b]
Diospyros mespiliformis	19[b]	38.6[d]	50.2[f]	31.2[c]
Balanites.aegyptiaca	25[c]	30.2[c]	19.3[b]	17.7[b]
Tamarindus indica	11[a]	20.8[c]	40.7[e]	22.5[c]

Means with different letters are not significantly different (P<O.05) according to Duncan's New Multiple. (DMRT)

Table 5. The effect of hot water and seed weight interact interaction on the seed germination.

Species	First germination appearance (Days)	One litre			Two litres		
		10g	50g	100g	10g	50g	100g
Acacia nilotica	5.0	2.2[c]	38.4[f]	46.2[f]	2.2[c]	38.4[f]	46.2[f]
Zizyphus spina-christi	11.0	14.0[d]	58.3[g]	50.3[g]	14.2	58.3[g]	47.3[f]
Zizyphus mauritiana	9.0	6.7[c]	28.6[e]	30.2[f]	6.7[c]	28.6[e]	30.2[f]
Diospyros mespiliformis	19.0	1.5[b]	2.9[c]	19.9[d]	1.5[b]	2.9[c]	19.9[d]
Balanites aegyptiaca	24	0.5[a]	1.5[b]	2.2[c]	0.5[a]	1.5[b]	2.2[c]
Tamarindus indica	8.0	4.1c	12.6d	29.9e	4.1c	12.7d	29.1[e]

Means with different letter are not significantly different (P<O.05) according to Duncan's New Multiple (DRMT)

DISCUSSION

The percentage germination of the seeds of the various species of woody trees used in this investigation showed clearly that ripe and dried seeds have significantly different physiological process from the green and light brown seeds. This is similar to the finding of Abdullahi (2015) in seeds of *Acacia senegal* which showed that the decline in percentage germination of the dry seeds suggests increasing hardening of testa with stage of maturity. The lower germination percentage of the green seeds compared to higher germination percentage in light brown suggests that the seed embryo was not fully matured.

In all the species tested for germination, the percentage germination of the seeds stored in the screened house either for 1, 2 or 3 months was significantly higher than the untreated ones stored for the same period. This is probably because the treatment had helped to break the dormancy of the seeds, thereby enhancing the rate of germination. The percentage germination of the treated seeds stored in the screen house was significantly higher than untreated seeds stored either in the refrigerator or laboratory. This is similar to the results obtained by Duru and Tips (1994) and Awodola (1993) which stated that storage for a long period at a relatively high temperature enhances seed germination, by reduction in seed coat impermeability. However, the percentage germination was lower with lower seed-weight to hot water volume ratios. This could be attributed to availability of excess high temperature water which could have had damaging effect in the seed embryo. At high seed weight to hot water volume ratio, temperature decreased quickly on immersion of seeds, with seed embryo not adversely affected.

CONCLUSION

The seeds of woody species ordinarily, have long dormancy period even under suitable environmental conditions. Their early germination with all the scarification methods is indicative of thick seed coat that prevented imbibitions of water, hence, delayed germination. It has been possible to shorten the period of first appearance of germination of the seed of all the species. Hence the various scarification methods are the factors that influence germination potentials of the seeds.

RECOMMENDATION

Foresters should raise seedlings from fully matured seeds. Harvested seeds should be stored in screen house, for a period of 3 months in most cases. Early germination of seeds is obtained when scarified at the seed circumference.

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Non-silk Benefits from Sericulture – A Review

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Abstract:

In developing countries, challenges facing sericulture are poor marketing channels for cocoon, inadequate technical-know-how and equipment for cocoon processing to its final products for utilization. All these mentioned factors reduce farmers' enthusiasm to engage in the enterprise. However, there are other overlooked areas of sericulture that are of benefits to man and nature beside silk. This paper uncovered other profitable non-silk benefits that can be derived from this venture. The silkworm pupae constitutes a major raw material in production of paints, va nishes and livestock feeds. The cultivation of mulberry plant is of purpose importance to medical science and environment. Many studies on mulberry plant revealed that the leaf, fruit and stem possess many properties which make them useful in the treatment of human diseases like anemia, insomnia and hepatitis. The extensive root system, high biomass production and strong environmental adaptability of mulberry plant give it a place in the control of desertification, water and soil conservation, management of saline land and bioremediation. Studies on the waste generated from the rearing process showed its importance in the management of infectious diseases such as headache and blood pressure. Flavonoids and other compounds present in silkworm excrement make i t a great natural colorant in food industry. In conclusion, attention should not only be given to cocoon as the only profitable yield from sericulture but also other benefits associated with this practice. This should encourage farmers to embrace sericulture as a means of profitable business to increase their livelihood and generate support from government and local investors.

Keywords: Sericulture, non-silk, silkworm pupae, mulberry and waste

INTRODUCTION

The word "sericulture" was derived from the word "su" (si) (Dewangan, 2013), it means rearing of silkworm for the production of silk. Sericulture has two sectors vis-à-vis farm (moriculture) and industry (Shrivastav, 2005). As highlighted by Ahmed and Rajan (2011), sericulture comprises of inter-linked activities like food plant cultivation, maintenance to feed the silkworm, silkworm rearing to produce the silk cocoons, reeling of the cocoons for unwinding the silk filament, yarn making, weaving and processing of fabric. In that light, sericulture has been found to be one of the economic enterprises that could be run profitably.

There are different kinds of silk produced by different insect especially lepidopteran in different part of the world. Notably are Anaphe silk, tasar silk, muga silk, eri silk, fagara silk, mussel silk, coan silk, spider silk and mulberry silk. Out of the entire world production of silk, more than 90% of the silk comes from cocoons of mulberry silkworm (*Bombyx mori*) (Valerie *et al*., 2015). Owing to several bottlenecks surrounding silk production from *B. mori* in Nigeria such as lack of appropriate system for cocoon and silk marketing, inadequate technical-know-how and lack of equipment for processing cocoon to silk, a lot of farmers are either dropping the venture for other one or are not interested at all. To this end, this paper tries to look into other non-silk benefits that accrue to sericulture venture with the view to sensitizing and encouraging farmers to stay in it and earn their living profitably.

A. BENEFITS FROM MULBERRY PLANTS

Mulberry (*Morus alba*) is a fast growing hardy perennial woody plant that belongs to the family Moraceae (Pan and Lou, 2008; Yang *et al*., 2010). Characteristics such as higher foliage yield, shorter gestation period and stronger environmental adaptability define its importance to man, livestock and the environment. The leaves of mulberry are being used extensively for the feeding of silkworm (*Bombyx mori*) for the production of silk (Ashmita *et al*., 2017). In addition to feeding of silkworm mulberry plant also is of nutritional, medicinal and environmental importance.

In a development, several researchers investigated and reported antioxidant potential of the extracts from different mulberry plant part such as leaves, branches, roots and fruit (Andallu *et al*., 2001; Andallu and Varadacharyulu, 2002; Arfan *et al*., 2012). Among the active compounds found in mulberry leaves are alkaloids such as 1-deoxynijirimycin and fagomine (Hu *et al*., 2013). These two are known to decrease blood glucose (Hao *et al*., 2018) Mulberry leaves are known to be well laden with phytochemicals like coumarins, flavonoids and phenols. These have made it to have significant usefulness in reduction of blood pressure and cholesterol level in human body (Sheng-qin and Wu, 2003; Zhang *et al*., 2009). In mulberry fruits, the most effective phenolic compounds reportedly found are the flavonols (Jin *et al*., 2017).
Furthermore, the roles of mulberry plant in traditional medicine cannot be overemphasized. Different mulberry plants have been used since time immemorial in treating different ailments. This is due to presence of many important bioactive substances such as polyphenol and antioxidative flavonoid compounds. The plant contains moranolin, moran (glycopeptides), hydrophobic flavonoids (flavones and flavonone) and 2-arylbenzofuran which play significant roles in hypoglycemic action (Singab *et al*., 2005; Fallon *et al*., 2008). As reported by Andallu *et al*. (2001), there was an improvement in glycemic control and reduction in very low density lipoprotein (VLDL) production in patients suffering from type II diabetes when treated with mulberry.

Mulberry fruits are known to be edible and well recognized for its sweet taste. They have several excellent characteristics like delicious taste, moderate size, attractive colour, high nutritive and medicinal values (Ashmita *et al*., 2017). They are rich in amino acids, vitamins and minerals such as Zn, Mn, Fe, Ca. The fruit juices of mulberry are used to cure mouth ulcers, fever, heart, throat, digestive enhance appetite, control excessive thirst, eye sight, anaemia, dizziness, insomnia, hepatitis, constipations, aid in weight loss, builds immunity, relieve tiredness and fatigue, and increase hair growth (Nazim *et al*., 2017). Apart from its benefit to human, several parts of mulberry leaves also serve as feed for livestock. For instance, leaf stalks and leftover such as twigs and shoots that are considered to be a waste serve as excellent feed for cows, sheep and other livestock. Another study also showed mulberry leaves contain beta carotene which are converted by poultry to vitamin A and xanthophylls which can be a source of pigmentation of egg yolk (Srivastava *et al*., 2006).

Environmentally, mulberry trees find relevance in prevention and control of desertification, water and soil conservation, management of saline land and bioremediation. Owing to its distinct characteristics such as extensive root system, high biomass production and strong environmental adaptability, mulberry plant is being exploited to stabilize the adverse effects of heavy metals in the diverse polluted soils (Peng *et al*., 2012; Delplanque *et al*., 2013; Zhou *et al*., 2015). Mulberry plantation was reported to also engender encouraging results in improving air quality, increasing water retention capacity, remediation of heavy metals from polluted soils, atmosphere and nurturing beneficial soil micro flora and fauna (Yongbing *et al*., 2017). It is important to mention that mulberry trees are good carbon sinkers. Estimation shows that 1 Mµ mulberry tree is capable of absorbing about 4162 kg of CO_2 and release 3064 kg of O_2annually. Research findings showed that heavy metals like Pb, Cd, Cu mainly are phytoremediated by different species of mulberry plants. As reported by Zhou *et al*. (2015), mulberry has the potential to remediate heavy metal in contaminated soils. Mulberry wood is also an essential material in production of sport items like hockey sticks, tennis rackets, badminton rackets, and cricket stumps (Bharathi, 2019).

B. BENEFITS FROM INSECT REARING WASTE

Rearing of silkworm (*Bombyx mori*) is often associated with challenge of waste which include excreta and leaf waste. It is estimated that 15 metric tonnes of waste is generated from one hectare of mulberry farm annually (Asmita *et al*., 2017). In another report, small scale farmers can generate between 250 to 300kg of silkworm waste which is equivalent to 2500 kg farm land (Wenhua, 2001). Owing to their high content of essential plant nutrients silkworm excreta is being used as farm manure. In Asian traditional medicine, silkworm excreta has an important role in the cure of infectious diseases such as headache, abdominal pain and blood pressure (Tulp and Bohlin, 2004; Vimolmangkang *et al*., 2014). The excreta has often been reported to be rich in flavonoids, chlorophyll, alkaloids, carotenoids and lutein compounds, all these make it to perform antioxidant activity (Xu *et al*., 2014). Besides this, high content of these compounds in the insect excrement presents it as a good source of natural colorant for the food industry (Vimolmangkang *et al*., 2014).

The silkworm excreta is a high quality substrate used to produce biogas through an anaerobic fermentation process since it ensures a favourable environment for the development and optimal metabolic activity of bacteria involved in the process. This substrate does not contain inhibitory compounds such as detergents, antibiotics or antiseptics which are all known to be toxic to bacteria (Dobre *et al*., 2014). It is known to have biodegradable organic matter with its C/N ratio being around the optimal level of 15-35 (Mao *et al*., 2015). These qualities make it suitable material in biogas production.

C. BENEFITS FROM SILKWORM PUPAE

After the production of silk from *Bombyx mori* through cocoon boiling, spent pupae are produced in large quantities, these constitute the bulk of by-product of silk production (Datta, 2007). Patil *et al*, (2013) reported that for every 1 kg of raw silk, 8 kg of wet pupae (2 kg of dry pupae) are produced. On further processing, valuable oil can be obtained from these pupae. This oil serves as a major raw material in production of paints, varnishes, pharmaceuticals, soaps, candles, plastic and bio-fuels (Trivedy *et al*., 2008). Silkworm pupae constitute a part in human nutrition. This has been so since time immemorial in Asia-silk producing countries and is considered a delicacy in regions of China, Japan, Thailand, India (Luo, 1997; Mitsuhashi, 1997; Yhoung *et al*., 1997; Longvah *et al*., 2011) and in other countries where sericulture has spread to including Nigeria. Due to high moisture content, fresh spent silkworm pupae are easily perishable and are therefore generally sun-dried and ground (Usub *et al*., 2008; Wei *et al*., 2009; Jintasataporn, 2012) for preservation and more uniform mixing in ration (Gohl, 1982). Because of its high protein content, silkworm pupae meal is being used to feed livestock such as monogastric species which include poultry, pigs, fish and also ruminants (Trivedy *et al*., 2008). In the conventional feeding of poultry, chief protein source have been fishmeal and soybean which are expensive, silkworm pupae meal is a valuable and cheaper protein source which can be used as alternative to protein sources that are costly.

CONCLUSION

Sericulture has over the time been a profitable venture in silk producing countries like China, India and some other parts of Asia countries. It is known to serve as a means of livelihood and source of employment to lots of people in the region. The technology is also believed to be the only cash crop in agricultural sector with quick yield within 30 days. Despite these great merits sericulture is still at low ebb, underdeveloped and given little or no attention as a viable investment in developing countries like Nigeria. The reason for this is lack of proper marketing system for cocoon in these countries among others. This paper has brought to notice many non-cocoon benefits as they are involved in food industries, livestock feed companies, pharmaceutical sector, traditional medicine, sport item industries, agricultural sector and environmental benefits in alleviating pollution. This sensitization is expected to spur the interest of farmers and other stakeholders to see sericulture enterprise as a profitable venture. This will enhance the livelihood of farmers and improve national economy.

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Seedlings Growth Performance of *Terminalia ivorensis* (A. Chev) as Influenced by Different Organic Fertilizers.

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Abstract

The experiment was carried out at the Federal College of Forestry, Jericho in Ibadan North West Local Government Area of Oyo State, Nigeria. The study investigated the effect of different organic fertilizers on the seedlings growth performance of Terminalia ivorensis (TI). The Experiment was laid out in Completely Randomized Design (CRD) with four (4) treatments replicated five (5) times for a period of 12 weeks. Three different fertilizers, poultry droppings, cow dung, horse dung, and topsoil (zero-fertilizer treatment) were used for the experiment. Each of the treatments was applied on TI seedlings. Data collected were subjected to descriptive analysis using ANOVA, while significant means were separated using Fisher's Least Significant Difference (LSD). Seedlings were allowed to stabilize for two weeks for nutrient assimilation. Information on seedling heights, collar diameters, number of leaves and leaf area were collected fortnightly. The results revealed that there were no significant differences in mean values of plant heights, collar diameter, leaf area, leaf production, fresh weight, dry weight, net assimilation rate, relative growth rate and absolute growth rate among the treatments ($P > 0.05$). Seedlings treated with poultry droppings (T_2) recorded highest mean values in seedling height (27.71cm), collar diameter (0.53mm), leaf number (18.10), leaf area (6.92cm^2), and fresh weight, dry weight and net assimilation rate (NAR) as value of 1.75g, 0.55g and 0.0042 (gwk-1). The highest mean values of the absolute growth rate (0.0785gwk-1) and relative growth rate (0.0934gwk-1) were recorded in the seedlings treated with cow dung (T_1). It was concluded that all the organic manures used had a positive effect on the physiological parameters of TI seedlings and TI seedlings will perform better with the application of poultry droppings. Hence, their use should be encouraged especially poultry droppings at the nursery stage for a healthy vigorous seedling production. Based on the results obtained, it is therefore recommended that poultry droppings should be used in raising the seedlings TI at the nursery stage.

Keywords: Completely Randomized Design (CRD), descriptive analysis, organic fertilizers, seedlings, *Terminalia ivorensis*, treatment.

INTRODUCTION

Terminalia ivorensis (TI), also known as Black Afara or Idigbo belongs to the family *Combretaceae*. It is a tree species found in lowland rainforest zones in Nigeria but is predominantly a tree of seasonal forest zones (Keay, 1989). Avery *et al*., (2002) noted that the species is one of the most important of some 200 species belonging to the genus Terminalia. *TI* occurs from Guinea-Bissau east to western Cameroon and spreads to other western Africa countries. The species is a good colonizer of abandoned farmland and is a strong light demander (Aphalo and Lehton, 2001). Katende *et al*., (1995) reported that the species has been planted in many tropical countries like Senegal, Uganda, Tanzania, India, Malaysia, the Solomon Islands, Fiji, Costa Rica, Panama, Brazil and Nigeria as a promising timber plantation species. The tree attains the heights of up to 50m and the stem girth of 5m, while young trees often attain only 1-1.5m height after 5 years, compared to some other timber species, which are fast-growing. For instance, *T. superba* could grow up to 1.8m in height in one year (MacGregor, 1984; Hazlett, 1989; Lori *et al*., 1999; Osei-Begyina, 2007).

Keay, (1989) reported that the branches are whorled in young shoots and foliage. Jones and Averre, (2000), described the species of *TI* can be used for construction and other wood-based purposes. It also serves as reforestation and afforestation species for devastated forest ecosystems. It occurs in evergreen and moist semi deciduous forests, where larger trees are most common in low-lying localities or lowlands (Bakshi *et al*., 1972; Keay, 1989). Orwa *et al*., (2009) noted that *T. ivorensis* is most abundant in the transition zone between humid semi-deciduous and evergreen forests. It is sometimes found in rainforest conditions but predominantly a tree of seasonal forest zones. Mbakwa (1990) stated that the tree is used in agro-forestry systems as a shade tree in cocoa, banana and coffee plantations and it is also planted as roadside tree. McCork (2004) stressed that deforestation, exploitation and encroachment of farmers into forest areas have made the species threatened. Rapid increase in population growth and agricultural activities in most tropical countries have resulted in the disappearance of most tree species including *T. ivorensis* thereby making seed collection not to be done or carried out at the appropriate time and season.

TI is an emergent in the upper storey of seasonal forest but sometimes loses its vertical growing leader resulting in considerable variation in height of mature trees. Regeneration is often sparse, but locally, secondary forests can be dominated by young trees of *TI*. As one of the principal timber species of West Africa countries, *TI* is widely harvested from natural forest and has been introduced into many other tropical countries as a promising timber plantation species. It is also grown as a shade tree in cocoa plantations in Nigeria (Igboanugo, 1990). It has been reported that the species is threatened by habitat loss and poor regeneration. However, an attempt at plantation growth has generally failed to make it to be classified as 'vulnerable' by the IUCN (Hawthorne, 1998). With so much emphasis today on ecosystem management and maintenance of natural forests, sustainable artificial regeneration of tree species for large-scale plantation development has become expedient, especially in the area, where oil exploration and the like have led to serious deforestation of several valuable timber species. However, not much work has been done in Nigeria. While seeds of *T. superba* do not experience challenges during germination, those of *TI* germinate with great difficulty (Roederer, 1988).

A better knowledge of conditions for raising a timber species like *TI* would go a long way in reducing initial cost of plantation establishment. Moreover, it has been noted that qualities of seedlings are usually influenced by the composition of the growing media (Salami, 2002; Baiyeri, 2003; Baiyeri & Mbah, 2006). The experiment focused on the effect of cow dung, horse dung and poultry droppings on the growth performance of *T. ivorensis* seedlings in order to determine the most appropriate organic fertilizer(s) suitable for the growth of *TI* seedlings at the nursery stage.

MATERIALS AND METHOD

Experimental Site

The experiment was carried out in the Forest Nursery Unit of Federal College of Forestry, Ibadan located within the Government Reserved Area (GRA), Jericho, Ibadan North West Local Government Area of Oyo State, Nigeria. This area falls within the Longitude 3°51.471'E and Latitude 7°23.694'N. It has annual rainfall of about 1400mm-1500mm with a peak in June and July and average relative humidity of about 65%. The average temperature is 32°C with two distinct seasons, which are dry, usually commencing from November to March and rainy season. (FRIN meteorological report, 2014). The experiment was carried out in nursery B, Federal College of Forestry, Ibadan, Nigeria.

Collection of Materials

Poultry droppings and cow dung were collected from the Agricultural and Extension Management Farm of the Federal College of Forestry Ibadan. Horse dung was collected from Polo Garden, Eleyele Ibadan, Nigeria. The seedlings of *TI* were procured from the Forest Nursery of the Department of Agricultural and Forestry, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria. The seedlings were watered to enhance its establishment and to avoid physiological shock before transplanting them into the experimental pots filled with top soil and organic manures.
The organic fertilizers i.e.; poultry droppings, cow dung and horse dung already collected and air-dried, were ground to powder form for easy mixing and fast decomposition in the soil. The mixture in the polythene pots were watered for two weeks to aid decomposition and reduction in the concentration of the organic manures. The seedlings were then transplanted into the potting mixtures.

There were four (4) treatments, namely: poultry droppings, cow dung, horse dung, and a control (zero-fertilizer treatment) which was replicated five (5) times. Two head pans of top soil were thoroughly mixed with half-filled head pan of organic manures and the mixture was used to fill the polythene pots, while those that were not subjected to organic fertilizer treatments, top soil was used to fill their polythene pots. Sufficient quantity of water was added to the filled polythene pots and allowed to drain before transplanting. The seedlings of *TI* were transplanted at 2-4 leaf stage into the filled drained polythene pots and watered daily to pot capacity for one week to enhance the establishment of the plants. The initial heights and collar diameters of all the seedlings were taken before the experiment commenced. The experiment was laid out in a Completely Randomized Design (CRD).

Data collection

During the period of growth, measurements of both the morphological and the physiological parameters were taken fortnightly for 12 weeks. Morphological parameters include; seedling heights, collar diameter, leaf number and leaf area. The physiological parameters measured at the end of the experiment were; relative water content, chlorophyll content and leaf turgidity.

Morphological Parameter.
Leaf Number per Seedling
The numbers of fully unfolded leaves per seedling were determined by physical count at the start of the experiment, and at every 2 weeks, until termination of the experiment.
Plant Height
The plant height (cm) was measured virtually using a meter rule from the base to the tip of the seedling at the start of the experiment, and at every 2 weeks, until termination of the experiment.
Collar Diameter of the Seedling
The collar diameter was measured by taking the circumference of the seedling stem with the aid of Vernier calliper.
Leaf Area
The Number of Nodes per seedling was determined by physical count at the start of the experiment, and at every 2 weeks, until termination of the experiment. The change in Number of nodes was calculated at the end of the experiment.

Physiological Parameters

Root: Shoot Biomass %
At the end of the experiment, the seedlings were destructively sampled for determination of root to shoot ration. This was achieved by dissecting the polythene pot or bag using a razor blade and carefully separates the seedlings from the soils with the entire root intact. Any soil attached to the root was shaken off immediately. Each seedling was then separated into shoot and root; oven dried at 70^0C for 48hours and weighed using a sensitive balance. Root to shoot biomass ratio was computed at percentage using the following formula:

ROOT: SHOOT BIOMASS % =

$$\frac{\textbf{Root dried weight}}{\textbf{Shoot dried weight}} \times \mathbf{100}$$

Leaf Turgidity
To determine the leaf turgidity, the leaf was soaked in water inside a Petri dish overnight and later weighed.
Leaf turgidity = weight of leaf (soaked in water) * 100
To determine the leaf of the species, the formula was used:
Relative water content = Fwt – Dwt / Turgidity – Dwt × 100
Fwt = Fresh water
Dwt = Dried weight
Turgid Wt = Turgidity weight

$$\text{Relative Water Content} = \frac{\textbf{Fwt- Dwt} \times \mathbf{100}}{\textbf{Turgidity – D}}$$

$$\textbf{Plant turgidity} = \frac{\text{Weight of plant (soaked in water) – Initial Fresh Weight X 100}}{\text{Initial Fresh Weight}}$$

To determine the relative water content of the species the formula below will be employed;
Relative Water Content = (F_{wt}- D_{wt}/ T_{wt} - Dwt) x 100

F_{wt}= Fresh weight.

D_{wt} = Dry weight.
T_{wt} = Turgidity weight.

$$\textbf{Net Assimilation Rate} = \frac{\text{(dry weight at end – dry weight at start) (log}_e\text{ leaf area at end – log}_e\text{ leaf area at start)}}{\text{(Time at end – time at start) (leaf area at end – leaf area at start)}}$$

$$\text{Relative Growth Rate} = \frac{\log_e(\text{Total dry weight at the end}) - \log_e(\text{Total dry weight at the start})}{\text{Duration of experiment}}$$

$$\text{Absolute growth Rate} = \frac{\text{Total dry weight at final time} - \text{Total dry weight at initial time}}{\text{Duration of experiment}}$$

Data analysis

Data collected were subjected to Statistical Analysis of Variances on the general linear model of SAS Software (SAS institute, inc.1999). Data on measured seedling growth parameters (i.e. height, collar diameter, leaf number and leaf area) under different organic fertilizer treatments were analyzed using the analysis of variance and means separated with Least Significant Difference (LSD) at 5% level of probability to further separate the means that were significantly different.

RESULTS

The effect of different organic fertilizers on seedling heights of *TI* seedling is presented in table 1. Treatment effect of different organic fertilizer on plant height was not significant ($P<0.05$) after the experiment. With the respect to the plant height, T_2 which is seedlings treated with poultry manure had the highest mean value of 27.71cm while the least mean value of 23.57cm was observed under seedlings treated with horse dung (T_3).

Collar Diameter of the seedling

The effect of watering regime frequencies on the collar diameter of *TI* seedlings is presented in table 1. Treatment effect of different organic fertilizers on the collar diameter was not significant ($P<0.05$) after the experiment. Collar diameter had the highest mean value of 0.53mm under seedlings treated with poultry manure (T_2), and least mean value of 0.32mm under the seedlings treated with horse dung (T_3).

Number of leaves per Seedling

The effect of different organic fertilizers on the number of leaves of *TI* seedlings is presented in table 1. Treatment effect of different organic fertilizers on the number of leaves was not significant ($P<0.05$) after the experiment. Considering the leaf number, it was observed that seedlings treated with poultry manure (T_2) produced the highest mean value which is 18.10 while seedlings treated with horse dung (T_3) produced the least mean value of 16.10.

Leaf Area

The effect of different organic fertilizers on the leaf area of *TI* seedlings is presented in table 1. Treatment effect of different organic fertilizers on the leaf area was not significant ($P<0.05$) after the experiment. The leaf area was highest at the seedlings treated with poultry manure (T_2) with the mean value of 6.92cm^2 and the seedlings treated with horse dung (T_3) produced the least mean value of 5.88cm^2.

Table 1: Effect of organic fertilizers on the morphological parameters of *Terminalia ivorensis* seedlings.

Treatments	Plant Height (cm)	Collar Diameter (mm)	Number of leaves	Leaf area (cm^2)
T_1	26.92^a	0.46^{ab}	17.60^{ab}	6.69^a
T_2	27.71^a	0.53^a	18.10^a	6.92^a
T_3	23.57^b	0.32^c	16.10^c	5.88^{ab}
T_0	26.10^a	0.36^c	17.30^{ab}	6.75^a

Mean values with the same superscript in each column are not significantly different ($P>0.05$). **LSD**

T_1: *Cow Dung*
T_2: *Poultry Droppings*
T_3: *Horse Dung*
T_0: *Top Soil (*zero-fertilizer treatment)

The result showed that different organic fertilizers had no significant effect on the physiological parameters of *TI* seedlings ($P>0.05$). Seedlings treated with poultry manure (T_2) produced highest mean values for the fresh weight (1.75g), dry weight (0.55g) and net assimilation rate (0.0042gwk^{-1}) while absolute growth rate (0.0785gwk^{-1}) and relative growth rate (0.0934gwk^{-1}) with the seedlings treated with cow dung (T_1) had the highest mean values. (Table 2).

Table 2: Effect of organic fertilizers on the physiological parameters of *Terminalia ivorensis* seedlings.

Treatments	Fresh Weight (g)	Dry Weight (g)	NAR	AGR	RGR
T_1	1.64^{a}	0.45^{a}	0.0022^{ab}	0.0785^{a}	0.0934^{a}
T_2	1.75^{a}	0.55^{a}	0.0042^{a}	0.0570^{a}	0.0503^{ab}
T_3	1.35^{b}	0.36^{ab}	0.0010^{b}	0.0195^{b}	0.0214^{b}
T_0	1.40^{b}	0.42^{ab}	0.0018^{b}	0.0070^{c}	0.0073^{c}

Mean values with the same superscript in each column are not significantly different (P>0.05). LSD

T_1*:* *Cow Dung*
T_2*:* *Poultry Droppings*
T_3*:* *Horse Dung*
T_0*:* *Top Soil* (zero-fertilizer treatment)

NAR: *Net Assimilation Rate*
AGR*: Absolute Growth Rate*
RGR*: Relative Growth Rate*

DISCUSSION

Generally, all the manures applied improved the growth of *TI* seedlings, as the measured seedling parameters were greater under the two fertilizer treatments (poultry droppings and cow dung) and control (zero-fertilizer application) compared to the fertilizer treatment treated with horse dung. Among all the fertilizers, poultry droppings consistently produced the highest effects on all the *T. ivorensis* seedling growth variables. This may be due to the fact that the manure had the highest rate of mineralization and assimilation than others, thereby quickening the nutrient uptake in plants resulting in seedling development. It could also be that some soil conditions such as air passages, nutrients, microbial activities and water percolation, down the horizon or soil play a supportive role in yield of the seedling species. This corroborates the finding of N'dayegamiye & Angers (1990), who noted that long-term organic residues or manure application increases microbial activity and potential mineralization of soil organic matter and soil conditions, and play supportive role in seedling growth and yield development in tropical rain forest species. The mineralization of phosphorus in soil during the growing season is very important for phosphorus availability to plants. Nevertheless, the excessive application of manure or of any phosphorus rich in organic.

CONCLUSION

This study shows that fertilization improved the growth of *TI*. Nevertheless, the effects of the fertilizers on seedling heights, collar diameter, leaf areas, leaf productions, fresh weight, dry weight and net assimilation rate were not significantly different from the control experiment. However, fertilization significantly improved *TI* seedling heights, collar diameter, leaf production, leaf area growth, fresh weight, dry weight and net assimilation rate with poultry droppings producing the highest mean growth effects at the nursery stage. In conclusion, poultry droppings had the highest mean growth effects on seedling fresh weight, dry weight, net assimilation rate, height growth, collar diameter development, leaf areas as well as leaf production. Hence, it can be said that, among the manures investigated, poultry droppings produced the best result in terms of *TI* seedling growths and development.

RECOMMENDATION

It is recommended that poultry droppings should be adopted for *TI* seedling growth improvement in subsequent propagation of the species. amendments play a significant role in decreasing the phosphorus sorption capacity in soil (Beauchamp *et al.*, 1986; Sharpley *et al*., 1993).

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Sustainable Management of Non- Timber Forest Products and Their Potentials on Livelihood in Nigeria

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Abstract

Non-Timber Forest Products (NTFPs) include all tangible fauna and floral products other than timber from natural forests or forest plantations. They play significant roles in rural livelihood of people in urban and rural settlements. NTFPs are among the most valuable resources for present and future food security. However, indiscriminate exploitation of NTFPs for diverse use has been a lot of challenges on their sustainability. This paper therefore reviews the management strategies required for sustainable management of NTFPs and their significant importance in sustainable livelihood. NTFPs are broadly classified into edibles and non-edibles. The edibles include edible plants and animals, honey, oils, fish and spices while non-edible products include grasses, ornamental plants, oil for cosmetic use and medicinal products. NTFPs can further be classified into tradable or non-tradable with the tradable NTFPs been significant at international trade. Towards the sustainability of NTFPs benefits, appropriate harvesting practices, post harvesting technologies, value additions and proper marketing systems are essentially required.

Keywords: Livelihood, sustainable management, NTFPs, exploitation, forest

INTRODUCTION

Non-Timber Forest Products (NTFPs) are defined as biological materials other than timber which are extracted from the forest for human use (Beer and McDermott, 1989). NTFPs encompass all tangible animals and plants products other than industrial wood, coming from natural forests plantations. The tropical forests contain a wealth of timber and non-timber products which have thus been exploited for food, fuel wood, watershed, pharmaceutical royalties, honey, snail and other marketable and non-marketable products (BNRCC 2011). NTFPs contribute to livelihood of about 2 billion of the world's poor people in urban and rural settlements and are among the most valuable plant resources for present and future food security (Ahenkan and Boon, 2011). They provide food, fuel, medicine and incomes and keep traditional knowledge alive, provide fodder, and materials for construction of traditional houses, fencing and barns. Wildlife which also constitutes a greater part of NTFPs if properly managed can provide good sources of animal protein and income to the immediate communities (Anamayi *et al*., 2005; Anamayi *et al*., 2010).

The United Nations and Food and Agricultural Organization claimed that at least 150 Non-Wood Products are found in international markets while Emery, (1998) identified 138 NTFPs in Michigan Upper Peninsula. Classifying these products into categories is an important first step of understanding the NTFPs industry. NTFPs are broadly classified into edibles and non-edibles and also to tradable or non-tradable. The edibles include edible plants and animals, honey, oils, fish and spices, while non-edible products include grasses, ornamental plants, oil for cosmetic use and medicinal products. The tradable NTFPs are significant at international trade. Edibles and Non-edibles can further be divided into four general categories:

Edibles are the most well known and documented edible forest products that are gathered from the forest. Since most of these products are not traded widely and are usually collected and consumed by the harvesters, it is difficult to assess their economic magnitudes. These products include mushroom, ferns, berries or other fruits, nuts, ramps (wild onions), herbs and spices.

Medicinal and dietary supplements: They are plant based products that are processed into medicines. Beginning in the late eighteenth century, over 100 plant species indigenous to the U.S were commonly accepted for their medicinal properties. The majority are wild harvested and traded as botanical products (Foster, 1995).

Floral products: These unique forest products may appear in floral arrangements, dried flower decorations, and ornamental plants, Common examples include products made from pine boughs, grape vines, moss, ferns, flowers, cone, mistletoe and holly (Hammett and Chamberlin, 1998).

Specialty wood products. In general, special wood products are considered non-traditional if produced directly from parts of trees and not from lumber or timber purchased from mills. In other words, the tree needs not to be cut down to produce these items.These include handicrafts, carving and turnings, musical instrument, containers (basket), special furniture pieces as well as utensils.

SUSTAINABLE MANAGEMENT OF NTFPS

Upsurge in Nigeria population has resulted in pressure on several natural resources with enormous effects on NTFPs. A lot of these forest products have been over exploited in many forest ecosystems. Therefore, there is a need for management of NTFPs on a sustainable basis for the present and future generation. Concern for forest conservation and bio-diversity issues has led to the management of NTFPs as a viable alternative to timber has begun to attract attention. A realization has already emerged to shift focus on NTFPs, since their extraction could meet the objective of revenue generation without affecting forest conservation measures. However the growth dependence of forest dwelling communities on forests for food, fodder, fuel wood, fruits, fibres, housing, medicines and many more have increasingly caused the over use of NTFPs (Nadkarni and Kuel, 2013)..Hence the future human needs for food, water, health, energy and settlements to a large extent depend on how the forests are managed. Livelihood sustenance issue also relates to sustainable harvest of NTFPs that ensures negligible impact on the structure and dynamics of the plant population. Therefore, efforts should be concentrated more on ecological sustainability at the harvesting levels (Chandrasekhar, 1998).

Sustainability depends upon political, socio-economic and a set of institutional factors. However, what appears to be crucial in the context of sustainability of forest resource is who these end-users are?(Chandrasekhar, 1998). The users may be government, community groups or local forest users who use the resources differently owing to their varied perceptions, purposes. Of all, however, the local users are the critical actors of both extraction and monitoring.

On this note, more crucial is a set of policy options in the forest management relevant to livelihood issues that could effectively sustain and widen the scope of capacity building of forest-dependent communities. This precisely relates to Sustainable Forest Management (SFM) that involves continuous provision of wood and non-wood benefits. The non-wood benefits consist of the highly heterogeneous NTFPs, and the services provided by the forest such as: bio-diversity conservation, watershed protection and carbon sequestration (Ahenkan and Boon,2011).The future human needs for food, water, health, energy and settlements to a large extent depend on how the forests are managed. Accordingly, needs for concerted efforts arise not only for its conservation, but also for sustainable development. Thus, sustainability subsumes productivity (growth) and equity (World Bank, 1992).

STRATEGIES FOR SUSTAINABLE MANAGEMENT OF NTFPS

Appropriate harvesting practices

Indiscriminate exploitation of NTFPs for diverse use has been a lot of challenges on their sustainability. In sooth, the sustainable harvesting practices do not require any sophisticated or special efforts. Only awareness and certain precautions are required. For instance, when the roots of medicinal plants are to be harvested, it should be done in a way that it would not lead to the mortality of the plant. Furthermore a reasonable percentage of the harvested roots must be preserved for planting the next season. Likewise, one or two roots can be left in the soil to sprout in the next rainy season, thus naturally propagating itself. More importantly, leaves, barks are to be harvested sustainably.

Post-harvest technologies

After harvesting, post harvesting practices such as drying, processing, storage and packaging can make a major difference to price and quality of produce. These practices would reduce wastage of harvested products. In situation where large quantity of NTFPs are harvested without proper post harvesting practices most of the NTFPs are wasted.

Value addition

Most of NTFPs sold by collectors/harvesters have no value-addition. The value addition is largely performed by market intermediaries and manufacturers and there is little value addition at the primary collector's level. Interventions like preparing time schedule for collection of material, identification of correct plant and their parts, maintaining hygienic conditions are done by harvesters while collection, following non destructive harvesting techniques, removal of foreign material from the collected product, sorting, drying and storage appropriately and packaging of collected material are carried out by intermediaries. Therefore, some value addition such as drying, chopping or cleaning at collector level would increase the value and quality of the NTFPs.

Marketing system

The NTFPs market system is complex and dynamic with multiple stages and actors involved in getting the product from forest to consumer. Thus the market is extremely imperfect and unstructured. The situation is such that forest dwellers collect NTFPs and sell it to local traders who in turn sell to traders at the urban centre from where the consumers buy Most forest people do not access to urban markets, no bargaining power when selling their products at local markets and no insufficient capital to invest in improving their livelihoods . Due to lack of direct access to markets, they depend on intermediaries to sell their products and thereby reducing their income. Therefore, information about the quantity and quality of the product, price and their market is very important. Different types of information, such as price, value addition options and sustainable harvesting techniques are required by communities in order to increase their bargaining power and receive higher prices for their products.

Avoidance of Deforestation and Land degradation

Deforestation and land degradation occur mostly as a result of human activities and cumulatively do have long lasting impacts on forest ecosystem (Muchena, 2008). The urbanization, industrialization and expansion of agriculture over decades involved the cultivation of marginal areas, or clearance of important natural habitats such as forests and wetlands. Such conversion is a major driving force behind deforestation and land degradation which threaten a lot of NTFPs.Loss of natural habitats has reduced vegetation cover and exposed soils to wind and water erosion. Wind and water erosion is extensive in many parts of Africa with about 25 per cent of the land prone to water erosion and about 22 per cent to wind erosion (Unasylva, 2006).Soil erosion reduces the productivity of land and farmers therefore have to depend on fertilizers and other chemicals for production.

IMPORTANCE OF NTFPS TO SUSTAINABLE LIVELIHOOD

A livelihood is a means of making a living. That is, means of securing the basic necessities (food, water, shelter and clothing) of life (*Ellis, 2000)*. It encompasses people's capabilities, assets, income and activities required to secure the necessities of life. A livelihood is sustainable when it enables people to cope with and recover from shocks and stresses (such as natural disasters and economic or social upheavals) and enhance their well-being and that of future generations without undermining the natural environment or resource base (*Ellis, 2000)*. NTFPs are often presented as a major contributor to livelihoods, as sources of food and cash, particularly for rural communities.

NTFPs are a dependable source of income and food supply in the rural areas (Cooks and Wiersum, 2003). Non-timber forest products constitute a critical component of food security and it is an important source of income for the poor in many developing countries (Cooks and Wiersum, 2003). Several opportunities for improved rural development are linked to NTFPs. In many areas, rural populations are traditionally depended on local forest resources to provide additional income through collection and marketing of NTFPs. Where employment opportunities from traditional industries are declining, workers looking for alternative income sources often turn to collection of these products from nearby forest (Charlie and Sheona, 2004).

Millions of people throughout the world make extensive use of biological products from the wild (Cooks and Wiersum, 2003). They are harvested for both subsistence and commercial use either regularly or as a fall back during times of need. They add to people's livelihood security, especially for rural dwellers. NTFPs also have cultural significance and value (Jimoh and Asinwa, 2012). Charlie and Sheona, (2004)looked into the role and importance of NTFPs in daily lives of rural people in South Africa and discovered that more than 85% of household used products such as wild spinaches, fuel wood, wooden utensils and edible fruits. It was also reported that more than half of the household investigated made use of edible insects, ,bushmeat, wild honey and reeds for weaving.

In Nigeria, food security of rural dwellers is improved by growing NTFPs in the home gardens and on farms. Leaves, rattan, honey, sap, gums from the small scale industries are important sources of income (Okafor *et al*., 1994). Due to the diverse varieties of species obtainable from NTFPs many households were able to meet their immediate needs by collecting these products from the nearby forest. Households also earn income to meet needs through the marketing of NTFPs harvested.

NTFPs Contribution to Multiple Income Sources

As a cardinal feature of multi-functional forest system, NTFPs contribute to diversified income sources ofrural communities. This diversity invariably increases the adaptive capacity and response options of the people to climate change shocks, since they depend on many species (Nadkarni and Kuel, 2013). The implication is that since the rural communities have an array of alternative income sources from NTFPs such as medicinal herbs, honey, mushrooms, dyes, bush-meat, snail farming and fruits and with proper enlightenment they are less inclined to engage in indiscriminate felling of trees as a means of getting income.

NTFPs Contribution to Carbon Sequestration

Forest stores large amounts of carbon in trees, under-storey vegetation, and soils. The forest has been estimated to globally contain 1.2trillion tonnes of carbon, which is over half of the total terrestrial vegetation and soils (Patosaari, 2007).NTFPs can contribute directly or indirectly to carbon storage or sequestration. The growth of fast-growing woody NTFPs like bamboo can be used to reduce emissions. With respect to indirect impact, the production of NTFPs like *Synsepalum dulcificum*, *Dacryodes edulis*, *Irvingia wombulu* and other fruit crops entails a functional forest and an incentive to protect forest systems. Thus the maintenance of such a forest cover can indirectly help to store and sequester carbon. Furthermore extraction of NTFPs (in terms of removal of biomass from the forest) as a limitation to carbon sequestration is comparably infinitesimal when their short re-vegetation and re-growth cycles are considered viz a viz those of trees. This also underscores the need to treat NTFPs differently in forest policies in order to harness their potential in forest conservation and carbon sequestration (Nadkarni and Kuel, 2013).

Potential of NTFPs in Biofuel Production

Energy which is the ability to work, plays significant roles in our life. Most energy demand is met by fossil fuels - oil, coal and natural gas (Leandro and Andriana, 2009). According to the IEA, (2013)an estimated 1.3 billion people do not have access to electricity and 2.6 billion people globally rely on biomass for domestic cooking most of who are in Sub Saharan Africa. Use of fossil fuels has increased along with improvement of standard of living, proliferation of the world´s population and rapid industrialization of the developed countries. It has been recognized for some time that current use of fossil fuels will not only deplete the world´s oil reserves but also have serious impact on the environment, leading to increased health risk and global climate change. Biomass energy refers to the energy available in non-fossil, living organic material. It can be harvested from plants, animals, insects, and waste; and can be developed into a variety of gaseous, liquid, and solid products (Kearns and Halseth, 2009). The world is currently moving from petroleum-based to a bio-based global economy. Biological wastes (including NTFPS wastes), which are usually seen as low-valued materials, are now being transformed to usable forms for the production of eco-friendly and sustainable fuels (Gomez, *et al*., 2008). This is because most biological wastes contain high levels of cellulose, hemicelluloses, lignin, starch, proteins, and lipids, which provide good options for the biotechnological production of bio-fuels without interfering with the ever-increasing need for world's food supply (Gomez, *et al*., 2008). NTFPS that can be converted into biofuel include bark, leaves, cork residue, cross-cut ends, edgings, grinding dust and saw dust through; thermal, chemical or biochemical conversion processes (Dubey, 2012). Apart from forest product wastes, *Jatropha curcas* which is a non-timber forest plant has been documented to have as high as 40% biofuel seed content. It is fast growing, prolific in nature and its the ability to thrive on marginal soils makes it most suitable for biofuel production (FAO, 2008).

CONCLUSION

Apparently, upsurge in population in Nigeria has resulted in more pressure on NTFPs. Many of which are threatened and if care is not taken, will go into extinction. Socio-economic values of NTFPs cannot be overemphasized. They contribute to improving nutrition either as part of the family diet or as a means to achieve household food security. They also contribute to the well-being of rural households, particularly the poor, in terms of food security, nutrition, health and subsistence. However, several anthropogenic activities such as indiscriminate harvesting, destruction of natural habitats, bushfires, population growth and high demand have been a lot of problem to the management of NTFPs. It is therefore necessary that appropriate strategies towards sustainable management of NTFPs should be enhanced. Invariably, domestication of NTFPs, improved, harvesting and processing techniques are necessary to facilitate NTFPsproductionand reduction of poverty particularly for the economically-marginalized and forest-dependent communities.

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SUB-THEME 9

Indigenous knowledge of Plants for Repertoire of Medicine

Efficacy of Medicinal Plants for the Treatment of Asthma

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Abstract

The objective of this paper is to provide information on the available medicinal herbs used for the treatment of asthma as well as the mode of preparation and administration, with a view to promoting significant studies on the biological activities of plants. Purposive sampling of fifty (50) herbs traders and herbalists were selected in Okitipupa Local Government Area for questionnaire administration. Most of the respondents were women with varieties of recipes given with their indigenous languages. The result revealed that 35 plants were used for asthma treatment. The phytochemical screening of six (6) of the plants were carried out viz: Crinum jagus, Terminalia glauccensens, Khaya ivorensis, Abrus precatorius, Olax subscorpioides, and Anogesissus leiocarpu s. Various plants collected as recipes include stem, bark, fruits, leaves, bulb, seeds, roots, and flowers. They were analysed for their active chemical component (alkaloids, flavonoids, saponin, tannins, ascorbic acid, moisture and mineral). Crinum jagus has the highest level of Na [45.5 mg/100 g] and K [16.5 mg/100 g]. Abrus precatorius has the highest Ca [31.8 mg/100 g] while Khaya ivorensis contained the highest level Fe [12.65 mg/100 g]. The work suggest that the plants were veritable and cheaper substitute for conventional drugs since the plants are easily obtainable and the extract can easily be made through a simple process.

Keywords: Medicinal plants, asthma, phytochemical screening

Introduction

Plant provides a variety of resources that contribute to the fundamental needs of both human being and animals such as food, clothing and shelter. Among plants of economic importance are medicinal plants. Plants have been utilized as therapeutic agents since time immemorial in both organized and unorgan ized forms (Girach *et al*., 2003). The curative properties of many herbal medicines have been recognized in many ancient cultures.

Medicinal plants have been the mainstay of traditional herbal medicine amongst rural dwellers all over the world since ancient time to date. The use of plant for curative purpose can be linked to the Sumerian and the Akkadian civilizations in about the third millennium BC. Hippocrates (ca. 460-377 BC), one of the ancient authors who described natural products of plant and animal origins of medicinal importance, mentioned approximately 400 different plant species that are of medicinal uses. Since the use of complementary and alternative medicines has greatly increased of recent, this has led to enhancing the market for herbal products all over the world (Bodeker *et al.*, 2002*)*. Natural products have been an inherent part of the ancient traditional medicinal system, e.g. Chinese and Egyptian (Sarker & Nahar, 2007). Over the years, they have assumed a very key role in modern civilization as natural source of chemotherapy as well as amongst scientist in search for alternative sources of drugs. About 3.4 billion people in the developing world rely on traditional medicine of plant origin for their primary health care.

According to World Health Organization (2000), Medicinal plant is defined as any plant which in one or more of its organs (example leaves, roots, rhizomes, stems, barks, flowers, fruits, grains or seeds), contains substances that can be used for curative purposes, or which are one of the substance used for chemo-pharmaceutical semi-synthesis. Such a plant will have its parts used in the control or treatment of a disease condition and therefore contains chemical components that are often referred to as phytochemicals ('phyto-' from the Greek word –*phyto* meaning 'plant') or phyto-constituents and are responsible for protecting the plant against microbial infections or infestations by pests (Abo *et al*., 1991; Liu, 2004; Nweze *et al*., 2004; Doughari *et al*., 2009). Phytochemistry on the other hand, is the study of natural products. Phytochemicals have been isolated and characterized from fruits such as almond and apples, vegetables such as broccoli and onion, spices such as turmeric, ginger, beverages such as green tea and red wine, as well as many other sources (Doughari & Obidah, 2008; Doughari *et al*., 2009).

Herbal medicines as the major remedy in traditional system of medicine have been used in medical practices since ancient times. In addition to their ancient historical used the therapeutic efficacy of many native plants for various diseases had been described by traditional herbal medicine. Though there have been tremendous progress in human medicines, infectious diseases caused by fungi, bacteria, viruses and parasites are still a major threat to public health. Their impact is particularly great in developing countries due to relative unavailability of medicine. Although some potent antibiotics are now available for the treatment of bacteria and fungi infection, however, due to increasing drug resistance among bacteria and fungi, this has made therapy of bacteria and fungi infection difficult. Bacteria and fungi have the genetic ability to transmit and acquire resistance to drugs. Plants are the richest source of natural antimicrobial agents. Traditional healers claim that some medicinal plants are widely used because of its easy availability and low cost. The active ingredients of many drugs found in plants are secondary metabolites. The mutual effect of the mixture of phytochemicals plays an important role in the use of plant extracts as an antimicrobial agent.

The antimicrobial activities of plant extracts may reside in a variety of different components, including aldehyde and phenolic compounds. A good percentage of the world population particularly those living in developing countries like Nigeria rely mostly on herbal medicines for their health needs. Herbs are widely exploited in the traditional medicine and their curative potentials are well documented. In the fight for survival, plants have evolved with many chemical defenses as means of survival to ward off attackers such as bacteria, fungi, insects, severe weather and in some cases, mammals that may threaten their existence. Secondary metabolites, though not essential for growth and development, do promote the spread and dominance of plant species in an ecological setting (Fellows and Scofield, 1995). As a result of this and the reported therapeutic activities associated with different phytochemicals, they are therefore worth the effort in research into the discovery of new drugs or as a possible alternative to the existing drugs.

The science of application of these indigenous or native medicinal remedies including plants for treatment of diseases is currently called ethno pharmacology but the practice dates back since ancient times. Ethno pharmacology has been the mainstay of traditional medicines in the entire world and currently is being integrated into mainstream medicine. The types of plants and methods of application vary from locality to locality with 80% of rural dwellers relying on them as means of treating various diseases. For example, the use of bearberry (*Arctostaphylos uva-ursi)*and cranberry juice (*Vaccinium macrocarpon)* to treat urinary tract infections in reported in different manuals of phytotherapy, while species such as lemon balm (*Melissa officinalis)*, garlic (*Allium sativum)* and tee tree (*Melaleuca alternifolia)* are described as broad-spectrum antimicrobial agents (Heinrich *et al*., 2004). One plant can be used in the treatment of several ailments, depending on the community. Several ailments including fever, asthma, constipation, esophageal cancer and hypertension have been treated with traditional medicinal plants (Saganuwan, 2010). The plants are administered in different forms such as poultices, concoctions of different plant mixtures, infusions as teas or tinctures or as component mixtures in porridges and some administered in different ways including oral, nasal (smoking, snuffing or steaming), tropical (lotions, oils or creams), bathing or rectal (enemas). Different plant parts and components (roots, leaves, stem barks, flowers or their combinations) have been employed in the treatment of infectious pathologies in the respiratory system, urinary tract, gastrointestinal and biliary systems, as well as on the skin (Rios & Recio, 2005; Adekunle & Adekunle, 2009).

There is insufficient information on the treatment of asthma with our indigenous plant in Ondo state, Nigeria. This objective is therefore carried out to identify and investigate the phytochemical and nutritional constituent of some selected indigenous medicinal plants obtained from Okitipupa Local Government area, Ondo state, Nigeria. The contribution of such information will expand the scope of knowledge on the phytochemical qualities and utilization of the selected plant part for asthma treatment.

MATERIALS AND METHODS

Study area, Collection and Identification of Plant Samples.

The study was carried out in Okitipupa Local Government area, Ondo State. Ondo State is located in the South-Western Part of Nigeria between Latitude 7º 09' N and Longitude 3º 13' E on the World map. Herbalists, traditional healers, herb sellers, old men and women who have deep knowledge of the herbs and those that inherited the knowledge from their forefathers within the area of study were all interviewed with the aid of questionnaires. Healing homes were not left out in this exercise. Relevant information regarding the plant species, recipes, their local names, mode of administration and dosage were also collected to enhance permanent record.

Preparation and treatment of the plant sample

The leaves were collected properly washed, air-dried and ground into fine powder and stored in air-tight plastic container prior to extraction/use.

Map of study area.

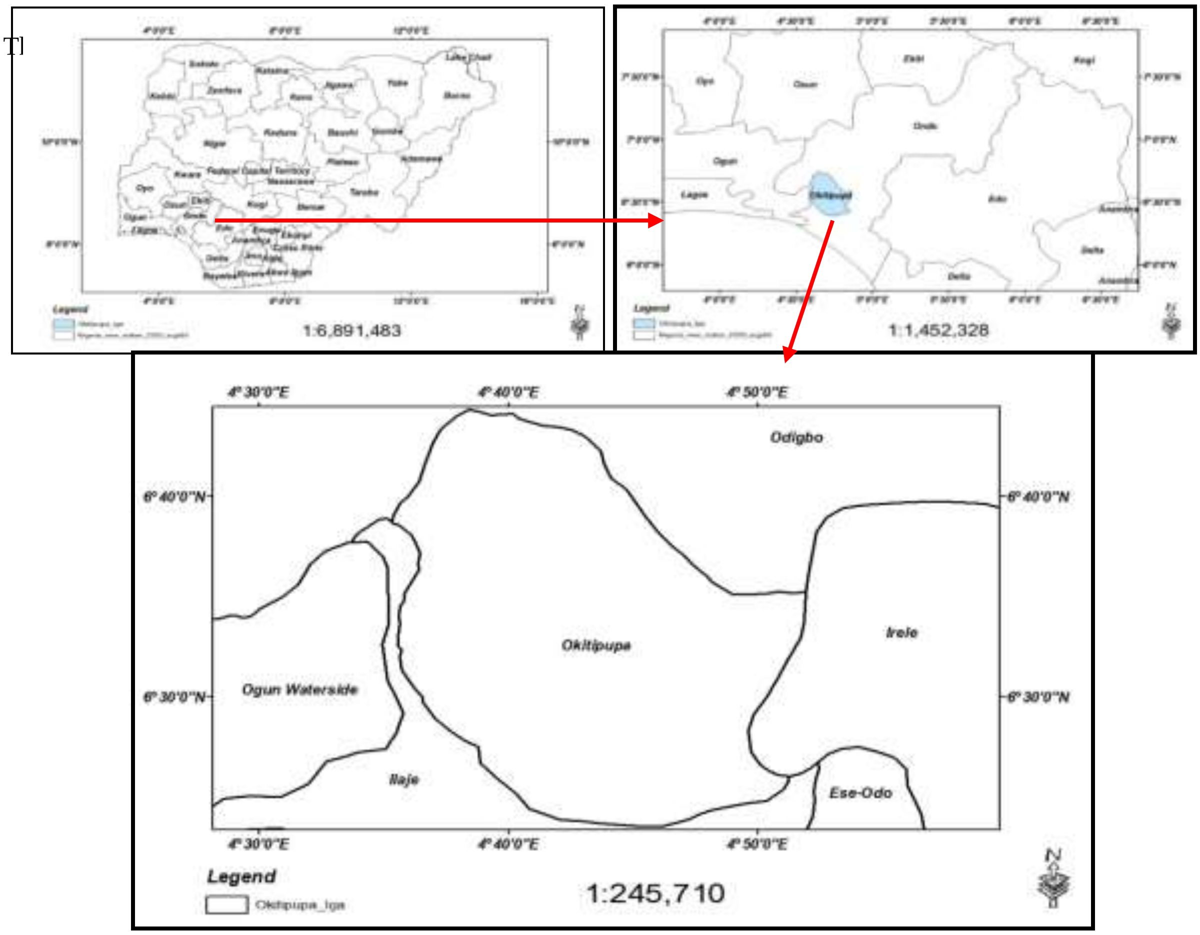

Figure 1: Map of the study area (Ondo State Nigeria)
Source: Faleyimu and Arohunmolase (2018)

Extraction procedures (preparation of extracts)

The analysis determined the biologically active compounds that contribute to the flavor, color and other characteristics of the plants. Each sample was washed with deionized water to remove dust particles, the part used from each plant were sun dried for 3-4 days. The part used were later milled to obtain the powder using an electric blender, the powder were soaked in 360 ml of sterile distilled methanol and 240 ml of sterile distilled water in ratio 3: 2 for four days at 30º C - 32º C. The extracts were filtered through a Millipore filter (0.25 µm). The resulting filtrates were concentrated under reduced pressure at 50ºC and then transferred into a well labelled sterile bottle (Kumar *et al*. 2009).

Test for alkaloids

0.2 g of extracts was shaken with 1 % HCl for two minutes. The mixture was filtered and drops of Dragendorff's reagent (a solution of iodine in potassium iodate) added formation of a reddish brown precipitate indicated the presence of alkaloids.

Test for saponins

0.5 g of the plant extract was shaken with 5 ml of distilled water in a test tube. Frothing which persists on warming was taken as evidence for the presence of saponins.

Test for tannins

0.2 g of extracts was stirred with distilled water, boiled for 5 minutes and then filtered. Ferric chloride solution was added to the filtrate. A blueblack, green or blue-green precipitate was taken as an evidence for the presence of hydrolystable tannins.

Test for cardiac-active glycoside (keller-killani test)

0.2 g of the extracts was dissolved in 2 ml of glacial acetic acid containing one drop of ferric chloride solution followed by the addition of 1 ml of concentrated sulphuric acid. A brown ring at the interface confirmed the presence of cardiac glycoside.

Test for flavonoids

2 ml of the extract was boiled in 10 ml of distilled water and filtered. The filtrate was divided into two different portions of A and B of 5 ml each.

(i) To portion A: 10% lead acetate solution was added in few drops. A yellowish precipitate was formed indicating the presence of flavonoids.

(ii) To portion B: 5 ml of 20% NaOH was added followed by the addition of dilute HCl in drops. A colorless solution was observed, an indication of the presence of flavonoids.

Test for phenols

5 ml of 90% ethanol was added to 1 ml of the plant extract. This was followed by the addition of a drop of 10% Ferric chloride solution. A pale yellow colouration was observed, an indication of the presence of phenol.

RESULTS AND DISCUSSION

Table1**:** Demographic characteristics of respondents

Age variable	**Frequency**	**Percentage (%)**
20-30	8	16
31-40	18	36
41-50	9	18
51-60	13	26
>60	2	4
Total	50	100

Sex	**Frequency**	**Percentage (%)**
Male	13	26.0
Female	37	74.0
Total	50	100

Educational level	**Frequency**	**Percentage (%)**
Primary education	6	12.0
Secondary education	32	64.0
Tertiary education	12	24.0
Total	50	100

Occupation	**Frequency**	**Percentage (%)**
Farming	13	26.0
Trading	26	52.0
Civil servant	6	12.0
Others	5	10.0
Total	50	100

Marital	**Frequency**	**Percentage (%)**
Single	7	14.0
Married	41	82.0
Divorce	2	4.0
Total	50	100

Table 1 showed that most of the respondents are between the ages of 31-40 years (36%), female (74%), have secondary school certificate (60%), mostly traders (52%) and married (82%)

Table 2: Medicinal plants and uses.

S/N	Local name	Botanical name	Family	Part used	Use/method of use.
1	Oganwo	*Khaya ivorensis* A. juss.	Meliaceae	Bark	The bark is washed and chopped into pieces and soaked in water for three days. Half a glass cup per day should be taken.
2	Abafe	*Piliostigma reticulatum (Stapf) Th. & H.D*	Leguminaceae	Bark	The bark should be washed alongside with *khaya ivorensis* and grinded into pieces and soaked in water for three days. Half glass cup should be administered.
3	Itaile	*Zingiber officinale* Rosc.	Zingiberaceae	Rhizome	The rhizome are cut into pieces, the ingredient is boiled. One cup daily.
4	Ira	*Bridelia ferruginea* Benth.	Euphobiaceae	Stem bark	The boil the ingredient with *Anogeissus lelocarpus* for 20-30 min. one glass cup daily.
5	Ifon	*Olax subscorpioiea* Oliver	Olacaceae	Root	Ingredient chopped with *Calliandra portoricensis* together for 3 days. A glass cup once daily is administered.
6	Ewon agogo	*Mimosa pigra*. Linn.	Mimosaceae	Root	The root should be rinsed with clean water and boiled with Olax subscorpioiea for 3 days. One glass cup daily
7	Ogede odo	*Crinum jagus (Thoms.)Dandy*	Amaryllidaceae	bulb	It was peeled and chopped and soaked in jin. A spoon should be administered.
8	Kanafuru	*Eugenia aromatica*. Linn.	Myrtaceae	flower	Chopped with *Crinum jagus and soaked in gin. A glass cup is administered.*
9	Emi ile	*Euphorbia hirta* Linn.	Euphorbiaceae	Plant	Along with *Tetrapleura tetraptera* Washed and cut all the recipes into pieces, soak in water in a covered glass jar and leave for three days. A glass cup three times daily
10	Aidan	*Tetrapleura tetraptera* (Schum. Et. Thonn) Taub.	Mimosaceae	fruit	Cut *Crinum jagus* into pieces, mix with scrapped portion of *Tetrapleura tetraptera* in a mortar. The herbs is soaked in water with alum. A cup administers daily.
11	Ayuu	*Allium sativum*. Linn.	Liliaceae	bulb	It can taken directly or Along with *Crinum jagus* and *Euphorbia hirta* Washed and cut all the recipes into pieces, soak in water in a covered glass jar and leave for three days. A small glass cup-

					full is taken three times daily.
12	Agbalumo	*Chrysophyllum albidum*. Linn.	Sapotaceae	Stem bark	Along *Garcinia kola* Washed and cut all the recipes into pieces, soak in water in a covered glass jar and leave for three days. A small glass cup-full is taken three times daily.
13	Ewe taba	*Nicotiana tabacum*. Linn.	Solanaceae	leaf	Leaf should be grinded to powdery form and sniffed.
14	Orogbo	*Garcinia kola*. Linn	Crusiaceae	seed	It should be eaten directly or Extract the cashew juice and mix with sugar, cut the Garcinia kola into pieces and soak in the juice.1 tablespoon-ful daily.
15	Agbon	*Cocus nucifera*. Linn.	Arecaceae	fruit	The fruit is grinded and soaked in water. Drink twice daily.
16	Kaju	*Anacardium occidentalis*. Linn.	Anacardiaceaea	bark	Cut into pieces the ingredients and boil. A small tumbler-full thrice daily.
17	Alubosa	*Allium ascalonium*. Linn.	Liliaceae	leaf	Boil with *Zingiber officinale* for 30 minutes. a glass cup twice daily.
18	Ominsimisin	*Abrus precatorius*. Linn.	Papiliaceae	leaf	An infusion of *Abrus precatorious* is administered while the *Vitex doniana* is used as a rubifacient applied to the patient's chest.
19	Idi odan	*Terminalia glauccesens*. Planch	Combretaceae	Stem bark	With *Allium ascalonicum* Boil the ingredients for 30 minutes. Adult: a glass cup twice daily, Children: a teaspoon twice daily.

Table 3: Method of preparation of herbs by respondents.

Methods of preparation	Frequency	Percentage (%)
Decoction (boiling)	20	40
Infusion (soaking)	15	30
Taking directly	5	10
Sniffing the herb	5	10
Rub on the body	5	10
Total	**50**	**100**

The Table 3 showed that 40% of the respondents boil the herbs before use, 30% soak them in water, 10% take the herb

SN	Samples	Alkaloid	Flavonoid	Saponin	Glcosides	Tannin	Ascorbic acid	Phenols
1	*Abrus precatorius (leaf)*	+++	-	+	+	+	-	+
2	*Crinum jagus(bulb)*	+	+	+	+	+++	+	++
3	Terminalia glauccescens (root)	+	++	++	+	+	-	++
4	*Khaya ivorensis (bark)*	+	+	-	+	+	-	-
5	*Olax subscorpioidea (root)*	++	-	+	+++	++	-	-
6	*Anogeissus leiocarpus (stem barks)*	+	+	+	++	+	-	-

directly, 10% rub herb on the body, and 10% sniff

Table 4: Summary of the phytochemical screening of the selected plants

Excessively Present (+++)
Highly Present (++)
Moderately Present (+)
Absent (-)

Table 5: Minerals and moisture contents of the selected plant samples (Mg/100 g)

		Minerals contents of the plant samples					
S/n	Samples	Ca	Fe	K	Mg	Na	Moisture (%)
1	*Crinum jagus*	25.1	8.45	16.21	0.34	45.5	25.3
2	*Abrus precatorius*	31.8	2.51	10.52	0.41	9.46	10.51
3	Terminalia glauccescens	6.12	0.32	2.62	5.22	6.43	10.44
4	*Khaya ivorensis*	23.1	12.65	5.45	4.37	6.76	11.93
5	*Olax subscorpioidea*	3.41	5.56	6.1	2.16	9.50	4.12
6	*Anogeissus lecocarpus*	12.33	3.34	10.78	7.34	8.43	45.23

Table 5 revealed that *Abrus precarious* has the highest Ca content among other plant part samples whose value was 31.8 mg/100 g. *Khaya ivorensis* had the highest Fe content with a value of 12.65 mg/100g while *Crinum jagus* had the highest K content with a value of 16.21 /100 g. The Mg content of *Anogeissus lecocarpus* was the highest of the plant part sampled with the Mg content of 7.34 mg/100 g. *Crinum jagus* had the highest Na content among other plant part samples whose value was found to be 45.5 mg/100 g.

Plate 1: *Crinum jagus*

Plate 3: *Khaya ivorensis*

Plate 2: *Terminalia glauccensens*

Plate 4: *Abrus precatorius*

Plate 5: *Olax subscorpioides*

Plate 6: *Anogeissus leiocarpus*

CONCLUSION

The result of the analysis carried out, supports the use of *Crinum jagus, Terminalia glauccensens, Khaya ivorensis, Abrus precatorius, Olax subscorpioides, and Anogeissus leiocarpus,* in folkloric medicine as an antibiotic and in the treatment of asthma and other light ailments. The pharmacological effect of the phytochemical constituents such as alkaloids, glycoside and flavonoids as well as the antimicrobial activity of the plant can explain the rationale for the use of this plant in the treatment of infections in traditional medicine. It is expected that using natural products as therapeutic agents will probably not elicit resistance in microorganisms. Therefore, the outcome of this research work suggest that the plant could probably be a veritable and cheaper substitute for conventional drugs since the plant is easily ob tainable and the extract can easily be made through a simple process. For this reason, it is imperative for ethnobotanists and pharmacognosists to do more analysis on the plants part mentioned in this study. Our medical health practitioner should also focus attention on more intense research on medicinal plants which can save the life of our people without side effect. Formulation of the dosage of the extracts from the recipes must be strictly adhered to, for maximum efficacy and also the avoidance of over dosage which may lead to other complications in patients. One major advantage of traditional medicine is that; it is cheaper than orthodox medicine. Information gathered from the herbalists shows that increasing number of people are turning to the use of anti-asthma which shows that they are effective and efficient in the management of asthma.

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Indigenous Knowledge of Selected Fruit Tree Species in Oba Hill Forest Reserve, Osun State, Nigeria

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Abstract

This study was carried out in Oba Hill forest reserve of Osun State, Nigeria with the aim of assessing the respondents indigenous knowledge about some selected fruit tree species. Two sets of semi-structured interview guides were used to obtain information from the randomly selected respondents in ten selected communities surrounding Oba hill forest reserve. A total of 100 respondents were sampled in this study, data were collected on the socio- economic characteristics of the respondents and their indigenous knowledge of the selected fruit tree species. Data analysis was performed using descriptive statistics and correlation was used to show the relationship between the indigenous knowledge and socio-economic variables. The result of this study revealed that the indigenous knowledge about the fruit trees varied among the rural people. There were variations in the use of the selected fruit tree species and the indigenous knowledge was not common among the youths but mainly common among the old people living in the communities, that have ancient knowledge about the fruit trees. There was variation in the use of the selected fruit tree species. The fruit trees were used as fertilizer, coronation, medicinal purposes, charcoal, production, shea butter, and food. The bark of the baobab tree was used to bathe underweight babies, the roots of walnut was used to cure snake poison and stomach ache, the fruits of shea tree was used to make shea butter. The local people also had various management practices such as weeding and pesticide control. The indigenous knowledge of the fruit trees must be passed on from generation to generation. Therefore, the findings from this study provided information that could promote sustainable use and conservation of the selected fruit tree species through a clear domestication strategy.

Keywords: Indigenous Knowledge, Oba Hill Forest reserve, Fruit trees, Forest communities, Nigeria

INTRODUCTION

Indigenous knowledge is central to Africa's development in all ramifications, especially in rural communities with special knowledge, with which human development is enhanced. Indigenous knowledge, cultural beliefs, taboos, totems, indigenous agricultural practices and these were used to conserve and manage natural resources. In many cases traditional knowledge has been orally passed for generations from one person to another and this can be expressed through stories, songs art and even laws. They are knowledge generated and transformed through a systematic process of observing local conditions, experimenting with solutions, and readapting previously identified solutions to modified environmental, socio-economic and technological situations (Brouwers, 1993). But if information passed on over generations is not preserved, knowledge about traditional methods of preparing them as food will be lost. Indigenous fruit trees have the potential to be a means of enhancing forest-based economic development. Sustainable management of forest products other than timber can create full or part-time employment opportunities for people living in or near forest areas therefore governments are placing special emphasis on promoting it (Corbridge and Kumar, 2002).

Indigenous knowledge in the use of these fruit trees has reduced among rural dwellers because of urbanization, lack of awareness, lack of full knowledge about the unique values. Dozens of indigenous fruit tree species, although relatively unknown in global markets, are locally of large importance for food security and income generation. Women are often strongly involved in and benefit from fruit processing and trade, particularly with regard to indigenous fruit trees (Schreckenberg *et al*., 2006). With appropriate promotion, the contribution of fruits to the livelihoods and health of farmers and consumers could be substantially increased. Fruits offer not only easily available energy, but also micronutrients such as vitamins and minerals necessary to sustain and support human healthy growth (Chikamai *et al*., 2004). Assessment and analysis of indigenous knowledge is very important in determining strategies for promoting domestication. Therefore, this paper focused on the indigenous knowledge of the people living in Oba hill forest reserve in the uses and management practices of three indigenous fruit tree species (*Adansonia digitata, Plukenetia conophora, Vitellaria paradoxa*) across gender.

METHODOLOGY

Study Area

The study was carried out at Oba Hill forest reserve, Osun State, Nigeria. The forest reserve is a forested area set aside for preservation or controlled use natural resources in Nigeria. Oba Hill lies it lies between Latitudes 7.80° and 7.83°N and Longitudes 4.09° and 4.14°E.and it has an elevation of 234 meters above sea level that covers about 52 km^2 of hilly terrain with deep gorges. IUCN (2003) reported that about 12% of the reserve had been planted with teak.

Broadly, the vegetation type consists of core forest formation surrounded by savanna ecosystem. However, the two vegetation types have been highly degraded due to encroachment by farmers (illegal), loggers, charcoal makers and hunters. Over the years, most of the savanna and forest ecosystems have been converted to farmlands, apart from two teak plantations (Akinsorotan, *et al*., 2020). Some savanna trees exist either on the farms or in the fallow portions (Nigerian Conservation Foundation, 2013). These include *Borassus aethiopum, Anogeissus lieocarpus, Lophira lanceolata, Sarcocephalus latifolius, Daniellia oliveri, Khaya senegalensis, Newbouldia laevis* and *Stereospermum kunthianum*. There are various communities (enclaves or migrant settlements) within and around the Reserve. The population of the communities varies from 80 to 80,000. The major occupation in the communities is farming with significant numbers involved in logging, hunting, charcoal making and petty trading.

Research Methods

A semi- structured interview guide/ questionnaire was used to obtain information from the respondents in the selected communities around Oba Hill forest reserve in Osun State. Ten rural communities were sampled and ten respondents with two key informants were selected in each rural community to give more information about the communities. The questionnaire was used to collect information on socio-economic characteristics such as age, marital status, family size, education background and gender of the respondents on uses and management practices of three indigenous fruit tree species (*Adansonia digitata, Plukenetia conophora, Vitellaria paradoxa*). The questionnaire was pre-tested before final administration to respondents. Descriptive statistics such as Frequency Distribution, Tables and Percentages were used for the interpretation of results. Correlation analysis was also used to show the relationship between indigenous knowledge and socio- economic variables of the respondents.

RESULTS AND DISCUSSION

Socio-economic characteristics of the respondents

The marital status of the respondents in the communities for both male and female was presented in Table 1. There were more married male respondents having the highest value of (87%), and less single male respondents having the least value of (2%) respectively. Compared to the female respondents in the study area, there were more married women in the study area (87%) and divorced women having the least value of (2%). Majority of the respondents from the communities visited were married with (87%) male and (87%) female respectively. The result also presented in Table 1 revealed that more male respondents had no formal educational qualification with the highest value of (32%) and the least educational qualification was tertiary education with (2%) respectively, compared to female respondents, (36%) had no formal education and least qualification were WASC and tertiary education with (6%) and (6%) respectively. The study revealed that majority of the respondents were educationally backward. About 32% and 36% of the respondents for the male and female respectively had no formal education while only 2% and 6% of the male and female respondents respectively had tertiary education. Low educational status observed among the rural populace is supported by studies earlier carried out by Adams *et al*., (2000). Stoian (2003), affirmed that education is one of the important human capitals, which plays important role in determining household's status in the society. Without education, people's attitude and knowledge cannot be developed and so with the society.

The result of respondents' sources of livelihood was also presented in Table 1. The result showed that, farming was their major source of income. For the male respondents, farming was their major source of livelihoods with the highest value of 64% and civil service was the least occupation (2%). For the female respondents, farming was their most reliable source of livelihoods with a value of 53% and least value were other means of livelihood like hairdressing, tailoring (4%). Source of livelihoods reflects the nature of local economy, various commercial and employment opportunities of the people of the area. A very high percentage of the respondents were farmers. The findings revealed that majority of the respondents were entirely engaged in farming as their primary occupation as confirmed by Adekunle *et al*. (1999).and Akinsorotan *et al*., (2020). The age ranges of the respondents are presented in Table 1. For the male respondents, the age between 51-60 years had the highest value of 30% while the age between 31—40 years and 81-90 years had the least value of 4% respectively. Compared to female respondents, the ranges between 51-60 had the highest value of 28% and the age range of 71-80 years and 81-90 years had the least value of 4%. It revealed that, 30% and 28% of the respondents' of the age range of 51- 60 years for male and female respectively had more knowledge about the tree species; The study revealed that, the youths had little or no idea of these old-fashioned methods as presented in Figure 1. This agrees with Nuffic (2002) that, indigenous knowledge is a powerful resource obtained basically from rural dwellers that have lived several years in the environment and this valuable knowledge is not documented for them to appreciate according to Vincent and Mercy (2011).

Table 1: Socio- economic Characteristics of the Respondents

Criteria	Variables	Male		Female	
		Freq	%	Freq	%
Marital status	Married	46	86.8	41	87.2
	Single	1	1.9	1	4.2
	Widow	4	7.5	4	8.5
	Divorced	2	3.8	1	2.1
Total		53	100.0	47	100.0
		Freq	%	Freq	%
	No formal education	17	32.1	17	35.5
Educational qualification	Primary school leaving certificate	12	22.6	11	24.1
	Secondary modern school	15	28.3	13	27.7
	WASC	8	15.1	3	6.4
	Tertiary	1	1.9	3	6.4
Total		53	100.0	47	100.0
		Freq	%	Freq	%
	Farming	34	64.2	25	53.2
Occupation	Civil Service	2	3.4	4	8.5
	Trading	3	5.7	16	34.0
	Others	17	26.6	2	4.3
Total		53	100.0	47	100.0
		Freq	%	Freq	%
	20-30	3	5.7	2	4.3
	31-40	2	3.8	6	12.8
Age distribution	41-50	7	15.2	11	23.4
	51-60	16	30.3	13	27.6
	61-70	14	26.6	11	23.4
	71-80	9	17.0	2	4.2
	81-90	2	3.8	2	4.2
Total		53	100.0	47	100.0

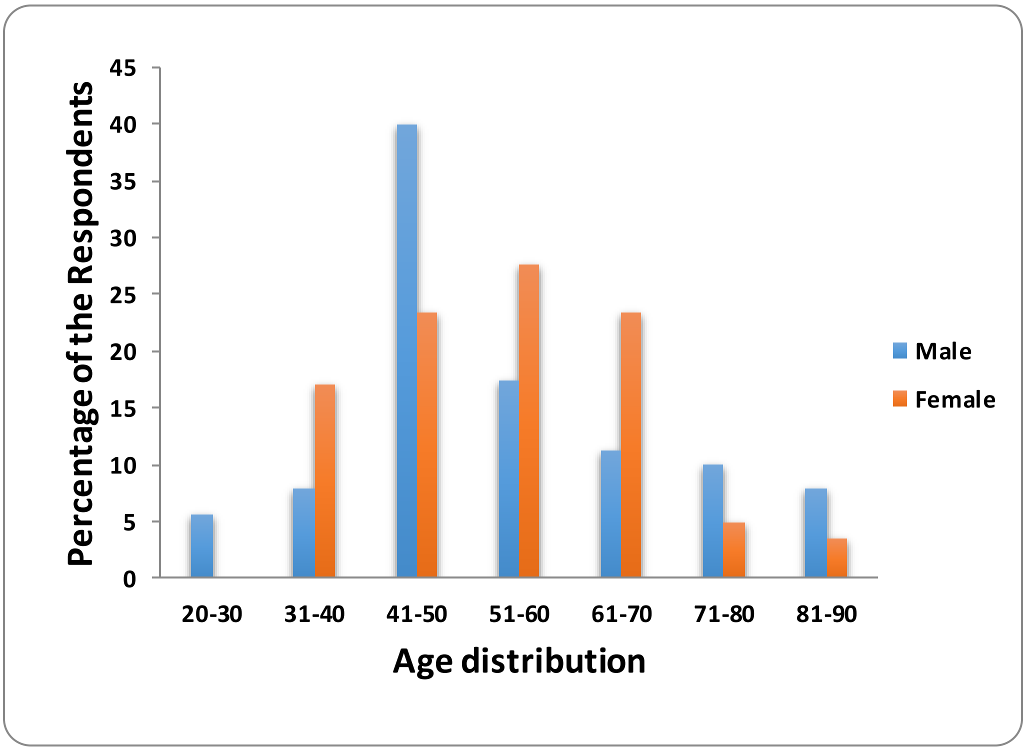

Figure 1: Age distribution of the respondents

Uses of the Selected Fruit Tree Species

Uses of *Adansonia digitata* (Baobab tree)

Table 2 presents the various uses of baobab, for male respondent, there were more unknown use of baobab having the highest value of (40%). Two percent (2%) of the respondents used it for coronation and sacrifice which is the least value. Compared to female respondents, (32%) of the respondents said they do not know which has the highest value, (2%) of the respondents used it for fertilizer, this had the least value. Fruit tree species are conserved for their multiple functions; food, medicine. The use of different parts of the tree species in various ailments contributes to the health security of the rural communities. It showed that there was more unknown use of Baobab for male respondents and female respondents (40% and 32%) respectively. The baobab products were also used to bathe underweight babies, fertilizer, rituals and herbal concoction.

Uses of *Vitellaria paradoxa* (Shea tree)

Table 2 presents the various uses of Shea tree. For the male respondents 60% of them used it to make shea butter while 6% used it for food. For female respondents, 41% of them used it to make shea butter while 11% of the respondents; used it for charcoal, herbal concoction and as food which was the least value. Majority of both the male and female respondents used the shea tree for shea butter. It was also used for carving of mortar and pestle, planks, charcoal and herbal concoction.

Uses of *Plukenetia conophora* (Walnut)

Table 2 showed the various uses of walnut, 72% of the male respondents ate it as food while 15% of them used it for medicinal purposes. Compared to the female respondents, 70% of the respondents ate it as food while 30% of them used it for medicinal purposes. Majority of the male and female respondents used walnut for food and medicine.

Table 2: Uses of the fruit tree species in the study area

Fruit tree species	Uses	Male		Female	
		Freq	%	Freq	%
	Herbal concoction	14	26.4	6	12.7
	Medicinal purpose	7	13.2	13	27.7
Baobab tree	I don't know	21	39.6	15	32
	To bathe underweight babies	8	15.2	9	19.1
	Coronation and sacrifice	1	1.9	3	6.4
	Fertilizer	2	3.8	1	2.1
Total		53	100	47	100
		Freq	%	Freq	%
	Charcoal	5	9.4	5	10.6
Shea tree	Carving mortar and pestle	9	17	13	27.7
	Shea butter	32	60.4	19	40.5
	Herbal concoction	4	7.5	5	10.6
	Consumption	3	5.7	5	10.6
Total		53	100	47	100
		Freq	%	Freq	%
Walnut	Consumption	38	71.7	33	70.2
	Medicinal purpose	15	28.3	14	29.8
Total		53	100	47	100

Methods of using the Selected Tree Species

Table 3 presented the various methods of using baobab. For male respondents, unknown use was the most prevalent with (38%) and 2% of the respondents claimed the wood was used for rituals. Also, for female respondents, (32%) of the respondents claimed they do not know what it is used for. Others methods of use includes the bark to cure diseases and to bathe underweight babies. The seeds were used to make beads and as fertilizers before planting maize and yam. The seed and bark were used to treat fever, this is supported by Brendler *et al.* (2003). According to De Caluwé *et al.* (2009), the various parts of the plant (leaves, bark, seeds) were used to treat almost any disease which include the treatment of malaria, tuberculosis, fever, microbial infections, diarrhoea, anaemia, dysentery and toothache. Bark was also used to bathe underweight babies and cure diseases as confirmed by Sidibe and Williams (2002). The seeds were used as fertilizer for planting yam and maize, beads and rituals. Wood was also used for making rituals. The number of rituals and religious uses can be assumed to be much higher in reality (Cunningham, 2001). Table 3 presented the various method of using walnut. For the male respondents, 45% of them claimed the fruits were for consumption, while 4% claimed that, the climber was used for rituals. For female respondents, 47% of the respondents claimed the fruits were for consumption while 2% of them believed the climber was used for rituals. Fruits of walnut were eaten to cure snake poison and stomach ache. The roots were used to cure stomach ache, and the leaves were used to cure malaria (Table 2). This is in agreement with Ajaiyeoba and Fadare (2006) that, walnut is used for the treatment of dysentery, malaria and to cure male infertility problems.

Methods of Using Shea tree

Table 3 shows that, 23% of the male respondents used the seeds to make shea while only 4% of them claimed that, the bark and leaves were used to cure sickness. For female respondents, 21% of them claimed that, the seeds were used to make shea butter while only 2% claimed that, the bark and leaves were used to cure sickness. The seeds of the Shea tree were used to make shea butter used for cooking and body cream. This agrees to Honfo (2012) that shea butter is used to prepare meals as cooking oil and as a cocoa butter additive in manufacturing chocolate. The wood of shea tree was used to carve mortar and pestle and to make charcoal. The respondents claimed that, the wood was the best in making mortar and pestle and for charcoal. The bark and seeds were used to cure sickness.

Table 3: Methods of using the selected fruit tree species

			Male	Female
Tree species	Part of the tree	Method of use	%	%
Baobab	Bark	Used to cure disease	18.9	27.6
		Used to bathe underweight babies	28.3	27.7
	Wood	Used for rituals	1.9	4.3
	Seed	Used to make beads	3.8	8.5
		Fertilizer	9.4	
	Unknown use		37.7	31.9
Total			100.0	100.0
			%	%
Walnut	Root	used to cure snake poison	18.9	21.3
		used to cure stomach ache	7.5	10.6
	Fruit	for eating	45.4	46.8
	Climber	used for rituals	3.8	2.1
	Unknown use		16.9	12.8
	Leaves	used to cure malaria	7.5	6.4
Total			100.0	100.0
			%	%
Shea tree	wood	charcoal	20.8	19.1
		for carving mortar and pestle	20.8	23.4
		for planks	15.1	10.7
	seed	used to make shea butter	22.6	21.3
	fruit	for eating	7.6	14.9
	bark/leaves	used to make herbal concoction to cure used to cure sickness	3.8	2.1
	unknown use		9.3	8.5
Total			100.0	100.0

Relationship Between the Socio-Economic Variables of the Respondents and Indigenous Knowledge of the Selected Fruit Tree Species.

Table 4 showed the relationships between socio-economic variables of the respondents and uses of fruit tree species. It revealed that there was a negative but significant correlation between the use of shea tree and educational qualification of the respondents in the study area at $p \geq 0.01$.

Management Practices of the Selected Fruit Tree Species

Table 5 presents the management practices of the selected fruit trees. For baobab, 51% and 32% of the male respondents respectively claimed weeding and pesticide control as their management practices. For Walnut, 49% and 36% of the respondent claimed that, weeding and pesticide control respectively as their management practices. For shea tree, 36% claimed weeding as the management control while 26%) claimed pesticide control. The female respondents, 57% and 29% of them claimed weeding and pesticide control respectively as their management practices for baobab. For walnut, 64% and 23% of the female respondents claimed weeding pesticide control respectively as the management practices while 57% and 38% of them claimed weeding and pesticide control as the management practices for shea tree as presented in Table 6.

Table 4: The relationship between the indigenous uses of the fruit trees and socio- economic variables

	Sex of the respondents	Marital status	Educational qualification	Main source of livelihood	Uses of Baobab	Uses of Walnut	Uses of Shea tree
Sex of the respondents	1	-0.015	0.039	-0.084	0.032	0.029	-0.109
Marital status	-0.015	1	-0.005	-0.019	-0.14	-0.093	0.054
Educational qualification	0.039	-0.005	1	-0.024	-0.124	-0.188	-.276**
Main source of livelihood	-0.084	-0.019	-0.024	1	0.097	0.195	0
Uses of Baobab	0.032	-0.14	-0.124	0.097	1	-0.146	0.094
Uses of Walnut	0.029	-0.093	-0.188	0.195	-0.146	1	0.025
Uses of Shea tree	-0.109	0.054	-.276**	0	0.094	0.025	1

**. Correlation is significant at the 0.01 level
*. Correlation is significant at the 0.05 level

Table 5: Management practices of the fruit trees for the male respondents

Managements of the fruit trees	Baobab		Walnut		Shea tree	
	Yes	No	Yes	No	Yes	No
Weeding	27(50.9%)	26(49%)	26(49.1%)	21(50.9%)	19(35.8%)	27(64.1%)
Pesticide control	17(32.1%)	36(67.9%)	19(35.8%)	34(64.1%)	(14(26.4%)	39(73.6%)

Table 6: Management practices of the fruit trees for the female respondents

Managements of the fruit trees	Baobab		Walnut		Shea tree	
	Yes	No	Yes	No	Yes	No
Weeding	27(57.4%)	20(42.6%)	30(63.8%)	17(36.2%)	23(57.4%)	17(42.5%)
Pesticide control	14(29%)	33(70.2%)	11(23.4%)	36(76.6%)	18(38.3%)	29(61.7%)

CONCLUSION

The study has shown that the indigenous knowledge of the selected fruit tree species in Osun State, Nigeria was not common among the youths but mainly common among the old people living in the communities, that have ancient knowledge about the selected fruit trees There was variation in the uses of the selected fruit tree species across gender. The fruit trees were used for coronation medicinal purposes, charcoal, shea butter, consumption and as fertilizer. The bark of the baobab tree was used to bathe underweight babies, the roots of walnut was used to cure snake poison and stomach ache, while the fruits of shea tree was used to make shea butter. The local people also had various management practices such as weeding and pesticide control. The indigenous knowledge of the fruit trees must be passed on from generation to generation.

RECOMMENDATIONS

In order to promote conservation of indigenous fruit trees, bye-laws and policies on conservation needs to be properly enforced in by local governments. Traditional rules and regulations governing conservation of natural resources should be documented out and well communicated to the people, especially the youths. This could be done through a wide consultation with relevant stakeholders in the country and incorporation of indigenous knowledge systems in the school and university curriculum.

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SUB-THEME 10

Forest Governance and Institutions in Nigeria

Participation of the Local Community on Watershed Management at Wurno Local Government Area, Sokoto, Nigeria

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Abstract

Failure of participation of local community at Wurno Local Government Area of Sokoto State to manage watershed directly seriously affect the quality of water either for drinking or recreation. This also leads to erosion that threat the watersheds. The study therefore, was conducted on participation of the Local Community on Watershed Management in Wurno Local Government Area of Sokoto with a view to providing policy option for watersheds that are healthy for the development of a community which in tum would contribute to the successful functioning of the ecosystem. The study design was socio-economic in nature. One Hundred and Twenty (120) set of questionnaires were administered to respondents in four agricultural zones in twelve settlements of Wurno Local Government, namely: Marafa Area, Kofar Chediya Area, Madaci Area, Maigeza Area, S/Fawa Area, Gidan Garka Area, Adarawa Area, Kofar Rima Area, Abujar Turu Area, Gidadawa Area, S/yari Area and Magaryawa Area). The specific objectives were to determine the differences in participation in community-based watershed management programs based on selected socio-economic characteristics. Simple statistical tools as frequency and percentage were used to analyze the data gathered from the field. The results showed that the participation of local community of Wurno Local Government in watersheds management programs was considerably low because 74.2% of the respondents were not into community-based watershed management, while only 25.8% were into community-based watershed management. Even a few that participated, they were very passive in action to disseminate information and for material benefits. The results also indicated that 54.2% of the respondents were members of at least one of the social groups captured in the questionnaire. Also, considering the reasons given by those that did not participate in community-based watershed management, through their decision could easily be influenced by using the proper means, most especially by the Government. This could be achieved through establishing an enlightenment programs by the Government which would encourage the local community of Wurno Local Government, to participate more in community-based watershed management programs. It is concluded that if given empowerment, such will i mprove the participation level of those that functionally participate than passive participation.

Keywords: participation, community, watershed management, Sokoto

INTRODUCTION

A watershed is an area of land that feeds all the water running under it and draining off of it into a body of water. It combines with other watersheds to form a network of rivers and streams that progressively drain into larger water areas. (Tiffany, 2008). Not only does water run into the streams and rivers from the surface of watershed, but water also filters through the soil, and some of this water eventually drains into the same streams and rivers. These two processes, surface runoff and infiltration are important because; for one, they affect water quality. This is because the water that runs off the surface of the Earth picks up water pollution and deposits the pollution in the streams and rivers as it drains the watershed. Along with many different types of pollution that are carried by surface runoff, soil also becomes a water pollutant as it is eroded from farm lands. Water that filters through the soil can also become contaminated with pollution that is left over from agricultural, industrial, commercial and other types of human activity. (Missouri, 2002). Watersheds cover a variety of resources including agricultural land, grazing land, forests, wetlands, common waterways and residential areas (Carlos *et al*, 2003).

Watersheds also have an ecological function, they provide the basis of livelihood for communities and their members, they live there, grow crops, use water and use wood for fire and construction (Joseph, 1999). This make management practice of watershed of great relevance in accordance to the social wellbeing of a particular community. According to Dhruv Jaiswal (1990) in his article, watershed management implies an effective conservation of soil and water resources for sustainable production with minimum non-point resources. It involves management of land surface and vegetation so as to conserve the soil and water for immediate and long-term benefits to the farmers, community and society as a whole. A watershed management plan is a process for achieving watershed resource goals, best driven by the community in partnership with the local watershed group, stakeholders, government and other interest groups to help guide restoration work, enhance the ecosystem and preserve watershed resources for future generations (SEA, 2008). To some extent, watershed management can help in dealing with the environment in an integrated way. This could be done for example, by developing a watershed plan at the basin scale. Environmental impacts both on-site and downstream could be understood through mechanisms like environmental impact assessments or through a dynamic model (Salah et al, 2008).

A watershed management can restore a vision of ecosystem health that recognizes the connections among the various dimensions of water resources and the life forms those resources support (Edelle et al, 2002). Both theoretical foundations and practical evidence have become available on the importance of active participation of communities in water resource management and conservation (Joseph, 1999). In its effort to provide long lasting solution to the problems being faced by the river basin areas in Nigeria, the government of Nigeria in collaboration with the World Bank and bring about the project called; Nigeria Erosion and Watershed Management Project (NEWMAP) is a World Bank assisted project aimed at addressing the Nigerian gully erosion crisis in Southeastern Nigeria and land degradation in Northern Nigeria on a multi-dimensional scale (NEWMAP). Investments include a strategic combination of civil engineering, vegetative land management and other catchment protection measures, and community-led adaptive livelihood initiatives are the integrated investment of watershed management project in Nigeria (NEWMAP). Watershed management brings about sustainable development to Nigerians' drainage basins by providing adequate intervention to control the degradation process, which will solve the ecological problems within the drainage basins in Nigeria (Eroye et al, 2015). It's among the economic benefit of watershed management being it a suitable approach to address poverty and need for food security of upland/mountain areas population as well as of people living downstream (FAO, 2003).

The aim of this research is to determine existence of community-based watershed management in the local community of Wurno Local Government Sokoto State Nigeria. This aim can be achieved through the realization of the following objectives:

- to identify the socio-economic characteristics of the respondents
- to determine if the people of Wurno Local Government participate in community-based watershed management.
- to discover differences of participation in community-based watershed management among the people of Wurno Local government.

MATERIALS AND METHODS

Twelve areas were randomly selected (Marafa Area, Kofar Chediya Area, Madaci Area, Maigeza Area, S/Fawa Area, Gidan Garka Area, Adarawa Area, Kofar Rima Area, Abujar Turu Area, Gidadawa Area, S/yari Area and Magaryawa Area) out of the total areas of Wurno town for the study. From each selected area, ten people were purposively selected to arrive at one hundred and twenty respondents. The purpose for this selection is to get reliable and accurate data for the research being Wurno Local Government one of the riverine areas in Sokoto State. And also, the considered areas are more approximate to the river that was located in the area. Wurno is a Local Government area in Sokoto State, Nigeria. The headquarters are in the town of Wurno, which is near the Gagere River. Wurno Local Government is located between latitude $13^0$17’25.73” N and longitude $5^0$25’25.43” E. It has a total area of 685 km^2 with the population of 162307 at the 2006 census.

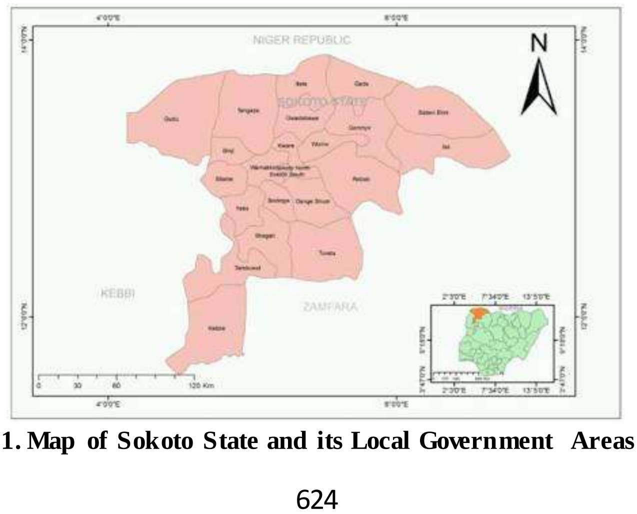

Figure 1. Map of Sokoto State and its Local Government Areas (LGA)

Figure 2. Satellite image of Wurno local Government (red circle)

RESULTS

Socio-economic Characteristics

Being the socio-economic characteristics of the individual one of the most important parameters as far as participation in to watershed management programs is concern, the Table 1.1 below shows the socio-economic characteristics of respondents in the study area.

Table 1.1: Socio-economic Characteristics of Respondents in the Study Area

Respondents	Frequency	Percentage (%)
Gender		
Male	97	80.8
Female	23	19.2
Total	120	100
Marital Status		
Married	76	63.3
Single	44	36.7
Total	120	100
Educational Level		
Non-Formal Education	62	51.7
Primary School	27	22.5
Secondary School	19	15.8
Higher Education	12	10
Total	120	100
Occupation		
Farmer	65	54.2
Government Employee	22	18.3
Private Employee	10	8.3
Self Employed	23	19.2
Total	120	100

Source: Field Survey 2019

Group Membership

The table 1.2 below shows the group membership of the respondents in the study area. The findings of study showed that majority of the respondents (54.2%) were member at least one local group.

Table 1.2: Group Membership of the Respondents

Respondents	Frequency	Percentage (%)
Group Membership		
Non-group	55	45.8
Village Council	9	7.5
Village Security Guard	12	10
Farmers Association	19	15.8
Community Association	9	7.5
Religious Association	16	13.3
Total	120	100

Source: Field Survey 2019

Participation in Community-based Watershed Management Programs
Table 2 shows the distribution of respondents based on participation in community-based watershed management programs.

Table 2: Participation in Community-based Watershed Management Programs

Respondents	Frequency	Percentage (%)
Yes	31	25.8
No	89	74.2
Total	120	100

Source: Field Survey 2019

Participation in Community-based Watershed Management Programs
Table 3 shows the distribution of respondents based on how they participate in community-based watershed management programs.

Table 3: Level of Participation in Community-based Watershed Management Programs

Respondents	Frequency	Percentage (%)
Passive participation	16	51.6
Participation in information giving	10	32.3
Participation by consultation	0	0
Participation for material benefits	5	16.1
Functional participation	0	0
Interactive participation	0	0
Institutionalized participation	0	0
Total	31	100

Source: Field Survey 2019

Participation in Community-based Watershed Management Programs
The table 4 below shows the distribution of respondents based on what hinder their participation in community-based watershed management programs.

Table 4: Perceived factors that prevent individual participation in Community-based Watershed Management Programs

Respondents	Frequency	Percentage (%)
I have no idea what watershed management is all about	39	43.8
I don't know of its benefits to my community	19	21.3
I don't think it is necessary	20	22.5
I don't want to participate	11	12.4
Total	89	100

Source: Field Survey 2019

DISCUSSION
In this research, respondents were asked a set of questions with regard to their socio-economic characteristics. This can be as according to (Reza, 2013) the socio-economic characteristics of the respondents were useful in understanding of the nature of the respondents. Findings of this research indicated that majority of the respondents are male (80.8%) and most of them married (63.3%). Also, the data showed that majority of the respondents has no formal education (51.7%) and the educational level is low (10%) higher education. The data also indicate that majority of the respondents are farmers (54.2%). The findings of this research also showed that most of the respondents are members in at least one local community group (54.2%).

Identifying the participation of respondents in the community-based watershed management is the second objective of this research work. In this study respondents were asked some number of questions to determine if they do participate or not. The findings of this research showed that majority of the respondents don't participate in the community-based watershed management programs (74.2%). This shows only 25.8% of the respondents do participate. But considering the reasons presented by the respondents that don't participate, that most of them are willing to participate is just that they don't it benefits to their society, or they don't know what watershed management is all about etc. As it was stated by (Meaza, 2015) community-based watershed management programs cannot be achieved without the willingness of local people to participate. Therefore, their decisions of not participation into community-based watershed programs can be influenced by authorities.

The data in this research also showed the 25.8% of the respondents that participate in community-based watershed management programs, they do so in three forms (Passive participation, Participation in information giving and

Participation for material benefits). Also, the data in this research indicated that most of the respondents that don't participate in watershed management, they do so because they have no idea what watershed management is all about (43.8%).

CONCLUSION

As a result of this research, the needed for the local community of Wurno Local Government to participate in community-based watershed management programs has been realized because of its great relevance in accordance to the social well-being of their community. If their watersheds are healthy will be able to become essential to the development and survival of a community and can at the same time influence the quality of life of people and contribute to the successful functioning of the ecosystem. The findings of this research study discovered that the community of Wurno Local Government, Sokoto State don't participate in watershed management programs. But taking into consideration the reasons behind their refusal of participation, their decision can be influence to enable them participate not only passive participation or participation in information giving, or participation for material benefits but also functional participation.

RECOMMENDATIONS

Based on the findings, the following recommendations were made

1. There should be an enlighten programs by the Government which will encourage the local community of Wurno Local Government, to participate more in watershed management programs considering their reasons of not partaking. And also, that will improve the participation level of those that participate to functional participation rather than passive or information giving participation.
2. The findings of this research shows the participation of local community of Wurno Local Government into social groups is relatively high, this can use by any Government agency or project such as NEWMAP or non-governmental organization, for access to these people to influence their decision of not participation into community-based watershed management programs.
3. Further research should be made to ascertain of any improvement in terms of participation of local people of Wurno Local Government in particular into community-based watershed management programs.

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Forest Governance and Institutions in Nigeria

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Abstract

Forest governance is a generic term for describing the way in which people and organizations rule and regulate forests. This relates to how they allocate and secure access to rights over and benefits from forests including the planning, monitoring and control of their use, management, and conservation. Forest Governance emerged in response to a changing vision of the roles and responsibilities of the government vis-à-vis other stakeholders from an 'old' style of governance where the government is steering to a new conceptual understanding in which several actors are co-steering. Forest governance will enhance, rule of law, participation, equity, openness, efficiency and effectiveness of decision. Effective forest governance processes engage forest stakeholders, address key forest-related issues and involve other sectors that affect or are affected by forest governance. Among them women in particular must be taken into account as they are one of the main groups using forests. It is essential that women be involved in these processes because rural women's dependence on forests is different from and often greater than men's due to the gender division of labour and different access to economic resources. The Nigerian Forests support a wide range of forest industries which include both the formal and informal sub-sectors. A vast majority of the Nigerian populace depend on these industries thus placing a lot of pressure on the forest resources of the nation. Federal Department of Forestry an agency under the Federal Ministry of Environment coordinated and supervised by National Council on Environment and National Forestry Development Committee are the bodies that govern and regulate Forests in Nigeria.

Keywords: Forest, stakeholders, Environment, Governance, Monitoring

INTRODUCTION

Forest policy and administration reflect an ideal approach to fulfill the objectives of furthering rural development, arresting forest degradation and ensuring sustainable forest development (FAO, 2010). However, forest policies and administration around the world have undergone a broad transformation based among other factors on the recognition of the growing variety of goods and services provided by the forests and trees at the local national and global levels (Lorenz and Sandhovel, 2001).

Forest governance is a generic term for describing the way in which people and organizations rule and regulate forests (FAO, 2010). This relates to how they allocate and secure access to rights over and benefits from forests including the planning, monitoring, and control of their use, management and conservation. Important aspects include: A coherent set of laws and regulations both within the forest sector and in other sectors that influence forest management, the coherent implementation of these laws, the decision making processes regarding rules, laws and regulations, clear mandates of and arrangements between different stakeholders viz: various units and levels of the government, NGO, community organizations and business sectors and staff capable of executing the tasks that have been assigned to them.

In general terms, governance refers to the formal and informal rules, organizations and processes through which public and private actors articulate their interests make and implement decisions. Forest governance is defined as the way in which public and private actors, including formal and informal institutions, smallholder and indigenous organizations, small, medium-sized and large enterprises, civil-society organizations and other stakeholders negotiate, make and enforce binding decisions about the management, use and conservation of forest resources(FAO, 2005). The concept of forest governance has evolved to engage multiple (public and private) actors at multiple scales from local to global. It may include: rules about how forests should be governed, governmental regulations about who benefits from forest resources, traditional and customary rights, use of private-sector mechanisms such as voluntary certification to support sustainable forest management (SFM) and legal timber supply and international measures to support timber legality and promote good governance, such as the European Union's Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan and payment schemes for environmental services, such as REDD+ (Reducing Emissions fromdeforestation and forest degradation in developing countries).

The term 'Forest Governance' emerged in response to a changing vision of the roles and responsibilities of the government vis-à-vis other stakeholders: from an 'old' style of governance where the government is steering to a new conceptual understanding in which several actors are co-steering(FAO, 2005). In the latter vision, the government does not bear sole responsibility for governance, but every actor has a role with specific responsibilities. Important aspects of this new situation are its multi-actor, multi-level (local, national, and international) and multi-sector nature recognizing that different stakeholders may embrace different values, interests and worldviews. The term 'Forest Governance' is to a large extent non-normative in that the concept does not describe or refer to any particular 'type' of governance system.

Effective forest governance processes engage forest stakeholders, address key forest-related issues and involve other sectors that affect or are affected by forest governance. Among them, women in particular must be taken into account as they are one of the main group using forests. It is essential that women be involved in these processes because rural women's dependence on forests is different from and often greater than men's due to the gender division of labour and different access to economic resources. The debate around forest governance has increasingly considered gender but there is little documented evidence of an actual increase in women participating in the process. In high-level national and international discussions and positions women are still underrepresented.

In community-based approaches, especially in South Asia, the bodies governing and setting the rules for accessing and managing forests such as a general assembly and executive committee were so-called "gender neutral". But women's participation was restricted because of conservative gender norms. Even when women participate, they often have only a passive or consultative role which allows them only to exchange opinions that have no guarantee of influencing decisions.

IMPORTANCE OF GOOD FOREST GOVERNANCE

In general, forest governance is considered "good", or "responsible", when it is characterized by the following elements: adherence to the rule of law; transparency and low levels of corruption; stakeholder participation in decision-making, adequate equal rights for stakeholders ;accountability, a low regulatory burden, a coherent set of laws and regulations both within the forest sector and in other sectors that influence forest management, the proper implementation of laws, political stability and sound capacities to govern efficiently and effectively(FAO, 2005).

In most countries the situation in and around forests is rapidly changing and has become increasingly dynamic and complex. An increasing number of often competing claims and uses are exerted on the country's forests by a growing range of actors each with their specific needs, interests and powers. So, there is a need to tackle this complex situation. The promotion of forest governance can bring about many benefits or fruits. Good forest governance makes it possible to optimize the production of goods and services from the forest.

Important fruits borne through good forest governance may increase the benefits provided from forests to people in more efficient ways by enhancing livelihoods. It may include decreased degradation and a more productive resource hence, a more reliable asset base for creating income and revenues. It might also help to facilitate further investments into forestry including the re-investment of revenues from forestry activities, and opening up of new opportunities created by internationally driven processes. These may generate additional forest revenues through increased (or at least sustained) access to international timber markets (in the case of 'legal-procurement regulations', including FLEGT, the US Lacey Act, and Australia's forthcoming legality-assurance legislation) or international payments for forest carbon capture, storage and avoided emissions (in the case of REDD+). Such results can only be realized and ensured in the longer term if an adequate forest governance system is in place.

PRESENT STATUS OF THE FORESTRY SECTOR OF NIGERIA

A recent forest resources study carried out by the Federal Department of Forestry, revealed that the forest estate of Nigeria has been very highly depleted. It was estimated that only about 974,674 hectares of the forest reserves is productive while another 2,342,147 hectares of free areas is partially productive (FDF, 1996). In view of this dismal trend in the forest resources of the country, the need to manage the forests of Nigeria on a sustained yield basis has never been more felt than in recent times. The growth rate of the natural forest is quite low; about 1 to 1.5 m^3 of round wood per hectare per annum and this is a serious constraint. Afforestation in the past has not responded with the required vigour as the area under forest plantations of all types by 1998 was only 184,611 hectares with a growing stock of 78,600,160 m^3.(source)

FOREST RESOURCES AND INDUSTRIES OF NIGERIA

The Nigerian Forests supports a wide range of forest industries, which include both the formal and informal sub-sectors. A vast majority of the Nigerian populace depend on these industries thus placing a lot of pressure on the forest resources of the nation. The formal sector is essentially wood based and is fairly well developed and comprise mechanical wood industries, including sawmills, veneer and plywood manufactures, particle board, paper and paper board manufactures. Furniture manufacturing is also carried out at a secondary level (FDF, 1996). The informal forest sector comprises an informal wood based sector which is the country's largest user of wood, (most of which are burnt as fuel) and the non-wood forest products sector. Forest industry is essentially controlled by the private sector in Nigeria.

Industrial Round wood

Round wood production in Nigeria comes mostly from the naturally high forest zone of the country, in particular from the Southern states of Cross River, Edo, Ogun, Ondo and Oyo States of Nigeria. Round wood is no longer exported from Nigeria since this has been placed on ban since 1976. Round wood includes industrial round wood, fuel wood and poles. Harvesting of industrial woods is carried out by mill operators, by independent registered loggers and by poachers. The mill operators are generally awarded five or twenty year concessions by the States and they either operate directly or subcontract to independent loggers. Illegal felling of logs remains a serious problem. The States are the custodians of the forest reserves and records of exploitation are not faithfully kept which makes sustainable management pretty difficult. Generally all round wood produced in Nigeria by 1997 is estimated at 117.694 million m^3 (Aruofor, 2000). There is a general shortage of round wood and face veneers. The recent forest resource study puts the volume of industrial wood in 1998 at 268.7 million m^3 for all forest types. The continued and sustained levels of round wood consumption in Nigeria are indeed a threat to the forest estate and a source of deforestation which is now a serious problem. This also stresses the need to embark on an aggressive afforestation programme.

Sawn wood

Sawn wood is produced by sawmills in Nigeria whose capacity is estimated at 11,684,000 m^3 per year in log equivalent (Alviar, 1983). The industry has a few large integrated mills among which are the African Timber and Plywood Limited Sapele, Piedmont at Ologbo, Premier Timber Industry Akure, Serom wood Industry Calabar, Iyayi Brothers, Benin City and others. Most of the saw mills have been fully depreciated and are suffering from obsolescence. The estimated total output of sawn wood by 1997 was 2,000,000 m^3 (Aruofor, 2000). Most of the production occurs in the coastal states and Cross River State. The major challenge facing the industry is that it lacks the capacity to process small diameter logs from forest plantations. Plantation wood will become more important as the large diameter trees become increasingly scarce. At present, the recovery rate of the saw mills is put at less than 53%. The major immediate problems facing the sawmill industry include: Old equipment and severe shortage of spare parts, frequent disruption of electricity supply, timber supply declining in volume and size of logs and quality, illegal felling and insecurity of tenure with respect to timber concession. It should be noted that even though production is declining, it remains still substantial and thus a source of deforestation.

Based Panels

There are eight veneer and plywood plants in the country using approximately 170,000 m^3 of logs per annum. Veneer slicing operations are all integrated within plywood mills. Plywood requirements for the country were estimated at 179,000 m^3 in 1990 and this was expected to increase to 285,000 m^3 in 2000 and 450,000 m^3 in 2010 (Gen. Wood, 1994). At the same time wood availability is expected to decrease from 170,000 m^3 in 1990 to an expected 119,000 m^3 in 2010. It is evident that demand for veneer logs outstrips supply. The total capacity of eight mills is 126,000 m^3/year and capacity utilisation by 1993 was 57.3%. Production in 1992 was 111, 7400 m^3 and this has dropped to about 94,625 m^3 by 1997 (Aruofor, 2000). Veneer mills are already experiencing difficulties in acquiring log supplies.

Particle Board

Particle board requirements for the country are estimated at 108,000 m^3 in 1990, 199,000 m^3 in 2000 (Gen. Wood 1994). Existing capacity is estimated at 70,000 m^3 comprising four mills. Production in 1993 was approximately 39,500 m^3 which is 44% of capacity utilisation. Production had remained about 39,500 m^3 in 1997. Current production is hampered by high cost of foreign exchange for new equipment, spare parts and glue acquisition. The particle board production lines in Nigeria are integrated with sawmills and plywood mills, the residues of which they recycle.

Pulp and Paper

These products have been the largest traditional forest products import in Nigeria. In the peak years of 1980 – 81, over 160,000 metric tons. were imported which represented nearly 95% of total consumption of printing and writing papers as well as Kraft paper and board at that time. Today importation is still relatively as high as 45,000 metric tons of printing and writing paper alone was imported into the country in 1994 (Aruofor, 2000). As at 1994, the two pulp and paper mills operating in Nigeria are the Nigerian Paper Mill Limited (NPM) at Jebba with a pulp capacity of 32,000 metric tons./year and a paper production capacity of 70,000 metric tons./year, and the Nigerian Newsprint Manufacturing Company (NNMC) at Oku Iboku. This mill has a pulp capacity of 70,000 metric tons/year and a newsprint capacity of 100,000 metric tons/year. However, a third mill, Nigerian National Paper Manufacturing Company with a capacity of 100,000 metric tons./year of pulp and writing paper is only partially completed and barely operating on imported pulp. In 1990 the total domestic production of paper was 43,498 metric tons which declined to barely 5,314 tons in 1993 due to long fibre shortages which constrained domestic production. There are in addition eight operative small size tissue-paper mills with a capacity of around 40 metric tons/day. The total existing paper capacity in the country is estimated at 50,000 metric tons/year for both newsprint and printing and writing paper and 70,000 metric tons/year for other papers.

OTHER FORESTRY PRODUCTS AND RESOURCES

Fuel wood and Charcoal

The predominantly rural population depends mainly on fuel wood to meet basic energy needs for cooking and heating. Recent studies revealed that Nigeria produces about 1 million tons of charcoal annually of which 80% is consumed in the cities (Federal Department of Forestry, 1996). (FDF, 1996) Fuel wood and charcoal account for about 50% of the national primary energy consumption. Fuel wood is demanded by both household and industrial sectors in all ecological zones of the country. It is estimated that about 90% of the rural households in Southern Nigeria and up -to 98% in the Northern Nigeria depend on fuel wood as their source of domestic energy. Industrial uses include those by institutions, food and craft industries. Fuel wood is very important in local restaurant, bakeries, local breweries, pottery, blacksmith and burnt brick factories. Institutions such as hospitals, prisons and schools also demand fuel wood for cooking. The per capita consumption of fuel wood in rural area is 393.43 kg/annum while the urban households consume 255.75 kg/ annum.

Non Timber Products:

These are all other material other than round wood and derived sawn timber, wood chips, wood-based panels and pulps that may be extracted from forest ecosystems and are utilised within household or are marketed or have social, religious and cultural significance. The list of non-timber forest products in Nigeria is inexhaustible and include such broad classes as leaves, fruits, barks, nuts, resins, honey, mushrooms, wildlife, cane, chewing sticks, medicinal plants to mention a few. The collection, processing and marketing of these products is realized informally by members of the family in various communities. They constitute a major source of household income in Nigeria. Studies carried out by the Federal Department of Forestry (FDF) revealed that the estimated annual income accruing to these products is about N 177.63 billion on a conservative note. The Federal department of Forestry is placing emphasis on non-timber forest products as part of a national campaign to mobilise the public. Such programmes include Rural and Communal Forestry, Bee Keeping, Indigenous Forest Fruit trees Production, Fruit Orchards establishments and wildlife multiplication and domestication.

Wildlife and Tourism

The wildlife of Nigeria is particularly varied because of the country's location, size and the ecological zones. The lowland Rain Forest Ecological Zone is the richest zone in Nigeria in terms of biodiversity and the most valuable forest resources (FDF, 1998). There are about 129 large mammal species in the rainforest and include African Elephants (*Loxodonta africana*), African buffalo (*Syncerus caffer*) and hippopotamus (*Hippopotamus amphibius*). Other large species include the large duikers (for example, *cephabphus nigger*) the Chimpanzee (*Pan troglodytes*), and the red river-hog (*Potamachoerus porcus*). In the savannas, they include the hartebeest (*Alcephalus buselaphus*) and warthog (*Phacochoerus aethiopicus*). In areas of derived savannah, forest species such as elephants and chimpanzees may be observed foraging on food crops adjacent to the forest. There are also a wide variety of small mammals including the grass cutter (*Thryonomys swinderiannus*), giant rats (*Cricetomys spp*.), tree squirrels (*Funisciurus spp*.) and a range of primates. Indeed there are 123 species in the Guinea savannas while 35 species of bats, 23 species of rodents and 20 species of carnivores among others are represented in the country. The lowland rain forest zone also provides habitat for about 200 species of birds. The effect of population pressures on this wildlife is very profound as they are indiscriminately hunted for food and trophy. Over 22 species are on the endangered list of animals in Nigeria. The main problems facing wildlife conservation in Nigeria include poaching, over exploitation, lack of accurate data, bush burning which destroys wildlife habitat especially in the savannah, overgrazing, poor funding of management and research and low managerial capability. The Federal Government has responded with the creation of 8 National Parks distributed across the major ecological zones viz:

National Park Area (ha) Year

Chad Basin 45,696 1991, Cross River 422,688 1991, Gashaka/Gumti 636,300 1991, Kainji Lake 534,082 1975, Old Oyo 251,230 1991, Yankari 224,400 1991, Kamuku 112,700 1999, Okomu 11,200 1999, Total 2,238,296. Thus the Local Governments in Nigeria are responsible for the administration of Communal Forest Areas (CFA), the State Governments control and manage Forest Reserves, Game Reserves and Game Sanctuaries. The Federal Government under the exclusive legislation list is responsible for the control, protection and management of National Parks. There are about 1,129 forest reserves, 29 game reserves and 4 game sanctuaries and 8 National Parks in Nigeria.

FORESTRY POLICY, LEGISLATION AND INSTITUTIONS

Institutional Structure

The Federal Ministry of Agriculture and Natural Resources (FMA & NR) had hitherto played a very important role in land use planning and forestry development through the Federal Department of Forestry which was one of its departments until recently. The Federal Ministry of Environment (FME) has been created and the Federal Department of Forestry has now been transferred to this new Ministry as a Presidential directive. Under the present arrangement, the FME operates through several Departments whose activities are coordinated at the National Council on Environment (NCE). The National Council on Environment (NCE) is the highest environmental policy formulating organ in the country and is chaired by the Honourable Minister of Environment. At the Forestry level however, the National Forestry Development Committee (NFDC) is the highest organ and is responsible for policy initiation and co-ordination in the forestry sector of Nigeria. The membership comprises the Federal Director of Forestry who is the Chairman, the State Directors of Forestry and Heads of Research Organisations in both Governments and Universities with Forestry Departments. The Forestry Association of Nigeria (FAN) is the forum where forestry professionals and practitioners both in the public and private sectors all over the country meet yearly to discuss forestry issues. It must be noted that under the current dispensation separate department exist in the ministry of Environment for conservation as well as drought and desertification control.

The Federal Department of Forestry

The Federal Department of Forestry (FDF) was created in 1970 and co-ordinates forestry activities throughout the country. Its functions are to initiate and to formulate national forest policy and land use planning, foster forestry and environmental development, promote and fund projects of national interest, co-ordinate and monitor State Forestry activities of Federal – foreign-funded projects and institutional development. Specifically, the main functions of FDF include: Advising the Federal Government on forestry development as well as liaising with the States' forestry services of the country, ensuring the application of sound and efficient management of the forest for sustainable production of goods and services throughout the country, co-ordination of all matters pertaining to conservation, protection, utilisation and renewal of the forest resources of Nigeria, co-coordinating Nigerian collaboration with International Organisations, disseminating technical and professional information and organising national and international technical assistance, directing the formulation of National Forestry Policy, Promoting and enhancing the development of forestry management capability, providing extension and advisory services to the States for the improvement and promotion of forestry ideals, assisting to monitor, evaluate and appraise forestry projects throughout the country.

The Department has 3 tiers of administration, at the Headquarters, Zonal Office and State-based Field Office level. In order to facilitate the execution of the programmes of the Department as enunciated in the National Forestry Policy, the Department is structured along the line stipulated by the new Civil Service Reform Guidelines of 1988. Three professional Divisions were approved for the Department namely: Forestry Management, Forest Resource Survey and Utilisation and Agro-forestry, Support Services and Extension. The Forest Management Division deals with internal, that is, ad-hoc departmental planning, coordinates field activities and oversees orderly development and execution of departmental projects. The Forest Resources Survey and Utilisation Division are broadly concerned with ensuring and promoting improved and efficient use of wood products and non-wood products. The Division also deals with forest inventories and the development and management of forestry data bank. The Agro-forestry, Support Services and Extension Division carry out forestry extension and supervise manpower development.

In order to facilitate field operations under forest projects either by the Department or in collaboration with the State Forestry Services, a field office exists in all the 36 States including the FCT. The field offices liaise with the State Forestry Services on behalf of the Department and ensure judicious use of funds and other inputs for the successful implementation of departmental programmes. In order to further facilitate communication between headquarters and the field officers, six zones were created, each comprising a number of groups of the State field offices. The Zonal officers coordinate the activities of the various field officers under them and ensure speedy communication between the field and headquarters. FDF has a specialised unit, Forestry Management, Evaluating and Coordinating Unit (FORMECU). FORMECU was created in response to a need for implementation of World Bank Assisted Forestry Project in Nigeria but now it virtually coordinates all Federal foreign assisted forestry projects in Nigeria. Under the present arrangement FORMECU is now subsumed under the Agro-forestry, Support Services and Extension Division.

State Forestry Departments
The Federal Republic of Nigeria consists of 36 states and Abuja, Federal Capital Territory (FCT). Each of the states and the FCT has an established forestry services as division under the appropriate Ministry. Each State Forest Service (SFS) is responsible for setting and administering policies for its forests. Each SFS Department is headed by a Director reporting to the Permanent Secretary, who reports to the Commissioner i.e. the Chief Executive Officer of the Ministry in the state.

Other Organisations
There are several Non-Governmental Organisations (NGOs) which contribute to the elaboration of the general land use plan and the sustainable management of forestry resources. Amongst some of the notable ones are Nigerian Conservation Foundation (NCF), NEST, NRCC, etc.

Forestry Policy
Nigeria is at present a wood deficit nation. In order to ameliorate the situation, the policy on forest resources management and sustainable use is aimed at achieving self-sufficiency in all aspects of forest production through the use of sound forest management techniques as well as the mobilization of human and material resources. The overall objectives of forest policy are to prevent further deforestation and to recreate forest cover, either for productive or for protective purposes on already deforested fragile land. Specifically, the National Agricultural Policy of 1988 in which the Forestry Policy is subsumed, provides for: Consolidation and expansion of the forest estate in Nigeria and its management for sustained yield, regeneration of the forests at rates higher than exploitation, conservation and protection of the environment viz: Forest, soil, water, flora, fauna and the protection of the forest resources from fires, cattle grazers and illegal encroachment, development of Forestry industry through the harvesting and utilisation of timber its derivatives and the reduction of wastes, wildlife conservation, management and development through the creation and effective management of national parks, game reserves, tourist and recreational facilities, etc.

These policy objectives have been well enunciated and appear well meant and the means for achieving them have been well articulated. Indeed one of the strategies for achieving the consolidation and expansion of the forest estate was the expansion of the forest estate from 10% to 20%. This so far has remained elusive. For the above policy or objectives to be achieved, significant legal and policy changes are needed. In addition the institutional framework and may be the constitutional changes in respect of forest ownership and development planning, as well as programme implementation must need be revisited and strengthened. The challenges call for private sector and public participation, the evolution of an appropriate national forestry legislation, aggressive and scientific forest management, capacity building and adequate financing of forestry development in Nigeria. Indeed the creation of the Federal Ministry of Environment and the transfer of the FDF to it is a step in the right direction.

Legislative Changes
Among some of the legislative changes that have so far occurred but do not seem to have a profound effect of enhancing forestry development in Nigeria are: Land Use Decree No. 6 of 1978 which vests all land in each state of Nigeria in the Governor of the State. The impact is mixed and there have been abuses, the Nigeria Forestry Act, 1937. Most land use, forestry and natural resources conservation laws were established early in this century. The act gave each Governor or Local Government Authority, the authority to constitute its own forest reserves. Some states have enacted specific regulations to monitor and control the reserves, but overall control is not effective. De reservation instead is frequent and penalties under most laws are uniformly low and rarely enforced.

National Park Decree:
This has led to the creation of the National Parks Governing Board and the creation of the Department of National Parks. Other laws which have provision for affecting nature conservation include: The Wild Animals Preservation Act of 1916, the Endangered Species Decree of 1985, the Public Lands Act of 1970 and the various National parks Decree for example Kainji Lake National Park Decree 1979. Each National Park is administered by a Park Management Committee chaired by an eminent professional who is appointed by the Minister, under the recommendation of State Government and managed by a General Manager. A variety of deficiencies exist in the existing State laws and legislation. There are the growing economic, social and legal complexities of the contemporary setting on the one hand and the increasing demand for diverse forestry goods and services on the other. It will appear that there is need to review and modify existing forest laws as well as evolve new legislation to harmonise the overlapping responsibilities of the Federal and State Government, Local Councils and the various multi-purpose parastatals for forest resources.

Forest Management
Forest Management in Nigeria started with the establishment of regional forestry authorities whose main function was the constitution of forest reserves. The total area of forest reserve today is put at 96,000 km^2. The term ‘forest reserve’ today is only a nomenclature used generally to indicate a land use designation and does not indicate that they actually contain forests or vegetation. A lot of it has been highly deforested. Generally the forest reserves are managed for the production of forest resources, which include timber and non-timber forest products.

Initially the forest resources in the high forest zone were managed for timber production on a felling cycle of 100 years. Minimum girth limits were set between the equivalents of 60 – 90 diameters at breast height (d.b.h) depending on the species (FDF, 1996). Forests in the Southern and South Central were sub-divided into numbered miles-square compartments and forests under exploitation were managed under working plans prepared by the Forestry Department. In response to exploitation pressures the felling cycle for natural forests was reduced to 50 years and even less. Natural regeneration of the exploited forests was stimulated by the Tropical Shelter wood System (TSS). Owing to the increased demand for forest land, slow and low growth rates of the natural forest and the consequent conversion of forests reserves to other land use, the TSS was abandoned in favour of artificial regeneration via Taungya System. The Tau ngya plantations while forming protective belts around the accessible parts of forest reserves also provided the pilot phase for subsequent major plantation schemes in the high forest zone. The management and control of forest reserves is vested in the State Governments. The Federal Department of Forestry has only monitoring functions and holds no executive authority in the management of forest reserves and other forest lands. The creation of the National Parks Board gave the Federal Government some measure of executive powers over the protection of the constituted National Parks.

Generally management of the forest reserves has been inadequate and forest management seems to have been replaced by the project syndrome. The paradigm shift was the conversion of a large portion of the forest reserves particularly in the Guinea Savannah and the High Forest Zone to forest plantations of exotic and indigenous species. The level to which this has been successful is debatable. Indeed State Forestry Departments have been unable to protect the forest estate adequately even the usual boundary maintenance was impossible (may be due to poor funding of forestry development), thus leading to a period of extensive encroachment in the form of vast farm lands, settlements and exc ision for other purposes. The private sector is not particularly involved in the management of forest reserves in the country. Their major interest has been in the conversion of forest resources an approach that has proved singularly inappropriate so far. In recent times, international initiatives to assist some State Governments in the management of forest reserves have been taken by Nigeria Conservation Foundation (NCF), World Wide Fund for Nature (WWF) and Department for International Development (DFID).

The main obstacles to forestry development and sustainable management in Nigeria may be summarised to include: Forest ownership that inhibits Federal intervention for sustainability, unlimited powers of State Chief Executives to de-reserve or exploit the forests, forest policy lacks legal backing and so cannot be enforced, poor State funding of forestry programmes and forest management, inadequate financing by Federal Government for forestry development, poor funding of forestry research and training, proliferation of agencies and duplication of duties resulting in cross-sectoral policies and lack of sectoral dialogue, absence of a reliable data base on which to base forestry planning and development, obsolete and unenforceable State Forestry legislation, forest tariffs, which are ridiculously low and are not revised frequently. These problems are further compounded by natural disasters such as drought and flooding, forest fires due to bush burning, extensive arable farming and over grazing of forest lands.

CONCLUSION

Enforcement of forest policies and governance can be achieved by the Nigerian government through their various conservation agencies and in collaboration with donor partners and national Non-Governmental Organizations (NGOs) should develop strategies that would constantly identify and seize opportunities to adapt forest policies to emerging realities of sustainability in forest management. In addition, forest administrators in Nigeria should develop platforms that would facilitate and encourage participatory forest management, Joint forest management and community-based forest management, seeing the reason to involve the local people in the management of their forest resources which have a lot of positive gains. Consequently, for forest policies to be successfully implemented in Nigeria, be it in states or federal level, it should keep pace with rapid global chang e in the roles forest play in climate change mitigation; address key societal issues within the broader and longer-term national development agenda, improve the livelihood strategy of the people and be based on sound information and implement lessons learnt from other countries. Thus, this would encourage a sustainable relationship between the locals and government agencies hence will enhance sustainable forest management in Nigeria. By doing the needful as highlighted above, there will be order and order creates room for increase.

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