PROMOTING INNOVATIVE RESEARCH IN FORESTRY SECTOR: PROSPECTS AND CHALLENGES

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TABLE OF CONTENTS

Editorial Team ix

Welcome address of the president **x**

Welcome Address – Sheila Ward: ISTF tools to promote tropical forests xiii

Host Speaker: Protected areas in Nigeria's emerging bio economy xv

Keynote Speaker: New developments and opportunities of tree ring research in Africa xvii

Guest Speaker: Potentials of Protected areas in Nigeria's emerging bio economy xix

LEAD SPEAKERS PAPERS

Gender Mainstreaming in Forestry development in Nigeria xxvi

Modern trends in landscape ecology and climate change mitigation xxviii

Market trends and industrial development of NTFPs xxxi

Valourization and sustainable utilization of forest products xxxiii

SUB-THEME: TREND IN LANDSCAPE ECOLOGY AND CLIMATE CHANGE MITIGATION MODERN. 1

Impact of Land Use and Land Cover Change on Katsina-Ala Forest Plantation, Benue State, Nigeria – Jande *et al.* 2

Climate Change and Adaptation Strategies on the Livelihood of Artisanal Fishermen in Southwest Nigeria – Simpson *et al.* 15

Analysis of Heavy Metals in *Azadirachta indica* A. Juss Leaves, as Bioindicator for Monitoring Environmental Pollution in Ibadan Southwest, Nigeria – Adetola *et al.* 28

Mitigating Climate Change through Sustainable Wood Utilization: A Review of Challenges and Way Forward – Areo *et al.* 32

Evaluation of Height-Diameter Models for Tree Species of Moraceae in University of Ibadan, Ibadan, Oyo State Nigeria – Ige and Olaniyan. 44

Envisioning Environmental Justice to Improve the Distribution of Urban Tree in Nigeria – Fasoro *et al.* 56

Comparative methods of biomass and carbon stock assessment of some selected tree species used for charcoal production in the guinea savanna ecological zone of Nigeria – Abubakar *et al*. 68

Land Use Land Cover Dynamics of Okomu National Park, Nigeria – Chukwu *et al.* 81

Ecological Niche Modelling for predicting the Impact of Climate Change on Habitat of *Cola nitida* (Vent.) Schott & Endl in Nigeria – Agwu *et al.* 92

Environmental Temperature Changes, Forest degradation and Food security in Nigeria – Fanfosi *et al.* 107

Economic Development Strategies for Utilizing the Improved Perception about Social and Environmental forestry in Nigeria – Ajayi CA 115

Crown Width Model for Hardwood Tree Species Found in Nnamdi Azikiwe University Awka, Nigeria – Ezenwenyi *et al* 127

SUB-THEME: TRENDS IN AGROFRESTRY RESEARCH, FOOD SECURITY AND BIODIVERSITY CONSERVATION 139

In vitro rooting of *Milicia excelsa* (Welw.) C.C. Berg. towards mass propagation – Afolabi *et al.* 140

Effects of garlic extract on growth performance of Sheep Fed on a Concentrated Diet in the Semi-Arid Zone of Borno State – Tada *et al* 147

Comparative evaluation of some Physico-chemical properties of Soil under *Parkia biglobosa* Plantation in Kabba, Kogi State, Nigeria – Isienyi *et al* 155

Assessment of Knowledge, Conservation Status and Silvicultural Practices of Three Indigenous Tree Species in Abia State, Nigeria – Nwajiobi *et al.* 165

Effect of Storage Media on the Germination of *Annona muricata* Linnaeus (Soursop) – Umeh and Nator 175

Early Growth Responses of *Tectona grandis* L. F. to Locally Manufactured Legume-Based Organic Fertilizer – Nwajiobi *et al.* 181

The Role of Human Activities on Tree Regeneration in the Agricultural Parklands of Northern Nigeria – Abdulrashid *et al.* 190

Antimicrobial Potentials of *Parkia biglobosa* Jacq, *Boswellia dalzielli* Hutch and *Carica papaya* L. Ethanolic Extract on Multi- drug Resistant Diarrheal *salmonallae* and *shigellae* Bacteria – Yahaya *et al.* 197

Allelopathic Effects of *Eucalyptus camaldulensis* DEHNH and *Azadirachta indica* AJUSS Leaf Powder on The Growth of Millet and Sorghum (POLACEA) – Salami *et al.* 208

Sustainable Land Conservation among Smallholder Agroforestry Farmers in Oyo State, Nigeria – Oyewo *et al.* 222

Role of *Xylopia aethiopica,* Rice husk and biocontrol agents on germination and vigour index of Sorghum (*Sorghum bicolour* L. Moench) infected with *Fusarium verticillioides* – Adejumo *et al.* 231

Effect of Substituting *Moringa oleifera* Leaves as Natural Sources of Methionine and Lysine on Nutrient Digestibility of Broiler Chickens in Semi-Arid Zone of Nigeria – Hamza *et al.* 240

Optimizing rooting potentials of *Tetrapleura tetraptera* (Schum. & Thonn.) Taub. through stem cuttings – Olaniyi AA 250

Microscopic Structure and Proximate Analysis of *Zanthoxylum gilletti* (De wild.) Waterman and *Zanthoxylum zanthoxyloides* Lam leaves – Lawal *et al.* 258

Therapeutic Potential of *Parquetina nigrescens (Afzel.)* Bullock: Bridging Ethnobotany and Modern Pharmacology – Ogunbamowo *et al.* 268

Effectiveness of DNA barcoding in identifying species of the African *Isolona* using selected chloroplast markers – Yusuff and Onefeli 285

Constraints to the Agroforestry Practices around Onigambari Forest Reserve, Oyo State, Nigeria – Aluko *et al.* 296

Heavy Metals Pollution and Some Water Quality Properties in Ikogosi Warm Spring, South-Western Nigeria – Akinsorotan *et al* 302

SUB-THEME: BLUE ECONOMY 312

Management of Variables Associated with Fish Farming in Ibadan, Oyo State, Nigeria – Ajagbe *et al.* 313

Influence of Health Shocks on Productivity of Cassava Farmers in Iwo Local Government of Osun State Nigeria – Salawu *et al.* 321

SUB-THEME: GENDER MAINSTREAMING 329

Empowerment of Feminist- Led Local Actions for Food Security through Agroforestry in Nigeria – Williams *et al.* 330

SUB-THEME: APPLICATION OF MACHINE LEARNING, ARTIFICIAL INTELLIGENCE AND BIG DATA IN FORESTRY RESEARCH 340

Linking Intact Forest Landscapes with Conservation and Security Planning along Lagos-Ibadan Expressway, Nigeria – Aina and Kehinde 341

The Role of Big Data in Promoting Forestry Research in Nigeria – Oyetunji *et al.* 352

Comparative Analysis of the Accuracy of Thirteen Photo-based Applications in the Identification of Trees Species in Northern Ghana – Abengmeneng *et al.* 362

Development of a Location-Enabled Application for Threatened Tree Species at the University of Ibadan, Nigeria – Mustapha *et al.* 372

Investigating the Efficiency of AI Methods for Predicting Moisture Diffusivity in var. Golab Apples: Fuzzy Logic, ANFIS, and Multi-gene Genetic Programming – Adeyi, A.J. 382

Leveraging Artificial Intelligence for Forest Data and Growth Prediction – Anagbor and Isienyi. 399

SUB-THEME: MARKET TRENDS AND INDUSTRIAL DEVELOPMENT OF NTFPs. 409

Promoting Innovation and Marketing of Natural Honey in Nigeria – Oyetoki *et al.* 410

Socioeconomic Characteristics of Fish Marketers in Ibadan, Oyo State – Ajagbe *et al.* 421

Agricultural Products marketers and their Constraints to use different modes of payments in Ido Local Government Area of Oyo State – Olayemi *et al.* 428

Evaluating the Economic Productivity and Marketing of Mango Fruits in Ogbomosho North Local Government Area, Oyo State, Nigeria – Azeez *et al.* 435

SUB-THEME: POTENTIALS OF PROTECTED AREAS IN NIGERIA'S EMERGING BIOECONOMY 440

Food preferences and foraging ecology of the Bronze Mannikin (*Spermestes cumulates*) Ilaro, Ogun State, Nigeria – Okosodo and Sarada 441

Possible Funding Sources for the Development of Private Forest Plantations in Nigeria – Fasoro *et al.* 450

SUB-THEME: VALORIZATION AND SUSTAINABLE UTILIZATION OF FOREST PRODUCTS 460

Relationship between anatomical and acoustic properties of *Gmelina arborea* wood - Olaoye *et. al.* 461

Sustainable Utilization of Non-Timber Forest Products in Nigeria: A Review – Ojomah, *et al* . 472

Bioethanol Production from *Eucalyptus camaldulensis* Dehnh Wood Waste Using *Bacillus subtilis* and *Escherechia coli* Isolated from Soil in Afaka Forest Reserve, Kaduna State Nigeria - Yahaya *et. al.* 479

Effect of Agro-Waste (*Arundo Donax* L.) Particles on Physical and Mechanical Properties of Polymer Composites - Ogunleye and Aina 488

Composition of Biogas from Cow Dung and Eucalyptus (*Eucalyptus camaldulensis. Dehnh*) Waste - Musa *et. al.* 498

Unlocking the Green Potential: A Comprehensive Exploration of Innovations in Sustainable Wood Waste Utilization for a Greener Tomorrow - Ayeni Olabisi, *et. al.* 505

Assessment of Charcoal Production in Toro Local Government Area of Bauchi State, Nigeria - Abubakar *et. al.* 512

Natural Durability Assessment of *Elaeis guineensis Jacq.* Wood Exposed to Termite Attack - Ogutuga *et. al.* 523

The Significance of Extractives in Enhancing the Natural Durability of Wood Species – Adegoke *et. al.* 530

Utilization of Honeybee Product in Poverty Alleviation of Rural Communities of Toungo Local Government Area of Adamawa State. Umar *et al.* 546

Assessment of the Training Needs of Extension Staff in Climate Change and its Impact on Agricultural Activities in Edo State, Nigeria. Simpson *et.at.* 558

Ethnobotanical Survey of Medicinal Plants in Daura Local Government, Katsina State, Nigeria. Aliyu, *et al*. 571

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WELCOME ADDRESS OF THE PRESIDENT

The Director General, Forestry Research Institute of Nigeria, The Keynote Speaker: Professor Achim Brauning, The Chairman of the Board of Trustees of ISTF Nigeria and Vice Chancellor, Redeemer's University: Professor S. O. Akindele, Conference Lead Speakers, All special guest, Members of the International Society of the Tropical Foresters (Global and Nigeria chapter), Members of the Press, Distinguished Ladies and Gentlemen.

It is with great pleasure that I welcome you to the 2nd Annual Conference of the International Society of Tropical Foresters-Nigeria (ISTF-Nigeria) 2024. The conference brings together professionals, esteemed members, colleagues, and friends from around the world. We are thrilled to have you here, and we hope you will find the next few days very informative, educative, inspiring, and enjoyable.

Firstly, I would like to express my gratitude to you for your contributions towards the growth of our society. Your dedication, expertise, and passion are the driving forces behind our mission to achieve conservation and sustainable management of tropical forests. Your presence at this occasion is a testament to the power of collaboration and the impact we can have when we come together as a global community.

This conference is a celebration of our shared passion for the green environment, and it provides a unique opportunity for us to come together, share ideas, and learn from one another. Over the next few days, we will have the chance to engage with distinguished speakers, present our research, and discuss the latest developments in our fields.

As an international society, we are proud to represent a diverse community of individuals from all corners of the globe. We believe that our diversity is our strength, and we are committed to fostering an inclusive and supportive environment for all our members and everyone connected to the society.

This year's conference promises to be an exceptional event, with a packed program featuring keynote speakers, panel discussions, workshops, and networking opportunities. We have worked hard to create a diverse and engaging agenda that will cater for your interests and needs. Throughout the conference, you will have the chance to engage with fellow professionals, share knowledge, and learn from different experiences. You will also explore the latest developments and innovations in our field, and to be inspired by the achievements and breakthroughs of your peers.

Before we begin, I would like to take a moment to acknowledge the efforts of our excos and organizing committee, who have worked tirelessly to bring this event together. Your hard work and dedication are greatly appreciated. This conference will not have been successful without the support of Director General of FRIN (Zachariah Yaduma Ph.D.) and member of the Management team, we are grateful.

This year we shall explore the theme: **PROMOTING INNOVATIVE RESEARCH IN FORESTRY SECTOR: PROSPECTS AND CHALLENGES!** I wish you all a productive, enjoyable, and memorable time over the next few days. I look forward to seeing you at the various sessions, social events, and networking opportunities.

Thank you, and let's make this conference a memorable one!

Engr. Nkechinyere Clara Isienyi
ISTF-Nigeria President

SHEILA WARD

PhD; Executive Officer, ISTF-Global

ISTF TOOLS TO PROMOTE TROPICAL FORESTS

ABSTRACT

The threats to tropical forests will increase in the future. ISTF-Global is developing strategies to assist members and chapters in facing these challenges.

1. We have joined several global partnerships, such as the UN Decade for Ecosystem Restoration, to link members to opportunities.
2. Funding for projects and research remains a high hurdle, to this end ISTF has incorporated the Terra Viva Grants Directory, to assist in locating funding.
3. An associated project on legacy datasets and publications is seeking to make globally available legacy information that can assist with local forest management and conservation. (Legacy refers to older resources that help establish historical baselines on forest conditions, etc.)
4. All ISTF needs to look at how to increase effectiveness on the ground in conserving, restoring, and sustainably using tropical forests.

ZACHARIAH BUBA YADUMA Ph.D

Director General,
Forestry Research Institute of Nigeria (FRIN)

PROTECTED AREAS IN NIGERIA'S EMERGING BIOECONOMY

ABSTRACT

Protected areas play a crucial role in Nigeria's emerging bioeconomy by conserving biodiversity, preserving ecosystems, and promoting sustainable utilization of natural resources. These areas, which include national parks, wildlife reserves, and forest reserves, are designated and managed for the conservation of natural resources and biodiversity.

Nigeria is endowed with rich biodiversity and natural resources, making her a key player in the emerging bioeconomy. Protected areas, such as national parks, wildlife reserves, and forest reserves, serve as important conservation and management sites created to safeguard the nation's valuable resources. One of the primary benefits of protected areas in the bioeconomy is the preservation of biodiversity. These areas contain a wide variety of plant and animal species, some of which are endemic to Nigeria. Protecting these species helps maintain the country's natural heritage and provides potential resources for future bio-based industries.

Moreover, protected areas support the sustainable use of natural resources. They serve as a source of raw materials for various industries such as pharmaceuticals, cosmetics, and food production. By implementing sustainable harvesting practices, these areas can provide a continuous supply of important natural resources without degrading the environment.

Another crucial aspect of protected areas in the bioeconomy is the promotion of ecotourism. Nigeria's protected areas host a diverse range of wildlife and natural landscapes, making them popular tourist destinations. This not only generates revenue for the government but also supports local communities through job creation and economic opportunities. Protected areas also support sustainable utilization of natural resources through ecotourism, research, and sustainable agriculture practices. Research conducted in these areas are significant to the advancement of scientific knowledge and innovation, leading to new ideas and technologies that can drive economic growth.

Furthermore, protected areas play a crucial role in climate change mitigation and adaptation by sequestering carbon, regulating water cycles, and enhancing resilience to extreme weather conditions. These help in the reduction of greenhouse gas emissions and promotion of the nation's climate resilience.

However, despite their importance, protected areas in Nigeria face various challenges, including inadequate funding and illegal activities. To fully harness their potential in the bioeconomy, it is crucial to address these challenges and implement sustainable management practices.

In conclusion, protected areas are essential components of Nigeria's bio economy, providing valuable ecosystem services, supporting sustainable resource management, and promoting economic growth. It is thereby imperative that these areas are effectively managed and protected to ensure their long-term sustainability and contribution to Nigeria's development goals. Continued investment in protected areas and the integration of biodiversity conservation into sustainable development strategies will be key to unlocking the full potential of Nigeria's bio economy.

PROF. DR. ACHIM BRÄUNING

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NEW DEVELOPMENTS AND OPPORTUNITIES OF TREE RING RESEARCH IN AFRICA

ABSTRACT

Tree-ring research has wides fields of application in climatology, hydrology, ecology, and forestry. A prerequisite for tree-ring studies is that a tree species forms anatomically distinct growth boundaries and tree rings which can be assigned to distinct time intervals and therefore are datable. While tropical trees have long been considered to form no tree rings, more and more African tree species have been identified to form tree-ring boundaries in recent years.

Even if only tree age can be precisely determined by tree-ring counting, it provides opportunities to study population dynamics and changes in tree mortality rates in endangered areas. By using multi-century tree-ring chronologies, inter-annual variations and long-term trends of the hydroclimate have been reconstructed as well as the impact of the atmospheric CO_2 level on tree growth. Analyses of tree-ring stable isotopes were used to reconstruct regional precipitation history and to assess species-specific adaptations of intrinsic water use efficiency to climate change. Quantitative wood anatomical analyses reveal the plasticity and adaptation of the hydraulic system of trees to hydroclimate.

However, to unravel the full dendroecological potential of certain tree species, a combination of research approaches often needs to be applied, including joint application of tree-ring measurements and quantitative wood anatomical analyses, stable isotope analyses and dendrometer measurements. For example, if the annual nature of anatomically distinct tree rings is doubtful, the annual growth dynamics can be analysed using dendrometers to develop cambial growth models. Tree-ring width and wood density measurements reveal changes in the carbon sequestration potential of tree species or forest stands. In case that tree-ring patterns are strongly influenced by human impact like pruning, stable isotope ratios of oxygen and carbon in tree-ring cellulose may still yield strong climate signals, enabling the assessment of inter-annual climate variability.

The lecture summarizes recent technological developments enlarging the applicability of tree-ring studies in Africa and gives examples of tree-ring studies in environmental research and forestry of tropical forests.

PROF. AMINU UMAR FAGGE

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POTENTIALS OF PROTECTED AREAS IN NIGERIA'S EMERGING BIOECONOMY

THE POTENTIALS OF PROTECTED AREAS IN NIGRIA'S EMERGING BIOECONOMY

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Abstract

Nigeria's protected areas encompass a diverse range of ecosystems, from rainforests and savannahs to wetlands and mangroves, and are essential for conserving biodiversity, preserving natural habitats, and safeguarding ecosystem services as well as holding a significant potential for driving economic growth, promoting sustainable development, and conserving biodiversity through bioeconomy. However, they face numerous challenges, including habitat destruction illegal wildlife trade and poaching that threatens 309 species, climate change, invasive species and inadequate funding and capacity. Addressing these challenges requires a multi-faceted approach that revolves around investing in fields of bioeconomy such as algaculture, biomining, forest bioeconomy and biomass energy to harness the substantial biomass potential of about 144 million tons per year, by utilizing its protected areas to create employment opportunities, generate revenue, and foster innovation while safeguarding its natural heritage for future generations. However, realizing this potential requires concerted efforts from government, civil society, the private sector, and local communities to overcome challenges and seize opportunities for a sustainable and prosperous future.

Key words; *protected area, Bioeconomy, Biomass.*

Introduction

Good morning, distinguished guests, ladies, and gentlemen. It is an honor to be here today to discuss a topic of great importance to Nigeria's sustainable development: the potentials of protected areas to Nigeria's emerging bioeconomy. As we navigate through the 21st century, the need to balance economic growth with environmental sustainability has never been more critical. Protected areas, such as national parks, wildlife reserves, and marine sanctuaries, are not only vital for conserving biodiversity but also hold significant potential for contributing to Nigeria's bioeconomy. Protected areas in Nigeria encompass a diverse range of ecosystems, from rainforests and savannahs to wetlands and mangroves. These areas are essential for conserving biodiversity, preserving natural habitats, and safeguarding ecosystem services. However, they also hold immense potential for driving economic growth and promoting sustainable development through the bioeconomy (Oyekunle,2024).

Understanding protected areas and Bioeconomy of Nigeria

Based on the widely accepted IUCN categorization, protected areas can be generally classed as;

- IUCN Category Ia -where all anthropological interventions except scientific study, environmental monitoring and education is prohibited. This is referred to as strict nature reserve.
- IUCN Category Ib - is the wilderness area which is slightly like 1a but slightly less strict with larger area. Biodiversity and ecosystem processes such as evolution are allowed to flourish.

- IUCN Category II is like wilderness area in terms of size but is less strict to human visitation. These are National Parks. They contribute to national economies of countries e.g. Serengeti national park.
- IUCN Category III is a smaller area that is specifically allocated to protect a natural monument and its surrounding habitats, sometimes classified as a historical or spiritual site. IUCN Category IV is like natural monument but focuses more on specific conservation of species and habitats.
- IUCN Category V provides for an explicit natural conservation plan of regions that have built up a distinct and valuable ecological, biological, cultural, or scenic character. It allows for commercial activities and allows the surrounding communities to contribute to sustainable management while going on with its cultural heritage.

Protected areas were started in Nigeria since the colonial era with the enactment of the regional game laws between 1916 and 1963. Reserved forest areas were converted to strict nature reserve, game reserve and national parks for the wildlife sector. Later, the Federal Natural Resource Conservation Council (NRCC) was created to provide coordination for conservation, policy formulation, securing the status of species / sites, monitoring of conservation activities as well as provision of funds for conservation and research work within the forestry and wildlife sectors. In Nigeria there are also 966 Forest Reserves. (Usman and Adefalu 2010).

The bioeconomy on the other hand encompasses all economic activities that utilize biological resources, processes, and principles to generate goods and services. It includes sectors such as agriculture, forestry, fisheries, biotechnology, and eco-tourism. In the context of protected areas in Nigeria, the bioeconomy focuses on harnessing the biological diversity and ecosystem services within these areas to create economic opportunities while ensuring environmental sustainability (Amos *et al*, 2022)

Generation of energy from fossil fuels contributes up to 80% of greenhouse gas emissions (GHG), and increase global warming with its attendant consequences Dunne (2024) predicted the situation to deteriorate with the rising human population that is predicted to reach 9 billion by the year 2050, this buttress the need to replace fossil fuels by bioenergy (Olanrewaju, et al, 2019). Other facets of bioeconomy such as forestry, agriculture, fisheries, and aquaculture need to be enhanced as well.

Biodiversity and Ecosystem Services

Protected areas in Nigeria are rich in biodiversity in diverse ecosystems, harbouring numerous plant and animal species, many of which are endemic or threatened. Nigeria is home to over 864 species of birds, 117amphibians, 203 reptiles, over 775 species of fish, 285 mammals, over 4,715 vascular plants, and likely many more undocumented species as documented by the National Strategy for Combating Wildlife and Forest Crime in Nigeria (2022-2026).The Niger Delta contains the largest mangrove forest in Africa, covering 1 million hectares out of the 3.2 million hectares of mangrove forest in Africa." The Niger Delta also hosts 11 Ramsar sites, which are wetlands of international importance, covering 1,076,728 hectares. These wetlands provide habitat for many endangered species, such as the Niger Delta red colobus, the Cross River gorilla, the African manatee, and the leatherback turtle" (Oyekunle, 2024). He also stated that there are 7 national parks, 32 game reserves, 994 forest reserves, 11 Ramsar sites, 2 World Heritage sites, and 1 biosphere reserve in Nigeria, covering about 10% of its land area.

This biodiversity provides the foundation for ecosystem services, including carbon sequestration, water purification, pollination, and soil fertility. These services are essential for maintaining ecological balance, supporting human well-being, and sustaining economic activities such as agriculture, fisheries, and tourism. Yet, these protected areas face many challenges such as inadequate funding, capacity, and management, encroachment and illegal activities, conflicts with local communities and recently, insecurity.

Eco-tourism and Recreation

One of the primary potentials of protected areas in Nigeria's bioeconomy is eco-tourism. These areas attract visitors from around the world who seek opportunities for wildlife viewing, birdwatching, hiking, and other outdoor activities. By promoting sustainable tourism practices, such as low-impact infrastructure development and community engagement, protected areas can generate revenue, create jobs, and support local economies while conserving biodiversity and preserving cultural heritage.

Bioprospecting and Biodiscovery

Bioprospecting is a systematic and organized search for useful product derived from bio resources including plants, micro-organisms, animals etc that can be developed further for commercialization and overall benefits of the society. Biodiscovery is research on samples of biological resources or extract with the purpose of discovering genetic or biochemical resources of present or potential value to humanity and the eventual commercialization of such native biological resources as governed by the provision of the legal act enacted. (Law inside, 2024)

According to Sawarkar et al (2019) Nature was the origin of all medicines. Ethno pharmacology has provided some very notable past success, including morphine, quinine and digitoxin etc. Reserpine was isolated from the plant *Rauwolfia serpentina* and was turned into antihypertensive drug. Ephedrine isolated in 1923 from *Ephedra sinca* formed the basis for the synthesis of salbutamol and salmetrol which are the antiasthmatic. drugs (beta agonist). Atropine comes from Belladonna and even aspirin was derived from salicin present in willow bark. Teprotide was isolated from the venom of the pit viper, *Bothrops jaraca* and this formed the skeletal framework of the captropril and enalapril, which are used in treating cardiovascular diseases. More recent developments in an association with traditional uses include artemisinin and its derivatives for malaria and prostratin as an anti-viral drug.

Bioprospecting with its potential as a rich source of new therapeutic agents is an important tool for drug discovery and research. However, collaborations between pharmaceutical companies and the countries supplying the indigenous knowledge and medicinal resources should be regulated for mutually beneficial relationship.

Protected areas in Nigeria are also valuable resources for bioprospecting and biodiscovery. The country's rich biodiversity offers untapped potential for discovering new species, genetic resources, and bioactive compounds with pharmaceutical, agricultural, and industrial applications. By conducting research and development in collaboration with local communities and indigenous knowledge holders, scientists and biotechnologists can unlock the therapeutic, nutritional, and commercial value of these biological resources, leading to innovations in medicine, agriculture, and biotechnology.

Sustainable Agriculture and Agroforestry

Many protected areas in Nigeria are in or adjacent to agricultural landscapes. By promoting sustainable agriculture practices, such as agroforestry, organic farming, and landscape restoration, these areas can enhance agricultural productivity, improve soil health, and conserve biodiversity. Agroforestry systems, for example, integrate trees and shrubs into agricultural landscapes, providing multiple benefits such as shade, windbreaks, nutrient cycling, and habitat for wildlife.

Forest Management and Timber Production

Nigeria's forests, including those within protected areas, are valuable sources of timber, non-timber forest products, and ecosystem services. Sustainable forest management practices, such as selective logging, reforestation, and forest certification, can ensure the long-term viability of these resources while promoting economic growth and social equity. By adopting sustainable forest management principles and investing in value-added processing industries, Nigeria can optimize the economic benefits of its forest resources while conserving biodiversity and mitigating climate change (Jordan *et al* 2007). For example, Adekunle et al (2014) estimated the total number of harvested trees from Oyo, Ondo, Ogun, Ekiti and Osun alone at 100,205; 111,789; 753; 15,884 and 18,153 respectively.

Fisheries and Aquaculture

As Nigeria the current 3rd largest producer of fish in Africa with 1,169,478 metric Nigeria's household fish consumption per capita is 13.3kg annually, which is low compared to the world's average, which is at 20.3kg per capita annually. The fisheries sector had a 3.24% contribution to the country's GDP (Adeite, 2023). Protected areas in Nigeria include coastal zones, wetlands, and freshwater ecosystems that support diverse fish species and aquatic resources. Sustainable fisheries management and aquaculture development can enhance food security, create employment opportunities, and alleviate poverty in coastal and rural communities. By promoting responsible fishing practices, habitat restoration, and community-based management initiatives, Nigeria can harness the economic potential of its fisheries resources while conserving marine biodiversity and preserving coastal ecosystems.

Biotechnology and Innovation

Protected areas in Nigeria serve as living laboratories for scientific research, innovation, and technology development. By fostering collaboration between academia, industry, and government agencies, these areas can support biotechnological innovations in areas such as genetic engineering, molecular biology, and bioinformatics. Research conducted in protected areas can lead to the development of novel bioproducts, biopharmaceuticals, and bioenergy technologies, contributing to economic diversification, job creation, and global competitiveness.

Challenges and Opportunities

Despite their immense potential, protected areas in Nigeria face numerous challenges, including habitat destruction, illegal wildlife trade, poaching, climate change, and inadequate funding and capacity. Addressing these challenges requires a multi-faceted approach that integrates conservation, sustainable development, and community engagement. By investing in ecosystem restoration, biodiversity conservation, and sustainable livelihoods, Nigeria can harness the full potential of its protected areas to build a resilient and inclusive bioeconomy that benefits both people and nature.

Conclusion:
Protected areas in Nigeria hold significant potential for driving economic growth, promoting sustainable development, and conserving biodiversity through bioeconomy. By leveraging the country's rich biological diversity and ecosystem services, Nigeria can create employment opportunities, generate revenue, and foster innovation while safeguarding its natural heritage for future generations. However, realizing this potential requires concerted efforts from government, civil society, the private sector, and local communities to overcome challenges and seize opportunities for a sustainable and prosperous future.

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PROF. JANICE E. OLAWOYE

GENDER MAINSTREAMING IN FORESTRY DEVELOPMENT IN NIGERIA

ABSTRACT

Forestry tends to be perceived as male dominated although women are heavily involved in forest work such as gathering fuelwood, medicinal plants, and other non-timber forests products, collecting food for family consumption as well as for income, and in processing secondary wood products. Ecological conditions of environmental degradation and climate change affect everyone, but women's ability to adapt may be more difficult to achieve. These conditions can greatly increase vulnerability of all people dependent upon the direct use of natural resources. The heavier dependence on forests by women means that they have more at stake than men when forests are degraded, or forest access denied. The needs and concerns of women are often neglected even though there are prospects for effective involvement of females. There are risks of ignoring gender in forestry development.

Gender mainstreaming seeks to redress gender imbalances while ensuring gender issues take a prominent position in the analysis of the situation as well as designing a response that will meet the needs of all stakeholders, male or female. Mainstreaming gender equality at all levels of the forestry sector has positive effects on many forest management issues including resource sustainability, forest regeneration and conflict management. There are challenges to ensuring gender mainstreaming in forestry development, one of which is low female involvement in decision making at the local and higher levels for planning and programme implementation. There is also little consensus concerning how to achieve it. Gender analysis must be done before gender mainstreaming to gain baseline information on gender: Gender-sensitive indicators should also be developed to monitor progress in gender mainstreaming. Among the conclusions and recommendations are the need to recognize locality-specific differences in gender roles and constraints, to ensure social inclusion of vulnerable groups and to understand the challenges of expecting rural dwellers, especially women to give greater time, labour and money to participate, particularly given their livelihood strategies and physical well-being. Accurate and reliable gender-sensitive data are needed and policies and programmes should be re-examined to promote gender equality/equity.

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"MODERN TRENDS IN LANDSCAPE ECOLOGY AND CLIMATE CHANGE MITIGATION"

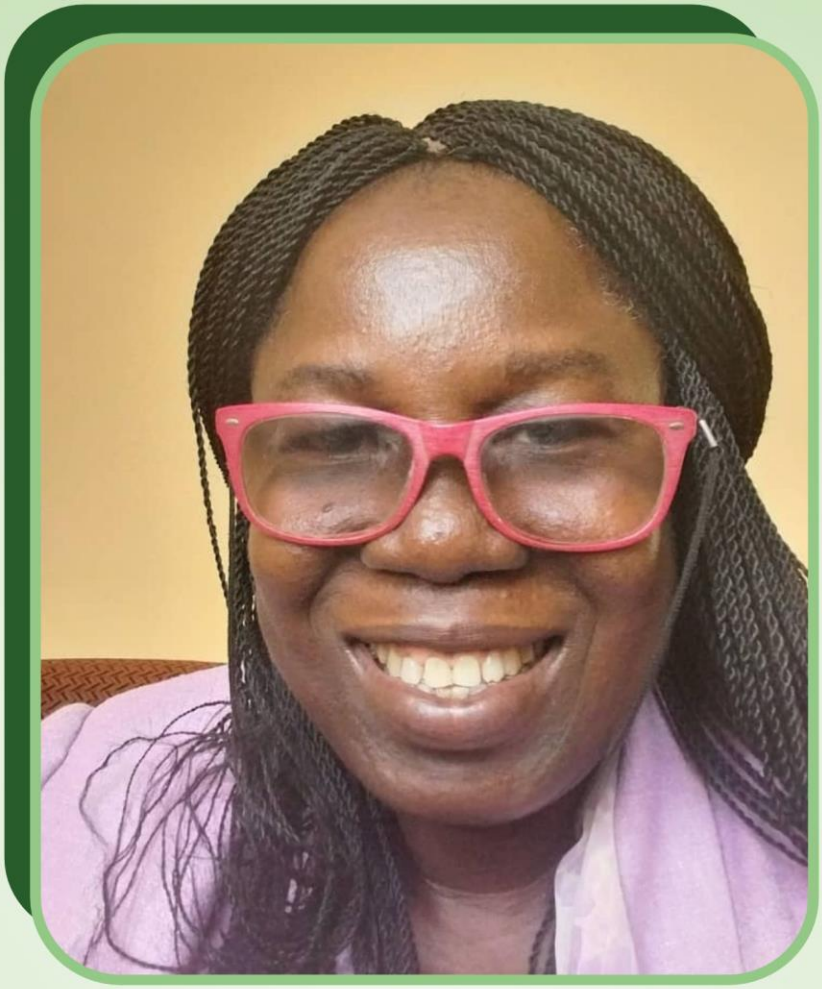
ABSTRACT

Landscape ecology focuses on understanding the interactions between natural and human-modified landscapes, and how these patterns and processes are affected by climate change. The launch of the United Nations Decade on Ecosystem Restoration in June 2021 labelled the decade 2021-2030 as Decade on Ecosystem Restoration spurred the increase of investment in landscape restoration, particularly in Africa. While increased investment has led to an increased number of restoration projects across the continent, it also led to the awareness that whereas forest management is a well-established educational domain, the concept of forest landscape restoration, which connects multiple disciplines within environmental and social sciences, is relatively new. Therefore, there is a shortage of well-trained professionals to do the job. The new trend is to build a new generation of 'restoration professionals' across the continent of Africa to launch a *Call to Action* to develop inter- and transdisciplinary restoration related curricula across the African continent which will impact on landscape ecology and climate change mitigation.

To achieve these, a partnership was formed with five universities in Africa: University of Development Studies of Tamale (Ghana), the University of Natural Resources and Environmental Management in Sunyani (Ghana), the University of Ibadan (Nigeria), the Centre for Applied Systems Analysis (Malawi), and the Rwanda Polytechnic, Kitabi (Rwanda). Other partners are CIFOR-ICRAF's Global Landscapes Forum, the International Union of Forestry Research Organisations (IUFRO) and the UN Convention to Combat Desertification (UNCCD). Two new concepts of Landscape Restoration and Transformative Education were used to adopt an explorative approach based on *learning-by-doing*.

The partners developed a set of principles on landscape restoration, supported by a conceptual landscape framework and the learning outcomes of a Restoration Education curriculum. The new curriculum focuses on developing capabilities and skillsets needed for restoration professionals to restore degraded landscapes in Africa. It is a blueprint for transformative Restoration Education, based on existing courses and complemented with innovative modules, short courses, summer schools and practical. Restoration Education is to be delivered in a blended learning format, with a package of resource materials, including principles, reports, power points, videos, and assignments, for universities to build their respective modules in detail. A preliminary outline of a toolkit for landscape restoration was

developed to complement the Restoration Education curriculum. The tools ranged from those for facilitating multi-stakeholder processes, to communication and advocacy tools, project planning tools, and implementation tools. In addition, a toolkit on innovative teaching methods was developed, to help teachers move away from the 'sage on stage' teaching approach of existing knowledge to facilitation and co-creation of new knowledge. There are sessions on the principles of transformative education which facilitates on-the-ground practice, moderates the process of restoration, and builds the transdisciplinary mindset. These resources have been organised using the modular delivery system and are available on a digital campus, which is a virtual space, where all stakeholders could have access to the resources, collaborate and utilise the information.



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MARKET TRENDS AND INDUSTRIAL DEVELOPMENT OF NTFPs

ABSTRACT

The significance of forest products apart from wood is increasingly being recognized across the globe. However, the potentials of Non-timber Forest Products (NTFPs) are not fully realized. Few NTFPs can transit from traditional, unofficial use to international markets, even though their frequently valuable nutritional composition and the identification of new potential applications offer additional prospects for innovation and rural development. Nigeria is blessed with reasonable number of NTFPs that could reach the international markets. For any selected NTFP it will take time to increase from about zero to several hundred tons annually, and for such to happen the industry must be created bottom-up with external funding to overcome the generally challenging business environment for NTFPs. This is triggered by the rising demand for natural, healthy foods and growing knowledge and appreciation for indigenous products, increasing numbers of entrepreneurs and development organizations entered the scene. Large number of Nigeria's NTFPs could reach the international markets with the overcoming of the common obstacles related to NTFP commercialization which are inclusive of corruption, secrecy, inadequate access to funds or human resources, poor facilities such as transportation systems or electrical supply, and unfavourable institutional frameworks, lack of technology and modern tools/equipment etc. This paper samples the success story of *Adansonia digitata* L. (baobab), of how the transformation of a traditionally used informal product into a formal value chain with a "***commercial focus"*** is perhaps the most innovative aspect of the high-end baobab industry.

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VALORIZATION AND SUSTAINABLE UTILIZATION OF FOREST PRODUCTS

ABSTRACT

This study reviewed the different approaches to recycling, sustainability, and utilization of wood waste from forest areas using existing data. Globally, vaporization plays a critical role in shaping the world and human activities with a direct impact on the harvesting and utilization of forest products which cause climate change. However, harvesting and utilizing wood and non-wood products continues to increase due to global demands. The world has a total forest area of 4.06 billion hectares (ha), which is 31 percent of the total land area according to FAO 2020 and about 1.15 billion ha of the forest land is primarily managed to produce wood and non-wood forest products. Global production and trade of all major wood-based products including round wood, sawn wood, wood-based panels, wood pulp, wood charcoal, and pellets since 1947 to the present state are reported in this study based on FAOSTAT forestry database and forest product statistics. The global growth in the production and trade values of forest products mostly wood-based products also increases in the volume of global wood waste generated. Nigeria generates about 1.8 million tons of sawdust annually and 5.2 million tons of wood waste annually.

Nigeria produces large volumes of residues which must be utilized, marketed, or properly disposed of through perfect techniques for forest land to be maintained. The lack of advanced technology in the wood industry has adverse environmental effects on sustainable ecosystems. Reuse/recycling of wood residues plays a key role in the development of products such as composites, wood-based panels, wood pulp, wood charcoal, and pellets. In 2018, these wood-based products' production, imports, and exports reached their maximum quantities since 1947 with huge revenue generated in countries like the USA, Canada, China, Australia, etc while the African continent still dragging foot. African countries need to wake up and increase their technology challenges to meet up with these developed countries of the world. Sustainably managed forest products through advanced technology will be a greater key for social economic development in Africa mostly in Nigeria. My advice to the Nigerian government and the policymakers is to provide support such as financial inventive and no custom duty rates on machines to wood-based manufacturers to be able to exploit advanced technologies and compete with international wood marketers.

KEYWORDS: wood waste; wood-based products, recycling, sustainability; Utilization

SUB-THEME: TREND IN LANDSCAPE ECOLOGY AND CLIMATE CHANGE MITIGATION MODERN

Impact of Land Use and Land Cover Change on Katsina-Ala Forest Plantation, Benue State, Nigeria.

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Abstract

The greatest threat to the preservation and survival of forests is the loss and degradation of forest habitat brought on by changes in land use and land cover. Monitoring of these changes is now necessary since changes in land use and cover are making Nigeria's forests deteriorate beyond its wild forests and progressively harming plantations and forest reserves as well. This study assessed the impact of land use and land-cover (LULC) changes on the Katsina-Ala Forest plantation. This study made use of primarily secondary data from pre-existing satellite imageries. Landsat TM of 1993, Landsat ETM+ 2013 and Landsat 8 OLI for 2023 images were sourced from a remote sensing satellite hosted by the University of Maryland in the United States of America. Images were subjected to various image processing techniques, and supervised classification was carried out on the multiple pictures. The classification resulted in classes of agricultural area, built-ups, forest cover, grassland/herbaceous and bare land. The trend of LULC in Katsina Ala Forest Plantation indicated that grassland increased by 4.14 ha and built ups increased by 2.34 ha, representing 8.36% 30 years between 1993 to 2023. Forested area decreased by -8.19Ha, representing 29.69% of the total change within the the same period. The magnitude of land use/land cover change within the 30 years showed that -8.19 ha of the forest area was lost to other forms of land use. Grass land and built-up areas gained 4.14 ha and 2.34ha, respectively, within the period. It was established that urbanization is the primary threat to Katsina Ala Forest Plantation, urgent measures need to be put in place to rescue ugly trends going on in the plantation. Also reafforestation of the reserve was recommended.

Keywords: Built-ups, Grassland, Threat, Urbanization, Reafforestation, Katsina-Ala

Introduction

The earth's life depends on forests. Along with the regulatory services needed to support climate, air, water, and pollination services, they offer ecosystem services that support human Additionally, forests provide the necessary support services to safeguard soil, maintain a stable climate, and improve primary productivity (FAO,2022). They also assist in meeting people's cultural and spiritual aspirations (FAO, 2016, 2018). By enhancing the diets of individuals who live close to forests and those who live outside them, forests play essential roles in society (Fatoki *et al.*, 2021). For example, urban and rural consumers enjoy fruits, berries, and nuts from the forest. In addition to adding diversity and flavour to meals, these forest foods and many more also include vital elements like vitamins, lipids, proteins, and minerals. Forest foods also act as

crucial famine or malnutrition insurance during times of crisis and seasonal food shortages brought on by floods, droughts, or war (FAO, 2018). Rural households are supported by forest resources, particularly in regions with high poverty rates. Even though not everyone who lives in or near forest areas is impoverished, the tropics are hotspots for poverty (FAO, 2018). It is nevertheless essential to underline how vital forests and trees are as a backup plan and a significant source of items for daily life that would otherwise need to be purchased. In addition to offering coping methods in times of crisis, forests also generate vital income for the rural poor, making them a significant part of various rural livelihoods. According to the Food and Agricultural Organization (FAO, 2018), nearly 2.5 billion people who practice subsistence agriculture worldwide use the ecosystem services that the forest offers. Despite the many advantages of forests, there is an unparalleled level of degradation of forests and their resources worldwide, primarily due to changes in land use and land cover (LULC).

Katsina-Ala has witnessed tremendous population growth over the years. It has given rise to a steady upsurge in urban population, especially in the town (Jande *et al.*,2020). It infers that the growth of the city will have a significant effect on the landscape on the outskirts of the city by changing them. As a result, there is a need for special care and constant evaluation of our decision-making to monitor and plan for the impact of this growth on its fringes. With the increasing importance of the urban area of Katsina-Ala town in driving changes in the surrounding environment, there is a burning desire to know how the metropolitan area of Katsina-Ala has impacted the forest resources in the area and how to plan (Jande *et al.*,2020). These persistent farming activities have and continue to degrade the forest reserve. Worst still, the tree logging activities have caused massive deforestation of the reserve. With the increasing population of communities in and around the Katsina Ala Forest Plantation, there is an increasing need to address the issues of land use to gain local participation in tree planting and other sustainable forestry practices. The study was conducted to provide needed data that will help policymakers and forest administrators in the state to make informed decisions on the management of the plantation.

Materials and Method

The Study Area

Katsina-Ala, created in 1976, is situated within Central Nigeria's lower River Benue valley. It lies between longitude 9° 15′ and 9° 56′ East and Latitude 6° 55′ and 7° 36′ North, as shown in Figure 1. The Local Government has a projected population of 341,038 by the year 2020 (Projected from NPC, 2006) (Jande *et al.,* 2020; Hundu *et al.*,2021) and occupies a landmass of 2688.64 square kilometres (Jande *et al.,* 2020). Katsina-Ala is the location of one of the oldest schools in Nigeria, Government College Katsina-Ala, founded in 1914. The climate of Katsina-Ala is made up of two different seasons: the rainy (wet) season and the dry season (Hundu *et al.,* 2021). The yearly rainfall is between 15cm and 18cm. Temperatures vary between 230C-380C for most of the year (Jande *et al.,* 2020; Hundu *et al.,* 2021). of Katsina-Ala is in the Guinea savannah, which contains a mixture of average-height trees and grasses. In addition to tall grasses, the Guinea savannah features isolated riparian forests along the riverbanks and swaths of woodland, scrubs, and shrubs (Abah, 2014). Some of the native tree's species in the area include; *Daniellia oliveri, Parkia biblobosa, Prosopis africana, Burkia africana, Lophira lanceolata,* and other scatted trees are among. River Katsina-Alan, a significant tributary of the river Benue, is the primary drainage feature in the region. It gets its sources from the mountains in Cameroon.

The river is utilized for transportation, tourism, fishing, and irrigated agriculture (Jnade *et al.*, 2020). Most of Katsina-Ala is rural, with villages scattered across small homesteads and a population density of roughly 180 people per km2. These people are primarily farmers. Most of the local Government's residents are Tivs, Etulo and Hausa (Hundu *et al.*, 2021). Over 80% of the total population depends on farming for their living, taking advantage of the rich alluvial soils of the Katsina-Ala valley.

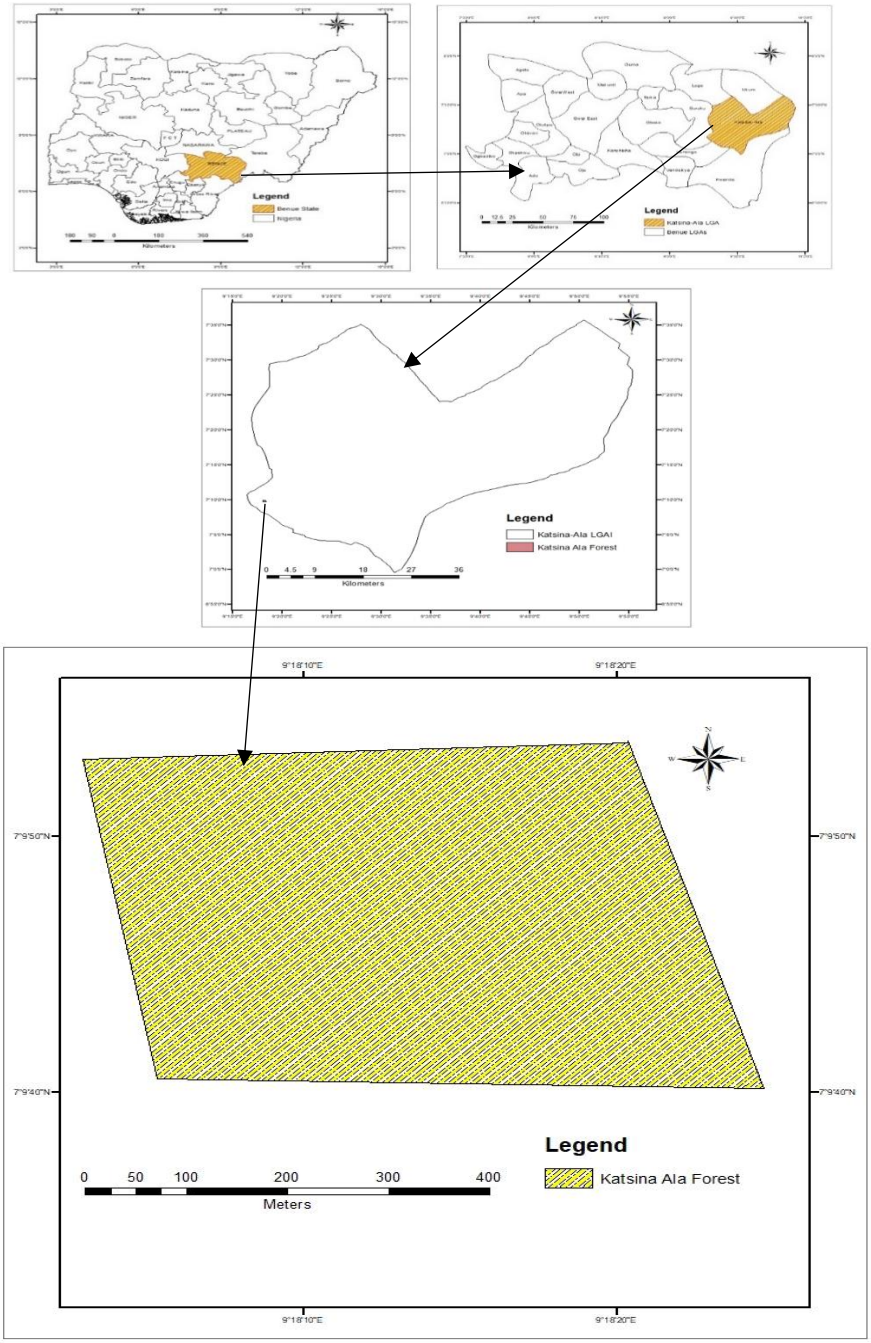

Fig.1 Maps of Study area
Source; Produced from GADM Shapefile using ArcGIS 10.1

Data Collection

This study mainly used secondary data. The data acquired from a remote sensing satellite were hosted by the University of Maryland in the United States of America (Global Landcover Facility through the online Earth Explore website. The Landsat TM of 1993, Landsat ETM+ 2013 and Landsat 8 OLI for 2023 (Table 1) and the classification scheme used in the study (Table 2) and analyzed.

Data Analysis

The tools used for data analysis were ArcGIS 10.1, used for pre-processing of images and vector data; ERDAS Imagine 2014, used for classification and accuracy assessment of classification; Idrisi Selva, used for change detection; Google Earth Image, used for delineation and ground-truthing and Global Positioning System-used for collection of sample points for classification and data validation. Mapping the types and extent of land use and land cover classes was achieved by examining Landsat TM of 1993, Landsat ETM+ of 2013 and Landsat 8 OLI of 2023 images acquired and their subsequent classification. To map the types and extent of LULC classes in the reserve, the data were subjected to some processing and analytical procedures, which included data pre-processing, image rectification, image enhancement, and image classification. Following image pre-processing, composite images for the three study years were created for image classification. These procedures involved the correction of Landsat images through haze removal, cloud removal and clipping the images using the shapefile of Agundu Forest Reserve digitized from Google Earth. The shapefile was then used to subset from the more significant scenes. The subset method in ERDAS 2014 was used, where the desired shapefile Katsina Ala Forest plantation was used as the Area of Interest (AOI). The choice of this method was based on its simplicity of use, its higher accuracy, and its ability to define the study area precisely. Supervised classification of Landsat image data for the three periods (1993, 2013 and 2023) was performed using the Maximum Likelihood Classifier to identify and map land use and land cover classes. To ascertain the areal extent and rate of change in the LULC in Agundu Forest Reserve, the following variables were computed.

Total area (T_a), Changed area (C_a), Change extent (C_e) and Annual Rate of change (C_r). These variables can be described by the following formula as given by (Yesserie, 2009)

$$C_a = T_a(t_2) - T_a(t_1) \quad \text{[1]}$$

$$C_e = C_a / T_a(t_1) \quad \text{[2]}$$

Where t_1 and t_2 are the land use and land cover studies' beginning and ending times.

Table 1: Characteristics of Landsat images used for the study

Year of Acquisition	Sensor	Path	Row	Multispectral Band	Thermal Band	Spectral Range (micrometres)	Spatial Resolution (pixel spacing)	Source
1993	TM	188	55	1to5 and 7	6	10.45-12.45	30	
2013	ETM+	188	55	1to5 and 7	6	10.45-12.45	30	USGS
2023	OLI and TIRS	188	58	1to7 and 9	10 and 11	10.60-12.51	30	

Source: Author's Compilation 2023

Table 2: Classification Scheme Used for this Study

S/N	Class	Description
1	Grassland	Grasses, shrubs, among others.
2	Built-up	Areas under urban and rural built-up, including homestead area All infrastructure—residential, commercial, mixed-use and the strial regions, villages, settlements, road networks, pavements, and ufactured structures.
3	Bare surface	Open dry sand on the body of water, excavation sites, open spaces, bare soils.
4	Agricultural land	Fallow land, earth and sand land in-fillings, construction sites, developed land, excavation sites, open space, bare soils, and the remaining land cover types.
5	Forest	Trees, natural vegetation, mixed forests, gardens, parks and playgrounds, grassland, vegetated lands, agricultural lands, and crop fields.

Source: Author's Compilation 2023

Results

Analysis of 1993 land use/land cover classification map of Katsina-Ala Forest Plantation

The land use/ land cover map accounts for the spatial distribution and area extent of various categories of land use/land cover over the study area. Figure 2 presents the study area's classified land use/land cover map for the year. The map shows five (5) categories of land use/land covers. They include built-up areas, forest cover, grassland, agricultural land and bare surfaces. The areal extent of these classes indicates that the dominant class is forest, which covers an area of 18.36 Ha (66.02%); this is followed by grassland with 4.95 Ha (17.80%), which is spread across the northern and southern sections of the study area, built up areas covers 0.36 Ha (1.29%). Agricultural land, on the other hand, occupies an area of 2.16 ha (7.77%), built-up areas cover an area of 0.36 ha (1.29%), and bare surface with 1.98 ha representing (7.12%) of the total area as the less dominant land use and land cover class. The total land area of the location is 21.33 Ha.

Analysis of Land use/land cover Classification of 2013 Satellite Imagery for Katsina Ala Forest Plantation

The land use and cover map of Katsina-Ala Forest Plantation for 2013 (Figure 3) reveals an increase in built-up areas. The result showed that the built up area increased from 0.36 ha (1.29%) in 1993 to 1.17 ha (4.15%) in 2013. The built-up expands towards the north and other sections of the map due to the continuous encroachment of people to the forest area. This increase is attributed to an increase in population growth. It was followed by the study of agricultural land area; findings reveal that agricultural land area decreased from 2.16 ha (7.77%) in 1993 to 1.62 ha (5.75%) in 2013.

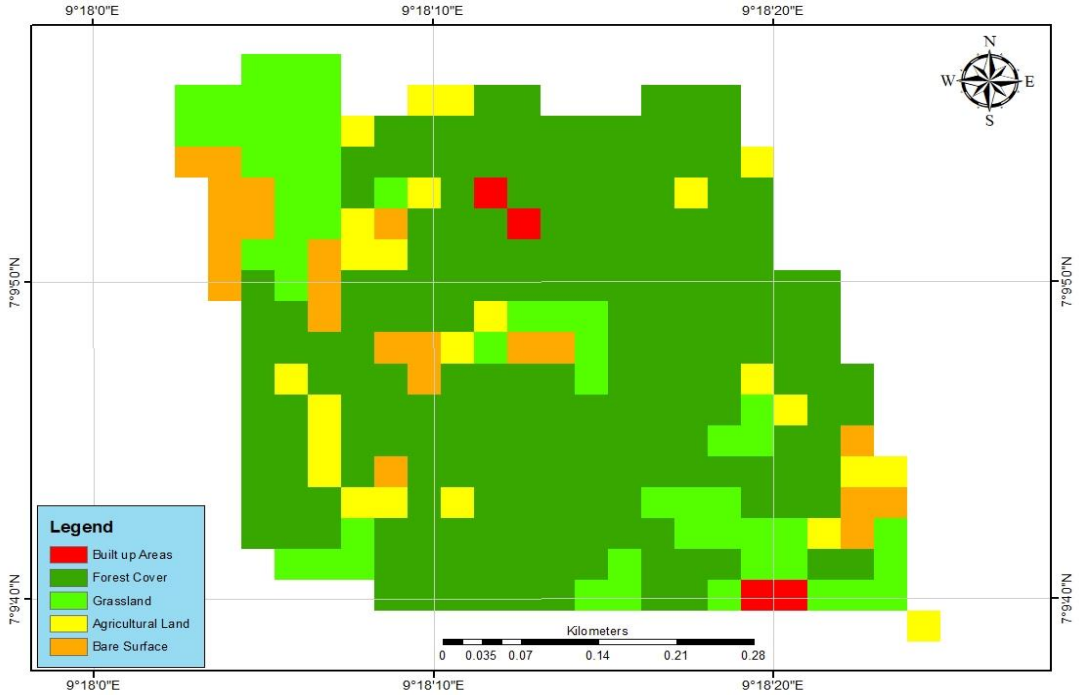

Figure 2: Katsina Ala Forest Plantation 1993 LULC map generated from Landsat 4 TM
Source: Author's Analysis, (2023)

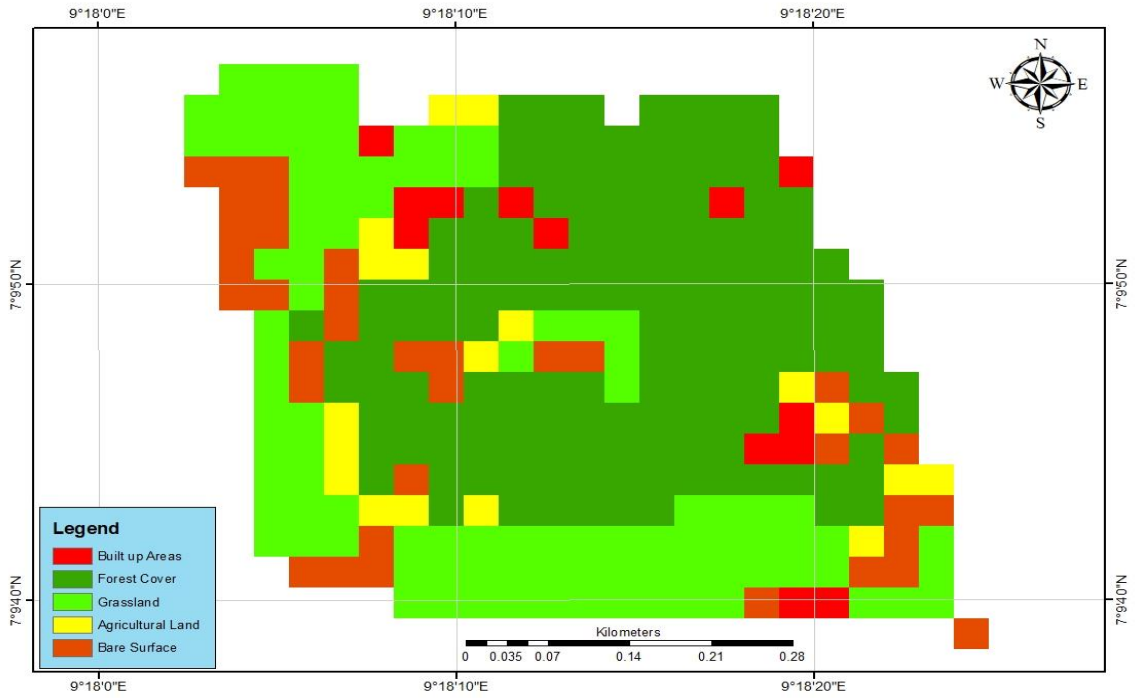

Figure 3: Katsina Ala Forest Plantation 2013 LULC map generated from Landsat 8
Source: Author's Analysis, (2023).

Analysis of Land use/land cover Classification of 2023 Satellite Imagery

Figure 4 shows the land use and land cover map of Katsina-Ala Forest Plantation for the year 2023; findings reveal that forest was still the most dominant land use and land cover type, although it continues to decrease across the study area, an indication of increased deforestation and lumbering. Findings show that forest decreased from 13.41 ha (47.60%) in 2013 to 10.17 ha (36.33%) in 2023. The result also shows that the built up area increased from 1.17 ha (4.15%) in 2013 to 2.70 ha (9.65%) in 2023 (Figure 4 The built-up expands towards the outskirt section of the study area as the area witnessed population expansion. Also, agricultural land area witnessed an increment from 1.62 ha (5.75%) in 2013 to 3.06 ha (10.93%) in 2023. Additionally, there was an increase in grassland area as findings indicate that grassland areas increased from 8.73 ha (30.99%) in 2013 to 9.09 ha (32.48%) in 2023. This increase in grassland may be attributed to the conversion of forest land cover to grassland. Similarly, the bare surface increased from 3.24 ha (11.50%) in 2013 to 2.97 ha (10.67%) 2013. Figure 4 shows the areal extent for each land use and land cover category for the study area.

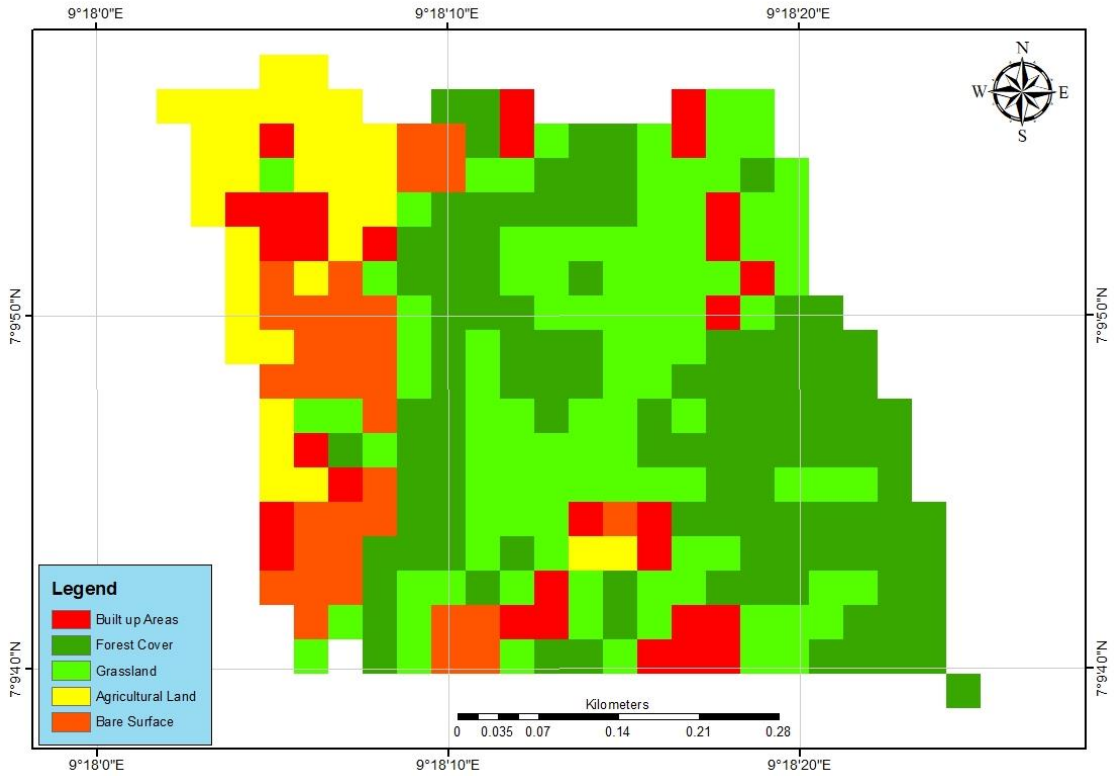

Figure 5: Katsina Ala Forest Plantation 2023 LULC map generated from Landsat 8 ETM
Source: Author's Analysis, (2023).

The trend of LULC Changes in Katsina-Ala Forest Plantation in 1993, 2013 and 2023

The result of the land use/land cover change in Katsina-Ala Forest Plantation indicates that the Grassland increased from 4.95 Ha (17.80%) in 1993 to 8.73 Ha (30.99%) in 2013. Similarly bare land increased from 1.98 Ha (7.12%) in 1993 to 3.24 Ha (11.50%) in 2013. Additionally, built-up areas increased from 0.36 (1.29 %) in 1993 to 1.17 Ha (4.15%) in 2013. On the other hand, forest area decreased from 18.36 Ha (65.02%) in 1993 to 13.41 Ha (47.60%) in 2013, which represents a 4.95 Ha decrease. Agricultural area declined slightly from 2.16 Ha (7.77%) in 1993 to 1.62 Ha (5.75%), representing a 0.56Ha decrease (Table 3). During 2013-2023 the result of the land use/land cover change in Katsina-Ala Forest Plantation revealed that the agricultural area increased from 1.62Ha (5.75%) in 2013 to 3.05 Ha (10.93%) in 2023, representing 1.44Ha increased. Built-up areas also increased from 1.17 Ha (4.15%) in 2013 to 2.70 Ha (9.65%) in 2023, grassland increased from 8.73 Ha (30.99%) in 2013 to 9.09 Ha (32.48%) in 2023. Forest area also decreased from 13.41 Ha (47.60%) in 2013 to 10.17 Ha (36.33%) in 202023, which represents a 3.24 Ha decrease. Furthermore, bare land decreased from 3.24 Ha (11.50%) in 2013 to 2.97 Ha (10.61%) in 2023 (Table 3).

Table 3: Trend of land use and land cover (LULC) changes of Katsina-Ala Forest Plantation 1993, 2013 and 2023

LULC	**1993**		**2013**		**2023**	
Land Cover Category	**Area (Ha)**	**Area covered (%)**	**Area (Ha)**	**Area covered (%)**	**Area (Ha)**	**Area covered (%)**
Built up Areas	0.36	1.29	1.17	4.15	2.70	9.65
Forest Cover	18.36	66.02	13.41	47.60	10.17	36.33
Grassland	4.95	17.80	8.73	30.99	9.09	32.48
Agric land	2.16	7.77	1.62	5.75	3.06	10.93
Bare Surface	1.98	7.12	3.24	11.50	2.97	10.61
Total	27.81	100.00	28.17	100.00	27.99	100.00

Source: Author's Analysis, 2023

The trend of forest Decline

In addition, Figure 7 shows the declining trend of forest cover across the study area. It indicates that forest declined from 66.02% in 1993 to 47.60% in 2013 and declined further to 36.33% in 2023. It shows that there is an increased level of forest resource exploitation taking place across the forest areas. Hence, there is a need for proper monitoring to stop or reduce the trend.

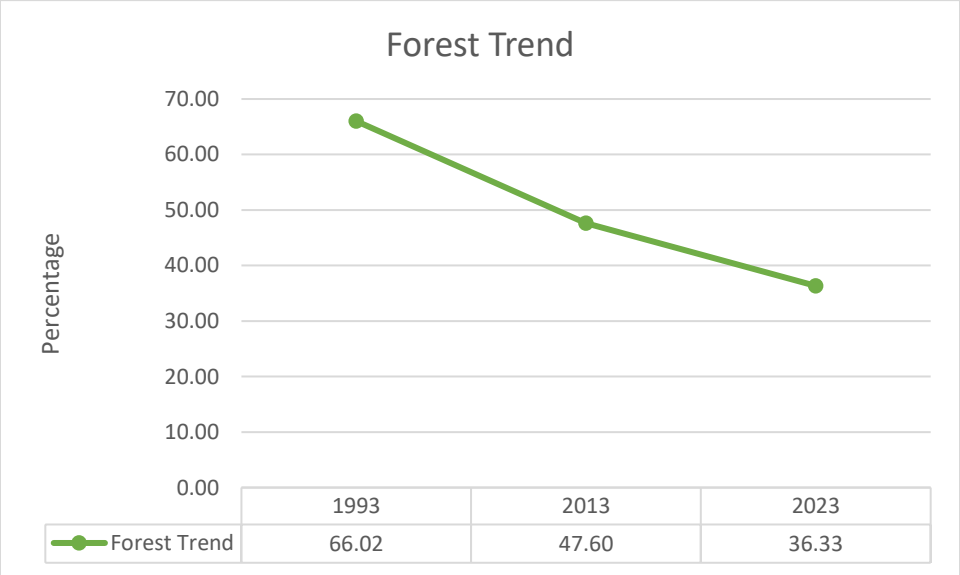

Figure 7: Trend of forest Decline

Magnitude and Percentage of Change in Land Use/Landover between 1993 and 2013

The magnitude of change of forest area for 20 years between 1993 and 2013 shows that forest decreased by -4.95 ha, representing a change (-26.96%) of total change at an annual rate of -1.35% for the period shown in Table 4. Built-up has yearly rate of change of 11.25%, while agricultural land has an annual rate of change of -1.25%. The period we have also witnessed an increase in grassland areas. The Grassland land increased by 3.78 ha, representing 76.36% of the total change, while there was an annual rate of change -3.18% in bare surface.

Table 4: Magnitude and Percentage of Change in LULC between 1993 and 2013

LULC Class	1993Extent (**Ha**)	2013Extent (**Ha**)	The magnitude of Change (**Ha**)	Percentage of Change%	Annual Rate of Change %
Built up Areas	0.36	1.17	0.81	225.00	11.25
Forest Cover	18.36	13.41	-4.95	-26.96	-1.35
Grassland	4.95	8.73	3.78	76.36	3.82
Agricultural Land	2.16	1.62	-0.54	-25.00	-1.25
Bare Surface	1.98	3.24	1.26	63.64	3.18

Magnitude and Percentage of Change in Land Use/Landover between 2013 and 2023

The magnitude of forest area changes for 10 years between 2013 to 2023 shows that forest decreased further by -3.24 ha representing a change (-24.16%) of the total change for the period as shown in Table 5. Forest cover had an annual rate of change of -2.42%, while grassland had the lowest yearly rate of change of -0.41%. The period also witnessed a further increase in built-up and bare surface. The built-up land increased by 1.53 ha representing 130% of the total change, while the bare surface decreased by -0.27 ha (-8.33%) at an annual growth rate of -0.83%. Agricultural land increased to 1.44 km^2(88.89%) at a yearly rate of 8.89% (Table 5).

Table 5: Magnitude and Percentage of Change in LULC between 2013 and 2023

LULC Class	2013Extent (**Ha**)	2023Extent (**Ha**)	The magnitude of Change (**Ha**)	Percentage of Change	Annual Rate of Change %
Built up Areas	1.17	2.7	1.53	130.77	13.08
Forest Cover	13.41	10.17	-3.24	-24.16	-2.42
Grassland	8.73	9.09	0.36	4.12	0.41
Agricultural Land	1.62	3.06	1.44	88.89	8.89
Bare Surface	3.24	2.97	-0.27	-8.33	-0.83

Source: Author's Analysis, 2023

Magnitude and Percentage of Change in Land Use/Landover between 1993 and 2023

The magnitude of forest area changes for 30 years between 1993 to 2023 showed that forest decreased further by -8.19 ha representing a change (-44.61%) of the total change for the period as shown in Table 6. Forest had an annual rate of change of -1.49% within the study years, while bare surface had an annual rate of change of 1.67%. The period witnessed an increase in the number of built-up and agricultural areas. The built-up land increased by 2.34 ha, representing 650% of the total change with an annual rate of 21.67%. Also, agricultural land increased by 0.9 ha (41.67%) at a yearly growth rate of 1.39%, as shown in Table 6

Table 6: Magnitude and Percentage of Change in LULC between 1993 and 2023

LULC Class	1993 Extent (**Ha**)	2023 Extent (**Ha**)	The magnitude of Change (**Ha**)	Percentage of Change	Annual Rate of Change %
Built up Areas	0.36	2.7	2.34	650.00	21.67
Forest Cover	18.36	10.17	-8.19	-44.61	-1.49
Grassland	4.95	9.09	4.14	83.64	2.79
Agricultural Land	2.16	3.06	0.9	41.67	1.39
Bare Surface	1.98	2.97	0.99	50.00	1.67

Discussion

The trend of LULC Changes in Katsina-Ala Forest Plantation in 1993, 2013 and 2023

The period of the first 20 years between 1993-2013 he witnessed a substantial increase in human activities in Katsina-Ala Forest Plantation. The result also shows a remarkable modification in the land cover of the forest plantation during the period of 30 years from 1993 to 2023. It was observed that percentage change in the proportion of Built-up areas, Bare land, Agricultural areas and Grassland/Herbaceous cover were increasing while forest area decreased steadily. The high increase and decrease were noticed between 2013 to 2023. Similar trends in land-use change and land cover change were reported by Jande *et al.* (2020) in Katsina-Ala town, Benue State, Nigeria, Ikyaagba *et al.* (2022) in Agan Forest Plantation in Makurdi, Gwatiyap *et al.* (2021) in Kurmin Dawaki Forest Reserve, Zangon Kataf Local Government Area, Kaduna State and Jande *et al.* (2018) in Yandev forest reserve within the same Gboko Local Government. It may be the faith of protected areas in Nigeria, as Mohammed *et al.* (2013) reveal a steady decrease in land cover in all the national parks in Nigeria. Jande *et al.* (2018) have indicated that this could be because of an increase in the local population, which puts more strain on the reserves. Because producing food requires more space, forest reserves may become productive areas suitable for cultivation if proper protection is not provided. The fallow system, which the locals use, maybe the cause of the high percentage of grassland/herbaceous cover that is observed in the area.

The magnitude of Land Use and Land Cover Change

Over the thirty years (30 Years), from 1993 to 2023, there was a noticeable shift in the amount of forest land and an increase in agricultural area and other land uses. Between 1993 and 2013, there was a significant amount of forest loss, measuring -8.19hectares, or a change of --44.61%

in the percentage of the reserve's forested areas that were removed with an annual rate of -1.49%. These figures were relatively lower that the values reported by Jande *et al.* (2018) in Yandev Forest Reserve, Ikyaagba *et al.* (2022) in Agan forest plantation in Makurdi, Ayua (2021) in Agundu Forest reserve in Gboko. It could indicate that compared to other forest estates in Benue state, Katsina-Ala Forest plantation is better. However, human activities like other reserves in the state take over the plantation, more so the magnitude of change of Grassland/Herbaceous Cover observed in the study was an indication that people were free to use the reserve at will. They were practising shifting cultivation in the forest reserve. Therefore, as the population increased, more parts of the reserve were converted to agricultural areas. This finding was in line with Ogunmola *et al.* (2014), who asserted that rapid population growth has remained the principal factor that has triggered and continued to stimulate the downward spiral of environmental resource degradation. Like Yandev Forest Reserve built-up area was the major problem in the Katsina Ala Forest plantation.

Conclusion

The study concludes that from the the first 20 years between 1993-2013, Katsina Ala Forest experienced a substantial increase in human activities. The result also shows a remarkable modification in the land cover of the forest plantation during the period of 30 years from 1993 to 2023. It was observed that percentage change in the proportion of Built-up areas, Bare land, Agricultural areas and Grassland/Herbaceous cover were on the increase while forest area decreased steadily. The high increase and decrease were noticed between 2013 to 2023. It was recommended that increased monitoring of forest reserves in the state be ensured and that key stakeholders be mobilized towards the sustainable use of the reserve. The use of a Geographic Information System (GIS) for prompt land cover change detection should be encouraged. Also, encouragement of planting of the already degraded areas of the reserve should be carried out. The Government should increase the number of monitoring personnel in the Department of Forestry to enable efficient forest reserve management.

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CLIMATE CHANGE AND ADAPTATION STRATEGIES ON THE LIVELIHOOD OF ARTISANAL FISHERMEN IN SOUTHWEST NIGERIA

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Abstract

The effect of climate change on the livelihood activities of artisanal fishermen and adaptation strategies was carried out in coastal areas of Southwest Nigeria. A multi-stage sampling procedure selected 240 respondents from Lagos, Ogun and Ondo States. Data were obtained using a structured interview schedule and subjected to descriptive and inferential statistical analysis at 0.05 significance level. Results indicated that 47.0% of the fishermen were between 40-50 years of age, 77.0% were male, 77.4% were married, and 63.0% had between 10 -18 years of fishing experience across the Coastal area of Southwest Nigeria. Major livelihood activities were fish marketing (82.5%), fish processing (77.5%) and fishing gathering (75.5%) in the selected area. The main effects of climate change on the fishermen's activities were flooding, ocean surge, rainfall intensity, and high temperature, respectively, across the selected states. The chi-square result reveals the relationship ($p < 0.05$) between the respondent sex, educational level, ethnicity, and the effect of climate change on the livelihood activities of artisanal fishermen in the study area. The correlation result also reveals the relationship ($p < 0.05$) between age, household size, years of fishing experience, and the effect of climate change on livelihood activities. The study concludes that Artisanal Fisherfolks experienced a high impact of climate change in terms of flooding, increased waves, ocean surges, etc., across the selected States sampled. The study recommended that artisanal fishermen and their organizations should be involved in policy and strategy formulation to mitigate climate change impacts on their fishing and livelihood activities.

Keywords: Artisanal, Climate change, Coastal communities, Fishermen, Livelihood activities, Southwest.

INTRODUCTION

Climate change and variability have adversely impacted the the environment, human health, food security, economic activity, resources, and physical infrastructures of the fishermen in the significant coastal area of Southwest Nigeria. Climate change is a climate change that is attributable directly or indirectly to human livelihood activities (i.e. on-farm, off-farm, and non-farm) (Cinner *et al*., 2018). It affects the atmospheric conditions of the earth, thereby leading to global warming. The Intergovernmental Panel on Climate Change (IPPC, 2007) defined climate change as statistically significant variations in climate that continue for an extended period, typically decades or longer. Climate change disturbs agriculture in several ways, one of which is its direct impact on the food production system in the country. Besides, almost all sectors in agriculture (i.e. crop, livestock, pastoralism, fishery, etc.) depend on weather and climate, whose

variability has meant that rural and urban farmers who implement their regular annual farm business plan risk total failure due to the effect of climate change occurrences (Ozor *et al.*, 2010).

The livelihood status of many coastal communities in the developing world, especially Nigeria, can be described as fragile and calls for concern from different tiers of Government. For such coastal communities, the added onslaught brought by natural disasters can prove to be an almost unbearable burden that extinguishes existing livelihood options, inadequate as they may be. As recognized in the Sustainable Small-Scale Fisheries (SSF) Guidelines, small-scale fisheries are classically partly an informal sector, which provides operators with the flexibility needed to make harvesting a food security safety valve (FAO, 2018). For it to serve such a function in the context of climate change adaptation, flexibility must not be challenged as an imperative adaptive mechanism (Cinner *et al.*, 2018).

Adaptive capacity is known to strengthen resilience, reduce vulnerability, and achieve robustness, i.e. the capacity of the system to withstand adverse conditions (IPCC, 2014). More specifically, climate resilience refers to the capacity of social, ecological, technical, or infrastructural systems to address problems while maintaining the same function, structure and overall identity; and to respond to opportunities (IPCC, 2007). The livelihood status of the fishermen encompasses not only activities that generate income but many other choices for analysis, including cultural and social options, that come together to make up the primary occupation of a household.

Climate change exacerbates non-climatic pressure on fisheries, such as over-exploitation, habitat degradation, fragmentation, and loss (Brander 2010). The synergistic effect of climatic factors – over fishing, water pollution and alien invasive species constraint inland fisheries (McIlgorm *et al.*, 2010) with consequent effect on fisheries-dependent livelihoods (Allison *et al.*, 2005, 2009; Auerbach, *et al.*, 2014). Fisheries support the livelihoods of half a billion people globally by ensuring food security, employment, and generation of foreign currency for nations (Allison 2009: FAO 2012).

Objective of the Study.

The specific objective of the study is to;

1. Describe the socioeconomic characteristics of the fishermen in the study area.
2. Determine the effect of climate change on the fishermen's activities in the study area.
3. Identify the adaptation measures/practices fishermen use towards climate change in the study area.

Hypotheses of the Study

Ho_1: There is no significant relationship between the socioeconomic characteristics of the rural farmers and the adaptation measures/practices being used by fishermen towards climate change in the study area.

Ho_2: There is no significant association between the livelihood status of the fishermen selected and the adaptation measures/practices being used by fishermen towards climate change in the study area.

METHODOLOGY

The entire southwest lies in the humid tropical zone bordered by a mangrove swamp forest in the South. Significant parts of the study area lie in the freshwater swamp forest and rain forest to the South, which turns to moist and dry woodland savannah towards the North. It has a land area of about 114,271 square kilometres East. The three (3) main agroecological zones in the region are the swamp on the Atlantic coast, tropical rainforest in the Middle and Guinea savannah in the North. This study is carried out in the coastal area of Southwest Nigeria, which covers Lagos, Ekiti, Ogun, Ondo, Osun and Oyo States. This Yoruba ethnic group is the largest ethnic group on the West African coast and one of the largest and longest established ethnic groups on the African continent. The Southwest coastal area has a marine shoreline of about 330km and rich water resources for fishing and other aquatic activities. Aquaculture forms the base of the overall development thrusts of the zone, with crop farming as the main occupation alongside livestock farming for the people in the area (Levy & Kenneth, 2024).

Population of the study: The population of the study is comprised of fishermen in the coastal area of Southwest Nigeria.

Sampling procedure and sample size: A multi-stage sampling method will be used in the selection of respondents in the study areas. The stages include: Out of the six (6) States, based on geo-political classifications, three (3) states were selected. In the first stage, purposive sampling was used in selecting the three (3) coastal states and one (1) Local Government Area, namely, Epe LGA in Lagos State, Ogun waterside LGA in Ogun State, and Ilaje LGA in Ondo State were purposively selected, and this was based on the fact that these LGAs were the prominent ones where intensive fishing activities take place and are well known (Adelekan and Fregene 2015).

Table 1: Sampling Procedure and Sample Size for artisanal fishermen

States	Fishing LGAs	Fishing villages	10% of fishing villages	Selecting villages	Registered fisher folks	10% of registered fisher folks
Lagos State	Epe	90	9	Epe, Eyin Osa, Ehin Osa, Odo Egiri, Odo Ayandolu, Ole Odo, Odo Gbawojo, Odomola, and Odo Ajogun	954	95
Ogun State	Ogun Water-side	23	2	Ilete Olosumeta, Igbeki, and Igbosere	632	63
Ondo State	Ilaje	13	1	Araromi and Enu Amo	424	42
Total					**2010**	**200**

Source: Fishermen Co-operative Society.

The second stage involved the selection of fishing communities. 10% of the fishing community was selected in Epe LGA due to the larger number of villages in the area, while 15% of the fishing communities were selected in Ogun and Ondo states, respectively, due to the small number of communities, Which gave nine (9) fishing communities from Epe, four (4) from Ogun waterside and two (2) from Ilaje LGAs. Fifteen (15) fishing communities were selected for the study.
The third stage involved (10%) of the fisher men in each of the 15 fishing communities selected for the study. Thus, a total of 200 fisher folks was chosen for the study, as shown in Table 1.

Method of Data Collection: Data were collected using a structured interview schedule that was administered to the respondents by the researcher and the trained enumerator.

Method of Data Analysis: Data were analyzed using descriptive statistics using frequency counts, mean, percentage, standard deviation and inferential statistics such as Chi-square and Pearson's product-moment correlation coefficient (PPMC).

RESULTS AND DISCUSSION

Socioeconomic characteristics of the Artisanal Fishermen in the study area.

Results in Table 2 revealed that (47.0%) of the respondents in the study area were between the age range of 40 – 50 years. It implies that the majority of them were in their economically active age bracket and therefore constitute a reasonable labour force that can cope with the rigours of fishing operations and is in agreement with Olusegun and Mathew (2016) that this age bracket is composed of the innovative, motivated and adaptable individuals in the coastal area of Southwest Nigeria. The majority (77.0%) of the respondents were males, an indication that males were more involved in the act of fishing in coastal areas than females because of the strenuous nature of the occupation, but females were majorly involved in marketing, processing and sorting were activities as their contribution to the livelihood activities in the study area.

Also, the majority (77.4%) of the respondents across the study area were married and literate, ranging from primary to tertiary education and, thus implies that they can read and write, therefore making it easy for extension agents to communicate and disseminate information about their fishing and climate activities to them without complaints. The majority (63.0%) of the respondents had 10 – 18 years of fishing experience, while 22.0% and 15.0% had between 1 – 9 years and above 18 years, respectively.

The finding also shows that the majority (71.5%) of the respondents across the three selected state indicates that they did not have access to extension agents. It shows that the majority of the artisanal fishermen sampled in the selected States did not readily have access to extension services when needed, which can negatively affect their productivity and livelihood activities. This finding agrees with the submission of Oose *et al.* (2015), who reported a lack and poor extension services to artisanal fishermen in coastal communities in Southwest Nigeria.

Livelihood Activities of Artisanal Fisherfolks

Findings in Table 3 showed that the majority (82.5%) of the respondents sampled (i.e. in Lagos, Ogun and Ondo States) engaged in fish marketing while 77.5% of them were involved in fish processing and the majority (75.5%) of them involves in fishing gathering as their livelihood activities in the coastal area in Southwest Nigeria. Also, the majority, 68.0% are involved in

coconut trading, as well as 63.0% of them engaged in oil palm processing. Over half (53.1% and 51.5%) of the respondents sampled were into poultry rearing and cassava processing in the coastal area. It implies that male fishermen engage in fish-catching activities because they can withstand the tedious and strenuous nature of canoe paddling to gather enough fish than their female counterparts. The result corroborated that of Olaoye *et al.* (2012), who observed that women are involved more in fish processing and marketing than other fishery activities in the coastal area of Southwest Nigeria.

Effect of climate change on the fishermen's activities

Table 4 below indicates that climate change has various socioeconomic impacts experienced and proficient at different levels by individuals, households and the whole communities. The mean value ($\bar{x}$) of the effect of climate change on the fishermen's activities in the coastal area in the selected states. Findings reveal that flooding was with the mean value of ($\bar{x}$ =2.43), while increased waves were ($\bar{x}$ = 2.24), ocean surge ($\bar{x}$ =2.23), rainfall intensity ($\bar{x}$ = 2.07) and high temperature ($\bar{x}$ = 2.06) respectively across the selected states.

Table 2: Distribution of respondents on socioeconomic characteristics.

Variables	Frequency	Percentages	Mean/std. Deviation
Age (years)			
30 – 40	55	27.5	
41 – 50	94	47.0	46.65/9.87
51 – 60	25	12.5	
Above 60	26	13.0	
Sex			
Male	154	77.0	
Female	46	23.0	
Marital status			
Single	46	23.0	
Married	154	77.0	
Religion			
Christianity	127	63.5	
Islamic	73	36.5	
Ethnicity			
Yoruba	153	76.5	
Ilaje	26	13.0	
Others	21	10.5	
Educational level			
No formal education	38	19.0	
Primary education	80	40.0	
Secondary education	73	36.5	
Tertiary education	9	4.5	
Household size			
1 – 4	57	28.5	
5 – 8	110	55.0	
9 – 12	33	16.5	
Years of fishing experience			
1 – 9	44	22.0	
10 – 18	126	63.0	
Above 18	30	15.0	
Contact with extension agent			
Yes	57	28.5	
No	143	71.5	

Source: Field Survey (2023)

It implies that flooding occurs with sea transgressions sometimes with heavy rainfall that could cause road tracks blizzard, house losses, public health hazards and loss of potable water owing to saltwater intrusions into wells, farmland losses and population displacement. Climate change effects on aquaculture sustainability have gained considerable interest due to the sector's significant contribution to global food security, nutrition, and livelihoods (Dabbadie *et al.*, 2018; FAO, 2020). Temperature plays a critical role in the growth and development of aquatic animals (Ngoan, 2018). Fish, being poikilothermic, may mainly be sensitive to temperature variations resulting from climate change (Sae-Lim *et al.*, 2017; Adhikari *et al.*, 2018). Therefore, prolonged temperature stress may affect aquaculture productivity in various ways centred on lowered output. The oceans store about 50 times more CO_2 than the atmosphere (Seggel *et al.*, 2016).

Furthermore, most of the available reports from experiments regarding the effects of ocean acidification on aquaculture species have been conducted in combination with rising temperature effects (Rodrigues *et al.*, 2015). Increased levels of rainfall, mainly if it occurs as heavier events, will increase the production risks in lowland areas (Bell *et al.*, 2010). These risks include losing fish from ponds during floods, invasion of ponds by unwanted species, and pond damage resulting from infilling and washing away of walls (Rutkayova *et al.*, 2017).

Table 3: Livelihood activities of Artisanal Fishermen (n = 200)

Livelihood activities*	Frequency	Percentage (%)
Fishing gathering	155	75.5
Fish marketing	165	82.5
Fish processing	161	77.5
Crop farming	87	43.5
Oil palm processing	126	63.0
Coconut trading	136	68.0
Boat making	94	47.0
Net fabricator and mending	64	32.0
Poultry rearing	106	53.0
Cassava processing	103	51.5
Petty trading	40	20.0
Fuel wood procurement	90	45.0
Fishing equipment selling	60	30.0
Artisan	74	27.0
Outboard engine repairer	34	17.0

***Multiple responses exist.**

Source: Field Survey, (2023).

Adaptation strategies are being used by fishermen to address climate change.
Artisanal fishermen have adopted different adaptive strategies in other parts of the state selected towards climate change impact. Table 5 below shows the mean and standard deviation of respondents that adopted various strategies for climate change adaptation in the selected states. Participatory community projects' implementation through relevant policies and regulations

towards sustainable livelihoods to mitigate climate change impacts was with the mean value of ($\bar{x}$= 3.01). In contrast, the restive and aggrieved communities should engage issues constructively to attract development rather than hostility and destruction of facilities ($\bar{x}$= 2.89), proper regulation and monitoring of industrial activities should be of internationally acceptable standards ($\bar{x}$= 2.86), enforcement of laws targeted at reducing anthropogenic pollution of water bodies and activities by all level of Government ($\bar{x}$= 2.79%) and strengthen government institutions in mitigating the effects of changing climate ($\bar{x}$= 2.77) in the study area. Other notable adaptative strategies were increased support to stakeholders through empowerment, provision of equipment and credit assistance ($\bar{x}$= 2.56), establishing community and stakeholders on the impacts of climate change ($\bar{x}$=2.55), and access roads network should be provided and maintained by riverine communities ($\bar{x}$=2.50) in the selected states.

Table 4: Effect of climate change on the fishermen's activities in the study area.

Effect of climate change	Mean effects	Decision effect
Flooding	2.43	High effect
Increased waves	2.24	High effect
Ocean surges	2.23	High effect
Rainfall intensity	2.07	High effect
Disease outbreak	1.98	Low effect
Wind storms	1.81	Low effect
Erosion	1.75	Low effect
Sea level rises	1.71	Low effect
Increased water salinity	1.70	Low effect
Changes in fish distribution	1.66	Low effect
High temperature	2.06	High effect
Reduction in quantity of fish cropping	1.53	Low effect

Source: Field Survey, (2023).

The important adaptations to maintain the contribution of fisheries to food security and livelihoods of coastal communities involve finding ways to minimize the gap between sustainable harvests from coastal fish habitats and the quantities of fish recommended for good nutrition of growing human populations (Bell *et al.*, 2018). There are adaptations to minimize the gap centre on avoiding and reversing the degradation of coastal fish habitats and maintaining healthy stocks of demersal fish and invertebrates. Most of these adaptations are integral to coastal zone management and sustainable fisheries management (FAO, 2015). Adaptations to fill the gap will need to focus mainly on making it easier for small-scale fishers to access the region's rich tuna resources, developing fisheries for small pelagic fish, expanding pond aquaculture, and improving supply chains to avoid waste (Johnson *et al.*, 2017).

Table 5: Adaptation strategies being used by fishermen towards climate change in the study area.

Adaptation strategies	Mean	Std/deviation
Establish community and stakeholders on the impacts of climate change	2.55	.954
Strengthen government institutions in mitigating the effects of changing climate	2.77	1.001
Enforcement of laws targeted at reducing anthropogenic pollution of water bodies and activities by all levels of Government.	2.79	1.093
Adequate training on modern fishing techniques (including Mari culture) and provision of incentives to fish farmers.	2.45	1.063
Access roads network should be provided and maintained by riverine communities	2.50	.984
Provision of rainwater collection systems should be provided, including public boreholes.	2.46	1.011
Increase support to stakeholders through empowerment, provision of equipments and credit assistance.	2.56	1.009
Strengthening of support for service providers at the community level through improved transport systems, fish farming equipment and processing centres.	2.40	1.015
Participatory community projects' implementation through relevant policies and regulations towards sustainable livelihoods to mitigate climate change impacts.	3.01	.914
Proper regulation and monitoring of industrial activities should be of internationally acceptable standards.	2.86	.923
The restive and aggrieved communities should engage issues constructively to attract development rather than hostility and destruction of facilities.	2.89	.999

Source Field Survey, (2023).

Hypotheses of the Study

Ho1: There is no significant relationship between the socioeconomic characteristics of the respondents and the effect of climate change on the livelihood activities of the Artisanal fishermen across the selected States.

Ho2: There is no Significant Difference Between the Effects of Climate Change on the Livelihood Status of Artisanal Fishermen. Across the Selected States we sampled.

The Relationship Between Selected Socioeconomic Characteristics of fishermen and Effects of Climate Change on Livelihood Activities of Artisanal fishermen in the study area.

The results of the Chi-square analysis in Table 6 below showed that there is a significant relationship ($p < 0.05$) between the respondent sex ($\chi^2 = 16.541$, df = 1), educational level ($\chi^2 = 13.621$, df = 3), ethnicity ($\chi^2 = 21.125$, df = 2) and the effect of climate change on livelihood activities of artisanal fishermen in the study area. However, the Table 6 results revealed that no significant relationship ($p > 0.05$) existed between marital status, religion, contact with extension agents and climate change's effects on artisanal fishermen's livelihood across the sampled States.

Table 6: Chi-square result on relationship between the socioeconomic characteristics of the respondents and the effect of climate change on the livelihood activities of the Artisanal Fisherfolks across the selected States.

Variables	χ^2 –value	Df	p-value	Decision
Sex	16.541	1	0.012	Sig.
Marital status	1.381	1	0.215	Not sig.
Religion	3.309	2	0.104	Not sig.
Educational level	13.621	3	0.010	Sig.
Ethnicity	21.125	2	0.002	Sig.
Contact with an extension agent	2.128	1	0.121	Not sig.

Source: Field Survey, (2023).

The correlation result in Table 7 reveals that there is a significant relationship ($p < 0.05$) between age ($r = 0.483$), household size ($r = 0.413$), years of fishing experience ($r = 0.642$) and the effect of climate change on livelihood activities of artisanal Fisherfolks in the study.

Table 7: Correlation result on the relationship between the socioeconomic characteristics of the respondents and the effect of climate change on the livelihood activities of the Artisanal Fisherfolks across the selected States.

Variables	r-value	p-value	Decision
Age	0.483	0.013	Sig.
Household size	0.413	0.001	Sig.
Years of fishing experience	0.462	0.041	Sig.

Source: Field Survey, (2023).

Results of ANOVA (Table 8) showed that there is a significant difference in the effect of climate change on the livelihood activities of artisanal fishermen ($F = 18.434$; $p = 0.001$) across the selected States in Southwest Nigeria at $p < 0.05$ level of significance. Similarly, Scheffe's post hoc test showed that the effect of climate change on the livelihood status of artisanal Fisherfolks was significantly different in Lagos State compared to that of Ogun State and Ondo State, respectively. However, Ogun and Ondo States share the same homogeneous subsections. The results revealed the tendency for Lagos State fishermen to record the highest effect of climate change, followed by Ogun State and then Ondo State. The implication is that the impact of climate change on the livelihood activities of artisanal fishermen varies slightly across the sampled States but confirms that there is evidence of significant difference.

Table 8: Test of difference between the effect of climate change on the livelihood of artisanal fishermen across the selected States in Southwest Nigeria using ANOVA.

Effect of climate change on livelihood activities	Sum of square	Df	Mean square	F-value	Sig.	Scheffe' Post Hoc Tests
Between groups	1854.023	2	536.031	14.258	0.001	Lagos 44.45[b]
Within groups	42646.136	197	45.232			Ogun 42.32[a]
						Ondo 40.65[b]
Total	44500.159	199				

Note: Sig. = Significant at p < 0.05 level of significance, df = degree of freedom; the Means for Ogun and Ondo are in homogeneous subsets.
Source: Field Survey, 2023.

CONCLUSION AND RECOMMENDATION

Consequently, from the result of this study, it could be concluded that artisanal fishermen were active and productive age, married, and the majority were educated for their fishing work using gill nets, sieve nets, surrounding nets, and cast nets for their fishing activities in the selected States. Some of the livelihood activities of the fishermen were fishing gathering, fishing marketing and processing, farming, oil palm processing, petty trading, coconut trading, etc. The fishermen experienced effects of climate change in areas of flooding, ocean surges, high temperature, and increased wave intensity rainfall, among another impact in the study area. The study also concludes Artisanal fishermen sampled experienced a high effect of climate change in terms of flooding, increased waves, ocean surges, rainfall intensity and high temperatures across the selected States sampled. Artisanal fishermen have adopted the adaptive strategies in different parts of the state chosen towards climate change impact and livelihood activities.

It is therefore recommended that to appease the impacts of climate change in coastal areas of Southwest Nigeria, extension agents knowledgeable in fisheries and climate change should be deployed to the study area by the Government as well as adequate funding as a strategy for strengthening awareness campaign/sensitization exercise on climate change. Also, incentive on fishing inputs at subsidized rate should be made available to all stakeholders in the fishing communities. There is a need for natural science and social science research collaboration on the oil-fisheries-livelihoods interface and subsequent interdisciplinary policy innovation from such research. The government should come early to the aid of fish farmers when cases of flood are reported; a thorough investigation should be carried out, after which such Artisanal fish farmers should be bailed out of the problem.

Artisanal Fishermen and their organizations should be involved in policy and strategy formulation in mitigation of climate change impacts on their fishing and livelihood activities because these are among the groups most vulnerable to the effects caused by climate change. Likewise, the climate change agenda needs to be mainstreamed to all government levels; otherwise, human, economic and physical negative impacts will be observed. More effort is required in order to enhance mindset change on causes of climate change to all stakeholders, including rural communities close to coastal areas, because they are the most vulnerable groups to the climatic change risks.

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Analysis of Heavy Metals in *Azadirachta indica* A. Juss Leaves, as Bioindicator for Monitoring Environmental Pollution in Ibadan Southwest, Nigeria

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Abstract

In Nigeria, there is little information about the status of air quality. Major cities like Lagos and Abuja have an environmental monitoring network for specific pollutants. Having a monitoring network in different cities is essential for quality air assessment, which has been proven to be a precursor for several health-related issues. Due to this reason, most countries have chosen to use plants as environmental bioindicators to assess the impact of a source of atmospheric pollution. Neem leaves can be used as bioindicators, bioaccumulators and biomonitors due to their ability to accumulate high concentrations of metals. The present study analysed heavy metals such as Mo, Ni, Pb, Sb, Se, Sn, V, and Zn in Neem Leaves (*Azadiracta indica*). The urban sampling areas selected for this study were Ibusogboro and Onipe, located in the Oluyole local government area, Oyo State, Nigeria. ICP-OES was used to determine the metals on the leaves. The study demonstrated representative average Zn> Mn> Cu> Cr concentrations in both sampling points. The values obtained for As, Pb and Cd were below the detection limit. These values indicated that the environmental contamination in the selected urban areas due to vehicular traffic has demonstrated the Neem leaves' efficacy as an environmental bioindicator.

Keywords: ***Azadirachta indica, Bioindicators*****, Environmental Pollution, Heavy Metals.**

INTRODUCTION

The primary causes of air pollution include incomplete fuel combustion, industrial emissions, inefficient fuel burning in transportation (which pollutes both fuels and vehicles), waste burning, and crowded living quarters (WHO,2018). These factors all contribute to the highly polluted air we currently breathe, which kills 7 million people annually (WHO, 2019). Pollutant levels in many cities worldwide are mostly caused by vehicular discharge, quarrying activities, and industrial discharge, surpass the WHO's recommended yearly average thresholds for air quality. According to several studies, specific metals like As, Cd, Fe, Zn, Cr, Cu, Al, V, Ni, and Pb and other particles have the most significant impact on health and the environment because they bioaccumulate in tissues and cause mutagenic processes in cells, among other disorders (Machad, *et al.*,2008).

Therefore, to control the consequences of environmental damage, Nigeria has adopted ecological principles in its Political Constitution, and the National Assembly, the FRIN ACT of 2018 executed this. For example, cities like Lagos and Abuja have an environmental monitoring network for specific pollutants. It is imperative for air quality monitoring to be strengthened in low- and middle-income countries, hence, standards are necessary to guide the effective use and

interpretation of data from sensors (WHO,2018); this is capital-intensive (Masoslo, 2015). Due to this high cost of implementation, several countries have chosen to use plants as environmental bioindicators to determine the impact of air pollution (Augustine *et al.*,2016). Because of their ability to absorb pollutants, various plant species are promising candidates for use as bioindicators, helping to identify low-cost contaminants and provide information on air quality. Bioindicators should have the following qualities: cheap, plentiful, and widely dispersed, with accumulating properties (Parmer *et al*., 2016). Neem plant (*Azadirachta indica* A. Juss) is a tropical tree species native to India that has been used historically to treat various illnesses since it was discovered between 1500 and 600 BC. Many portions of neem plants have yielded over 200 chemicals that have been identified (Kumar *et al.*,2016). The leaf has a high concentration of fatty acids, amino acids, tyrosine, alanine, glutamine, cysteine, carbohydrates, proteins, minerals, calcium, and phosphorus. Substances such as terpenoids, flavonoids, alkaloids, glycosides, ascorbic acid, and azadiractin, among others (Gupta *et al.*,2017), are examples of some of the phytochemical substances that the plant produces.

Neem trees can be utilized as bioindicators, bioaccumulators, and biomonitors because of their capacity to collect large quantities of metals and assess environmental contamination and health risks, according to a 2020 study conducted in Ecuador (Morales *et al*., 2020). According to estimates from Nigeria, the amounts of Pb, Cr, Zn, Cu, Mn, and Ni found in the leaves of neem trees exposed to vehicle emissions along the Katsina to Dutsinma to Funtua road in Katsina state show the presence of highly harmful metals like Pb and Ni (Lawal *et al.*,2011). Because of its quick growth rate and ability to capture pollutants from the atmosphere, *Azaridachta indica* is a valuable plant for biomonitoring heavy metals (Babayo *et al*., 2015). The study estimates heavy metal accumulation levels in Neem leaves exposed at different points in the Oluyole local government area, Oyo State, Nigeria.

METHODOLOGY

Description of the Study Area

The study was carried out in the city of Oluyole LGA in the Ibadan metropolis, which has a warm and humid tropical climate. The rainy season is very cold, and the dry season is warm; Oluyole is within the forest savannah eco-climatic zone with an average annual rainfall of about 1225mm and an average annual maximum and minimum temperature of 34.80^{o}C and 24.30^{o}C. The rainy season commences around the end of March and ends around the first week of November. This study determines the presence of heavy metals (Pb, As, Zn, Cd, Ni, Mn, Cr, Cu) in Neem leaves (*Azadirachta indica*) at the selected sampling points of different parts of the Oluyole area (Ibadan, Nigeria) during March 2024: as shown in Table 1, in which the concentration of heavy metals was determined using spectroscopic techniques such as ICP-OES (Induction Coupled Plasma Optical Emission Spectroscopy).

Table 1: Sampling Site Coordinates

Locations	Coordinates
Ibusogboro	7°10'10.5"N 3°52'41.3"E
Onipe	7°12'0"N 3°53'0"E

Digestion of Plant Sample for Heavy Metal Analysis

The heavy metal digestion procedure outlined by (Zaki, 2015) was adopted to analyse heavy metals in plant samples. The plant sample underwent initial washing with distilled water, and the weight of each part of the sample was recorded. Subsequently, the sample was subjected to a 48-hour oven-drying process in an aluminium bowl, and the weight of the dried sample was documented. Approximately 2 grams of the oven-dried sample were placed in a volumetric flask. To this, 10 mL of distilled water was added, followed by 25 mL of nitric acid. The mixture was allowed to stand overnight. The flask was then heated to boiling for two hours. After cooling, 10 mL of perchloric acid was introduced to the flask, and it was heated once more for an additional hour to reach boiling. A yellow coloration of the sample indicated the completion of the digestion process. In case the colour turned dark, 2 to 3 mL of nitric acid was added, and the heating process was reiterated until the sample was yellow. Finally, distilled water was added to the volumetric flask up to the 200 mL graduation mark. The flask's contents were stirred for 5 minutes, then cooled and filtered using a 0.45-micron filter paper. The resulting filtrate was utilized to determine the concentration of heavy metals in the plant samples through Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES).

RESULTS AND DISCUSSION

Taxonomical Classification of The Plant

The taxonomical description of the leaves of the *Azadirachta indica* plant used in the study is shown in Table 2

Table 2: Taxonomy of Neem Tree

Kingdom	Plantae
Order	Rutales
Sub order	Rutinae
Family	Meliacea
Subfamily	Melioideae
Tribe	Melieae
Genius	Azadirachta
Species	Indica

Concentration of heavy metals in leaves of *Azadirachta indica* tree

The results of the concentration of heavy metals (As, Cd, Cr, Cu, Mn, Ni, Pb, Zn) in the neem leaves from the two sampling points in the study sites are expressed in Table 3. The table indicates a progressive increase in the concentrations of heavy metals weekly in both sampling points, and this suggests that as vehicular movement increases daily, the amount of accumulated heavy metals on the leaves also increases. The result corroborates the work of Morales *et al*. (2020), which shows that the metal accumulation was highest in the fourth week. The table also indicates the highest concentration in the third week in both areas (Zn > Mn> Cu> Cr). It agreed

with the work of Morales *et al.*, (2020), who used Neem leaves in their study. Heavy metal concentrations in As, Pb, and Cd are below detection limits, hence indicating that these metals cannot be a possible source of contaminants in the area. The work of Augustine *et al.* (2016) agreed with the present study.

Table 3: Weekly Heavy Metals Concentration (mg/kg) Per Location

Metals	Week 1		Week 2		Week 3	
	Ibusogboro	Opere	Ibusogboro	Opere	Ibusogboro	Opere
As	BDL	BDL	BDL	BDL	BDL	BDL
Cd	BDL	BDL	BDL	BDL	BDL	BDL
Cr	1.27	2.86	3.32	4.67	5.20	6.4 0
Cu	16.40	39.49	59.65	82.97	69.22	98.17
Mn	76.46	86.87	75.82	96.22	106.11	126.22
Pb	BDL	BDL	BDL	BDL	BDL	BDL
Zn	151.08	133.56	459.04	415.03	498.33	557.43

BDL – Below Detection Limit

Patel *et al.*, (2015) in their study demonstrated that Azadirachta *spp* had the highest value of Cr, Cu, Fe, Zn and Pb concentrations due to its interaction with bioactive compounds such as Azaridactin, nimbidin and nimbolide, because these compounds are non-biodegradable and are challenging to eliminate from the environment due to metabolic activity. The results showed that Neem is a heavy metal hyperaccumulator, especially Zn because it has the highest bioaccumulation factor. A study by Augustine *et al.*, (2016) in Lafia, Nasarawa State, Nigeria, also reports high values of Zn in Neem leaves, indicating that it can be attributed to heavy traffic and corrosion of vehicle parts such as brakes, radiators, and engines. This agrees with the present work of Adetola and Adekoya (2024), which also confirmed a higher Zn concentration in Neem leaves. Neem leaves are a good hyperaccumulator for metals such as Zn, Mn, Cu, and Cr, proofing the presence of contaminants in the air around us and the effectiveness of this plant as an environmental bioindicator.

CONCLUSION

It was concluded that heavy metals were present in Neem leaves in the study areas in the following order: Zn> Mn> Cu> Cr, based on the concentration of metal detected. Also, it was revealed from this research that Pb, As and Cd were found below the detection limit, indicating that there is no possible environmental threat from these three metals. The samples collected in the Opere area showed a higher concentration of heavy metals than those from the Ibusogboro area. The results demonstrated that Neem has a metal absorption capacity due to the functional groups present in its chemical structure. They also indicate that they serve as environmental bioindicators. This research further confirms the danger of environmental/health risks associated with contaminated air in this area.

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Mitigating Climate Change Through Sustainable Wood Utilization: A Review of Challenges and Way Forward

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Abstract

The utilization of wood has been an integral part of human evolution for centuries, fulfilling essential roles in construction industries, provision of heating energy, and cultural practices. However, with escalating global environmental concerns and the urgent need to address climate change, the sustainable utilization of wood has emerged as an imperative and critical strategy in combating climate change for sustainable forest management. Thus focusing on the significance of tackling climate change through sustainable wood utilization, highlighting its potential to promote responsible forest management, conserve biodiversity, and foster economic development. By examining the ecological, financial, and social dimensions of sustainable wood utilization, this paper emphasizes its vital role in meeting present and future needs while ensuring forest ecosystems' long-term health and viability. The unchecked illegal felling operations that forests have suffered, owing to rampant demand for choice wood and because the durability of wood species has been compromised as a result of poor management objective of the forest. Processing of wood without precision equipment, as obtained in many of the sawmills and timber markets across the country, has not only added to unsustainable utilization of the lean wood but also put pressure on the ecosystem services the forest should be rendering. Many end users of wood that we have in the country do not treat the wood before making such wood to suffer the attack of deteriorating agent in service. The intensity of unchecked exploitation resulted in deforestation and unsustainable logging practices, which have led to the destruction of vast tracts of forested land, contributing to biodiversity loss and exacerbating climate change. The study reviews various aspects of sustainable wood utilization, including value-added processing, waste reduction, wood preservation, and extending service life. Through a comprehensive review, the paper elucidates the challenges and an opportunity associated with sustainable wood utilization and proposes innovative approaches to maximize benefits and minimizing environmental impact. Ultimately, it to provide valuable insights for the concerned government and stakeholders to promote the sustainable utilization of wood as a fundamental component for practical sustainability and forest estate conservation efforts.

Keywords: Carbon sequestration, service life, wood, preservation, deforestation.

INTRODUCTION

Wood has played a crucial role in human civilization for thousands of years, serving as a cornerstone material for construction, fuel, and various cultural practices (Kozak *et al.*, 2019). It has also played an essential role in the satisfaction of Man's basic need such as for transportation, energy production, provision of shelter, durable and non-durable items of several kinds (Abel, 2023). Unlike fossil fuels, wood is renewable and has the potential to serve as a carbon-neutral or even carbon-negative material when managed sustainably (FAO 2020). Trees absorb carbon

dioxide from the atmosphere as they grow, sequestering carbon in their biomass and storing it for their lifespan (Ogunwusi, 2012). By utilizing wood products in construction, furniture, and other applications, we can effectively lock away carbon and prevent it from contributing to greenhouse gas emissions. However, with the escalating global environmental crisis and the urgent need to address climate change, the sustainable utilization of wood has become an increasingly pressing issue. Forests play a crucial role in regulating the global climate, serving as carbon sinks and habitats for countless species of plants and animals (IPCC, 2019).
Furthermore, sustainable wood utilization offers a means of promoting responsible forest management practices. By adopting sustainable forestry practices, such as selective logging, reforestation, and agroforestry, we can ensure forest ecosystems' long-term health and resilience while simultaneously harnessing their carbon sequestration potential. Conserving biodiversity is another critical aspect of combating climate change through sustainable wood utilization. Forests are home to approximately 80% of the world's terrestrial biodiversity, providing habitat for diverse species (IPBES, 2019). However, deforestation and habitat degradation threaten the survival of countless plant and animal species, leading to cascading ecological consequences. By prioritizing sustainable forestry practices that minimize habitat disturbance and protect critical biodiversity hotspots, we can safeguard the intricate web of life that depends on forest ecosystems for survival.

Moreover, the sustainable utilization of wood holds significant economic potential, particularly for communities reliant on forest resources for their livelihoods. Sustainable forestry practices can generate income through timber sales, ecotourism, and the production of non-timber forest products (NTFPs), according to FAO (2020). Investing in sustainable forest management initiatives and supporting local communities in implementing these practices can create economic opportunities while preserving the ecological integrity of forest ecosystems.

Thus, the sustainable utilization of wood presents a multifaceted solution to the pressing challenge of climate change. By harnessing wood's renewable and carbon-sequestering properties, we can promote responsible forest management, conserve biodiversity, and support economic development. However, realizing the full potential of sustainable wood utilization will require concerted efforts from governments, industries, and civil society to prioritize conservation and sustainable development goals.

Causes of Climate Change

Climate change occurs in different sectors across the globe. The causes result from several developments in infrastructure, industrialization, urbanization, natural disasters and pollution. Anthropogenic activities, mainly the emission of greenhouse gases, are the dominant cause, with CO_2 making up about 75% of the emissions. The abundance of CO_2 is due to the burning of fossil fuels (Weber and Stern, 2011). Also, methane released from landfills and animal waste, gases from filling refrigerators, industrial processes, chemicals from products and fertilizers, deforestation and desertification contribute to climate change (Yew and Yew, 2020).

Global Effects of Climate Change

Over the years, several effects have been seen such as the ice melting by the heat, shifting patterns of rainfall and precipitation, and rising sea levels. Several studies have shown that a further increase in the earth’s temperature could spell disaster with a huge consequence. There could be frequent flooding, excessive drought and famine, and increased disease susceptibility.

These devastating effects will be witnessed everywhere, both on a local scale and a global scale (Nda *et al.,* 2018).

FOREST AND CLIMATE CHANGE MITIGATION

Forests as carbon sinks

It refers to one of the carbon storages in nature, and it includes all the processes, activities, and mechanisms by which plants remove CO_2 from the atmosphere. Forest carbon sinks provide a critical function in the reduction of greenhouse concentrations, most especially carbon dioxide in the atmosphere, which slows down the effectof global warming (Chen *et al.,* 2021). According to Chen *et al.* (2021), forests represent the largest terrestrial carbon sink and constitute the primary component of terrestrial ecosystems. They are commonly denoted as the "lungs of the earth" owing to their capacity to sequester carbon dioxide while emitting oxygen, and due to their substantial biomass, they serve as significant reservoirs for carbon storage.

The increase in greenhouse gases and the global warming rate can be strongly mitigated by creating and managing forests, which help absorb and sequester CO_2 from the atmosphere (Whitehead, 2011). The role forests play in the long-term regulation and reduction in atmospheric was observed by (Whitehead 2011) where there is a substantial annual variation between the Northern and southern hemispheres, and it is a result of remarkably more forested areas in the Northern hemisphere, which contributes immensely to the uptake of CO_2 in contrast to the southern hemisphere. According to McKinley *et al.* (2011), in the United States, 12 – 19 % of the fossil fuel emission is offset by the forest. Additionally, it has been suggested that, in the short term, curtailing the rate of deforestation will yield a more significant reduction in atmospheric carbon dioxide (CO_2) levels compared to afforestation or reforestation efforts.

The increase in deforestation over the years has also caused the increase in the concentration of carbon in the atmosphere, especially in South Africa, America and Southeast Asia (McKinley *et al.,* 2011). Natural disturbances such as fire and pests that destroy the forest reduce the forest's carbon accumulation potential, which amounts to about 100 million ha reduction annually (Nabuurs *et al.,* 2007).

Mechanism of Carbon Sequestration in Forests

Carbon sequestration refers to capturing and storing carbon (Sha *et al.,* 2015). Forest trees and other vegetation take in CO_2 from the atmosphere via the process referred to as photosynthesis, then the conversion of the absorbed carbon into carbohydrate compounds, which make up the tree biomass and storing it in their various parts such as the tree trunks, branches, leaves and roots, also within the Soil particularly as soil organic matter. The larger the trees, the more carbon accumulated and stored in their trunks and branches. Also, mature forest ecosystems tend to store more carbon than younger forests. Carbon storage is also a function of tree species type as some tree species retain more carbon than other trees (Chen *et al.,* 2016).

SUSTAINABLE FOREST MANAGEMENT

Sustainable forest management (SFM) helps maintain healthy forests and their carbon sequestration capacity by integrating these practices into comprehensive management strategies that address environmental, economic, and social objectives (Olawoki, 2021). By implementing selective logging, SFM minimizes the negative impacts of timber harvesting on forest

ecosystems, such as soil erosion, habitat fragmentation, and biodiversity loss. This ensures that forests remain resilient to disturbances and continue to provide critical ecosystem services, including carbon sequestration (Putz *et al.,* 2008). Reforestation efforts under SFM restore degraded landscapes and enhance carbon storage by expanding forest cover and restoring ecosystem functions. Furthermore, forest monitoring within SFM enables managers to assess the effectiveness of management actions in enhancing carbon sequestration, identify areas of concern, and adapt management strategies accordingly. By promoting sustainable practices and adaptive management, SFM helps maximize the carbon sequestration ability of forests, contributing to global efforts to mitigate climate change (Pan *et al.,* 2011).

Selective logging, reforestation, and forest monitoring are integral practices within sustainable forest management (SFM) that contribute to maintaining healthy forests and their carbon sequestration capacity. Selective logging involves the targeted harvesting mature trees while preserving the overall forest structure and biodiversity. By removing only, a limited number of trees and avoiding clear-cutting, selective logging minimizes habitat disturbance and promotes natural regeneration, ensuring the long-term health and productivity of forests (Asner *et al.,* 2009). Reforestation involves planting or natural regeneration of trees in areas that have been previously deforested or degraded. This practice helps restore forest ecosystems, enhance biodiversity, and sequester carbon dioxide from the atmosphere through photosynthesis (Chazdon *et al.,* 2009). Additionally, forest monitoring plays a crucial role in SFM by providing data on forest health, ecosystem dynamics, and carbon stocks. Through remote sensing, field surveys, and data analysis, forest monitoring allows managers to assess the effectiveness of management interventions, detect changes in forest conditions, and track carbon sequestration rates over time (Simard *et al.,* 2020).

FOREST AND WOOD INDUSTRY

Forests serve as the primary source of raw materials for wood and pulp production (Molinaro and Orzes, 2022). During harvesting, the trees are felled and then processed into different products as intended by the wood industry. One of the facilities where the felled logs are converted into lumber is the sawmill (Teischinger, 2017). In the mill, the wood logs are processed into boards and other wood products. The processing of these logs can involve different techniques such as debarking, pilling, sawing, shaving, chipping, etc. These resulting products are used for various purposes, including furniture making, packaging, and other applications. Other wood processing facilities produce wood-based materials such as veneer, particle boards, plywood, and fibreboard. These products are manufactured from slicing, peeling, chipping, and pressing to create composite materials with unique properties and characteristics. Another industry focus is production and transformation into finished items, including furniture, cabinetry, flooring, doors, windows, and decorative items. These products are created and crafted from various woodworking techniques, such as cutting, shaping, carving, sanding, and finishing (Molinaro and Orzes, 2022).

WOOD PRODUCTS AS A SUSTAINABLE MATERIAL

Wood products offer significant advantages as a sustainable material compared to alternative materials like steel and concrete, particularly regarding their life cycle carbon footprint. Life Cycle Assessments (LCAs) consistently demonstrate that wood products have lower embodied carbon emissions than steel and concrete due to the carbon sequestration inherent in wood (Glover *et al.,* 2002). During the growth phase, trees engage in photosynthesis, a process by

which they uptake carbon dioxide from the atmosphere, sequestering carbon within their biomass.

When harvested and processed into wood products, this stored carbon remains locked within the material, effectively sequestering carbon and mitigating climate change (Gustavsson *et al.*, 2010). In contrast, producing steel and concrete involves high energy consumption and significant emissions of greenhouse gases, contributing to their comparatively higher carbon footprints (Werner *et al.*, 2016).

Furthermore, wood products have the potential to store carbon over the long term when used in building construction and furniture manufacturing. Buildings constructed with wood products, such as timber frames and engineered wood systems, act as carbon sinks by storing carbon in the structural components. The stored carbon in these wood products effectively combat the emissions associated with their production and contribute to the overall carbon neutrality of the built environment (González-García *et al.*, 2019). Similarly, wood furniture and interior fittings continue sequestering carbon throughout their lifespan, further enhancing their sustainability credentials.

Emerging technologies like engineered wood products offer additional environmental benefits by efficiently using wood resources and reducing reliance on traditional materials like steel and concrete (Akhator *et al.*, 2017). Engineered wood products, such as glued-laminated timber (glulam)and cross-laminated timber (CLT), are manufactured from smaller wood components bonded together using adhesives, resulting in more robust, more versatile building materials (Ekundayo *et al.* 2021). Compared to traditional materials, engineered wood products demand a less energy and produce fewer emissions during manufacturing, leading to lower overall carbon footprints (Karacabeylia and Douglas, 2013). Additionally, engineered wood products can be prefabricated off-site, reducing construction waste and minimizing environmental impact on-site.

Efficient wood processing and waste minimization are essential aspects of sustainable wood utilization that further enhance the environmental performance of wood products. By optimizing milling and manufacturing processes, reducing energy consumption, and maximizing the utilization of wood resources, the industry can minimize waste generation and environmental impact while maximizing the carbon storage potential of wood products (Winistorfer *et al.*, 2005). Waste wood materials can be recycled or repurposed for energy generation or other applications, further extending the sustainability benefits of wood products (Owoyemi *et al.*, 2016).

SUSTAINABLE UTILIZATION OF WOOD

Wood has been utilized in a broad range of applications, from structural components in construction works to the production of paper, furniture and engineered wood products. Wood's versatile nature is seen in various forms of application. Sustainable utilization of wood entails all practices geared towards attaining the maximum values and longevity of wood products and reducing waste generated and any environmental impacts. It involves the adaptation of technologies and strategies that encourage the management and conservation of forests, ultimately leading to reduced carbon emissions.

Firstly, sustainable wood utilization focuses on responsible harvesting practices. This includes selective logging methods that minimize damage to forest ecosystems and reduce the risk of deforestation. By harvesting only mature trees at a rate that allows for natural regeneration,

sustainable forestry practices help maintain the biodiversity of forest ecosystems and preserve critical habitats for wildlife (Putz *et al.,* 2008). Furthermore, it also involves maximizing the value of wood products while minimizing waste. This can be achieved through innovative approaches such as timber recycling, where wood from demolished structures is salvaged and repurposed, reducing the demand for virgin timber and the pressure on forests.

Additionally, sustainable wood utilization encompasses the promotion of alternative materials and technologies that reduce the environmental impact of wood products. For example, developing engineered wood products allows for the construction of sustainable buildings with lower carbon footprints than traditional materials like concrete and steel (Lee *et al.,* 2014).

DIFFERENT WAYS BY WHICH SUSTAINABILITY CAN BE ENSURED IN WOOD PROCESSING INDUSTRIES ARE;

(1). The Use of Wood Preservatives

Preservatives are important in enhancing the durability and longevity of wood products, particularly those exposed to harsh environmental conditions or susceptible to decay and deterioration. Pressure treatment, one of the most common methods of preservation, involves impregnating wood with preservative chemicals under pressure to penetrate deep into the wood fibres, protecting it from fungal decay, insect damage, and weathering. Using spent automobile engine oil, Solignum and Timbguard^{TM} has been reported to be effective in treating wood in Nigeria. The use of preservatives extends the service life of wood products, allowing them to withstand outdoor exposure and reduce the need for frequent replacement, thereby conserving natural resources and reducing the environmental footprint associated with wood production (Lebow, 2010; Owoyemi *et al.,* 2020 and Humar, 2017). Tondi *et al.* (2012) studied the mechanical and fire properties of Tannin-boron wood building preservatives. Adejoba and Areo (2006) and Singh and Page (2016) reported that CCA (Copper, chrome and arsenate) will increase the durability of the treated wood exposed to ground contact. Also, Mohamad-Nasir *et al.* (2019) concluded that the wood species treated with DOT (Disodium octaborate tetrahydrate) has a higher durability against termite and white-rot fungi.

(2) Use of Wood Composite

Wood composites offer a promising solution for sustainable wood utilization within the wood industry. These materials combine wood fibres or particles with binders and additives to create products with enhanced performance characteristics. One major importance of wood composites is their ability to efficiently utilize lower-grade or recycled wood materials that might otherwise go to waste (Bergman and Bowe, 2010). By incorporating these materials into composite products, the industry can reduce the demand for virgin timber and alleviate pressure on natural forests. Moreover, wood composites typically have lower environmental footprints than solid wood products. The manufacturing process can be more efficient in terms of energy and water usage and waste generation. Additionally, using wood composites instead of non-renewable materials like plastics or metals can help mitigate carbon emissions and promote a more circular economy, aligning with sustainability goals.

Furthermore, wood composites can be engineered to exhibit specific properties such as enhanced strength, durability, and resistance to moisture, pests, and decay. This versatility allows for creating long-lasting products suitable for various applications, including

construction, furniture, and automotive components. The ability to customize wood composites to meet specific performance requirements and aesthetic preferences further enhances their appeal and utility.

In addition to their performance benefits, wood composites also offer opportunities for end-of-life considerations. Many wood composites are recyclable or biodegradable, providing options for environmentally responsible disposal. Proper waste management practices, such as recycling programs or composting initiatives, can further extend the sustainability benefits of wood composites, ensuring that they contribute positively to the overall environmental impact.

Challenges and Solutions

Addressing the challenges and considerations associated with sustainable forest management (SFM) and wood products utilization involves navigating a complex landscape of environmental, economic, and social factors. One significant challenge is balancing competing land uses and interests within forested areas. Forests provide many ecosystem services, including biodiversity conservation, water regulation, and carbon sequestration, but they are also subject to pressures such as urbanization, agricultural expansion, and infrastructure development (Mitchell *et al.,* 2013). Sustainable forest management requires careful planning and coordination among stakeholders to ensure that forests are managed to meet the needs of both people and the environment. Another challenge is the threat of deforestation and forest degradation, especially in the tropics, where forests are being cleared for agriculture, logging, and other land use conversion. Deforestation causes biodiversity and ecosystem services loss and releases carbon dioxide into the atmosphere, contributing to climate change (Lambin and Meyfroidt, 2011). Sustainable forest management efforts must address deforestation drivers such as agricultural expansion, infrastructure development, and illegal logging through effective policies, law enforcement, and community engagement.

Furthermore, ensuring the sustainability of wood products involves considerations related to forest certification, legality, and supply chain transparency. Forest certification schemes like the Forest Stewardship Council (FSC) assure that wood products come from responsibly managed forests. Still, challenges remain in ensuring widespread adoption and implementation of certification standards (Cashore *et al.,* 2006). Additionally, addressing issues of illegal logging, timber trafficking, and supply chain integrity requires concerted efforts by governments, industry stakeholders, and civil society organizations to enforce regulations and promote transparency throughout the supply chain. Moreover, sustainable forest management must consider the socio-economic dimensions of forest-dependent communities and indigenous peoples who rely on forests for their livelihoods and cultural identity. Balancing conservation objectives with the needs and rights of local communities requires participatory approaches to decision-making, equitable benefit-sharing mechanisms, and recognition of traditional knowledge and customary land tenure systems (Reed *et al.,* 2018).

CONCLUSION

The sustainable utilization of wood is paramount for addressing global challenges such as climate change, loss of flora and fauna, and poverty among rural dwellers. Exploring the aspects of sustainable wood utilization, from responsible forest management practices to innovative product development and waste reduction strategies. By adopting sustainability principles, such as selective logging and reforestation, stakeholders' stakeholders' involvement can ensure the

long-term health and productivity of forest ecosystems while supporting economic development and social well-being. Also, forest certification can help to monitor and track the harvest and production of wood. Judicious utilization of wood, preservatives, and wood seasoning will go a long way to increase the life cycle of the wood, thereby reducing demand from the forest. Furthermore, the carbon sequestration potential of wood products and emerging technologies offer promising opportunities to mitigate climate change and promote a circular economy. However, challenges remain, including the need for greater stakeholder collaboration, policy support, and investment in sustainable forestry practices. Moving forward, industry stakeholders and civil society actors must continue prioritising the sustainable utilization of wood as a fulcrum of sustainable development and environmental conservation.

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Evaluation of Height-Diameter Models for Tree Species of Moraceae in University of Ibadan, Ibadan, Oyo State Nigeria

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ABSTRACT

Early studies on height-diameter relationships in tree species have provided valuable insights into the general patterns observed in the Moraceae. To assess the stock of tree species of Moraceae in the University of Ibadan, Oyo state, it is essential to utilize dependable height-diameter models. The aim of this study, therefore, was to evaluate selected models for the prediction of heights of trees of Moraceae for conservation of the species. Data on the height and diameter of 79 trees belonging to Moraceae were subjected to four selected models to predict stem height: Naslund, Meyer, Wykoff and Power models. The suitability of these models was evaluated, and the best selected based on the least Root Mean Square Error (RMSE), Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC) and highest R^2. Data were analyzed using descriptive statistics and regression at $\alpha_{0.05}$. Model fitting and validation were evaluated using a ratio of 75:25. The best-selected model for the height-diameter relationship was the nonlinear model: $TH = 1.3 + 2.48 * dbh^{0.51}$ (AIC = 412.9164, BIC = 419.149, RMSE = 7.6103, R^2 = 0.4666). The stem height can be estimated using the selected model.

Keywords: H-D relationship, growth models, *Moraceae*, University of Ibadan

Introduction

To analyze, simulate, and manage forests, measurements of tree heights and diameters are crucial (Ige *et al*., 2013). According to Feldpausch *et al*. (2011), the link between height and diameter is also influenced by species, climate, soil conditions, region, and the variety of tree species. According to Peng *et al*. (2001) and Ige et al. (2013), tree heights estimate timber volume, site index, and other significant factors about forest growth and yield, succession, and carbon budget models. As a result, it is preferable in inventory studies to traditionally measure the diameter at breast height (dbh) of all the trees in the stand, and height is measured on a sub-sample of trees. This is because measuring tree height is difficult, time-consuming, and expensive, especially in dense stands (Moore *et al.,* 1996; Hasenauer and Monserud, 1997; Uzoh and Oliver, 2006; Uzoh, 2017). A tree stand can be used to measure a variety of diameters, including the diameter at the base (Db), the diameter at breast height (dbh), the diameter at the middle (Dm), and the diameter at the top (Dt). Because trees show their growth at this point and can be measured at a lower cost than total tree height, it might be argued that diameter at breast height (dbh) measurements are more correctly acquired and more commonly utilized. Typically, it is measured at 1.3 meters above sea level. To estimate the heights of the remaining trees in the stand and lower the expenses associated with forest inventory, effective correlations between tree height and diameter are used (Paulo *et al*., 2011). Because individual tree diameter or stand level growth is estimated based on site productivity and stand

characteristics, finding accurate and simple to-use height-diameter relations is crucial for inventory design, monitoring, and forest growth simulators (Palah *et al*., 2003; Adame *et al*., 2008; Ahmadi *et al*., 2013). According to earlier research (Huang *et al*., 1992; Shamaki *et al*., 2016), various height-diameter equations have been created utilizing DBH solely as the predictor variable for determining total height. Although the height-diameter relationship isn't constant between stands or over time (Curtis, 1967; Ferraz Filho *et al*., 2018), this issue is frequently handled by developing models with extra variables to account for the dynamics of the stand. However, the relationship between a tree's diameter and its height varies among specific forest structures (Calama and Montero, 2004). It is influenced by the stand's parameters as well as the growth environment (Sharma and Zhang, 2004). Due to stronger inter-individual competition, trees growing in high-density stands will have smaller diameters than those growing in low-density stands for a given height (Lopez *et al.*, 2003; Calama and Montero, 2004; Ige *et al*., 2013).

Several researchers have developed allometric models to predict height based on diameter measurements of tree species in Moraceae. In a study by Silva *et al*. (2010) conducted in the Brazilian Amazon, they developed height-diameter equations for Moraceae tree species. The models showed significant variation among species, indicating the need for species-specific equations rather than a universal model. This highlights the importance of considering species-level variations when studying Moraceae's height-diameter relationships.

Materials and Methods

Study site

This study was carried out on all tree species belonging to Moraceae at the University of Ibadan, Nigeria (Fig 1). These trees are located around the school's administrative blocks and residential and conservation areas. University of Ibadan's campus is situated on latitude 7˚26' 85.0" N and 7˚27'08.7" N; longitude 07˚26' 85.0" E and 03˚53' 55.2" E, with elevation ranging from 205m to 227m above sea level.

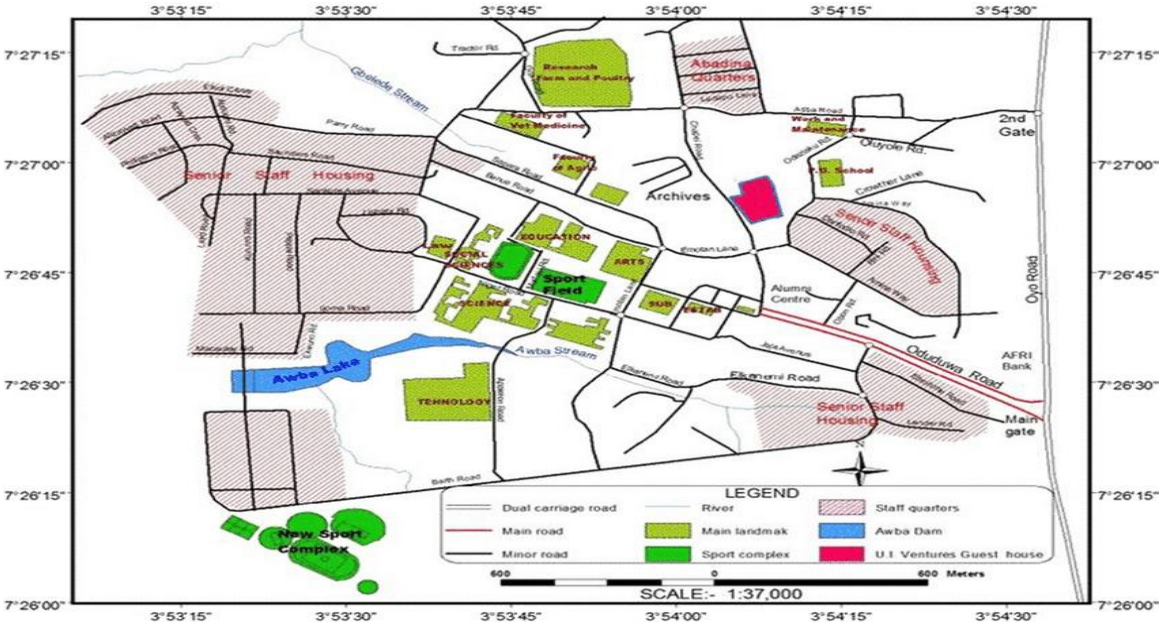

Fig 1: Map of University of Ibadan, Ibadan, Oyo state Nigeria

Data collection and analysis

Data was collected on all tree species belonging to Moraceae using the walking survey method. The tree species around the administrative, residential, and conservation (botanical garden and zoological garden) areas were identified and enumerated at the species level. The data collected were individual tree measurements for diameter (overbark) at base (Db), breast height (dbh), middle (Dm) and top (Dt) positions along the stem, and tree total height. The tree's total height, Dm and Dt, were measured using the relascope, while Db and dbh were measured using diameter tape.

Tree Height – Diameter Model

Four relationship models were selected to predict the height of all the Moraceae family tree species in the study area. The chosen models are of the form presented in Table 1

Table 1: Selected height-diameter models

Name	Model	References
1. Naslund	$h = 1.3 + \frac{D^2}{(b_0 + b_1 D)^2}$	Pukkala *et al*., (1990), Mehtätalo *et al*., (2017)
2. Meyer	$h = bh + b_0\,(1-exp\,(-b_1 Di))+\epsilon i$	Huang *et al.* (1992)
3. Wykoff	$h = 1.3 + exp\left(b_0 + b_1/(D+1)\right)$	Mehtätalo *et al*. (2015)
4. Power	$h = 1.3 + b_0 D^{b_1}$	Eerikäinen (2003); Mensah *et al*., 2018

Where h is the total tree height in m, D is the diameter at breast height in cm, and the fixed model parameters areb_0, b_1 and b_2 and ϵi = error term.

Model Assessment Criteria

The evaluation of the candidate models was based on graphical and numerical analysis of the residuals. To decide on the best-fit models, the smaller the Alkaike Information Criteria (AIC), Bayesian information criterion (BIC) and Root mean square error (RMSE) and the higher the Coefficient of determination (R^2), the better the model.

1. Root Mean Square Error (RMSE): this is the sum square of the vertical distances between the data point and its corresponding data point on the regression line. The RMSE must be relatively small for the model to be considered valid.

   RMSE = $\sqrt{\frac{\Sigma(\boldsymbol{Y_i - Y'})^2}{\boldsymbol{N}}}$
2. Bayesian Information Criterion (BIC): for a valid model, its BIC must be relatively low.

   BIC = n ln ($\frac{\boldsymbol{rss}}{\boldsymbol{n}}$) + p lnn
3. Alkaike Information Criteria (AIC): for a model to be considered based on AIC, it must be relatively low.

   AIC = n ln ($\frac{\boldsymbol{rss}}{\boldsymbol{n}}$) + 2p

Where Yi is the actual value, and Yi is the theoretical value predicted by the model, rss is the residual sum square, n is the sample size, p is the number of parameters, and = average tree height.

The model's evaluation was further verified using a graphical analysis of the residual to determine whether the assumption of normalcy was upheld.

Methods of Data Validation

The model generated was validated using different independent data sets; this is the 25% data set remaining from the total data, where 75% of data was used in fitting the model. The validation data sets were used to validate the models using Student's T-test where their means would be compared at 5% probability level to check if the sample mean genuinely represents the population mean.

Results

Model function across the areas.

Table 2 revealed the results of the four selected allometric models. It was observed that in the conservation areas, Model 2 performed better than the others with the least goodness of fit indices; AIC, BIC, and RMSE of 219.55, 223.65, and 9.61, respectively and the coefficient of determination of 0.22, while the second-best model was model 1 with the coefficient of determination of 0.34. Furthermore, in the administrative/residential areas, Model 2 had the lowest AIC, BIC and RMSE of 179.77, 183.98, and 4.38, respectively with the highest R^2 of 0.63. The second-best model was Model 1, which had lower AIC, BIC, and RMSE of 219.70, 223.81, and 9.64, respectively and a coefficient of determination of 0.57. Also, in the administrative/residential areas, the second-best model was model 4 with AIC, BIC, and RMSE of 182.37, 186.57 and 9.64, respectively. The pooled data also revealed the superior model for the study strata. Model 4, with the lowest AIC, BIC, RMSE, and the highest R^2 of 412.92,

419.15, 7.61 and 0.47, respectively. It was then followed by Model 1 with the AIC, BIC, and RMSE of 420.99, 427.22 and 8.15, respectively.

Table 2: Model function for Moraceae tree species in the University of Ibadan

Areas	Models	Parameters		Fit indices			
		b0	b1	AIC	BIC	RMSE	R^2
Conservation							
Areas	1	3.19	0.16	219.70	223.81	9.64	0.33
	2	29.15	0.02	219.54	223.65	9.61	0.22
	3	2.62	-26.38	219.93	224.03	9.67	0.28
	4	4.88	0.37	223.54	227.64	10.30	0.15
Admin/residential							
Areas	1	3.20	0.17	188.13	192.33	5.04	0.57
	2	27.96	0.02	179.77	183.98	4.38	0.63
	3	2.39	-22.62	192.63	196.83	5.43	0.48
	4	2.79	0.45	182.37	186.57	4.57	0.59

Table 3: Model function for pooled data

Model	Parameters		Fit indices			
	b_0	b_1	AIC	BIC	RMSE	R^2
1	2.60	0.17	420.99	427.22	8.15	0.37
2	30.81	0.02	422.25	428.48	8.24	0.42
3	2.56	-27.51	426.27	432.50	8.52	0.35
4	2.48	0.51	412.92	419.15	7.61	0.47

Model Validation

The validated models performed well and showed no significant differences in the observed and predicted values for Models 1 & 2 (Tables 4 and 5). In the data collected from trees in the administrative/residential areas and for the pooled data, models 4 and 1 performed better than others. The fitted models and their goodness of fit indices results showed that the selected models are best suited for predicting the height-diameter relationship for the strata.

Residual analysis for best models

The residual analysis for the best models for the administrative/residential areas was shown in Figures 2 and 3 (Model 2 and 1), for the conservation areas. The figure showed in a graphical representation if the assumption of independence of variables was assumed. The scatter diagram showed that the residual errors were normally distributed and showed no pattern. Additionally, the figures (Figures 4 and 5) also showed the scattered diagram of the best model (Models 2 and 4) for the administrative/residential areas and for the pooled data (Models 4 and 1). The residual errors of the independent variables of the pooled data are represented in Figures 6 and 7. In all the graphical representations, the assumption of independence was assumed, and the models' errors were usually distributed. Thus, it could be observed that all these relationships appear to be positive and, therefore indicate that the increase in the value of one variable will lead to a rise in the other variable. Furthermore, the scattered diagram shows that the variables have a linear relationship.

Table 4: Model validation for across the areas

Model No	The mean of the observed value	The mean of predicted value	T-value	P-value
Model fitted for conservation areas				
2	25.10	23.84	0.28	0.78
1	23.00	24.78	-0.39	0.70
Models fitted for administrative areas				
2	20.92	17.39	0.98	0.34
4	19.70	20.03	-0.09	0.93

Table 5: Model validation for the pooled data

Model No	The mean of the observed value	The mean of predicted value	T-value	P-value
4	24.75	24.66	0.03	0.97
1	21.52	22.93	-0.52	0.61

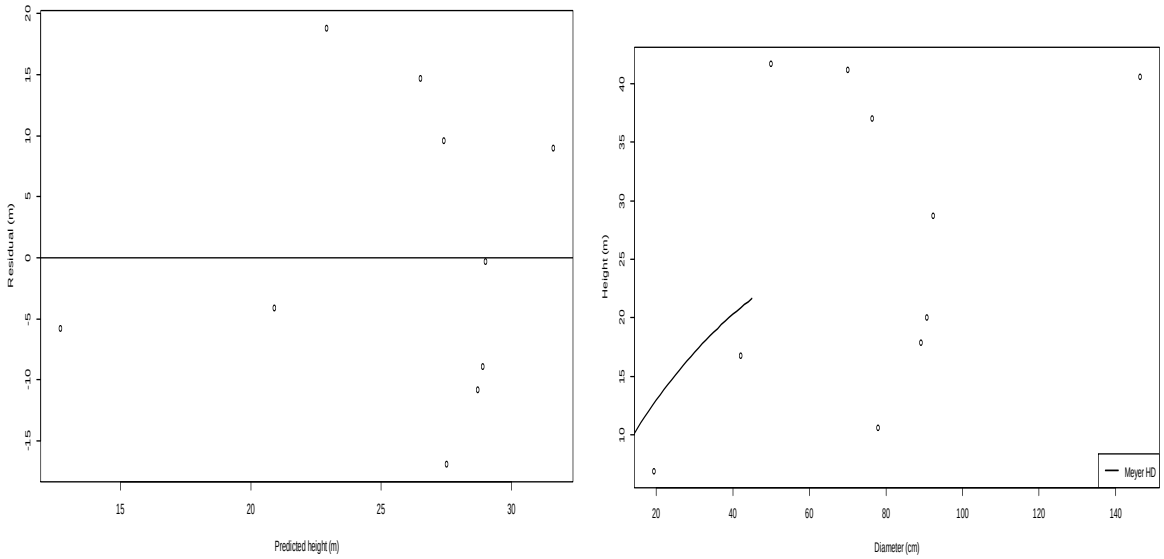

Fig 2: Model 2 for conservation areas

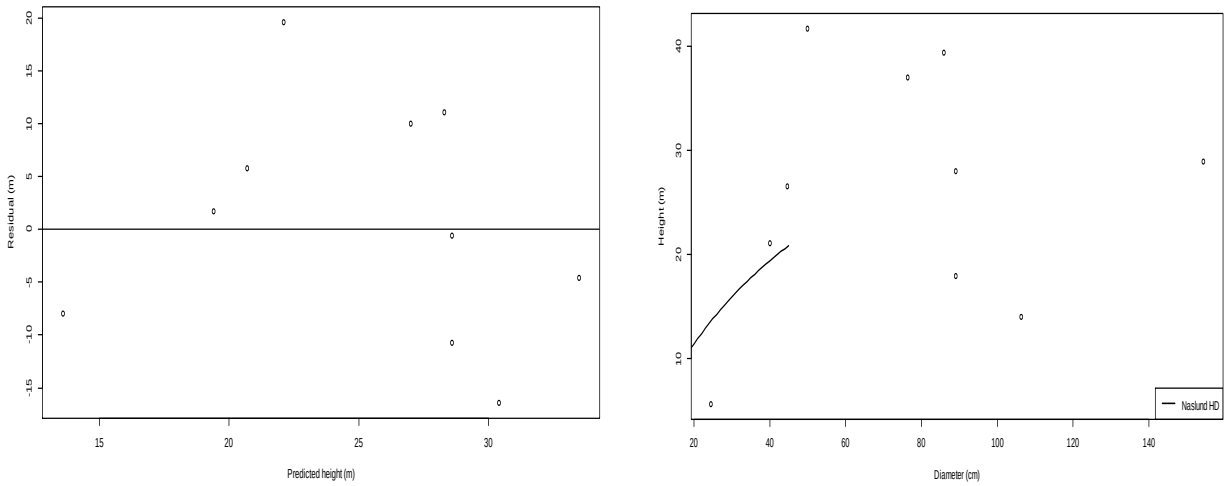

Fig 3: Model 1 for conservation area

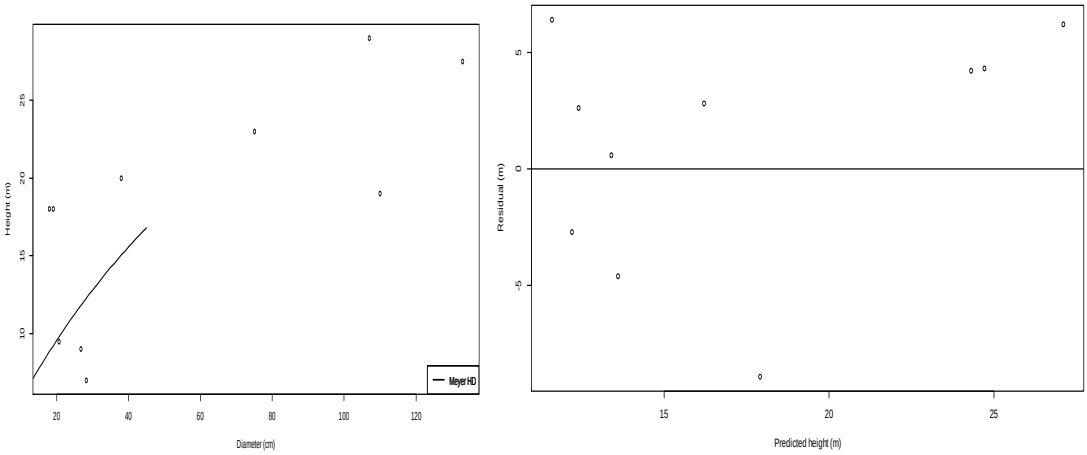

Fig 4: Model 2 for administrative/residential areas

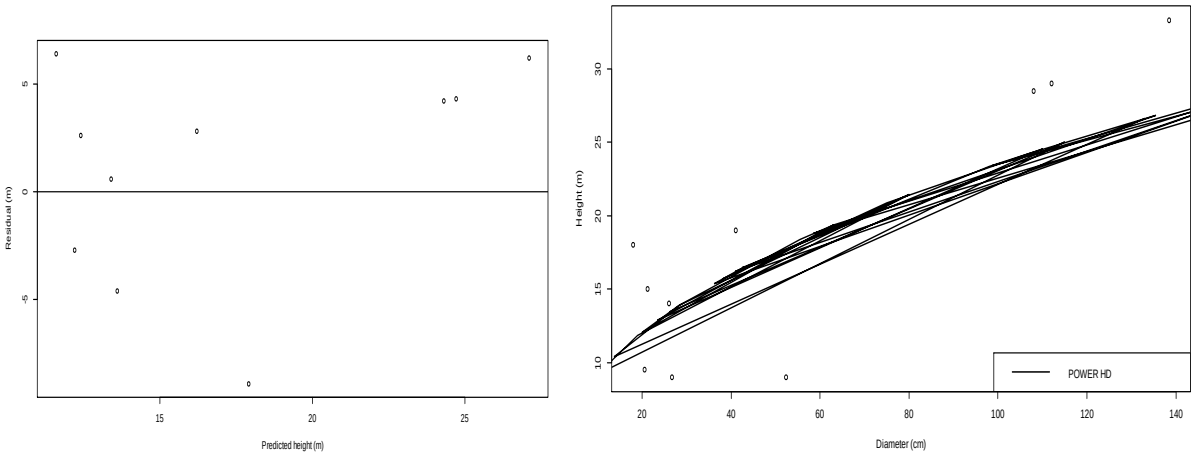

Fig 5: Model 4 for administrative/residential areas

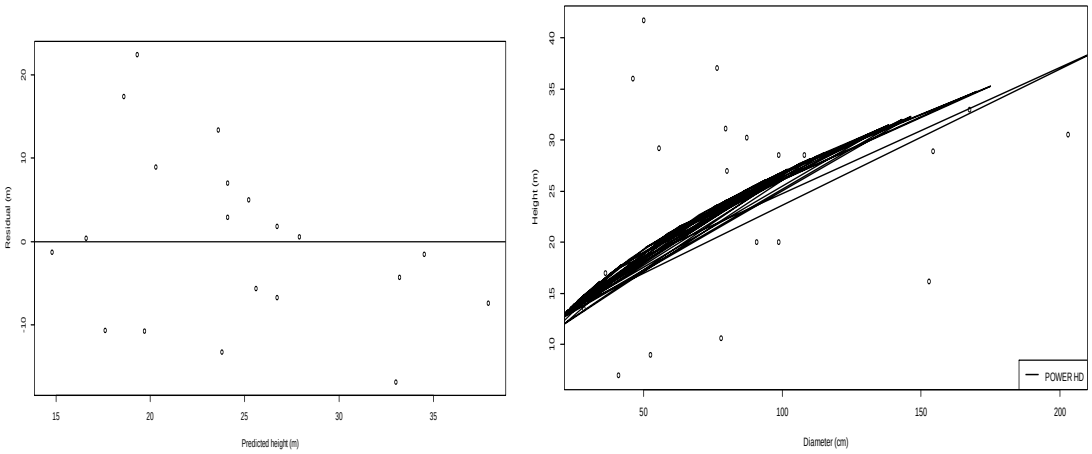

Fig 6: Model 4 for pooled data

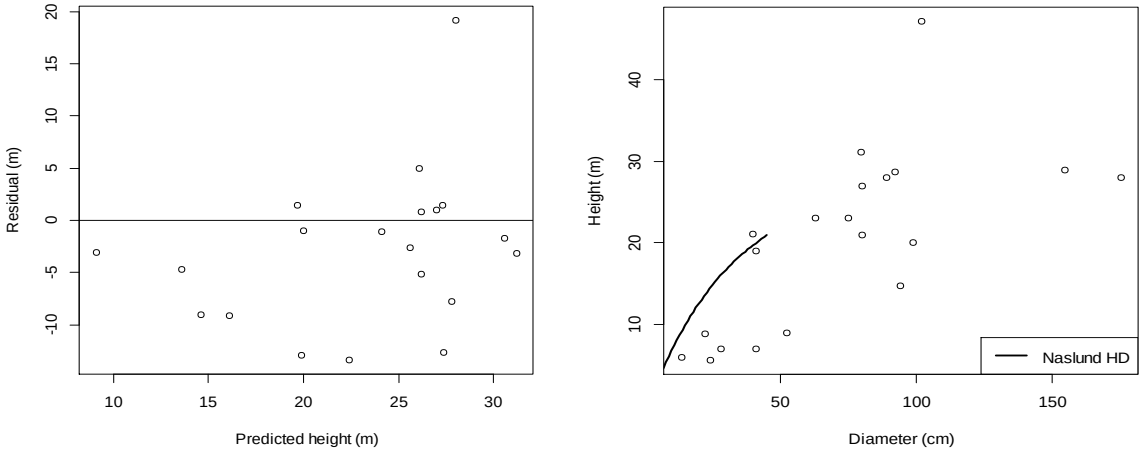

Fig 7: Model 1 for pooled data

Discussion

The best model (Pooled); $TH = 1.3 + 2.48 * dbh^{0.51}$ with the least AIC, BIC, RMSE and the highest coefficient of determination showed superior suitability in estimating height from the diameter at breast height in the study area. This is suitable for stem height estimation of the family species in the study area, and it confirms that the DBH is a good variable in the prediction of stem height, and stem height can easily be estimated using DBH. This DBH result agrees with the reports of Moore *et al.* (1996), that the tree height, though difficult, time-consuming, and expensive to measure, especially in dense stands, the diameter at breast height of the sampled trees within the stand can be used to estimate the height of the stand. This means that when the traditional inventory approaches are difficult to implement, that is, if all the height measurements of the stand are difficult to measure, the DBH of all the trees in the stand and the height measured from a sub-sample of trees can be used to estimate the height of the trees in the stand (Hasenauer and Monserud, 1997; Uzoh and Oliver, 2006; Uzoh, 2017).

Furthermore, validation and accuracy, as well as consistency tests of models carried out using the student T-test, show no significant difference between the predicted and observed value for all the models having a p-value greater than 0.05. This connotes that the developed models are suitable for stem height prediction of the tree species in the Moraceae family in the study area. The scattered diagram also shows that the variables have a linear relationship. Hence, this is true for the tree stem height.

Conclusion and Recommendation

The utilization of height-diameter models in forest management is crucial for understanding and predicting the growth characteristics of tree species. This study specifically highlights the significance of such models in predicting the growth characteristics of tree species belonging to the Moraceae family, using DBH as a critical predictor. The finding of this study demonstrates that DBH can serve as a reliable indicator for estimating the height and growth patterns of Moraceae tree species in the University of Ibadan. This information will aid the proper and effective management of the tree species, allowing for better long-term planning and sustainable management practices. Furthermore, a nonlinear tree height-diameter model $TH = 1.3 + 2.48 * dbh^{0.51}$ was observed as the best model and was used to calibrate the tree height-diameter model for pooled data, and it can be used to predict stem height for Moraceae family tree species in the University of Ibadan. The model should be useful in all incidents or cases of pre and post-harvest operations of Moraceae family tree species in the University of Ibadan, Nigeria

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Envisioning Environmental Justice to Improve the Distribution of Urban Tree in Nigeria

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ABSTRACT

Urban trees are increasingly seen as essential infrastructure due to growing worries about the effects of climate change, and they are frequently included in initiatives aimed at promoting urban sustainability and mitigating or adapting to these issues. Therefore, while the advantages of urban trees have received a lot of attention, the distribution of urban trees and how the unequal distribution of the urban tree canopy may be related to socioeconomic processes like social stratification—as shown by associations with age, income, ethnicity, and education—have received less attention. Certain metropolitan areas in Nigeria have an unequal, unfair, or inequitable distribution of green spaces. Several hazardous land uses have adversely impacted numerous metropolitan regions. According to research, different cities have different socioeconomic factors linked to canopy cover. As a result, many of these cities bear an unfair share of the consequences that pollution has on human health and the environment, as well as the adverse effects that pollution has on commercial, industrial, and municipal operations, as well as the implementation of federal, state, local, and tribal programs, and policies. According to environmental justice theory, access to environmental and community facilities and resources is crucial for improving one's quality of life. In this regard, urban trees are vital community resources (such as parks, gardens, and urban greenways) that must be considered in the larger context of urbanization. To minimize risks, it is also essential to guarantee that urban people have access to these resources. This study, therefore, summarizes environmental justice principles to inform urban forestry practices and gives recommendations to enhance Nigerian cities' environmental conditions.

Keywords: environmental justice, urban trees, canopy distribution, ecosystem services

INTRODUCTION

Nigeria's climate is changing, as demonstrated by rising temperatures, fluctuating rainfall, rising sea levels and flooding, drought and desertification, land degradation, and increased frequency of extreme weather events (Elisha *et al.*, 2017). The World Bank (2018) reported that climate change is accelerating faster than scientists predicted, prompting the World Meteorological Organization to warn that a lack of aggressive mitigation measures will most likely result in a catastrophic temperature increase of 3-5 degrees Celsius (5.4-9.0 degrees Fahrenheit) above preindustrial levels by 2100. Foster *et al.* (2022) stated that developing countries such as Nigeria will be disproportionately affected, with people with low incomes,

women and girls, youth and children, indigenous peoples, and climate migrants bearing the brunt of the impact of climate change due to limited resources and low adaptation capacity.

In addition, the urban tree cover has changed significantly over time, and the canopy loss is not happening somewhat. Environmental justice is vital within cities because of unique metropolitan characteristics such as socioeconomic and ethnic diversity and high density (UN Habitat, 2010). Stratification, a long-standing social process based on factors including class, caste, gender, profession, race, ethnicity, age, and aptitude, usually coexists with diversity. Urban inhabitants are categorized socially, which affects people's and communities' capacity to tolerate climate pressures and reduce or adapt to climate dangers (Marino and Ribot, 2012). Differences between strata might lead to discrimination and unequal treatment of individuals based on group membership, generating equity concerns (Dovidio *et al.,* 2010). Poorer people and ethnic minorities, for example, tend to dwell in more susceptible areas and congested regions of cities, making them more exposed to the effects of climate change and reducing their adaptive capacity to bear risks.

Stratification, a long-standing social process based on characteristics including class, caste, gender, profession, race, ethnicity, age, and aptitude, usually coexists with diversity. Urban inhabitants are categorized socially, which affects people's and communities' capacity to tolerate climate pressures and reduce or adapt to climate dangers (Marino and Ribot, 2012). Fasoro and Ajewole (2022) also confirmed that trees are an essential part of Nigeria's infrastructure and significantly impact the character and quality of life in our rising city. Trees are an essential environmental asset that offers numerous benefits to urban people. They are a precious asset that delivers ecological, economic, and social advantages, including public health support, wildlife habitat, carbon sequestration and pollutant absorption, stormwater management, and recreational spaces. These diverse advantages contribute to the city's health, equity, and climate resilience goals.

Nigeria's urban tree canopy includes trees in public spaces such as parks, natural areas, and right-of-way, private lands such as neighbourhoods and residential zones, and educational institutions such as universities and the Arboretum. Strategically planted trees in cities can minimize energy expenses. Trees planted to block sunlight during the hottest sections of the day can lower cooling costs, while those planted as windbreaks help prevent storm damage, erosion, and flooding. Furthermore, the presence of trees may have sociopsychological effects on urban people. Trees can help to alleviate the impact of environmental weariness by acting as points of contrast in densely populated areas. When visible, urban trees can improve emotional health, work happiness, and general quality of life. Urban trees can also foster strong emotional relationships between city dwellers and their neighbourhoods.

Unfortunately, accelerated urbanization, industrialization, and, most importantly, human population growth all contributes to the loss of urban tree cover. Vegetated landscapes have shifted to impervious surfaces, such as asphalt, concrete, and steel, with low albedo. Furthermore, anthropogenic activities have boosted greenhouse gas emissions and anthropogenic heat generation from industrial operations and cooling systems. As climate change worsens in Nigerian cities, the consequences for the environment, public health, and the economy are far-reaching. These factors increase people's susceptibility to the effects of climate change and reduce their ability to adapt and fight adverse events.

Like any other resource, access to the positive externalities associated with urban trees is not evenly divided among urban dwellers. Gerrish and Watkins (2018) confirmed that not all communities have equal access to high-quality green spaces, with lower-income and

racialized regions frequently having less tree cover. Scholars and activists see the absence of access to urban trees as an issue of environmental justice (Riley and Gardiner, 2020). Given the numerous advantages that urban trees offer, "uneven distribution of trees contributes to an uneven quality of life" (Perkins et al., 2004). Thus, all neighbourhoods must have access to tree canopy. Indeed, access to the benefits of urban trees is an environmental justice issue.

Acknowledging that not every individual or state contributes equally to environmental degradation is crucial. Not all segments of society lead unsustainable lifestyles. Unfortunately, the consequent harm disproportionately affects individuals who contributed the least to environmental degradation. In prosperous and impoverished countries, the poor and vulnerable bear the brunt of national and global elites' consumer-driven lifestyles. One of the defining characteristics of environmental injustice is the disparity between those who benefit from economic activity and those who suffer negative social and environmental consequences. This study, therefore, presents environmental justice principles to inform urban forestry practices and makes recommendations to improve the environmental conditions of Nigerian cities.

WHY ENVIRONMENTAL JUSTICE?

Environmental justice dates to the late 1970s and early 1980s when Americans fought for communities of colour and lower-income communities against disproportionate environmental costs and harms. The term "environmental justice" was used to refer to differences in the exposure of different racial and ethnic groups to environmental threats such as pollution, toxic waste, and flooding. As well as excluding these groups from the decision-making process and implementing national environmental policies (Laurent, 2010). These disparities were highlighted in terms of racial advancement and civic activism. In recent decades, environmental justice research has evolved from avoiding exposure to environmental waste and pollution to accessing environmental and community resources as a measure of the quality of life (Witten *et al.*, 2003).

These community resources include outdoor recreation and parks, urban greenways, public playgrounds, and urban tree cover. Because urban trees bring significant economic, social, and ecological advantages to urban people, unequal access to the localized benefits of parks, green spaces, and trees in cities is a matter of environmental justice. The uneven distribution of urban trees is frequently due to socioeconomic issues rather than ecological ones (Landry and Chakraborty 2009). It is important to note that the variables influencing the distribution of urban trees are frequently a combination of present drivers (e.g., where new trees can be planted, financing for maintenance) and historical processes (e.g., socioeconomic stratification, neighbourhood succession (Warren *et al.,* 2010). These factors work together to create the current disparity in tree canopy cover, and researchers discovered that the socioeconomic characteristics related to canopy cover vary between cities. Many studies confirmed that canopy cover positively correlates with education, income, age, disability, homeownership, employment, gender, and socioeconomic status.

Bullard (2021) defined environmental justice as the principle that "all people and communities are entitled to equal protection of environmental and public health laws and regulations". "All individuals, regardless of race, colour, national origin, or income, should be treated fairly and meaningfully in establishing, implementing, and enforcing environmental laws, regulations, and policies. Fair treatment means that no population is forced to bear a disproportionate share of the negative human health or environmental impacts of pollution or environmental consequences resulting from industrial, municipal, and commercial operations

or implementing federal, state, local, and tribal programs and policies." Environmental justice refers to the cultural norms, attitudes, rules, regulations, behaviours, policies, and decisions that promote sustainable communities and allow individuals to interact with the trust that their surroundings are safe, nurturing, and productive. Environmental justice is fulfilled when people can realize their full potential without experiencing restrictions or barriers. Environmental justice is supported by well-paying and safe jobs, good schools and recreation, decent housing and appropriate health care, democratic decision-making and personal empowerment, and communities free of violence, drugs, and poverty (Walker, 2012).

According to Schlosberg and Collins (2014), environmental justice encompasses civil rights, public health and safety, and proximity to diverse environmental advantages and hazards. In other words, environmental justice seeks to ensure everyone has a clean and safe place to live, work, and play. The environmental justice movement's original action and research focused on disproportionate exposure to environmental hazards (for example, toxic waste storage, power plants, oil and chemical refineries). Since then, the definition of environmental justice has expanded to encompass access to environmental amenities, desirable land uses, and freedom from environmental hazards (Boone *et al.,* 2009; Rigolon, 2016; Walker, 2012). Thus, environmental justice seeks to safeguard all individuals, regardless of race, national origin, or income, from the disproportionate effects of environmental risks.

To understand why environmental justice is essential, consider how people are classified in every situation based on age, race, gender, ethnicity, religion, income, education, etc. This category marginalizes some. As a result, applying an environmental justice framework to urban planning, particularly in the context of urban forests, can help address access and implementation of urban greening goals. This framework has three pillars: distributive, procedural, and recognitional justice.

ENVIRONMENTAL JUSTICE FRAMEWORK

Environmental justice framework is the three dimensions of equity that shape the resilience of vulnerable communities and determine whether they are equipped to handle shocks and stressors related to environmental or climate disruptions.

Distributional Justice

Cities' uneven investment in tree planting and maintenance operations can be regarded as a distributive injustice. According to Schlosberg (2007), distributional justice results from a mix of recognitional and procedural inequalities in which certain groups lack access to environmental amenities and reside near environmental harm. Distributional justice requires that all residents of a country or community have equal access to various public facilities. Distributive justice is an essential issue that focuses on the equitable allocation of green space among different socioeconomic groups to ensure that everyone benefits from tree canopy (Grant *et al.,* 2023). Englund *et al.* (2019) defined distributive justice as equitable access to goods and infrastructure, environmental amenities, services, and economic opportunities. It involves equitable distribution of environmental resources such as tree canopy and ensuring that those in greatest need have access to the advantages that trees give. As a result, creating a perfect evaluation system is critical for improving landscape justice and equity.

Recognitional Justice

Recognitional justice requires the inclusion and prioritization of diverse perspectives, experiences, preferences, values, and knowledge of disadvantaged (e.g., racialized, low-income) and neglected groups (i.e., those living in low-canopy neighbourhoods, those historically excluded from decision-making) in urban forest planning and tree-planting and stewardship events (Campbell *et al.,* 2022; Grant *et al.,* 2022). Englund *et al.* (2021) stated that recognitional justice acknowledges the intersecting identities of diverse community members (e.g., race, gender, class, and age), recognizes that historical injustices shape such identities and can influence individual vulnerability to shocks and stresses, the ability to access resources, and capacity to participate in decision-making; and fosters respect for different groups. Recognitional justice directly impacts distributional and procedural justice results, and it is concerned with whether disadvantaged groups' perspectives, experiences, and knowledge are recognized and prioritized in policy creation and decision-making (Fraser, 1997).

Procedural Justice

Englund *et al.* (2021) reported that procedural justice refers to equitable participation in decision-making processes, such as public participation in plan development, efforts to increase ongoing public participation in city governance, and targeted outreach to marginalized groups frequently underrepresented in traditional public engagement processes. Measures of procedural justice include ensuring that members of the public have access to accurate information and resources (e.g., about the benefits/burdens of trees, tree care and maintenance responsibilities, location/time of tree-planting and stewardship events) and that public engagement campaigns and broader decision-making processes are fair, accessible, and transparent. (Nesbitt *et al.,* 2018; Verheij and Corrêa Nunes, 2021). Walker (2009) stated that procedural justice is concerned with correcting the absence of fairness, openness, and access in decision-making procedures that influence distributional justice outcomes. In this instance, the public's participation is fair regardless of status.

INEQUITABLE URBAN TREE CANOPY DISTRIBUTION IN NIGERIA

Wang et al. (2012) reported that urbanization is a pervasive and fundamental land-use change process that is becoming increasingly relevant to environmental research. Rapid urbanization significantly affects the structure of ecological systems inside metropolitan areas, including reduced air and water quality, habitat destruction, and altered microclimatic patterns. These impacts and the broader links between urbanization and the environment must be recognized to preserve and improve biodiversity, sustainability, and ecosystem services in urban areas. As urbanization and population growth accelerate, maintaining livable and healthy cities has become a significant problem worldwide. Providing urban green spaces has become one of the significant ways to encourage physical activity and boost human well-being, which has piqued the interest of researchers and policymakers.

Trees are referred to as "the lungs of a city," a metaphor highlighting the importance of trees and other green spaces in the urban environment. Urban green space encompasses city and municipal parks, woodlands, community gardens, and natural conservation areas. Nowak *et al*. (2020) confirmed that urban forests are important to most urban ecological systems. Urban trees provide various environmental advantages, including rainwater interception, urban microclimate adjustment, air pollution reduction, and enhanced animal habitat (Nowak and Dwyer 2007). Promoting the utilization of green space is an essential strategy for improving physical, social, and mental health and the quality of life for urban dwellers. According to UN Habitat (2022), by 2070, about 60% of the world's population will live in

cities, facing chronic and new urban difficulties. In this framework, "Make cities and human settlements inclusive, safe, resilient, and sustainable" is one of the most notable Sustainable Development Goals (SDGs) in the 2030 Agenda for Sustainable Development (Mccullough, 2019).

In Nigeria, considerable pressure has been on green spaces, particularly in urban areas, resulting in their depletion. This depletion has harmed the environment. Elisha *et al*. (2017) confirmed that Nigeria's climate is changing, with more prolonged and more intense rains causing massive runoffs and flooding in many country sections. Friel *et al.* (2011) predicted that cities would be hit worse by the negative consequences of global climate change. Schwarz *et al.* (2015) confirmed that climate change disproportionately affects vulnerable groups due to limited resources and inadequate adaptive capacity. Reckien *et al.* (2018) confirmed that cities without a reasonable and practical urban development plan are more likely to experience higher-than-average climate change impacts due to high population growth rates, with nearly 90% of the urban population expected to increase between now and 2050.

Although the Nigerian constitution, Chapter II, Section 20 provides the human right to a safe and healthy environment. However, tree cover varies by land use class and across the city landscape due to various factors such as available greenspace and management operations such as tree planting, removal, mowing, and upkeep. However, an area with a low tree canopy does not automatically indicate that it has the most significant demand for tree cover. Some locations may be plagued by industrial pollution and high asthma rates, demanding increased tree canopy to combat air and soil quality (phytoremediation). Each place has its own unique set of difficulties and needs. It can also imply linking tree canopy goals to existing equality goals in other community plans, such as using tree canopy to help with energy equity goals (Daley, 2020). Landry and Chakraborty (2009) stated that the geography of land use in a city is affected by the distribution of resources and services available to citizens and their preferences and capacity to access them. Donovan and Butry (2011) stated that desirable features such as a dense urban tree canopy frequently raise housing prices, attracting residents who can afford the higher housing costs associated with such features while excluding those who cannot, resulting in unequal access to this critical amenity. This confirms that residents with more excellent socioeconomic status usually have more economic and political resources to select neighbourhoods that meet their preferences and prevent undesirable land uses and facilities from locating in those neighbourhoods.

Zakari-Jiya *et al*. (2022) reported that Nigeria has approved certain international treaties relating to environmental rights and enacted some environmental laws asserting the right to a clean and healthy environment. Unfortunately, the implementation of the rules is complex due to many factors. Furthermore, social categories (income level, education, etc.) significantly impact tree cover distribution in cities since low-income and minority populations are more likely to live in high-risk, vulnerable, and congested metropolitan regions than wealthy individuals. As a result, policies that prioritize vulnerable cities' resilience or adaptive capacity to capture communities' ability to capitalize on new opportunities, enable change, and inform decision-making and institutional management, should be implemented (Zhuang *et al.*, 2023).

HUMAN HEALTH IMPLICATIONS OF INEQUITABLE URBAN GREEN SPACE ACCESS

There are apparent geographical disparities in climate-related health outcomes, including the risk of exposure to catastrophic events and food insecurity. Urban green spaces such as street trees, urban parks, and gardens are a valuable environmental source for urban dwellers to improve physical, mental, and social health. Urban trees play a role in carbon absorption and storage, eliminating atmospheric pollution, reducing noise, and regulating microclimate. Interactions with street trees, urban parks, and gardens can encourage physical activity, thereby reducing obesity, heart disease, kidney disease, and type II diabetes and thus improving the physical health of people (Astell-Burt and Feng, 2020). The natural scenery in urban parks relieves mental fatigue, provides relaxation from hectic daily routines, and boosts cognitive function. Furthermore, urban green space offers a variety of chances for people to participate in public activities, thereby encouraging social contact. These advantages are critical in minimizing the effects on human health and reducing the frequency of environmental dangers.

However, the unequal distribution of natural resources (trees) endangers humans and the ecosystem. Environmental injustice exists in areas with reduced tree canopy cover, which can exacerbate health concerns for already vulnerable populations. These situations render them more vulnerable to the effects of climate change, reducing their ability to adapt and withstand adverse conditions. As confirmed by Gonzalez *et al.* (2021), air pollution kills over seven million people each year, while a lack of access to fresh water and sanitation has been linked to the death of five million people each year. The ability of a society to cope with disasters is determined by its internal strengths and weaknesses - the level of social, economic, and cultural vulnerability. Its ability to cope varies according to its social circumstances: poor and rich, women and men, young and elderly, indigenous, and so forth. As a result, promoting social justice in urban resilience planning frameworks and integrating environmental policy across diverse planning and decision-making sectors is critical.

PARTICIPATORY APPROACH: Public participation in urban forest management and decision-making

To avoid rigid and top-down solutions, cities must encourage and disseminate a science-informed policy-making process that considers different stakeholder interests. It can be accomplished through participatory methods considering community members' perspectives on resilience objectives and feasibility. Public involvement is a crucial technique for including humans in ecological management. The urban natural environment, like the built environment, requires capital for maintenance, as do urban natural environments. Including public input in planning and conservation decisions is an essential strategy for protecting public health. Promoting participatory landscape development can be a long-term learning process, but it is also important in promoting environmental justice. Citizens can participate in the urban greening through thoughtful urban planning that considers community needs. For example, conflicts between housing interests and green space preservation have posed issues in nations such as India Gonzalez *et al.,* 2021). Interdisciplinary communication among scientists, planners, and local stakeholders can help to increase the acceptance and implementation of green space planning initiatives. The social elements of climate governance argue that stakeholders must grasp the harmful effects of a changing climate on infrastructure and services to address these concerns at the local level adequately. Englund *et al*. (2021) affirmed that climate and environmental action plans should be long-term, adaptable, and dynamic.

Local governments can enhance procedural and distributive fairness while improving mitigation and adaptation methods by incorporating urban forestry, equity, and community engagement efforts into climate and environmental action planning frameworks. However, special consideration should be given to urban forestry efforts to reduce disparities in low-income communities. In urban forestry, resiliency management could incorporate community and municipal stewardship, emphasising the neighbourhoods that require the most monitoring and maintenance support. Furthermore, many of these areas have historically been underserved; therefore, relevant stakeholders must establish trust and rapport with these groups. Municipalities can also collaborate with community members to create equality toolkits, which provide principles for all agencies to follow when developing new plans. Active support from political entities, agencies, volunteers, and nonprofits can bolster these efforts while incorporating urban tree canopy goals in cross-sectoral climate action planning processes.

CONCLUSION

Environmental justice is a relatively recent concept in urban forestry but does not address all social and environmental issues. Equity in urban forestry is not about educating residents about the benefits of planting trees as objects in the landscape; instead, it is about making resources, decision-making, and trust available to allow communities to live with self-determination. Policies and initiatives must be assessed and altered to ensure resilience and equitable objectives are met. Periodic monitoring and assessment utilizing fair indicators and progress measurements, budgetary transparency, and equitable resource allocation mechanisms are required to guarantee that monies reach their intended recipients and result in equitable resilience outcomes. Incorporating multiple intervention tactics is crucial for achieving environmental justice and integrating its platform into other sectors. Effective policies that support sustainable development are linked to the fundamental principles of environmental justice.

To address urban canopy disparities through urban planning and reforestation. Tree planting programs can improve equity in urban canopy cover while supplying the infrastructure and housing required for future population expansion. To establish an evenly distributed forest canopy in Nigeria, we must take several innovative initiatives, such as:

1. Strengthen collaborations to plant new trees on private and public property: For decades, partnerships between government agencies, non-governmental organizations (NGOs), and the commercial sector have resulted in widespread societal benefits. This collaboration should evaluate how resources like parks and other green areas are spread throughout the community. Locke *et al.* (2013) concluded that independent effort is insufficient because no agency, organization, single landowner, or corporation has enough cash or land to meet a city's (urban tree canopy) goal. Coordination and collaboration are required and depend on establishing shared or complementary interests, program categories, or areas of action." Focusing primarily on environmental justice priority areas (areas with low or no tree canopy cover), planning for and funding their establishment, and long-term care.
2. Prioritize preserving and caring for trees already in the environment because it is the most effective strategy to ensure future canopy. For tree preservation, it is vital to emphasize that money is a critical service for urban forestry initiatives and management. To guarantee that urban forestry budgets are sustainable and immune to economic and other external influences, financing must come from various stable, long-term sources to cover maintenance and staffing requirements.

3. Incorporate up to date (current and future) climate change impacts into planting and management techniques to prepare for problems such increased heat, water scarcity, and emerging pests and diseases.
4. Develop and enforce laws and regulations - To preserve urban trees, cities should develop policies and ordinances to achieve urban tree canopy goals. Comprehensive plans are only as robust as their implementation, and rules can ensure that specifications are legally binding. Tree ordinances should clearly define goals, assign responsibilities with authorized authority, establish basic performance requirements, be flexible, describe enforcement mechanisms, be part of a holistic management plan strategy, and be designed with community input. Cities should continue to put in place a robust regulatory framework that aligns our tree conservation and protection aims with the housing production and development demands of our towns.

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Comparative methods of biomass and carbon stock assessment of some selected tree species used for charcoal production in the guinea savanna ecological zone of Nigeria.

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Abstract

Nondestructive method of above-ground biomass (AGB) and carbon stock assessment is the most frequently used method to quantify the amount of carbon sequestered by the trees/vegetation because it involves assessing the biomass and carbon without cutting down the tree. However, to validate the claim of the biomass and carbon stock of the nondestructive method, the destructive method must be employed to ascertain the actual biomass and carbon stock by harvesting the tree. This study incorporated both the destructive and nondestructive methods of biomass and carbon stock assessment. The independent t-test result ($t = 3.351$, $p = 0.00475$) between the two methods revealed that the destructive method had higher biomass ($M=0.425$, $SD=0.14313$) than nondestructive method ($M=0.2338$, $SD=0.07463$) at an alpha value of 0.05. The ANOVA among the harvested species for charcoal production further revealed a significant difference in the mean biomass, where *Vitellaria paradoxa* and *Parkia biglobosa* had the highest value. At the same time, *Pterocarpus erinaceus* and *Daniellia oliveri* recorded the least biomass and carbon stock of the tree species used for charcoal production in the study area.

Key words: aboveground biomass; carbon stock; tree species; charcoal; savanna

Introduction

Carbons exist as carbon dioxide in the atmosphere and constitute a very small percentage of about 0.04%. However, it plays a vital role in supporting life on Earth. The CO_2 plants fix during photosynthesis is transferred across the different carbon pools. Green plants manufacture their food through photosynthesis, and it is this food can be transported to all parts of the plant through phloem tissue for the growth and development of the plant. When these plants or trees die or are burnt, the carbon stored in them is released back into the atmosphere (Vashum and Jayakumar, 2012). In terrestrial ecosystems, the living biomass of trees, the understorey vegetation, and the dead wood (standing and fallen), woody debris and soil organic matter constitute the main carbon pool. According to Eggleston *et al. (*2006), there are five carbon pools in the terrestrial ecosystems involving biomass, namely, the above-ground biomass, below-ground biomass, dead mass of litter, dead wood, and soil organic matter. The CO_2 plants fix during photosynthesis is transferred across the different carbon pools. When these plants or trees die or are burnt, the carbon stored in them are released back into the atmosphere. This natural cycling of carbon has been maintained and controlled by a dynamic balance between biological and inorganic processes since earth's geological history (Vashum and Jayakumar, 2012). The aboveground biomass of trees is

mainly the most significant carbon pool, and it is the most essential and visible carbon pool of the terrestrial ecosystem (Ravindranath and Ostwald, 2008). Generally, the estimated biomass components are the aboveground live biomass, which includes the trees and the shrubs excluding the roots, dead aboveground biomass like litter and fallen branches and the below-ground biomass, which comprises the roots.

The change in the forest areas and the changes in forest biomass due to management and re-growths greatly influence the transfer of carbon between the terrestrial ecosystem and the atmosphere (Houghton, 2005). Hence, estimating the forest carbon stocks is mainly essential to assess the magnitude of carbon exchange between the forest ecosystem and the atmosphere. Assessment of the amount of carbon sequestered by a forest will estimate the amount of carbon emitted into the atmosphere when this forest area is deforested or degraded. Furthermore, it will help us quantify the carbon stocks, enabling us to understand the status of carbon stocks and derive the near-future changes in the carbon stocks (Gibbs *et al*., 2007; Houghton, 2005). However, savanna tree species are often scattered, crooked, and bent. They equally (like all other woody tree species) constituted a great biomass of terrestrial ecosystem and stored a significant amount of carbon. Most studies on tree biomass and carbon stock assessment often neglect the savanna regions concentrating more on forest areas and plantations. Information on savanna vegetation such as volume, biomass composition, and and carbon sequestration capacity, is very scanty. There is a growing demand for reliable information on forest and tree carbon stock at both country and global levels. It requires transparent and verifiable methods, quantification of uncertainties and appropriate monitoring systems for carbon stocks. The objectives of this study were to estimate the biomass and carbon stock of some savanna tree species used for charcoal production, using both destructive and nondestructive methods.

Study Area

This study was carried out in the Guinea savanna of Moro Local government area of Kwara State, situated between latitudes 8°20′ N and 8°50′ N and Longitudes 4°25′ E and 4°65′E (fig.1) with a tropical wet and dry climate and average yearly rainfall of about 1200 mm. Its mean annual temperature is about 26.2 °C, which peaks at about 30 °C in March and about 45% humidity. The wet season is generally experienced between April and October, and the dry season is between November and March. April is the warmest month, and December has the lowest average temperature of about 22.5^{o}C with an average of 264 mm. (Abubakar et al., 2023).

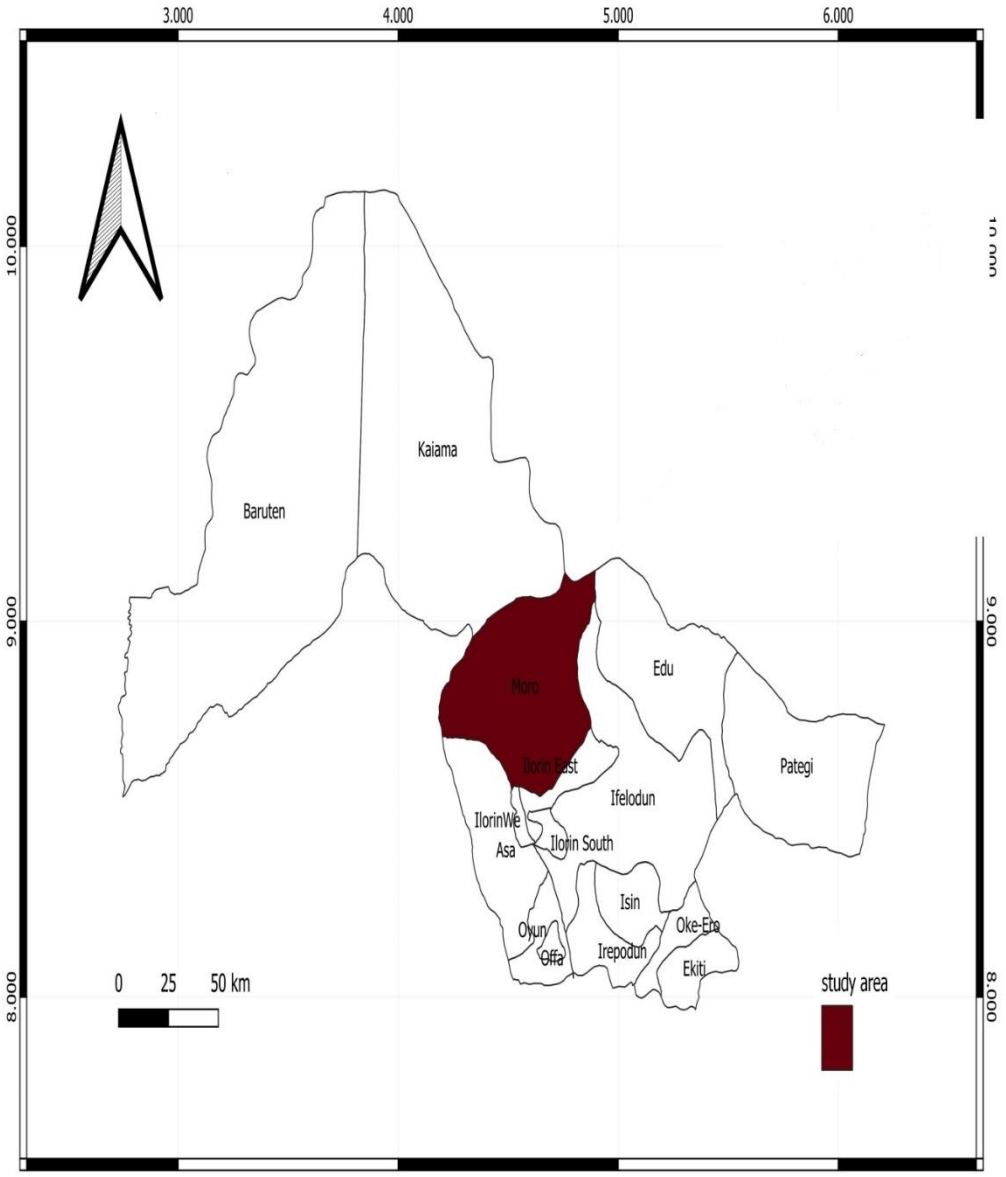

Figure1: Map of Kwara State showing the study area

Field sampling design

Destructive and non-destructive methods of sampling were employed. For the destructive process, since it involved the complete cutting down of trees, Charcoal producers in the study areas were contacted to take advantage of the time of their charcoal production (they usually obtain permits from management). The non-destructive method, which involved measurements without felling the tree, was employed, where all the tree variables were measured using spegiel relascope and diameter tape. Core samples were also taken to determine wood density using an increment borer.

Non-destructive method

The diameter at base (db) and diameter at breast height (dbh) were measured with Diameter tape while diameter at middle (dm), diameter at top (dt) and total height of the potential charcoal trees marked for felling by the charcoal producers were measured using Spiegel relascope. For the destructive method of biomass estimation, tree variables such as length of stem and diameter at the base, middle and top were measured with diameter tape for more precision after tree felling. A core sample of the trees was extracted using an Increment borer at 1.3m (dbh) of the tree bole. The length of the core extracted was measured in centimetres; the diameter of the core was obtained using the diameter of the increment borer (0.4cm) used for the extraction. The samples were taken to the laboratory for oven-drying to obtain the dry weight of the core samples.

Destructive method

The felled trees were de-branched to obtain a clean bole. Each bole was then crosscut into sizeable length to enhance weighing on the weighing scale on the field. Fresh weight of the clear stem, all branches and all foliage were obtained right on the field (fresh weight) using a 150kg weighing balance (plate 1). A sample of discs from the stem (g), a sample of the branch (g) and a sample of foliage (g) were collected and weighed using a portable 5kg weighing balance (plate 2). The discs and the samples of the branches and leaves were taken to the laboratory for oven drying. Discs and branch samples were dried at 103±2 ^{0}C until a constant weight was attained, while foliage samples were dried at 65 ^{0}C (Tella and Fuwape, 2005). Using the ratio of fresh weights to dry weights of the discs ($\frac{dw.sd}{fw.sd}$ x fw.cs) the bole fresh weight would then be converted into dry weights (Fuwape and Akindele, 1997). Likewise, the dry weight of the branch and foliage was determined through the same method.

Data Analysis

Nondestructive method of biomass and carbon stock assessment

An Independent samples students'- t test was conducted to compare the means values of non destructive and destructive biomass and carbon stock assessment methods.

Tree volume

The trees' volume was estimated using Newton's formula, as described by Adekunle *et al.* (2013).

$$V = h\left(\frac{Ab+4Am+At}{6}\right) \vee \frac{h\pi}{24}(D^2_b+4D^2_m+ D^2_t) \quad \text{..... (1)}$$

Where,
V= volume of tree (m^3)
h = height (m)
Ab = area at base (m^2)
Am = area at middle (m^2)
At = area at top (m^2)
Db= diameter at base (cm)
Dm = diameter at middle (cm)
Dt = diameter at top (cm)

The volume of core sample

Since the shape of the core sample is cylindrical, equation (2) below was therefore used to estimate the volume of the core samples.

$$V_s = \frac{\pi d_s^2}{4} l \quad \ldots\ldots (2)$$

Where;

d_s=diameter of the core sample, (cm)

l = length of the core sample, (cm)

V_s= volume of the core sample (cm^3)

The density of the core sample

The density of the core sample was obtained by dividing the dry weight (mass) of the sample by the volume of the core sample obtained.

$$D_{cs} \frac{mass}{vol.} \quad \ldots\ldots (3)$$

Where;

D_{cs} = density of the core sample, (g/cm^3)

mass = dry weight of the core sample, (g)

vol_{cs}= volume of the core sample, (cm^3)

Tree species density

This was obtained by dividing the values with a conversion factor of $\left(\frac{1}{1000}\right)$. That means that the density of the core sample in g/cm3 was converted to tree density in kg/m3 by multiplying it by 1000.

Biomass and carbon stock

The biomass of the tree was obtained after all the water had been removed through oven drying (dry matter). The biomass of the tree species was then computed by the formula in Equation 4

$\text{Biomass}_{tree} = \textit{desity}_{tree} \times \text{vol}_{tree}$ …….(4)

Since the carbon constituted about 50% of dry matter (biomass), the carbon stock was computed by multiplying the biomass obtained by 0.5 or dividing the biomass by two as in equation 5 (Akindele, 2018)

$\text{Carbon stock}_{tree} = \text{Biomass}_{tree} \times 0.5$ ……..… (5)

The total carbon stock was then converted to tons of CO_2 equivalent by multiplying it with the molecular weight of carbon and oxygen (44/12) or 3.67, as shown in equation 6 (Pearson *et al.*, 2007).

CO_2 equiv. = Carbon stock $_{tree} \times \frac{44}{12}$ ……..… (6)

Destructive method of biomass and carbon stock assessment

Analysis of variance (ANOVA) was performed to check the significant difference in total biomass and carbon stock among the four savanna regions using R statistical software. An Independent samples students'- t test was also conducted to compare the means values of destructive and non-destructive biomass and carbon stock assessment methods. The following variables of the destructive method were computed.

Stem biomass

To compute the dry weight of a stem, a ratio of dry to wet (fresh) weight of the sample disc was used. This was calculated by dividing the dry weight by the wet weight of the sample disc from the tree stem and then multiplied by the weight of the clear stem obtained in the field.

Dry weight of stem (biomass) = $\frac{dw.sd}{fw.sd}$ x fw.cs ……..……. (7)

Where: dw.sd = dry weight of sample disc (g)
fw.sd = fresh weight of sample disc (g)
fw.cs = fresh weight of clear stem (kg)

Branch biomass

To compute the dry weight of a branch, a ratio of the dry to the wet (fresh) weight of the sample branch was used. It was obtained by dividing the dry weight with the wet weight of the sample branch and then multiplied by the weight of all branches obtained in the field.

Dry weight of branch (biomass) = $\frac{dw.sb}{fw.sb}$ x fw.ab …….. (8)

Where: dw.sb = dry weight of sample branch (g)
fw.sb = fresh weight of sample branch (g)
fw.ab = fresh weight of all branches (kg)

Foliage biomass The dry weight of foliage (biomass) was also computed by the dry to wet (fresh) weight ratio of sample foliage. The ratio obtained was then multiplied by the weight of all foliage obtained in the field.

Dry weight of foliage (biomass) = $\frac{dw.sf}{fw.sf}$ x fw.af…….. (9)

Where: dw.sf = dry weight of sample foliage (g)
fw.sf = fresh weight of sample foliage (g)
fw.af = fresh weight of all foliage (kg)

Total tree biomass

The total dry weights of the tree components (stem, branch and foliage) were combined to form a tree's total biomass.

Tree biomass = $\frac{dw.sd}{fw.sd}$ x fw.cs $\frac{+dw.sb}{fw.sb}$ x fw.ab + $\frac{dw.sf}{fw.sf}$ x fw.af ……. (10)

Where: dw.sd = dry weight of sample disc (g)
fw.sd = fresh weight of sample disc (g)
fw.cs = fresh weight of clear stem (kg)
dw.sb = dry weight of sample branch (g)
fw.sb = fresh weight of sample branch (g)

fw.ab = fresh weight of all branches (kg)
dw.sf = dry weight of sample foliage (g)
fw.sf = fresh weight of sample foliage (g)
fw.af = fresh weight of all foliage (kg)

Carbon stock

Since the carbon constituted about 50% of a dry matter (biomass), the carbon stock was computed by multiplying the biomass obtained by 0.5 or dividing the biomass by 2, thus:

$$\text{Carbon stock}_{tree} = \text{Biomass}_{tree} \times 0.5 \quad (11)$$

The total carbon stock was then converted to tons of CO_2 equivalent by multiplying it with the molecular weight of carbon and oxygen (44/12) or 3.67 (Hauchhum, 2017).

$$CO_2 \text{ equiv.} = \text{Carbon stock}_{tree} \times \frac{44}{12} \quad (12)$$

RESULTS

Biomass and carbon stock assessment of non-destructive method

The biomass and carbon stock of some selected tree species were assessed. The summary of the measurements of twenty (20) selected tree species is presented in Table 1. The wood densities of the selected tree species for charcoal production were also assessed and presented in Table 2. The results revealed 1.88 tons of biomass and 0.94 tons of carbon stock from the 20 selected tree species (table 6).

Table 1: Summary of tree measurement data from non-destructive sampling

Tree species	F	Mean Dbh (cm)	Mean H(m)	Mean Den. (kg/m^3)	Mean Vol. (m^3)
Anogeissus leiocarpus	2	24.53	8.75	860	0.11
Burkea Africana	3	24.77	10.21	830	0.11
Daniellia oliveri	3	26.24	9.75	640	0.14
Parkia biglobosa	2	27.71	9.88	760	0.16
Prosopis Africana	3	28.21	10.93	820	0.15
Pterocarpus erinaceus	2	27.42	8.40	710	0.14
Syzygium guineense	3	25.78	10.23	640	0.13
Vitellaria paradoxa	2	27.44	9.56	860	0.13
Subtotal	**20**				

Table 2: Wood densities used for biomass estimation.

Tree species	Wood den. (g/cm^3)	Wood den. (kg/m^3)	Source
Anogeissus leiocarpus	0.86	860	Field survey, 2021/2022
Burkea Africana	0.83	830	Field survey, 2021/2022
Daniellia oliveri	0.64	640	Field survey, 2021/2022

Parkia biglobosa	0.76	760	Field survey, 2021/2022
Prosopis Africana	0.82	820	Field survey, 2021/2022
Pterocarpus erinaceus	0.71	710	Field survey, 2021/2022
Syzygium guineense	0.64	640	Field survey, 2021/2022
Vitellaria paradoxa	0.86	860	Field survey, 2021/2022

Table 3: Mean biomass of tree species of nondestructive method

Tree species	Biomass
Prosopis africana	120.63[a]
Parkia biglobosa	119.50[a]
Vitellaria paradoxa	108.90[ab]
Pterocarpus erinaceus	97.03[abc]
Anogeissus leiocarpus	91.83[bc]
Burkea Africana	89.58[bc]
Daniellia oliveri	87.76[bc]
Syzygium guinenses	81.12[c]

Means followed by the same letter(s) are not significantly different at 0.05 level of significance.

Biomass and Carbon Stock Assessment of Destructive Method

Twenty (20) selected tree species were harvested, and the biomass and carbon stock were assessed. The summary of tree measurements of the twenty (20) tree species selected is presented in Table 4. The results revealed 3.44 tons of biomass and 1.72 tons of carbon stock from the 20 harvested tree species (table 6).

Table 4: Summary of tree measurement data from destructive sampling

Species	F	Mean Dbh (cm)	Mean H(m)	Mean weight Stem (kg)	Mean weight branch (kg)	Mean weight foliage (kg)
Anogeissus leiocarpus	2	24.53	8.75	276.20	226.90	24.60
Burkea africana	3	24.77	10.21	456.20	413.30	33.50
Daniellia oliveri	3	26.24	9.75	390.30	299.20	57.90
Parkia biglobosa	2	27.71	9.88	351.90	404.70	65.00
Prosopis africana	3	28.21	10.93	566.20	437.30	78.60
Pterocarpus erinaceus	2	27.42	8.40	246.80	210.80	18.00
Syzygium guineense	3	25.78	10.23	484.90	359.50	106.80
Vitellaria paradoxa	2	27.44	9.56	360.00	328.80	117.00
Sub total	**20**					

Table 5: Mean biomass of tree species of destructive method

Tree species	Biomass
Vitellaria paradoxa	213.39[a]
Parkia biglobosa	207.97[a]
Prosopis Africana	200.56[ab]
Burkea Africana	198.29[ab]
Syzygium guinenses	155.89[bc]
Anogeissus leiocarpus	154.78[bc]
Pterocarpus erinaceus	148.66[c]
Daniellia oliveri	141.54[c]

Means followed by the same letter(s) are not significantly different at 0.05 level of significance.

Table 6: Biomass and carbon stock estimates of destructive and nondestructive methods

					Destructive method		**Nondestructive method**	
Selected tree species	**F**	**Mean dbh (cm)**	**Mean H(m)**	**Stem length (m)**	**Total biomass (t)**	**Total C.S. (t)**	**Total biomass (t)**	**Total C.S. (t)**
Anogeissus leiocarpus	2	24.53	8.75	2.75	0.31	0.15	0.18	0.09
Burkea Africana	3	24.77	10.21	3.10	0.59	0.30	0.27	0.13
Daniellia oliveri	3	26.24	9.75	2.97	0.42	0.21	0.26	0.13
Parkia biglobosa	2	27.71	9.88	2.85	0.42	0.21	0.24	0.12
Prosopis africana	3	28.21	10.93	2.87	0.60	0.30	0.36	0.18
Pterocarpus erinaceus	2	27.42	8.40	3.10	0.30	0.15	0.19	0.10
Syzygium guineense	3	25.78	10.23	2.93	0.47	0.23	0.24	0.12
Vitellaria paradoxa	2	27.44	9.56	2.60	0.43	0.22	0.22	0.11
Subtotal	**20**				**3.41**	**1.71**	**1.88**	**0.94**

DISCUSSION

Biomass and carbon stock of the selected tree species of nondestructive method

The biomass of the twenty (20) selected tree species used for charcoal production was assessed through destructive and nondestructive methods. The results revealed the above-

ground biomass of 3.45 tons and 1.88 tons of destructive and nondestructive methods, respectively, from the 20 selected tree species. The analysis of variance (ANOVA) of nondestructive method revealed a a significant difference among the biomass of the tree species. *Prosopis africana* and *Parkia biglobosa* were ranked first (p> 0.05), followed by *Vitellaria paradoxa*, while *Syzygium guinenses* recorded the least biomass and carbon stock (table 3). This is evident because the height, diameter at breast height (dbh) and basal area of the stated trees was relatively higher compared to those that recorded the least biomass. Agboola *et al.* (2021) reported a total biomass of 277,047 kg in the neighbouring rainforest of Oyo State, where they encountered 89 tree species from the 6 plots (25m x 25m). Several tree species encountered by Agboola *et al.* (2021) were also part of the tree species selected for this research. The aboveground carbon stock range of 98.67–555.96 Mg C ha^{-1} was also reported by Agboola (2021). The value of carbon stock obtained in this research was based on individuals' trees, not per plot or hectare (plotless), it corresponded to this if the carbon stock were to be reported per tree basis.

Okoh *et al.* (2019) reported carbon stock of litter production of four tree species of guinea savanna. *M. lucida* had the highest sequestered carbon in litterfall and litter biomass (0.607; 1.107 tones m^{-2} y^{-1}), while *Prosopis africana* had the lowest (0.113; 0.116 tones $m^{-2}y^{-1}$. This result is similar to 0.02 tC (though not per m^2) of *Prosopis africana* obtained in this research.

The results from Ibrahim *et al.* (2018) on carbon contents of wood and bark of some tropical tree species indicated that *Khaya senegalensis* had 49.5% and 44.77% total carbon content of the bark and wood, respectively. This is similar to what is obtained by this research, where *Khaya senegalensis* recorded a total carbon of 0.07 tC.

Biomass and carbon stock of the selected tree species of destructive method

The biomass of the selected tree species used for charcoal production was assessed using the destructive method of assessment. The analysis of variance (ANOVA) of the destructive method revealed that, there is a significant difference among the biomass of the tree species. *Vitellaria paradoxa* and *Parkia biglobosa* were ranked first (p> 0.05), followed by *Prosopis africana* and *Burkea africana* whereas *Pterocarpus erinaceus* and *Daniellia oliveri* recorded the least biomass (table 5). Odiwe *et al.* (2017) reported above-ground biomass in a neighbouring State (Osun) of 5 tree species, with *Celtis zenkeri* (985.58±88.99 kg) having the highest above-ground biomass than the other four species studied. Chave *et al*. (2014) reported values varying from 291.8 to 559.7 M ha-1 in a pan tropical forest.

Difference between destructive and nondestructive methods of biomass assessment

The independent samples t-test was used to evaluate the differences between the two methods. The biomass of the destructive method (M=0.425, SD=0.14313) compared to the nondestructive method of the eight tree species (M=0.2338, SD=0.07463) demonstrated a significant score t = 3.351, p = 0.00475. Since the p-value is less than the alpha value (0.05), it is significant. The difference in means between the group *destructive method* and the group *nondestructive method* is not equal to 0. Thus, there is a significant difference in biomass between the two methods of assessment. The destructive method revealed higher biomass than the nondestructive method of biomass and carbon stock assessment.

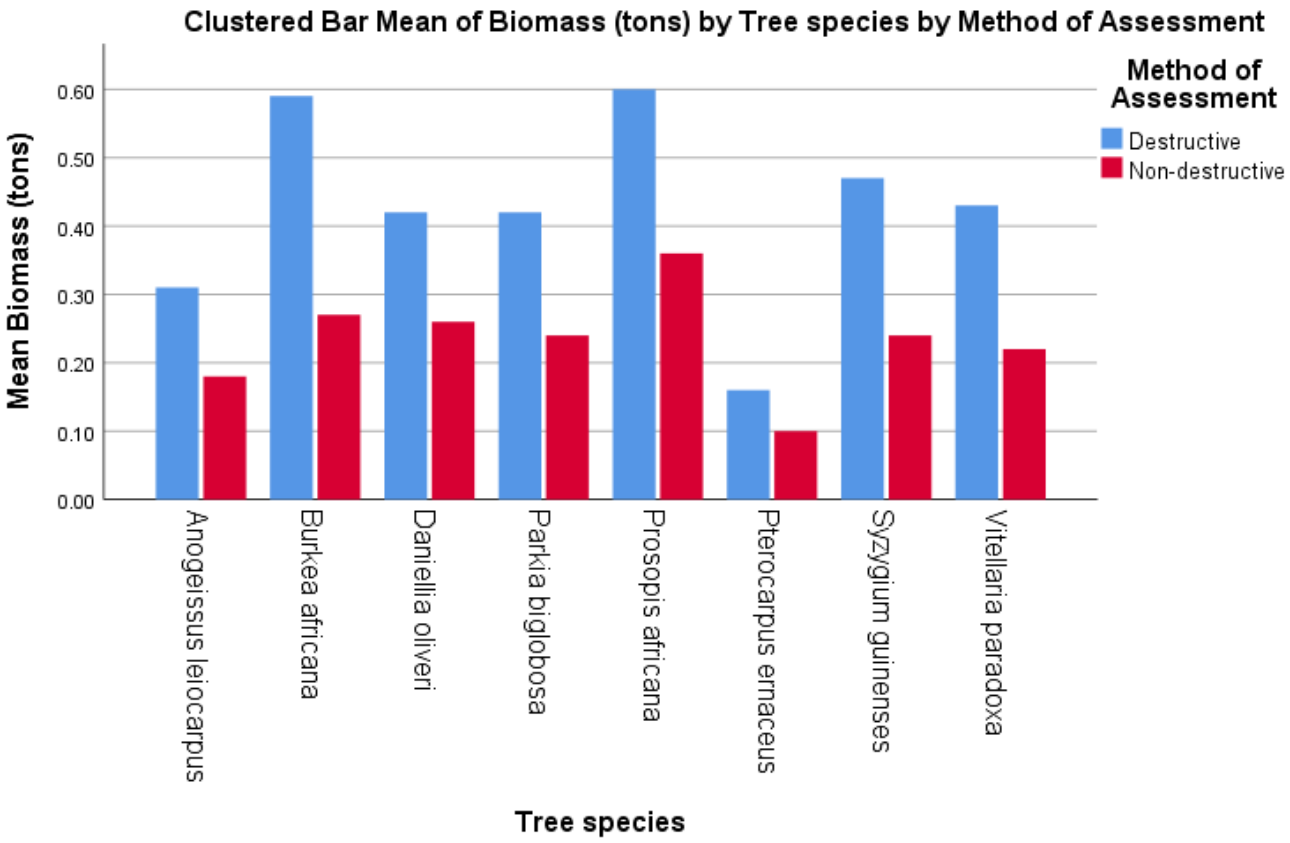

Figure 2: Biomass of Destructive and Nondestructive Methods among the tree species

Conclusion and Recommendation

Biomass and carbon stock assessment is one of the most widely used methods to quantify the amount of carbon sequestered by trees/vegetation. The two most used methods (destructive and nondestructive) were compared. The results show that the destructive method yields more biomass and carbon stock than the nondestructive method. This is evident because the destructive method considers all the tree components (stem, branch and foliage) in assessing the biomass content, whereas the nondestructive method only assesses the biomass of the tree stem. Furthermore, the results of the ANOVA among the tree species harvested for charcoal production revealed a significant difference in the mean biomass, where *Vitellaria paradoxa* and *Parkia biglobosa* had the highest. At the same time, *Pterocarpus erinaceus* and *Daniellia oliveri* recorded the least biomass and carbon stock among the tree species used for charcoal production in the study area.

Appendix 1: ANOVA tables for the destructive and nondestructive method

Nondestructive method

Source of variation	Df	Sum of Squares	Mean Square	F	Sig.
Tree species	7	4152.247	593.178	4.300	.013*
Error	12	1655.243	137.937		
Total	19	5807.490			

Destructive method

Source of Variation	Df	Sum of Squares	Mean Square	F	Sig.
Tree species	7	15293.607	2184.801	4.439	.012*
Error	12	5906.765	492.230		
Total	19	21200.372			

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Land Use Land Cover Dynamics of Okomu National Park, Nigeria

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ABSTRACT

Okomu National Park (ONP) is one of Nigeria's few remaining rich and dense tropical rainforests and a habitat for many endangered species. This study assessed the changes in the land use and land cover (LULC) of ONP for sustainable management. The data was collected from LANDSAT imageries from 2002, 2012, and 2022. Supervised classification using the Maximum Likelihood algorithm in the Quantum Geographic Information System (QGIS) was applied to the imageries and classified into six LULC classes: agricultural land, bare land, forested land, water bodies, built-up area, and herbaceous land. The LULC changes were analyzed by subtracting the reference year from the base year. The results revealed both an increase and a decrease in the different LULC classes for the period under study. In 2002, forested and built-up lands had the highest (50.61%) and lowest (1.42%) area covers. The same trend occurred in 2012 and 2022, with forested land having the highest cover of 49.84% and 58.35%, respectively, while the built-up area had the lowest area cover of 0.47% and 1.72%, respectively. Between 2002 to 2012, the highest increase occurred in bare land (25.65 km²), followed by herbaceous land (3.29 km²). The forest area increased by 17.48 km², with a 23.11 km² decrease in herbaceous land from 2012 to 2022. The study concludes that the park is dominated by forest land, which increases annually. It is recommended that more conservation efforts should be done in the southwestern part of the park.

Keywords: Forest, GIS, Land Cover, LULC, Land Use, Okomu, Remote sensing

INTRODUCTION

Land is becoming a scarce resource due to population growth and industrialization. The rapid spread of anthropogenic activities can also be attributed to the decrease and degradation of land (Biswajit, 2011). Thus, it has become important to regulate exploited areas for sustainable development and environmental protection. Hence, information on land use land cover is essential for the selection, planning, and implementation of land use and can be used to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting from the changing demands of the growing population (Zubair, 2006). "Land use" is the term used to describe how people use land resources. It varies depending on what they use it for, such as producing food, housing, recreation, extracting and processing materials, or maintaining the biophysical features of the land itself (Netsanet, 2007). According to Akile and Beyene (2014), human demands, environmental features, and processes are the two main influences shaping land use. Land cover, on the other hand, is the biophysical state of the earth's surface differences so that they are correctly used in studies of land and immediate subsurface. It describes the physical state of the land surface, such as cropland, mountains, or forests (Turner *et al.,* 1994; Moser, 1996)**.** Land cover deals with the quantity and type of surface vegetation, water, and earth materials (Turner *et al.,* 1994).

Land use land cover (LULC) dynamics in a protected area such as Okomu National Park (ONP), Nigeria, reflect the progressive conservation efforts, management effectiveness, and land use policy at play along spatial and temporal scales (Olaniyi, 2018). Its studies and monitoring are mainly

imperative to provide evidence-based support to improve land management policies and practices coupled with understanding the dynamics and forecasting the natural landscape patterns and trend of changes related to ecosystems at local, regional, and global scales (Lu *et al.*, 2004; Cotter *et al.*, 2014). Previous studies described Okomu National Park (ONP) as one of the few remaining rich and dense tropical rainforests in Nigeria, and it is the last habitat for many endangered species (Oladejo and Eghenure, 2021; Osadolor and Chenge, 2023). According to the National Park Service (NPS), Okomu National Park is "the pride of our natural heritage" and the smallest of the seven National Parks in Nigeria. The park is a suitable habitat for numerous endangered flora and fauna species (NPS, 2014).

Olaniyi (2018) reported that ONP continues to shrink as villages encroach on it, and it is now less than one-third of its original size. Hence, this study aimed to assess Land Use Land Cover Dynamics of Okomu National Park to reveal changes in the park from 2002 to 2022 and provide up-to-date information for sustainable management.

MATERIALS AND METHOD

Study Area

The study was conducted in Okomu National Park, Edo State, Nigeria. The park has an area of approximately 200 km² and is situated between the rivers Osse and Siluko to the East and West, respectively and between Longitude 5°09'28.09"E and 5°20'15.51"E and latitude 6°14'57.55" N and 6°24'55.64"N (Figure 1). The climate of Okomu is tropical, with well-marked rainy and dry seasons; mean annual rainfall is about 2,100mm, with most of it falling between February and November and the highest in June, July, and September. The park contains the last remaining low rainforest ecosystem in southwestern Nigeria. The topography of Okomu National Park is sloping and ranges between 19m and 105 m above sea level (Orhiere, 1992; Olaniyi, 2018; Chukwu *et al.*, 2018; Oladejo and Eghenure, 2021). The park was gazetted from the former Okomu Forest reserve in 1935. The formal handing over of the protected area by the Edo State Government to the National Park Service was on 26th May 1999, which coincided with the signing of decree 46 of 1999 (now Act of the National Assembly, cap 65 of 2004) that established the sanctuary as a National Park into law the same day (NPS, 2014).

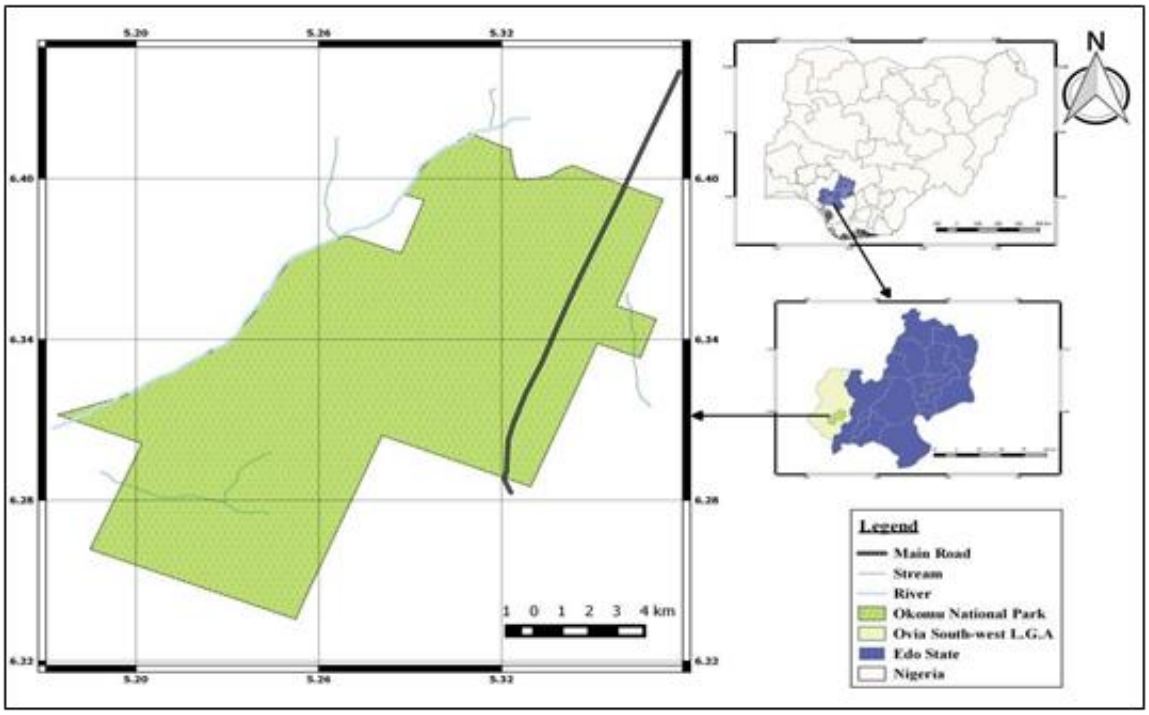

Figure 1: Map of Okomu National Park
Source: Chukwu *et al.* (2018).

Data Collection
Data used for this study was obtained from both primary and secondary sources. The primary data was obtained from direct field observations using a Global Positioning System (GPS) to acquire the coordinates of specific areas. The secondary data were from satellite imageries: Landsat 7 Enhanced Thematic Mapper Plus (ETM+) for 2002 and 2012, and Landsat 9 for 2022.

Data Processing and Analysis
All data preprocessing procedures were performed using QGIS (Quantum Geographical Information System) 3.30 software. The Semi-automatic classification plugin in QGIS 3.30 was used to calibrate the satellite images of the selected years to reduce radiometric errors. Radiometric calibration converts the digital number of pixels into spectral radiance values and the radiance into reflectance values (Raabe and Stumpf, 1997). To remove the influence of the atmosphere, the satellite images were atmospherically corrected using the Semi-automatic classification plugin in QGIS 3.30. The satellite images were processed using the QGIS 3.30. The mapped-out area for the analysis was subjected to a supervised classification analysis, and at this stage, the domain of the spatial parameters mentioned was adopted and subjected to the maximum likelihood classifier of the QGIS software.

In this study, land use/land cover classification used the following six classes: Water body, Built-up, Bare, Forest, Herbaceous, and Agricultural lands (Table 1). The LULC classification adopted the class features of Anderson *et al.* (1976) using the maximum likelihood model of the supervised classification, revealing the current land use in the area in the results output. Pixels were assigned to a class based on its feature vector by comparing it to predefined clusters in the feature space, and training sites were selected on the satellite images for each class. Other ancillary software used are Microsoft Word 2013 and Microsoft Excel 2013.

Table 1: Land use land cover class descriptions

LU/LC Classes	Description
Agricultural Land	Idle land being used for small-scale farming of rain-fed crops and cultivated areas.
Bare land	Areas with no dominant vegetation cover, including exposed rocks
Forest land	Areas with open woodland (15–65%), herbaceous layers, and closed broadleaved deciduous trees (>70–60%)
Waterbody	Areas permanently covered by water, which includes man-made dams and ponds.
Built-up area	Land that has been built on. It includes commercial, residential, industrial, and transportation infrastructure.
Herbaceous land	Including land with herbaceous closed vegetation (15–100%), permanent marsh, sparse tree, and shrub savannah

Land use changes were analyzed using contextual time analysis, subtracting the reference year from the base year. Tables and Percentages were used to provide insight into the extent of changes.

RESULTS
The land use/land cover classifications for 2002, 2012, and 2022 are shown in Figures 2- 4. Generally, over thirty years (2002- 2022), the changes in area coverage varied from one LULC class to another, with forested areas experiencing the most increase and water bodies undergoing the most decrease in area coverage.

The area covers and rate of change of LULC were presented in Tables 2 and 3, respectively. In 2002, Forestry and built-up lands had the highest and lowest percentage of area covering, 50.61% and 1.42%, respectively. The same trend occurred in 2012 and 2022, with Forested land having the highest cover of 49.84% and 58.35%, respectively, while the built-up area had the lowest percentage of area cover of 0.47%and 1.72 %, respectively. The trend of vegetation cover over the period revealed an increase in forested area, with a decrease in Herbaceous lands (Figure 6).

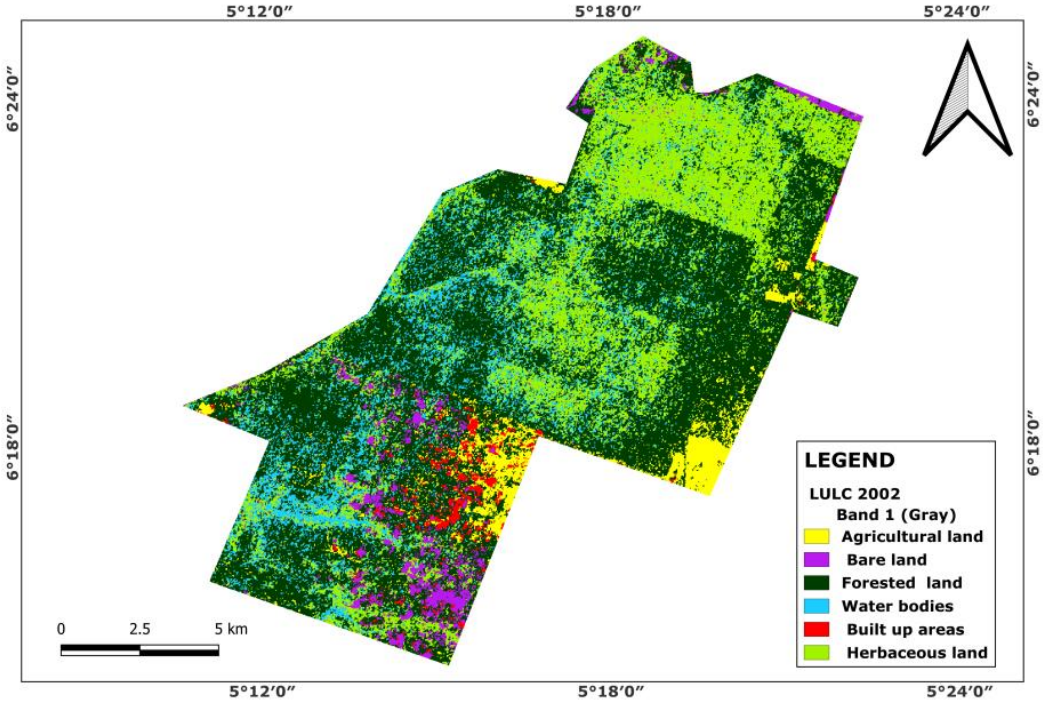

Figure 2: LULC of Okomu National Park for the year 2002

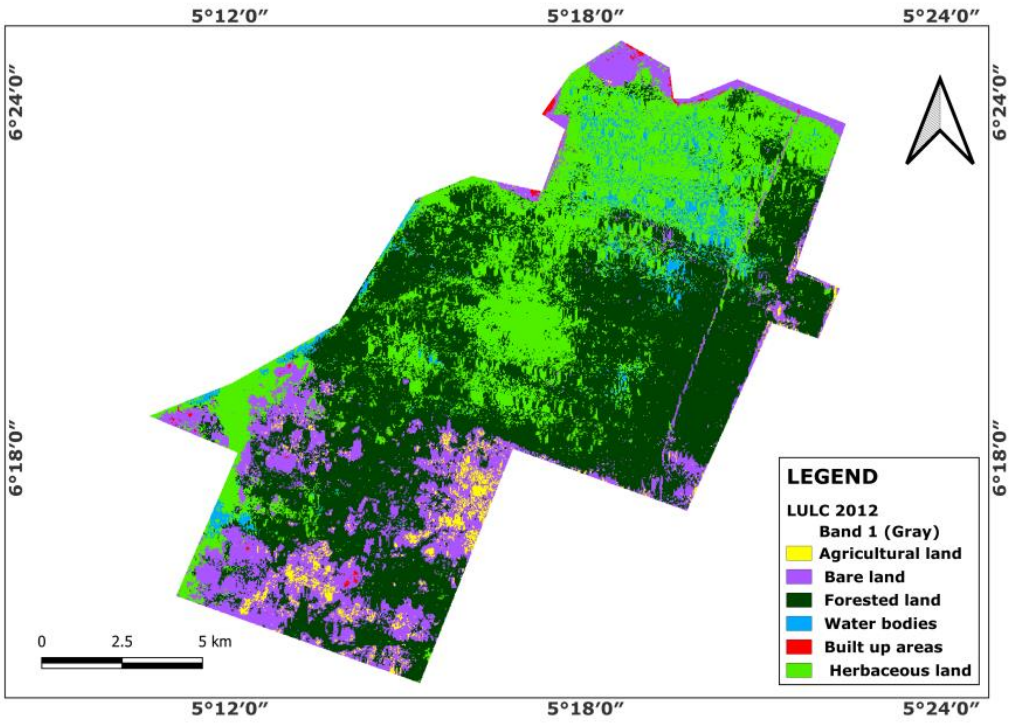

Figure 3: LULC of Okomu National Park for the year 2012

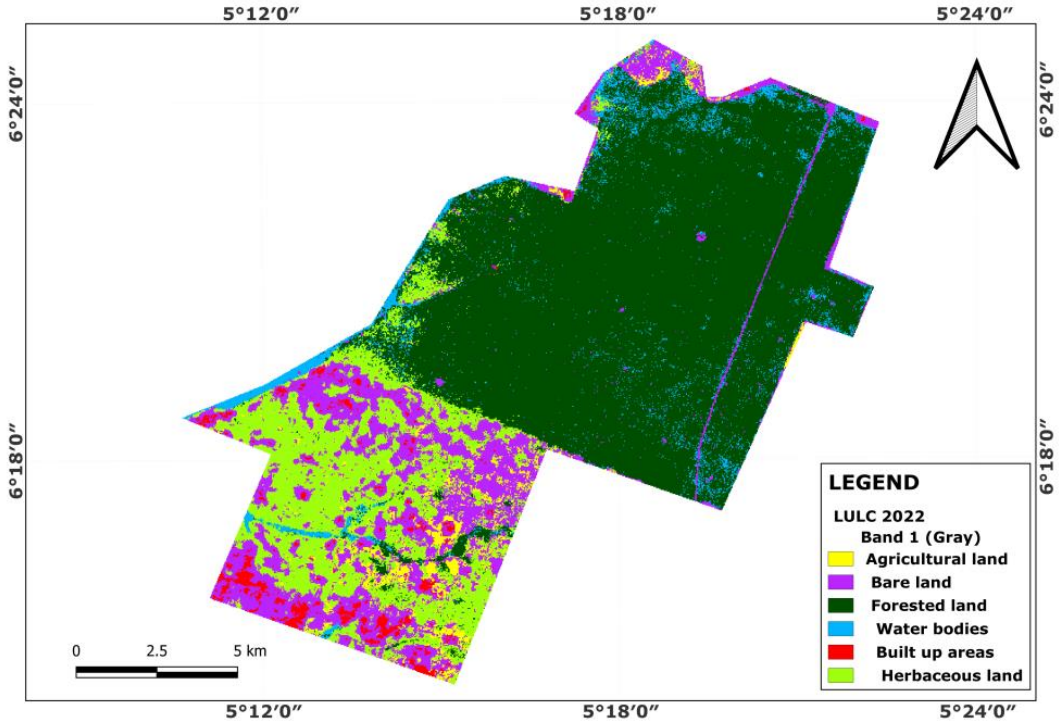

Figure 4: LULC of Okomu National Park for the year 2022

Table 2: Attributes of the LULC of Okomu National Park, Nigeria

LULC Classes	Area Cover					
	2002		2012		2022	
	km²	%	km²	%	km²	%
Agricultural land	9.90	4.82	4.34	2.11	5.28	2.57
Bare land	7.96	3.87	33.61	16.36	32.91	16.01
Forested land	104.01	50.61	102.43	49.84	119.91	58.35
Water bodies	26.87	13.08	7.50	3.65	9.82	4.78
Built-up area	2.92	1.42	0.47	0.23	3.54	1.72
Herbaceous land	53.86	26.21	57.15	27.81	34.04	16.56
Total	**205.5**	**100.0**	**205.5**	**100.0**	**205.5**	**100.0**

The LULC Changes of Okomu National Park are presented in Table 3. Between 2002 to 2012, the highest increase occurred in Bare land (25.65 km²), followed by 3.29 km² in herbaceous land. Forest area increased by 17.48 km², with a -23.11 km² decrease in herbaceous land between 2012 and 2022, making them the LULC classes with the highest and lowest rate of change (Table 3).

Table 3: The LULC Changes of Okomu National Park, Nigeria

LULC Classes	2012-2002		2022-2012	
	Change (km²)	Rate of change (km²/yr)	Change (km²)	Rate of change (km²/yr)
Agricultural land	-5.56	-0.56	0.94	0.09
Bare land	25.65	2.57	-0.70	-0.07
Forested land	-1.58	-0.16	17.48	1.75
Water bodies	-19.37	-1.94	2.32	0.23
Built-up land	-2.45	-0.25	3.07	0.31
Herbaceous land	3.29	0.33	-23.11	-2.31

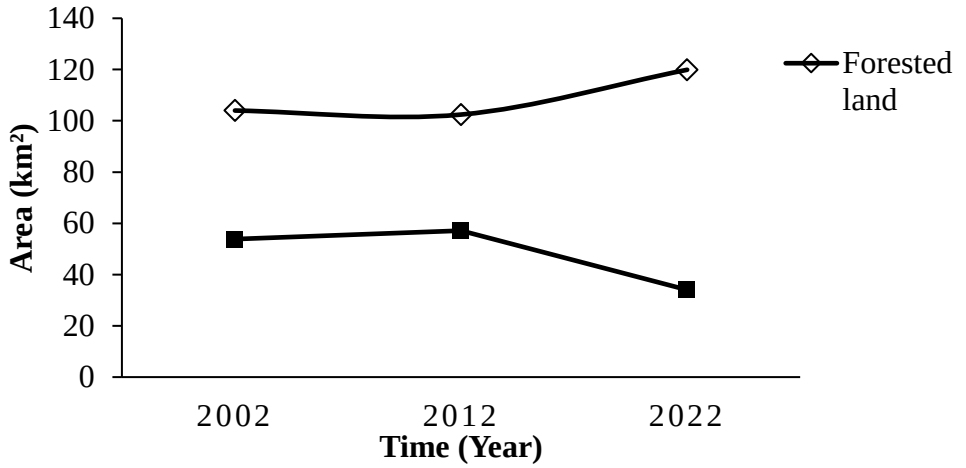

Figure 6: Vegetation Trend of Okomu National Park, Nigeria, from 2002 to 2022

DISCUSSION

This study integrated multi-temporal image classification with a geographical information system to reveal changes in the forest landscape of Okomu National Park. The study showed that changes occurred in all the LULC classes for the years studied. It agrees with Olaniyi (2018), Oladejo and Eghenure (2021), and

Osadolor and Chenge (2023), who made similar observations for the study area and its environs. The result of the study indicated that ONP has been dominated by forest, herbaceous, and bare lands. The bare and herbaceous lands might imply deforestation. This supports the claims made by Osadolor and Chenge (2023) that, despite the park management's intense efforts to stop encroachment and poaching, the forest gaps in ONP were signs of illegal logging.

The results further indicated a continuous increase in forested land. It could imply the conversion of other LULC classes to forest land and high conservation efforts in the park. It also suggests that the forested areas' natural recovery was aided by the protected area's existence. This biological succession resulted from the park's efficient ecosystem management (Djenont *et al.,* 2018; Olaniyi, 2018). This was also evident in the present study, which indicated a negative trend in the rate of change on bare and herbaceous lands per year between 2012 to 2022.

The study also revealed that Agricultural activities and built-up areas were highly reduced within the National Park; hence, agricultural activities, bare and herbaceous lands were concentrated in the southwestern part of the park; this also agrees with Olaniyi (2018), who made a similar observation and attributed the activities at the southwest edge of the National Park to a driver of LULC changes called "Okomu extension". Olaniyi (2018) further stated that the secondary forest and vast extent of high forest in the Okomu extension were converted to open shrub vegetation before the concession of the area to the protected area.

Furthermore, the study indicated a continuous increase in forest land from 2002 to 2022, which disagrees with Osadolor and Chenge (2023), who reported a continued decline of forest to other land cover classes with an annual rate change of 10% between 2000 and 2020. The disagreement might result from the differences in the scope of the area covered by both studies. The earlier included other forest areas and communities around the National Park, while the current study only focused on the ONP. However, the increase in the forest area indicates high conservation efforts by the National Park Service and other Non-Governmental Organisations (NPS, 2014).

CONCLUSION

The study revealed that changes occurred in the land use and land cover of Okomu National Park within the years investigated. The study concludes that the park is dominated by forest land, which increases yearly. It is therefore recommended that more conservation efforts, such as intensive tree planting, should be focused on the southwestern part of the park to reduce the agricultural activities and bare land and facilitate the conversion of herbaceous lands to forest.

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Ecological Niche Modelling for predicting the Impact of Climate Change on Habitat of *Cola nitida* (Vent.) Schott & Endl in Nigeria.

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Abstract

Cola nitida is an Indigenous multipurpose tropical tree species found in the tropical rainforest zone of West and Central Africa, and they play a significant role during traditional ceremonies. The species have been reported to be over-exploited and close to commercial extinction. Immediate conservation action is required for this species. This study assessed the impact of climate on suitable habitats for the cultivation of *C. nitida* in Nigeria. Application of bioclimatic modelling with soil data using Maximum Entropy (MaxEnt), two future climate models (HadGEM2-ES and CNRM-CM5) and two climate scenarios, Representative Concentration Pathways (RCP) 4.5 and 8.5 for the horizon 2050 were used as predictor variables for projections. The model's performance was validated by the area under the curve (AUC) and accurate skill statistics (TSS). The model revealed that climate change will significantly influence the future distribution of *C. nitida*. The future projections showed a substantial decrease in the suitable area for the species from the two climatic models used. About 20,403 $km^{2,}$ corresponding to about 38.6 % of Nigeria's surface area, are currently ideal for the cultivation of *C. nitida. T*he model reveals that it is expected to decrease by 27.3 and 21.2 %, respectively, under RCP 8.5 under HadGEM2-ES and CNRM-CM5 2050, and by 28.3 and 26.1% respectively under RCP 4.5 HadGEM2-ES 2050 and CNRM-CM5 climate model for 2050 horizon. The future projections showed a substantial decrease in the suitable area for *C. nitida* for the two-climate model and the scenarios used. Only the rainforest and derived savanna zones are currently ideal for cultivating the species, but it's expected to reduce drastically in 2050 due to climate change. Plantations establishment of *C. nitida* should be encouraged to enhance conservation options and the inherent agro-ecosystems services it provides.

Keywords: *Cola nitida*, species range, climate scenarios, bioclimatic, MaxEnt.

Introduction

Assessing spatial dynamics of suitable habitats of useful species is an essential step towards their domestication (Oladélé, 2011). Several modelling strategies for predicting the potential impacts of climate change on biodiversity have been developed over time. These have often focused on identifying a species 'bio-climate envelope' through techniques that correlate current species distributions with climate variables or through understanding species' physiological responses to climate change (Guisan and Zimmermann, 2000). This is because climate can exert a dominant control over species' natural distribution. Attempts to predict climate-change impacts on species relied on the species–climate 'envelope' modelling approach (ecological niche models). This can be achieved by using present-day distributions of species combined with environmental variables to project distributions of species in future climates (Pearson and Dawson, 2003). Despite the inherent limitations of correlative models (Guisan and Zimmermann, 2000), projections arising from

species–climate envelope models have been used to support estimates of species' extinction risk under climate change for a variety of taxa in different parts of the world (Thomas *et al.*, 2004; Bakkenes *et al.*, 2002; Erasmus *et al.*, 2002; Peterson *et al.*, 2002). The application of future climate change scenarios enables the potential redistribution of the species' climate space to be estimated. Kakpo *et al.* (2019) documented that knowledge of the spatial distribution of a species is critical for evaluating extinction risks and forecasting possible future threats from factors such as climate change (Pacific *et al.* 2015; Urban 2015; Ganglo and Kakpo 2016). Ecological niche models (ENMs) are used to understand the ecological requirements of species, predict geographic distributions, and forecast the effects of environmental change (Peterson *et al.*, 2011; Ganglo *et al.*, 2017; Djotan *et al.* 2018). Studies of geographic distributions of vector species using ENM techniques relate occurrence records and environmental characteristics across species distributions (Kakpo *et al.* 2019).

Cola species is a tropical African genus of the Malvaceae family, which comprises about 125 species. *Cola* species are evergreen, mostly small, or moderately sized trees, although a few grow to 25 m. Several *Cola* species are widely cultivated in tropical countries like Africa. *Cola nitida* is among the most used species in the genus. *C. nitida* was initially distributed along the west coast of Africa from Sierra Leone to the Republic of Benin, with the highest frequency and variability occurring in the forest areas of Côte d'Ivoire and Ghana (Opeke, 1992). *Cola nitida* (kola nut) is mainly found in the wild in Nigeria and is not well cultivated. It is an essential economic cash crop for a significant proportion of rural populations in Nigeria. The species is used as a masticatory stimulant by Africans and has numerous uses in social, religious, ritual, and ceremonial functions by the natives in the forest region of Africa (Asogwa *et al.*, 2006). It is used during ceremonies related to marriage, child naming, and installation of Chiefs, funerals, and sacrifices made to the various gods of African mythology (Egbe 1989, Opeke 2005). There is also increasing demand for its usage in pharmaceutical industries and the production of soft drinks, wines, and candles (Ogutuga, 1975). Asogwa *et al.* (2012) reported that the problem of low yield of kola could be traced to changing climatic conditions. Dinar *et al.* (2006) reported that Nigeria is vulnerable to climate change, which is evident by the low crop yield of this species in the study area. This shows the need to initiate studies to understand the impact of climate change on the distribution of this species. It has been acknowledged that *C. nitida* can meet the social and cultural needs of the populace. The decline in the population of the species has been reported (Asogwa *et al.* 2006), hence, the loss of ecosystem services provisioning by the species. Despite this, these species have received little attention in ascertaining the significant impacts of climate change on suitable habitat and distribution. This knowledge gap was carefully examined through this study; the knowledge is vital in developing scientific solutions to inherent climate change-induced difficulties towards the conservation of *Cola nitida* in Nigeria.

Material and Method

Study Area

The study was carried out in West Africa, focusing on Nigeria, located in the Gulf of Guinea. Nigeria has an area of 923,768 square kilometres, including about 13,000 square kilometres of water. The country has five major geographic regions (a low coastal zone along the Gulf of Guinea; hills and low plateaus north of the coastal zone; the Niger–Benue River valley; a broad stepped plateau stretching to the northern border with elevations exceeding 1,200 meters; and a mountainous zone along the eastern border, which includes the country's highest point). The climate is arid in the north, tropical in the centre, and equatorial in the south. The mean maximum temperatures are 30º C–32º C in the south and 33º C–35º C in the north. The annual rainfall

decreases northward; rainfall ranges from about 2,000 mm in the coastal zone (averaging more than 3,550 mm in the Niger Delta) to 500–750 mm in the north.

Data Collection

Sixty-two (62) occurrence points (coordinates) were collected from fieldwork across Nigeria, and an additional occurrence of 213 points were obtained within West Africa from the Global Biodiversity Information Facility portal (GBIF, 2018). Hence, a total of 258 points were collected (Figure 1). The occurrence data were filtered carefully by sorting and removing duplicate records with ENM tools known as Perl script. The data were then reduced to 143 points, used for the model (Figure 2). Climatic data in this study comprised data from environmental layers, which is one of the critical factors influencing species occurrences niche over broad extents (Parviainen *et al.* 2008; Pearson and Dawson 2003). Nineteen (19) bioclimatic environment layers at a 30 arc seconds resolution, obtained from Worldclim, were examined (DAN *et al.* 2011; Idohou *et al.* 2016). The relationship and correlation among all variables were carefully analysed using the Pearson correlation coefficient to eliminate closely related variables. Variables below 0.80 were selected (Elith *et al.* 2010). To assess possible influences of climate change on the habitat and distribution of *Cola nitida.* The current model rule sets were conveyed to the selected future climate models (HadGEM2-ES and CNRM-CM5) (Idohou *et al.* 2016; Good *et al.* 2013). The two selected climate models are based on the 8.5 and 4.5 Representative Concentration Pathways (RCP) for the year 2050 outlook of expected rainfall and temperature. In the scenarios, demographic and land use were incorporated in the model (Moss *et al.* 2010). Selected species distribution modelling in the Benin Republic of West Africa has been done with the RCP 8.5 and 4.5 (Kakpo *et al.* 2019; Hounkpèvi *et al.* 2016).

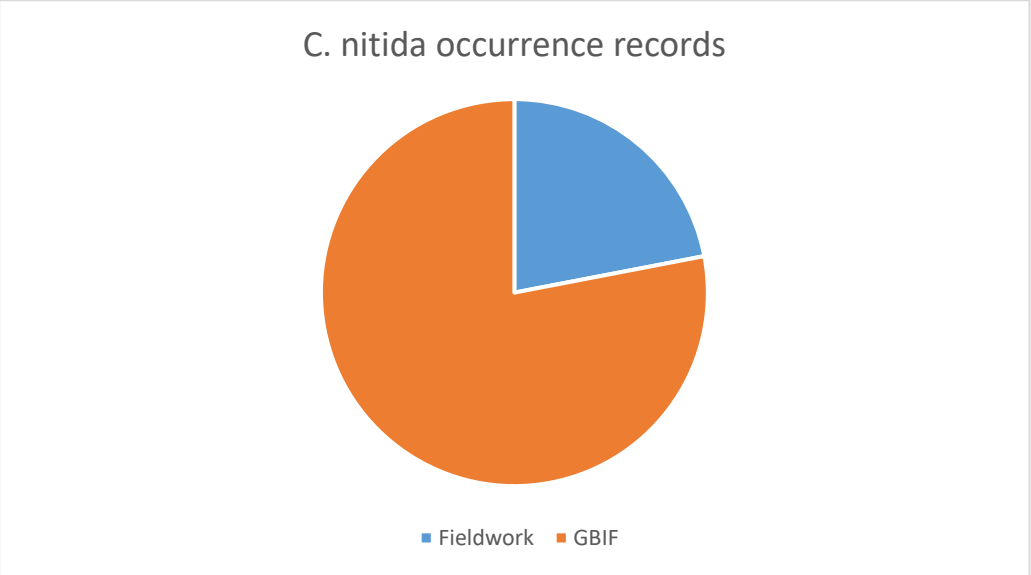

Figure 1: Species occurrence records for *C. nitida*

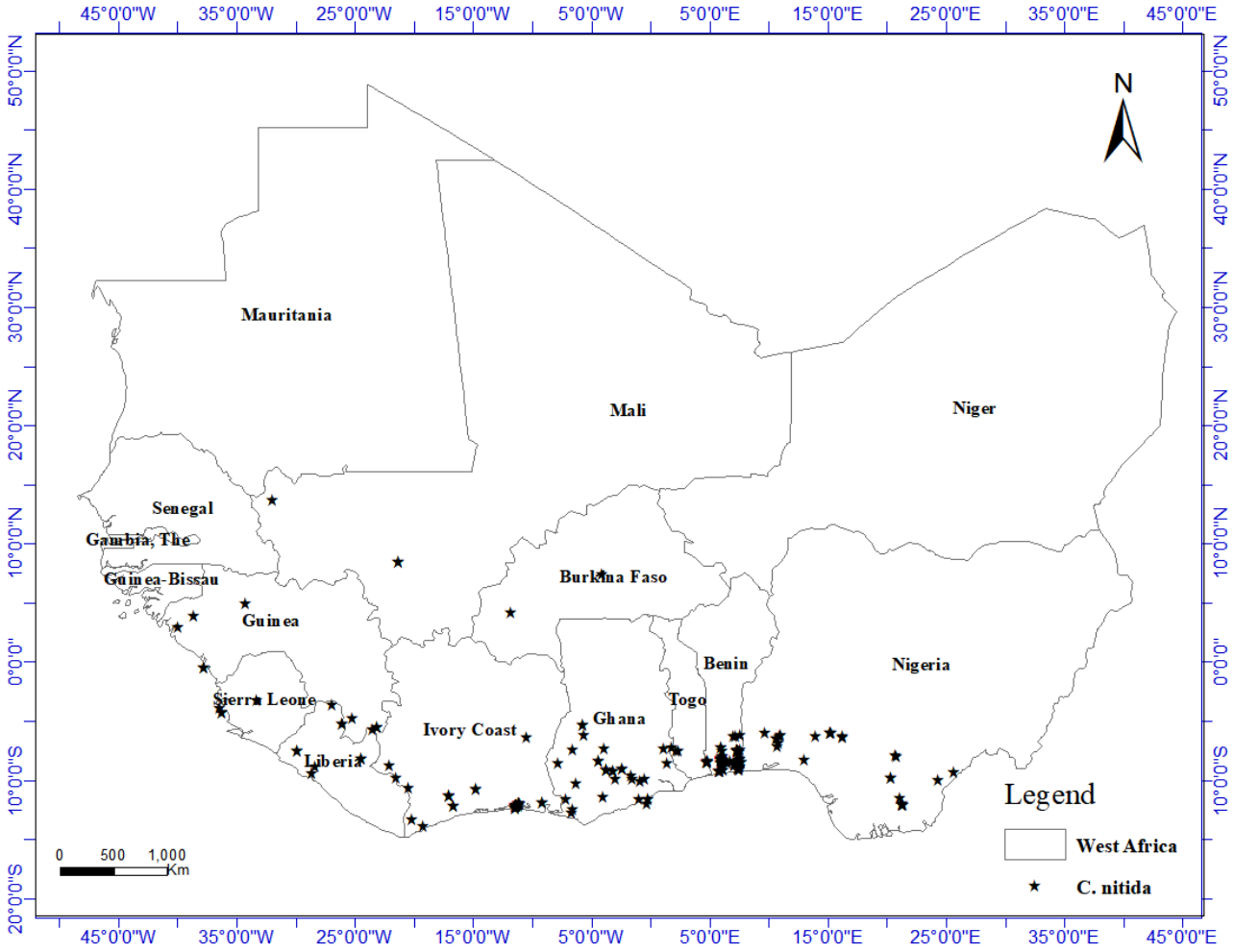

Figure 2. Occurrence points and sampling of *C. nitida* across the West Africa Landscape

Species distribution modelling

The maximum entropy approach (MaxEnt) has been used for species distribution modelling. The software is based on probability density estimation, which uses species occurrence coordinates, location, and bioclimatic variables to predict temporal and spatial species distribution. The selected variables in the distribution model were subjected to the Jackknife test to ascertain the percent contributions. Data were examined and corrected for geographic sampling bias using background data, which was reported to be substantial improvement in model performance as Syfert et al. (2013) described. We generated background data, also known as ‘‘pseudoabsences,’ which has an identical geographical sampling bias to that of the presence data. For this study, 70% of the species occurrence points were used as training data and the remaining (30%) were used as testing data to test the model’s predictive strength. For each species, we executed 10 replicates using cross-validation/repeated split samples to measure the variability in the model and then averaged the results. The threshold for maps was reduced to binary to avoid the effects of fitting (Peterson *et al.* 2007).

Model evaluation.

Models were divided into a subset for training or building the models (75%) and testing (25%) of the models for performance assessment. Receiver operating characteristics were used to appraise the

performance of MAXENT's ability to predict the distribution of *C. nitida* in Nigeria. The sensitivity and specificity of the model were assessed using the area under the curve (AUC). When the AUC (Figures 3 and 4) value of a model is ≥ 0.75, such models are said to predict spatial and temporal occurrence of species accurately (Idohou *et al.* 2016, Hounkpèvi *et al.* 2016). The capacity of the models to predict actual presence and absence was further validated with TSS. The accuracy of the TSS in the prediction model is evaluated with a TSS of ≤ 0, indicating a random prediction, while a model with a TSS greater than 0.5 and close to 1 has good predictive power (Allouche *et al*., 2006). The logistic probability distributions generated by MaxEnt using the 10th percentile training presence logistic threshold were used to assess the potential habitat suitability of the species in Nigeria. Suitability of occurrence was based on areas above the threshold, whereas regions below the threshold were considered not suitable (Hounkpèvi *et al.* 2016, Scheldeman and van Zonneveld, 2010). Map production for habitat suitability and unsuitability was done in ArcGIS 10.3 (ESRI, 2014).

Results

Contribution of Environmental variables and Model validation

The correlation analysis and Jackknife AUC test identified six bioclimatic variables as the most contributing environmental variables to the model across the study region. The model revealed that Precipitation of the Driest Quarter is among the most contributing variables and predictors driving the species distribution for *C. nitida,* and its contribution was about 56.7 %. Other contributing variables for *C. nitida* were the Mean Temperature of the Driest Quarter, Precipitation of the Warmest Quarter, Annual Mean Temperature and Temperature Annual Range. These variables significantly affect the gain when used in isolation or removed from the modelling process. The model had a goodness-of-fit value (cross-validated average AUC = 0.97 ± 0.02) for *C. nitida* (Fig. 3). This low standard deviation value indicates a limited dispersion of AUC values among the replicates. The True Skill Statistic (TSS) test values with 10th percentile training presence (the threshold values) were 0.26. Areas with occurrence probability above this threshold were then considered suitable for the species, while the remaining areas were considered unsuitable. The TSS values of 0.87 showed very good predictive power and yielded statistically significantly better predictions than random. Concerning the importance of bioclimatic variables and model performance, the results showed that six out of the 19 bioclimatic variables contribute to environmental variation across the study region for the suitability of *C. nitida* in Nigeria (Table 1).

Table 1: Variables contribution in each of *Cola nitida* species model

	Variables	***Cola nitida* Model**
Bio19	Precipitation of Warmest Quarter	12.6
Bio17	Precipitation of Driest Quarter	56.7
Bio15	Mean Temperature of Driest Quarter	4.2
Bio13	Precipitation of Wettest Month	5.8
Bio7	Temperature Annual Range	17
Bio1	Annual Mean Temperature	3.5

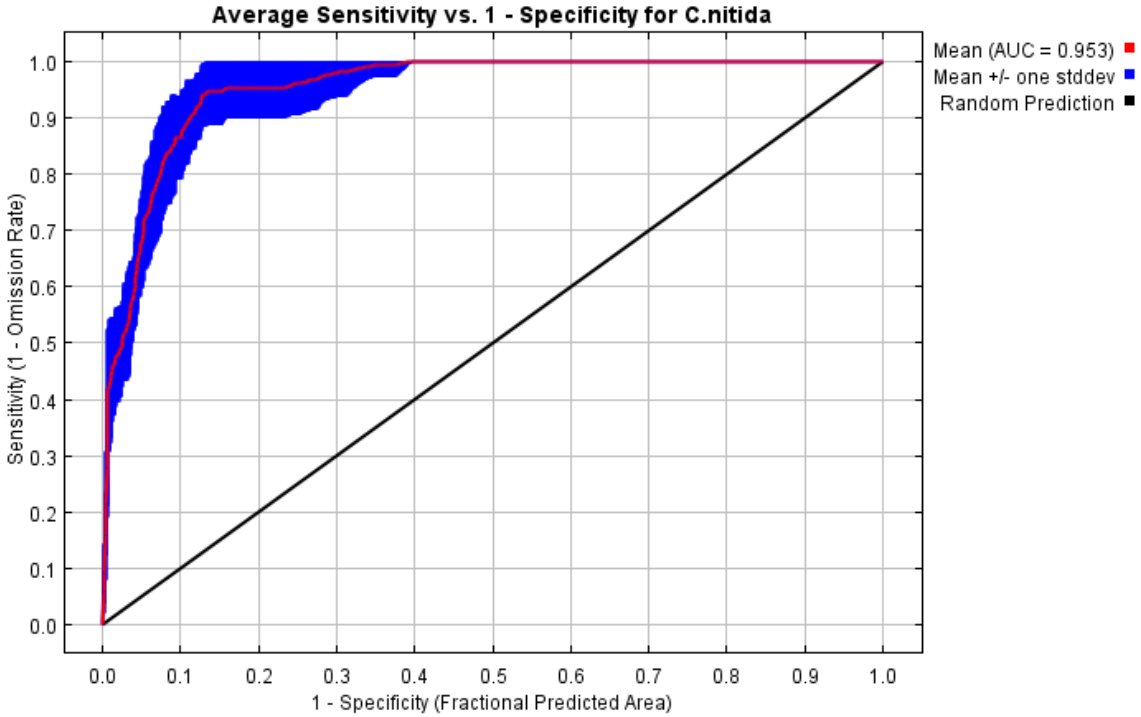

Figure 3: Receiver operating characteristic

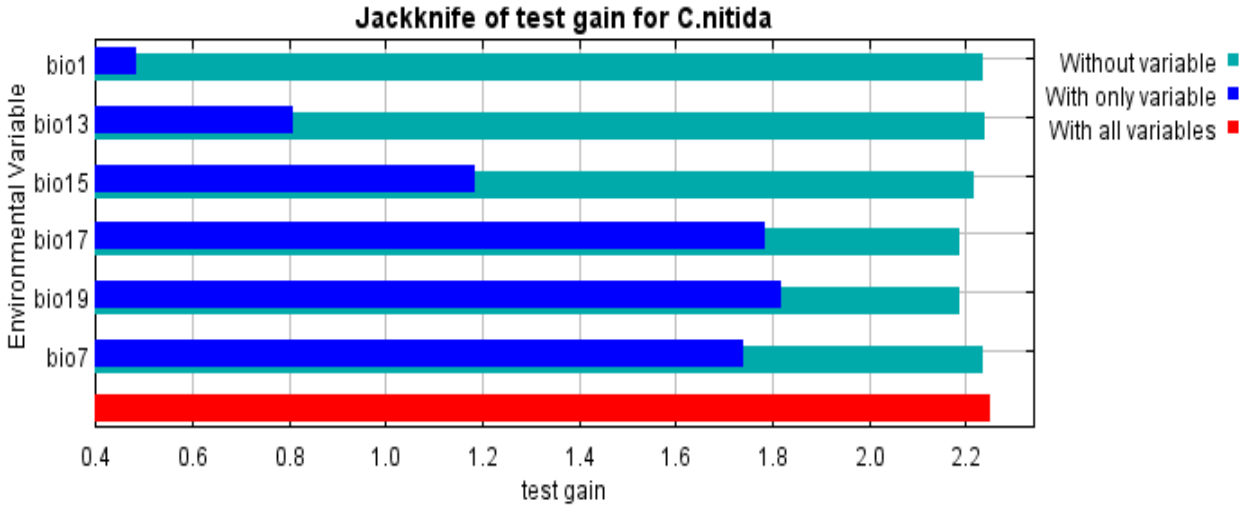

Figure 4: Jackknife tests of gain for *C. nitida*

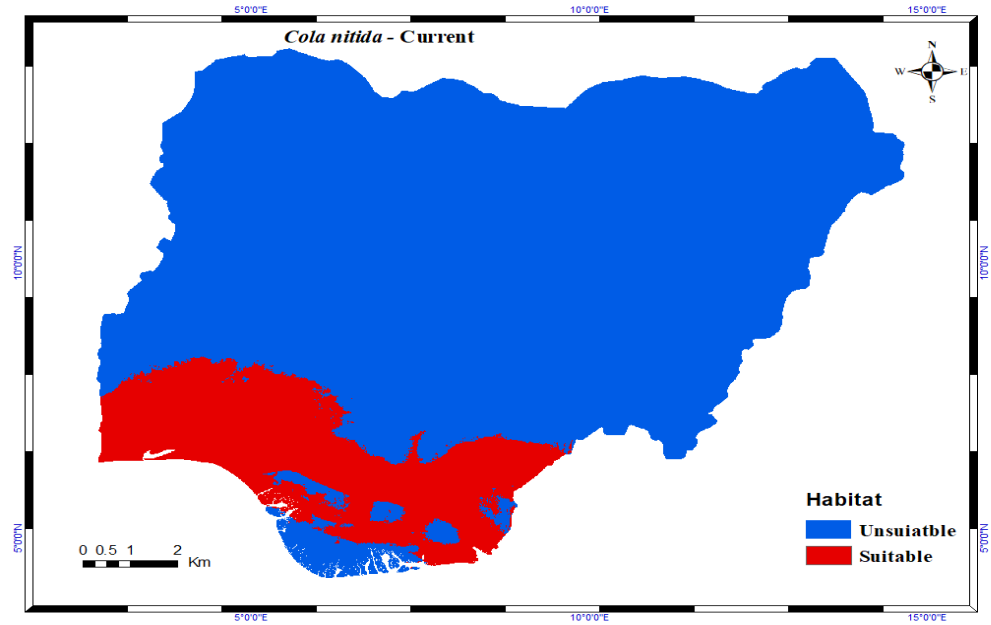

Figure 5: *Cola nitida* distribution model in Nigeria mapped under current climatic conditions.

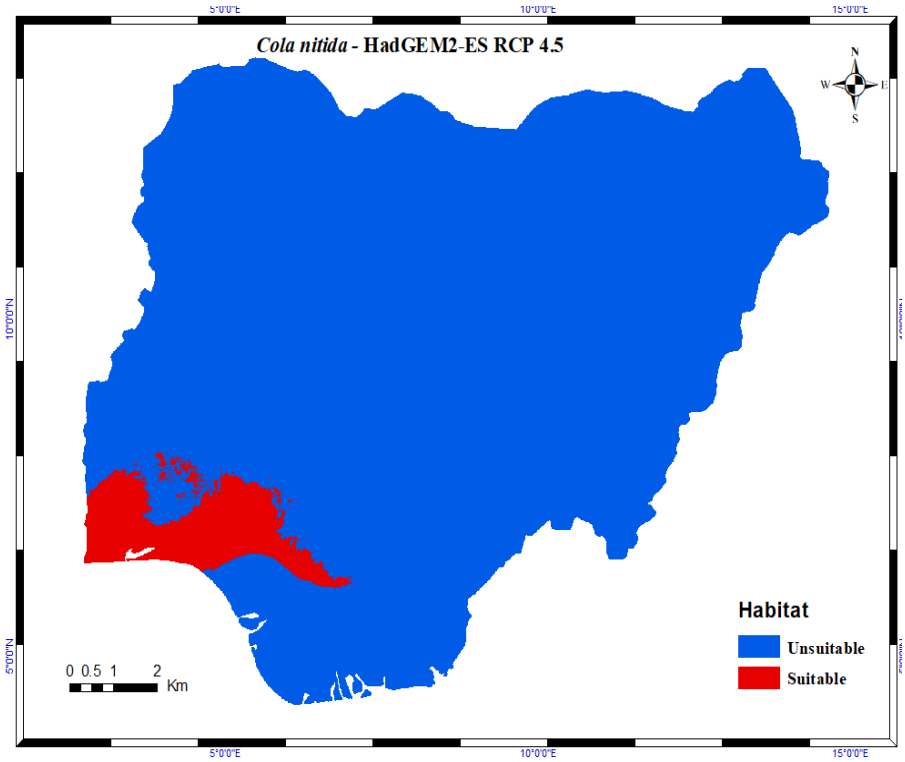

Figure 6a: *Cola nitida* distribution model in Nigeria mapped under future climatic conditions.

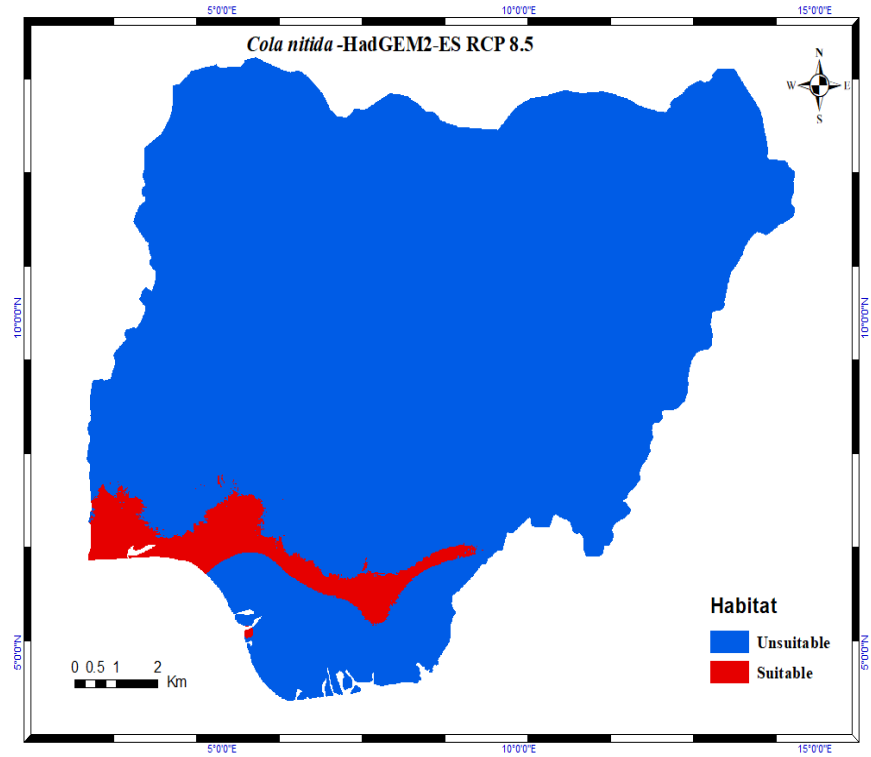

Figure 6b: *Cola nitida* distribution model in Nigeria mapped under future climatic conditions.

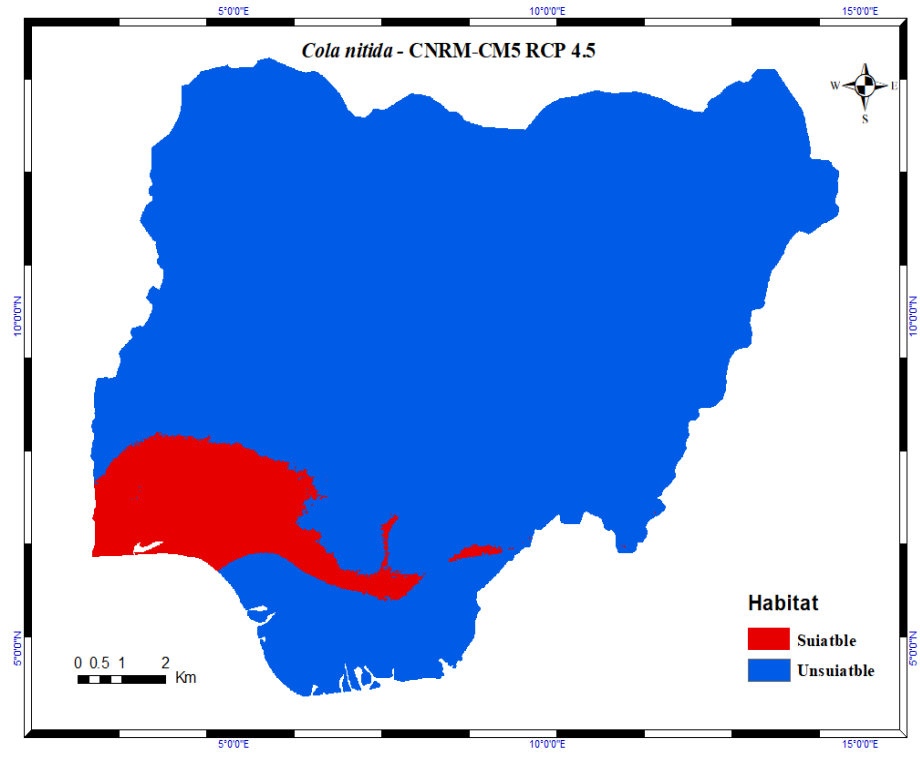

Figure 7a: *Cola nitida* distribution model in Nigeria mapped under current and future climatic conditions.

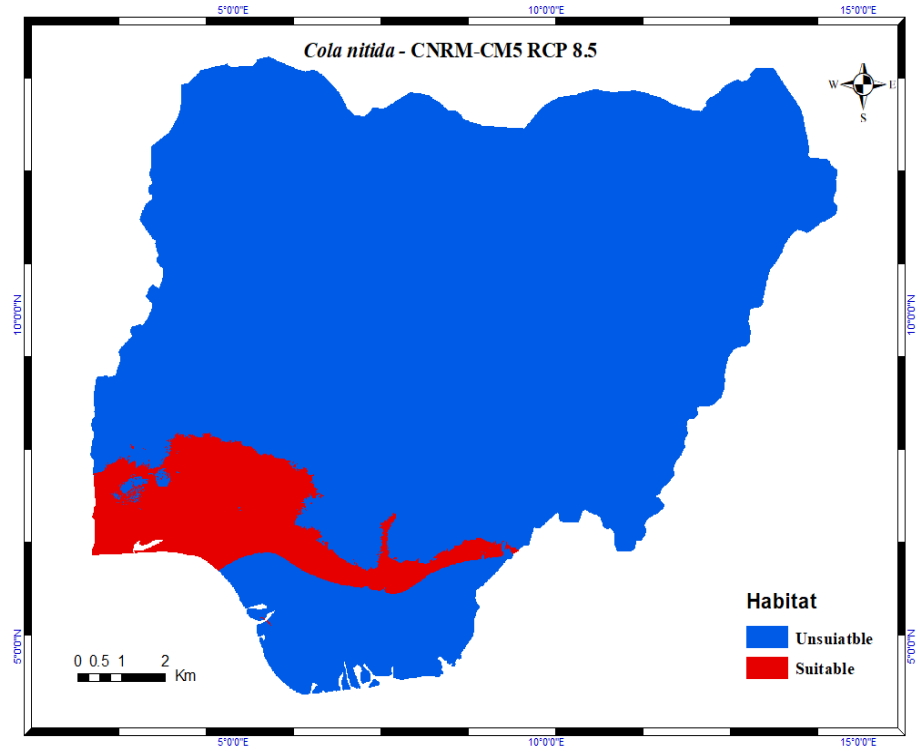

Figure 7b: *Cola nitida* distribution model in Nigeria mapped under current and future climatic conditions.

The Current and Future suitable habitat for cultivating *Cola nitida* in Nigeria.

The model revealed that about an area of 558,300 km^2 of Nigeria's land size, which corresponds to 38.6 % of Nigeria's land surface area, is currently suitable for the cultivation of *C. nitida* (Fig. 5). The suitable area in Nigeria is limited to a moist, humid area and some parts are of derived savanna zone. Hence, this shows that the species is a tropical rainforest species (Fig. 5). The future projections showed a substantial decrease in the suitable area for the two-climate model and the two RCP scenarios used for the study (Table 2, Fig. 6). The model HadGEM2-ES 2050 predicted under RCP 4.5 and 8.5 that the suitable area will reduce from 36.6 % to 10.3 and 11.3% respectively, which indicates a loss of about 26.3 and 25.3 % respectively (Fig. 6 & 7). The future distribution with CNRM-CM5 by the year 2050 under RCP 4.5 and 8.5 scenarios will reduce to 12.5 and 17.4 % (Table 2, Fig. 7). The model predicted that about 102,916 and 157,562 of total Nigeria's land area will be suitable for cultivation of *C. nitida* under RCP 8.5 for CNRM-CM5 and HadGEM2-ES 2050. Only some parts of the humid area and little parts of the derived savanna zone will remain suitable.

Table 2: Dynamic of suitable areas for *Cola nitida* accounting for the present and the two future models

Species			*Cola nitida* Suitability	
			Unsuitable	Suitable
Present		Area (km2)	558,300	351,556
		Trend (%)	61.3	38.6
HadGEM2-ES	RCP 4.5	Area (km2)	816,958	93,809
		Trend (%)	89.7	10.3
	RCP 8.5	Area (km2)	807,851	102,916
		Trend (%)	88.7	11.3
CNRM-CM5	RCP 4.5	Area (km2)	796,922	113,846
		Trend (%)	87.5	12.5
	RCP 8.5	Area (km2)	752,294	157,562
		Trend (%)	82.6	17.4

Discussion

Climate change is becoming evident across regions and in many sectors that are important to society. Darrah *et al.* (2017) reported that it is essential to identify species with a high risk of extinction, and effort should be made to encourage their domestication. Species distribution modelling has been widely used to determine habitat suitability patterns at large spatial scales and to produce spatially explicit and comprehensive maps that are particularly useful for identifying areas where conservation efforts are mostly needed. Previous works (Walther, 2003; Adomou *et al.*, 2006; Sommer *et al.*, 2010; Hounkpèvi *et al.*, 2016) had reported biotic and abiotic factors' potential role in species distribution modelling and habitat suitability patterns. IPCC (2007) and Busby *et al.* (2010) showed that climate change will affect the distribution of several species. Species distribution modelling techniques considering information on habitat requirements derived from known occurrence sites is widely used to predict species' potential habitat under current or possible future conditions (Phillips *et al.* 2006; Sommer *et al.* 2010; Schwartz 2012).
MaxEnt is a mostly used ecological modelling tools for predicting suitable habitats and assessing species' geographic range and their realized niche (Breiner *et al.* 2017). It is a machine learning method that estimates species distribution across a study area by calculating the distribution probability of maximum entropy, subject to the constraint that the expected value of each feature under this estimated distribution should match its empirical average (Phillips *et al.* 2006). MaxEnt has been widely used for niche modelling to assess the impact of climate change on species, which largely depends on environmental factors. The current study used direct bioclimatic variables (such as temperature and precipitation) as recommended and reported to be more efficient when the modeling is over large areas (Guisan and Zimmermann 2000).

The results of this study revealed that the present distribution range of this species is more marginal in the tropical, moist and some part of the derived savanna area of Nigeria. The

studied species is indigenous evergreen tropical rainforest tree species. *C. nitida* grows in moist deciduous lowland forests, wet land with a high-water table and occurs in hot, humid climates such as derived savannas (Orwa *et al.*, 2009). The suitable areas shown by our models that *C. nitida* conforms to the ecological and geographical descriptions of the species by Orwa *et al.* (2009). According to the results presented, the favourable zones correspond to parts of the moist (coastal areas) and lowland rain forests and derived savanna in Nigeria. Our study observed that precipitation and temperature are essential variables in the occurrence of *C. nitida* in Nigeria. The results confirmed an earlier report by Idohou *et al.* (2016) that the balanced influence of environmental factors (precipitation and temperature) are important factors in controlling species occurrence patterns in subtropical and tropical zones.

Precipitation of the Driest Quarter was discovered to be the most contributory environmental factor for the distribution of *C. nitida.* It provides total precipitation during the driest three months of the year, which can be helpful in examining how such environmental factors may affect species seasonal distributions. It is very appropriate because *C. nitida* is a moisture-dependent species. Precipitation of the warmest quarter is also among the contributing factors which is the quarterly index approximates total precipitation that prevails during the warmest quarter and can be helpful for examining how such environmental factors may affect species seasonal distributions. Temperature annual range measures temperature variation over a given period and is useful when examining whether species distributions are affected by ranges of extreme temperature conditions. The species maintain their occurrence range in the current distribution area and show variation in the potential future habitat suitability. Variations have primarily been reported in climate change modelling kinds of literature and often due to variations in climate scenarios (Araujo and New, 2007; Thuller, 2004). The results agree with the findings of Kakpo *et al.* (2019), who reported that under the RCP 4.5 and RCP 8.5, future projections showed a high decrease in suitable habitat for *M. excelsa*. They documented that the Miroc 5 model predicts under the RCP 4.5 a loss of 42.3% of the currently suitable habitats and about 39.4% under the RCP 8.5 by 2055. This decrease in habitat suitability could be due to significant changes projected for bioclimatic parameters such as precipitation and temperature (Daïnou *et al.* 2012). The fluctuations in climate variables such as precipitation and temperature will impact biological diversity and the geographical distribution of suitable habitats (Busby *et al.* (2010). Our results are also in the same direction as those of Thomas et al. (2004) and Thuiller et al. (2014), who documented that many European species could be threatened by future climate change. They opined that under the assumption of no migration, more than half of the species they considered would become vulnerable or committed to extinction by 2080 (Thuller, 2014). According to Thomas *et al.* (2004), a reduction in the potential geographic range of a species could likely lead to an increased risk of local extinction. A decrease in range size implies that smaller stochastic events affect a more significant proportion of the species' total population, especially in fragmented landscapes (IUCN, 2011). The results of this study do not agree with that of Hounkpèvi et al. (2016) who reported that climate change will positively impact the future habitat suitability of *Vitex doniana* in Benin Republic, West Africa.

Conclusion

Cola nitida is listed among priority species for immediate conservation action in sub-Saharan forests, and hence, its suitable ecology and distribution are very important for conservation plans. The present study estimated current and future distribution and suitable ecology for the cultivation of *C. nitda* in Nigeria. The results revealed that *C. nitda* can survive and be more

subservient in moist, humid areas and some parts of the derived savanna zone in Nigeria. The study has shown that climate change will have a significant negative impact on the future suitable ecology of *C. nitida* in Nigeria, based on the two 2050 climate models used for the study. The suitable habitat is predicted to decrease in Nigeria under two climate models and scenarios used to study, which are both representative concentration pathway scenarios. Despite the ecological and socio-economic potential of *C. nitida*, the species still received little attention in the conservation plan in Nigeria. Immediate action should be initiated to conserve this valuable species. The species was reportedly over-exploited due to numerous human activities and climate change. The results have led to some conclusions that may be a helpful tool to guide resource managers and decision makers, government agencies and research institutes on the need to conserve this important species and the scientific rationale to facilitate conservation action has been highlighted.

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Environmental Temperature Changes, Forest degradation and Food security in Nigeria

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Abstract

This study examined the impact of forest degradation, precipitation, relative humidity, and temperature anomaly on food insecurity, controlling for sub-national HDI and drought. The data for this study were secondary data obtained from World Development Indicators. The data on climate, such as temperature in ^{o}C, average annual precipitation in mm (millimetres) and relative humidity in percentage (%) from 2003 to 2023, were obtained from the Nigerian Meteorological Agency located at Bill Clinton Drive, Nnamdi Azikiwe International Airport, FCT, Abuja, Nigeria. The result showed that carbon emission was positively significant and revealed a 27.9% considerable impact on moderate to severe food security in Nigeria. With an increase in carbon emission, there is an increase in moderate to severe food insecurity by 27.9% in Nigeria. Temperature changes between 0.2-0.4 ^{o}Celsius and 0.6-0.8 ^{o}Celsius showed statistical significance, indicating moderate to severe food insecurity. In precise terms, this suggested that an increase in temperature between 0.2-0.4 degree Celsius will increase the level of moderate to severe food insecurity in Nigeria by 22.6%. For severe food insecurity, Commercial wood extraction/harvest, precipitation and fuelwood and non-timber forest products reverse roles on their effect on food insecurity. Conclusively, the significance of temperature changes and forest depletion on food insecurity cannot be overlooked. The study showed that temperature rise significantly increases severe food insecurity.

Keywords: Climate change, depletion, wood, temperature and food insecurity

Introduction

Climate Change is the 21st Century global reality and conceivably the greatest environmental threat (FAO, 2019). In the past few decades, climatic changes have been observed globally, and in Nigeria, the changing climate is evident from the increase in temperature and rainfall variability, amongst other changes (Iwuji *et al.*, 2022). Numerous studies, such as Ukaegbu *et al.* (2017), have demonstrated how concerning these fluctuations might be when compared to significant meteorological indicators like temperature, precipitation, and humidity. Climate change constitutes one of the challenges to food security. Its impact on food security has been concerning and unsettling. It is a significant contributor to the unprecedented hunger that has affected many people and livelihoods, thereby contributing to food insecurity in the country. According to the World Food Programme (2023), Nigeria, Africa's biggest economy and most populous country, has the world's fifth highest burden of people experiencing food crisis or worse, exceeded only by Yemen, Ethiopia, Afghanistan, and the Democratic

Republic of the Congo. Nigeria's human development potential remains unfulfilled, and its most vulnerable people continue to suffer critical levels of food insecurity and malnutrition driven by persistent conflict, organized violence, recurrent climate shocks and broad exposure to the impact of climate change.

According to the United Nations Nigeria (2022), developing countries are the most vulnerable and affected by climate change's effects. The main reason is the harmful effects of climate change resulting from disasters and the lack of capacity to cope with these forces. Likewise, drought and rising temperatures also threaten food security. Climate change may limit water availability and negatively impact agricultural productivity through reduced water availability, increased extreme events such as floods and storms, heat waves, and increased pest and disease outbreaks. Additionally, research by the [National Oceanic and Atmospheric Administration] (NOAA, 2020) shows that the average temperature of land and oceans (0. 130F/0.080C) in the decade since 1880, but the average increase since 1981 (0.180F/0.320C) has more than doubled that rate. It is also known that temperature changes have different effects on hydrological processes, directly or indirectly (Diagi and Weli, 2017). Paradoxically, human activities continue negatively impacting the environment, leading to climate change. Forests play an essential role in the global climate system by using carbon dioxide and releasing oxygen through photosynthesis (Brack, 2019). However, the role of forests in environmental degradation cannot be overemphasized, as forests play a significant role in the use of carbon emissions worldwide and can replace fossil fuels, which continue to be contributors to world warming. This is one of the many benefits forests provide to the world's environment (FAO, 2019). In this context, forests also regulate waterways and protect soils.

Among the effects of climate change on forests, A decrease in the health and productivity of forests and a change in the physical structure of some trees are essential because they threaten tree production, outdoor recreation, 'water quality, animals, and carbon storage costs [Intergovernmental Panel on Climate Change] (IPCC, 2007). Therefore, the way to protect, preserve and protect forest degradation is a good way because the conservation of natural resources has been proven to be the key to the future. Forests: Forests affect the land by providing food, forest products, clean water, natural beauty, biodiversity, outdoor recreation, natural resource activities, renewable energy, and carbon sequestration. To mitigate the effects of climate change, many development organizations and national governments have recognized the critical role of forests (Griscom *et al.,* 2017; Watson *et al.,* 2018). The unique role of forests in combating climate change is based on their ability to sequester carbon and reduce greenhouse gas emissions (IPCC, 2014). The climate in Nigeria has changed over the years; this is evident; the temperature is increasing; distorted rain patterns; sea level rise and flooding across the country; droughts and deserts were recorded; land degradation; extreme weather; affected freshwater resources and ecosystem loss (Gemeda and Sima, 2015). Similarly, forests are an important economic development resource for many developing countries such as Nigeria (Philip *et al.,* 2014). This is because Nigeria is highly dependent on natural resources such as forestry, agriculture, and climate (Afolabi, 2020).

In addition to global climate change mitigation and adaptation measures, Nigeria has developed and implemented measures to address the various impacts of climate change. For example, Nigeria Intended National Contribution (NINDC) aims to address the effects of climate change. The overall goal of this policy focuses on implementing measures that will

reduce the effects of climate change on food security and increase the pace of economic development. For example, the National Adaptation Strategies and Plan of Action for Climate Change in Nigeria (NASPA-CCN) sets climate change priorities to increase resilience to the adverse impacts of climate change (Afolabi, 2020). However, with appropriate forest management measures, Nigeria's forests can be used to address the country's climate change challenges. Additionally, climate change mitigation through forestry provides a cost-effective and sustainable response to Nigeria's climate change and food security challenges. This article generally examines climate change, deforestation, and food insecurity in Nigeria.

Methodology

Nigeria is located between latitudes 4ºN and 14ºN and longitudes 3ºE and 15ºE (Elan, 2008) and accounts for approximately 14% of the West African land area (Federal Ministry of Environment [FME] 2014). Nigeria has tall forests, virgin forests, forests, and farms. Nigeria has an abundance of forest resources. The country forests reserve occupies 110,890 km^2 of Nigeria's 910,770 km^2 total land area (Ba *et al.,* 2024). Approximately 445 gazette reserves are covering five ecosystems of freshwater/mangrove, lowland rainforest, savanna, and Sahel/Sudan savanna (Afolabi, 2020). More than 5% of all land is devoted to nature conservation. The forest area is unique due to its high rainfall (500mm-3000mm), biodiversity and temperature of 27 ºC (Afolabi, 2020). These ecological dynamics divide Nigerian forests into five forest ecosystems: freshwater/mangrove, rainforest, savannah, Guinea savannah and Sudan/Sahel region Guinea, Sudan and Sahelian savannas) (Eludoyin *et al.,* 2014).

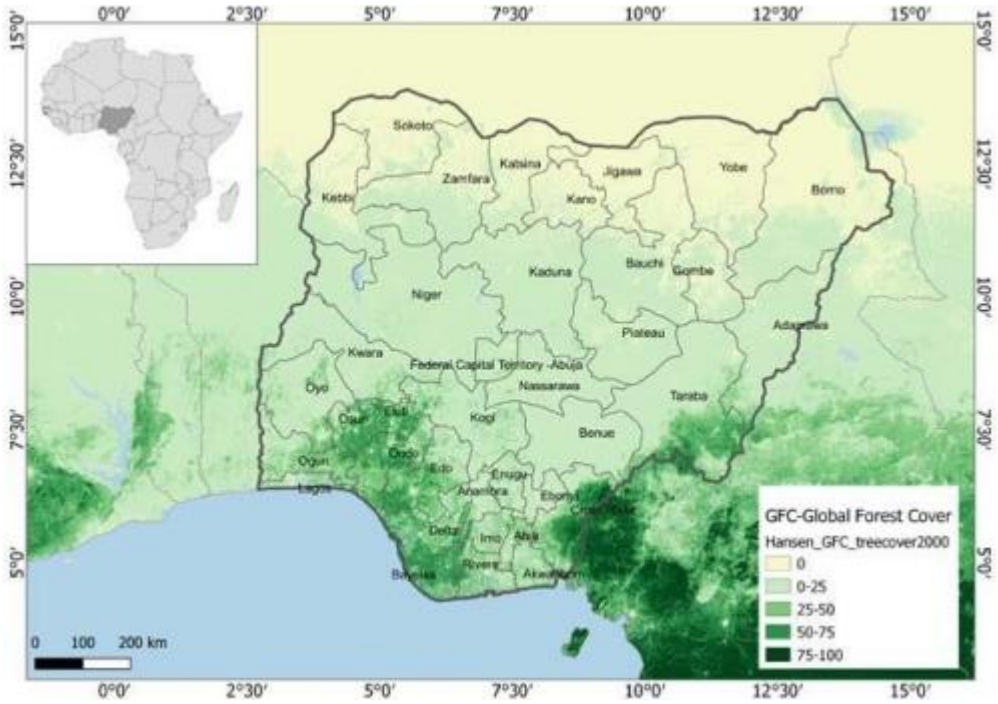

Figure 1: Nigeria forest ecosystem
Source: (Afolabi, 2020).

Data Collection and Statistical Analysis

The data for the study were secondary data from the World Development Index, and climate data from 2003 to 2023 were from the Nigerian Meteorological Institute located at Bill Clinton Drive, Nnamdi Azikiwe International Airport, FCT, Abuja, Nigeria. Data collected include annual agricultural production and temperature in ^oC, average annual precipitation in mm (millimetres) and relative humidity in percentage (%). Based on the Food Insecurity Experience Index (FIES), which estimates the percentage of the population experiencing food insecurity compared to national limits, data on the prevalence of food insecurity was used in this study. An eight-question survey module was used to create the FIES-based scale, which was then used to calculate the likelihood of severe or severe food insecurity. To implement the concept of climate change, the study focused on precipitation, relative humidity, and abnormal temperature values, which are defined as the annual temperature difference in ^0C compared to the 40-year average temperature between 1980 and 2020. This assessed the impact of deforestation, rainfall, relative humidity, and abnormal temperature on food security, local HDI resilience and drought. Six-month precipitation standard deviation (SPI), a general indicator of agricultural drought and suitable for analysis, was used as the drought index. The regression equation, as applied by Dasgupta and Robinson (2022), is expressed as follows:

$$FIES_{it} = \beta 1(\iota t)V_{it} + \gamma'(\iota t)X_{it} + \alpha i + \mu_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (1)$$

The panel data regression model with time-varying coefficients and both location and time-fixed effects, where $FIES_{it}$ is the probability of moderate to severe food insecurity or likelihood of severe food insecurity; V_{it} is the temperature anomaly; and X_{it} is a vector of relevant variables affecting food insecurity including precipitation and relative humidity, while μ_{it} is a random error term. All variables were recorded for Nigeria with index i = 1, ..., N and over several years t = 1, ..., T. The time-varying coefficients allowed the researcher to examine whether the relationship between precipitation, relative humidity, temperature anomaly, and food insecurity has evolved.

Results and Discussion

The time-varying regression results are presented in Table 1. It measured the impact of temperature anomaly, relative humidity, and precipitation on food security for the years the FIES data are available. The incidence of moderate-to-severe food insecurity (positive responses to questions 1-6) suggests that for a 1% increase in precipitation, moderate-to-severe food insecurity is reduced by -7.2% and even though this is not statistically significant at 1%, 5% and 10% level of confidence, it is congruent with a prior expectation that in a largely rainfed agro-ecology like Nigeria, increasing rainfall may improve the food security status of respondents. This is similar to the findings of (Quadri and Sulaimon, 2024), where temperature (0.259) and rainfall (0.608) have a significant impact on food security.

The effect of increasing relative humidity is similar to that of precipitation. The regression results showed that every unit increase in relative humidity will reduce moderate to severe food insecurity slightly by -1.5% in the study area. Similarly, increasing relative humidity negatively affects food security by -1.5% and is is significant at $p<0.05$ level. From Table 1, carbon emission, relative humidity, and temperature change were statistically significant at 1%, 5% and 10% confidence level and had a moderate to severe influence on food insecurity.

Carbon emission was positively significant and significantly impacted moderate to severe food security in Nigeria. With an increase in carbon emission, there is an increase in moderate to severe food insecurity by 27.9% in Nigeria. The global account of deforestation and forest degradation as a contributing factor was evident. According to Sule *et al.* (2024), deforestation in Nigeria is occurring at approximately 3.5% annually, resulting in the loss of natural forest cover. According to Saidu *et al.* (2022), CO_2 production through deforestation in Nigeria from 1970 to 2016 using the ARDL method with Granger causality is a significant factor for forest and environmental degradation. Also, the coefficient of fuelwood and non-timber forest products negatively and significantly influences moderate to severe food insecurity. It showed that the higher the fuelwood and non-timber forest product, the less the moderate to severe food insecurity. Forest resources contribute economic value to the livelihood outcome of foresters (Kanga, 2022). Consumption and trading of these resources attract higher livelihood sustainability to the people.

Additionally, the result showed that temperature anomalies signal a rise in moderate to severe food insecurity. Temperature changes between 0.2 - 0.4^{o}C and 0.6 - 0.8^{o}C showed a statistical significance at 5% and 10% confidence level, indicating moderate to severe food insecurity. The implication was that an increase in temperature between 0.2-0.4oC will increase moderate to severe food insecurity by 0.2285 whereas a a temperature rise between 0.6-0.8^{o}C will increase food insecurity by 0.2515. The stress that cultivated crops and animals reared in an open grazing context go through is a primary driver of declining food production due to weather shocks and droughts. With more than 60% of Nigerian crop farming under rainfed agriculture, increasing temperatures above the national average may cause significant food and crop losses, thereby worsening the food security status of households in Nigeria. For severe food insecurity, Commercial wood extraction/harvest, precipitation and fuelwood and non-timber forest products reverse roles on their effect on food insecurity. While a 1% increase in rainfall reduced severe food insecurity by 26.5%, the coefficient of fuelwood and non-timber forest products reduced severe food insecurity by 48.1%, and commercial wood extract/harvest declined severe food insecurity by 9.4%. Both carbon emission and precipitation were statistically significant at a 10% confidence level while Commercial wood extraction/harvest was statistically significant at 5% confidence level. It corroborates the findings of Fagbemi *et al.* (2024), where carbon emission brought about an adverse effect on food insecurity.

The coefficient of commercial wood extract/harvest and relative humidity was statistically significant at 5%. While these two results differ from moderate to severe food insecurity, it may suggest the need to further review the effects of precipitation and relative humidity on specific food crops to derive appropriate policy decisions from their impact on food security and other crucial SDG goals.

Table 1: Food Insecurity Experience Scale regression results

Explanatory variables	Coefficient	Std. Err.	t	Coefficient	Std. Err.	t
	Moderately_severe				***Severe***	
Commercial wood extraction/harvest	0.0040	0.0078	0.51	-0.0935	0.0126	2.07**
Carbon emission	0.2785	0.1591	1.75*	0.4419	0.2515	1.76*
Fuelwood and non-timber forest products	-0.0388	0.0125	-3.10***	-0.4806	0.6336	-0.76
Precipitation	-0.0718	0.1045	-0.69	-0.2585	0.1372	-1.88*
Relative humidity	-0.0151	0.0062	-2.20**	-0.016	0.006	-2.35**
Δ in temperature (<0.2)	-0.0395	0.1645	-0.24	-0.0099	0.0386	-0.26
Δ in Temperature (0.2-0.4)	0.2285	0.1085	2.11**	-0.1121	0.0531	-2.11**
Δ in Temperature (0.4-0.6)	0.0029	0.0104	0.28	0.9530	0.5413	1.76*
Δ in Temperature (0.6-0.8)	0.2515	0.1125	2.23**	0.3577	0.3171	1.13
Δ in temperature (>0.8)	0.0468	0.1609	0.29	1.8069	0.6270	2.88***
_cons	5.5475	1.2572	4.41***	-1.1003	0.6329	-1.73*

Source: Author, 2024; *, ** and *** are 1%, 5% and 10% statistical significance respectively.

Conclusion

The study estimated the effect of environmental temperature change and forest degradation on food insecurity in Nigeria. The result presented in this study was evidence that there exists a causative relationship between temperature anomalies and food insecurity in Nigeria. Equally, the significance of temperature changes and forest depletion on food insecurity cannot be overlooked. The study showed that a rise in temperature significantly increases severe food insecurity.

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Economic Development Strategies for Utilizing the Improved Perception about Social and Environmental forestry in Nigeria.

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Abstract

This review focused on response to the raised questions of concern about "Are there remedies? May be If we improve on the tree planting programme"; the question often asked is, "why is it not so in Nigeria"; and the rhetorical question of how can you legislate and manage resource that is owned by someone else? Could be submitted as part of innovative thinking behind why 'Economic Development Strategies for Utilizing the Improved Perception about Social and Environmental Forestry in Nigeria' become necessary in the 21st century to solve challenges facing forestry development in Nigeria. This review strategy was discussed at two inaugural lectures, jointly sponsored by University of Ibadan in 2012 and 2014, respectively, in the social and environmental forestry Department. These inaugural lectures helped establish a common ground, and facilitated some consensus building on problem identification, important actions needed, scope for regional cooperation, and questions of key stakeholder players support among the forest sector in Nigeria as well as Sub-Saharan Africa, including government officials and representatives from Departments, Ministries, agencies, NGOs, the private sector, traditional rulers, and academia. The limited success of past command-and-control policies in containing forest depletion points to a greater reliance on market forces and pricing in the drive for more efficient use and conservation of the forest resource base. Forests are better managed as business enterprises such that at any point in time in that country, at least 25 percent of forest yield is available for export, of course after domestic needs and strategic reserves have been catered for. An important outcome of the two inaugural lectures, initiated by University of Ibadan, faculty and department will also foster regional cooperation (e.g., research), promote intra-state trade, and discuss transboundary issues (including protection of watersheds, conservation of biodiversity, and wildlife protection).

Keywords: sustainable economic development, policy; forest yield; social and environmental forestry; tree planting.

Introduction

Forestry worldwide is at a crossroads due to the rapidly changing climate; energy, biodiversity, financial and food security crises; and socioeconomic and political uncertainties that deepen deforestation and forest degradation. Innovation, transition, and reconstruction of forestry, oriented by policies at the local level and across scales, are necessary to respond to challenges and build green, healthy, prosperous and resilient futures (Nijnik and Melnykovych, 2024). Thematic focus on forests, people and poverty eradication were among other several laudable efforts in Nigeria Ministries and Departments to mitigate some of the above raised issues of concern. For instance, the Federal Ministry of Environment in 2001 carried out National Tree

Planting Campaign under the Federal Department of Forestry (FDF). The success or failure of this programme for over two decades will only be best understood when likely environmental indicators activities projected during the event is assessed sequentially in the twenty first century happenings of today.

The scenario painted from the foregoing problems has further been worsened by the claims that some well placed foresters have themselves undermined the development of forestry in Nigeria. This claim has bought to the fore the most recent well deserved recognition effort of the Forestry Research Institute of Nigeria as "*Nigeria's Leading Parastatal for Forestry Research and Development".* Drawing from well articulated conclusion of the erudite professor of Biometrics inaugural lecture that single tree cannot make a forest. The raised question of concern then was why do we still have a single Forestry Research Institute of Nigeria to solve challenges facing forestry development in Nigeria? This according to him is not realistic; the need for more Forestry Research Institute of Nigeria was paramount. While the erudite scholar encouraged the need to encourage innovation of new institutes that should include:(i) Institute of Forest Biology and Silviculture; (ii) Nigerian Institute of Ecology; (iii) Institute of Forest Economics/Management; (iv)Institute of Wildlife; and (v) Institute of Forest Surveys. The response to this raised question of concern could be submitted as part of innovative thinking behind why 'Economic Development Strategies for Utilizing the Improved Perception about Social and Environmental Forestry in Nigeria' become necessary in the 21st century to solve challenges facing forestry development in Nigeria.

In a similar manner that has further given enough credence to why the only Forestry Research Institute of Nigeria has now metamorphosed through the old practice of "Taungya system" that is now widely known with different innovative forms of 'Agroforestry'. Agroforestry in this context is a collective name for land-use systems in which trees are used on the same units of land as agricultural crops or animals. Trees and crops may be combined in space, e.g., hedgerows in between crops, or in time, e.g., a field-fallow rotation. Improved perception about social and environmental forestry in Nigeria' holds a great potential. The yet to be addressed raised question of concern however has been on whether there are remedies to all or some of these issues of worry! This is because till date, Nigeria has no National Forestry Act, which further suggest that Nigeria is still using the old act handed down to us by our colonial masters. The sorry state of this status quo could be explained for some conclusions as well as recommendation of innovative bold steps through academic presentation to further request and implore the National Assembly to pass the National Forestry Act Bill submitted since year 2000. According to this source, the expected National Forestry Act should clearly spell out the Annual Allowable Cut which can fully restore the productivity of the natural tropical rain forest.

It has been submitted that if we improve on the tree planting programme which could been said not to have been keeping pace with rapidly developing countries population explosion over a fixed land mass in Nigeria alone already portend serious environmental problems. This is because likely probable solution now lies in the friendly approach of right perception about social and environmental forestry. While more than a decade ago, (Akindele 2010; Osho, 2012) affirmed strongly that tree planting will enhance tree stocking/vegetation. They however did not fail, to warn that this cannot be achieved unless there is adequate supervision and good extension services. This could further suggest a great lacuna that still exists in the Ministry of Environment

where forestry sector is largely situated to absorb qualified forestry graduates as part of solving the national youth restiveness and unemployment problems. The advanced recommendation that the Government should put in place a technical board to carry out the maintenance of the planted trees remained largely an unreached goal. Osho (2012) claimed there is great concern over the eventual loss of the tropical rain forest in Nigeria. In his submissions he warned that the ever-increasing pressure from state governments for Internally Generated Revenue (IGR) derivable from logging forced the forestry officials to break the rules of sustainable management of the forests. The present policy of 100% removal of all trees of merchantable sizes is over-exploitative of the timber resources of the forest (Osho and Akinsanmi 1990), no matter the cutting cycle.

These concerns further advanced plausible reasons for the need of appropriate machines to convert smaller diameter logs that are still not readily available till date. It was based on this line of thought that the source suggested why local manufacturers could be encouraged to direct their efforts to make such machines. The fear has been raised on another major effect of the abuse of our forest such as the effect on global climatic patterns, loss of or reduced ability to sequester carbon leading to the green house effect. In the context of unforgettable damages inflicted on our infrastructures because of flood that ravaged some areas of Lagos and Oyo States recently over a decade ago has been associated to how deforestation reduces the ability of a country to achieve sustainable economic development. The impact of climate change on food and human security in Nigeria revealed that climate change has negatively affected food security in Nigeria. It has also led to continuous armed confrontations over natural resources thereby undermining human security in the country (Ani, et al.2022; Tables 1,2 ,3). The fact that innovation in forestry has come through different phases cannot be gainsay during our National Development. Weiss, *et al.* (2020) took cursory systematic literature review of four decades of innovation research in forestry and the forest-based industries. Their search for articles that specifically mention "innovation/innovativeness" and "forest/wood/timber" from a social science perspective resulted in 230 studies. They concluded and established concepts and approaches from innovation research are well received in forest sector innovation studies, although newer trends could be taken up more progressively.

Innovation is a driver of economic development and competitiveness of countries, sectors, and firms (Schumpeter, 1934). For firms, innovation is necessary to adapt to changing economic and social environments, and to exploit new opportunities from emerging demands. This is also true for the forest sector, whereby global competition pressures seem to capture the attention of firms and policy makers more than emerging opportunities (Hansen et al., 2006; Kubeczko et al., 2006; Weiss, 2019). Popoola, (2014) suggested policies and strategies that could encourage private participation in forestry. This is because according to him, forests are better managed as business enterprises such that at any point in time in that country, at least 25 percent of forest yield is available for export, of course after domestic needs and strategic reserves have been catered for. Private forestry is so organized in Germany that it is possible to determine how many cubic meters of wood is added to the national stock per minute. The question often asked is, why is it not so in Nigeria? The innovative research in forestry that has continued to be handicapped by poor funding as well as low place of National budgetary allocation over many years could give possible answer. In the same vein of thinking the submission of Osho (2012) that all forest reserves in each state should be jointly by an agency through Public Private Participation (PPP)

as is being done in other countries of the world may be an ideal innovation yet to be fully tapped into in Nigeria. The promotion of social and environmental forestry ideology was also suggested in the form of compensation that should be paid to the local communities who own the forest lands. The rhetorical question of concern in this respect is how can you legislate and manage resource that is owned by someone else?

Because most experiments on growth and yield take far longer than the lifespan of the individual forest scientist. It has been recommended as an innovative strategy for more mathematicians and statisticians to be encouraged to come and help investigate the mysteries surrounding the disappearance of the old dense jungles of natural tropical rainforests in Nigeria. In the face of stark reality that the tree climbers' taxonomists and the silviculturist cannot alone navigate very easily in these forest jungles advanced enough support for the simulation studies that would be adopted by more of the 'mathematical forester' as submitted by Osho (Op Cit.). According to this source, 'mathematical forester' can use computers even in the midnight to investigate decades/centuries of forest growth for some information. This is because Osho (2012) claimed Population Growth Matrix in 1993; Growth and Yield model; were foremost innovative research that attracted great acceptance from 250 requests for the reprint of the paper from all over the world such as Johannesburg in South Africa including some countries in North America, South America, Europe, and Asia. This is because of the high promise which the model generated amongst modelers. The major attribute of the foremost innovative forestry research work was its simplicity of application. The simplicity is such that a tree population growth matrix was used to formulate sustainable harvest models in a Nigerian tropical rainforest with varying cutting cycles of between 18-54 years. Results showed that 36-year rotation was the best instead of the current practice of 50 years (Osho 1995; Osho, 2012).

According to Popoola (1995; 2014) land remains the single most significant factor of production. In the context of land-based biological production process such as forestry, it determines the amount and the direction of movement of the other factors viz-a-viz labour, capital and management. Without land or space, these factors cannot be functional. This explains why over the years, land values have continued to appreciate (Popoola 1990). Land tenure and land use have remained major issues in national planning and development. Most of the growth and development over the years has been at the expense of forests and forestry. Sadly, the extant land laws do not encourage private/non-governmental investment in forestry, yet non-governmental involvement can shape forestry development positively. Several models have been advocated for private/non-governmental forestry. They include:

- Community Based Forest Management (CBFM)
- Private Forestry (PF)
- Joint Forest Management (JFM)
- Participatory Forest Management (PFM)

In Nigeria, CBFM has been discussed at various fora. However, only Cross River State offers a resemblance of best practice of this model. Joint Forest Management is not common. Private Forestry, though not institutionalized has gained some measure of popularity, borne mainly out of individual/corporate interests and passion for tree growing.

Economic Development Strategies for Perception about Social and Environmental Forestry in Forestry Research Institute of Nigeria

The Forestry Research Institute of Nigeria (FRIN) activities are documented through the main avenue of publications. The main form of innovative publications includes Research Paper (Forest series and Savanna Series). Technical notes, Annual Reports, Quarterly reports, and monthly newsletters. Research findings also published in national and international scientific journals worldwide. As part of the Institute Services to the public, the institute offers consultancy services in the following areas of demand needs of the public: These include forest plantation, establishment and management, supply of seeds and seedlings for afforestation, identification, and classification of plant specimens landscaping, saw milling, wood seasoning (drying), wood preservation (chemical treatment), furniture construction and wall paneling. Others are in areas of band saw maintenance, termite control and phytosanitry services. Besides services to the public, FRIN research innovation and breakthroughs could be seen in different shapes and forms. The foremost is the techniques for National Forest Management. This comprised the production of forest stands that has been greatly improved by a changeover from natural regeneration of forest stands to plantation development. This has been through the institute's research activities involving successful selection and introduction of fast-growing exotic species. The research results of the institute include mechanized afforestation techniques in semi-arid areas, which formed the basis for large scale plantation establishment in all ecological zones of the country by the institute. The results of the work of the institute in the negotiation propagation of Obeche (*Triplochiton scleroxylon*) has made large scale establishment of plantations of the very important economic tree species possible. The development of agroforestry practices suitable for adoption by farmers comes next as the institute most beneficial combination of forest tree crops and arable crops that have been worked out. Identified species used for agroforestry practices include *leucaena leucocephala, Albizia lebec, Gliricidia sepuin, sebania seban* and *cassia siamea, etc.* Pulpwood species could be another advanced form of research activities of the institute. Two trees' species; Gmelina (*Gmelina arborea*) and pines (*Pines sp*) were specifically recommended and are now being grown as pulpwood species. Worthy of mention is the established fact that the Institute, through activities forest products research, innovation of new tree species, hitherto unused, the number of trees recommended and being utilized has now increased by more than 300%. The fact that the institute has played a major role in the development of standard wooden structures for the Nigerian Standard Organization (NSO) under timber utilization cannot be overemphasized.

Wood waste utilization has been submitted as another major research innovative breakthrough recorded in the use of wood waste to produce building materials. This has led to the production of wood cement blocks, wood cement floor/wall tiles, and wood cement ceiling boards… The institute has taken an innovative step towards the production of the first simple and compound (NPK) ignite based organic fertilizers in Nigeria. These have the dual advantage of being able to supply plant nutrients and organic matter simultaneously to the soil while at same time enhancing the biochemical and physical properties of soil continuous cultivation. In the content of Environmental management FRIN has further emerge with natural innovation solution through its research into shelterbelt management and sand dine stabilization. In the Institute, there are now possibilities for the stabilization of the sand dune areas in the arid zone. The work of the Institute in erosion control has assisted in the control of environmental degradation in erosion-prone area of the country. The achievement of Natural Resources conservation in the

Institute has made enormous contributions in natural resources conservation, not only to boost forest development but also to foster public education in general. In this respect, Strict Natural Reserves (SNRs) maintained by the Institute in some ecological zones now serve as field laboratories for foresters, ecologists and environmental etc. The Institutes herbarium with a collection of over 120,000 plant species, has been recognized as one of biggest in West Africa and is well know all over the world.

The FRIN bulletin acknowledged ecological surveys carried act by the institute was reported to have led to the production of vegetation and ecological maps for the country. This may also suggest why the taxonomic studied in FRIN over the years has resulted in publications which have over time become standard text of reference books in tertiary institutions. Some these books are "Flora of West Africa, Nigerian Trees, among others". The Institute Sanitary and cane Rat Domestication unit is a breakthrough that has been recorded has involving relatively small capital. These innovative technologies are being adopted by low-income farmers and other individuals and would be important alternative leverage to the current poverty alleviation programme of the Federal government. The introduction of mulberry sericulture to Nigeria has been successful through the successful establishment of the mulberry (*Morus alba*) by the Institute. This innovation has also been successfully introduced at vocabulary Training Centre Ilesha by the production of Silk Cloth. The institute is working a collaboration with Oyo and Ondo States governments in the development in the development of sericulture. Until recently, FRIN was the only establishment in Nigeria which trains forest superintendents and other categories of staff required to meet middle and cover manpower needs in forestry related matters. There are now numerous colleges under the institute for the purpose of training of technical and sub-technical personal on the forestry sub-sector of the economy.

Although the Forestry Research Institute of Nigeria Act has now been enforced; this could also further advance plausible reasons behind why the institute now has national spread through the hubs and outstations under Forestry Research Institute of Nigeria. These include: (i) Southern Guinea Research Station, Mokwa; (ii) Rainforest Research Sattion, Ore; (iii) High Forest Research Station, Awi; (iv) Swamp Forest Research Station, Onne; (v) Arid Zone Research Station, Damasak; (vi) Humid Research Station, Umuahia; (vii) Trial Afforestation Research Station, Afaka, Kaduna; (viii) Moist Forest Research Station, Benin; (ix) Savanna Forest Research Station, Zaria;(x) Shelterbelt Research Station, Kano; (xi) Montane Forest Research Station, Jos; (x) Onigambari Research Station, Ibadan; Moist Savanna Forest Research Station, Isiagu, Ebonyi State; Gombe Research Station, Gombe State; Derived Guinea Savanna Research Station, Ogbomosho, Oyo State; Nothern Guinea Savanna Research Station, Nasarawa, Nasarawa State; and Sudano-Sahelian Research Station, Sokoto, Sokoto State. This national spread through the hubs and outstations under Forestry Research Institute of Nigeria has also furthered training of qualified manpower for sustainable economic development through FRIN training colleges. These also include: (a) Federal College of Forestry, Ibadan, Oyo State; (b) Federal College of Forestry, Jos, Plateau State; (c) Federal College of Wildlife Management, New Bussa, Niger State; (d) Federal College of Forestry Mechanization, Afaka, Kaduna State; (e) Federal College of Forestry Resource Management, Sakpoba, Edo State (South South); (f) Federal College of Forestry Resource Management, Isiagu, Ebonyi State (South East); and (g) Federal College of Forestry Resource Management, Maiduguri, Borno State (North East).

Strategic Implications

The dynamic transcends the forest sector, implying that single-sector approaches to sustainable economic development are no longer relevant. Just as the forest sector cannot be analyzed in isolation from the wider political economy, forestry cannot be dealt with in isolation from other forms of land use and other natural resource systems. In short, what is required is a cross-sectoral approach, placing forestry firmly within a Social and Environmental Forestry framework, i.e, a "nexus" of interactions among socio-economic wellbeing of communities around forestry, agriculture, poverty, population, and technology. In this respect, within the social and environmental forestry sector, itself, there is considerable scope for improvement. The limited success of past command-and-control policies in containing forest depletion points to a greater reliance on market forces and pricing in the drive for more efficient use and conservation of the forest resource base. This implies a new role for government: one based on public discussion and debate, and which clearly recognizes the comparative advantages of local communities, the private sector, and NGOs, versus the state. Governments should provide an enabling environment for economically efficient and environmentally sound forest sector activity; ensure better pricing to reflect the full scarcity of forest resources, and tax resource users accordingly to internalize externalities. In short, public sector efforts should be limited to those activities that cannot or will not be carried out by farmers, local communities, and private enterprises on their own accord .i.e., environmental conservation (where the market often fails), research, human resource development, and donor coordination. The scaling down of government involvement in production will also release scarce resources for these purposes. And governments should focus on strong alliances with local people, local institutions (formal and informal), and the private sector in forest management.

Nigeria as well as other developing countries will also need to focus on the demand side by reducing waste in the harvesting and processing of wood, and by introducing conservation measures to improve efficiency in wood utilization. An effective strategy for conservation and sustainable use of Nigerian forests should begin with the Nigerian people, including local people and traditional practices, since there is no dichotomy between forest conservation and development and their well-being in the long term. The response to the fundamental challenges for the social and environmental forestry sector in Nigeria will vary according to prevailing conditions within each Nigerian community. There are some areas in the region, for example, a new generation of projects has been launched, attempting to tackle some of these cross-sectoral issues more explicitly. Although it is too early to judge the success of the new projects, many of them appear to share several conceptual weaknesses (e.g., regarding the process for delivering policy and institutional reforms, and mechanisms for generating popular participation). In Nigeria, CBFM has been discussed at various fora. However, only Cross River State offers a resemblance of best practice of this model. Joint Forest Management is not common. Private Forestry, though not institutionalized has gained some measure of popularity, borne mainly out of individual/corporate interests and passion for tree growing. What role should the Bank play in the future development of the Social and Environmental Forestry sector in SSA? Based on the 1991 World Bank Forest Sector Policy, the seminal paper, "Saving Africa's Rainforests" (Ismail Serageldin, 1993), principles have been developed to guide Bank lending to the sector. Social and Environmental Forestry sector in Nigeria will need to adhere to this guiding principle. In another twist of event, evidence advance that instance in Central Africa, where greater time is available for stewarding

the deforestation process towards a more socially optimal outcome has emerged recently. But even here, the precautionary principle dictates that high priority should be assigned to curbing uncontrolled forest depletion and degradation, and to promoting sustainable use of forest resources.

For sub-Sahara Africa (SSA) in general, the existing institutional and policy framework will need to be re-ordered to strike the right balance between economic development and conservation aims. African governments will also need to change the perception of their role in sector development to become more effective custodians of society's interests. Good macroeconomic policies are essential for a dynamic and efficient forest sector. Activities generating negative externalities, such as the exploitation of pristine forests rich in biological diversity, should be curbed by appropriate pricing and taxation policies and complemented by strict enforcement on the ground. Such targeted state intervention is not only conducive to greater public sector effectiveness, but also releases scarce resources for alternative uses. The emphasis in this context is that Nigerian governments will need to consider important issues outside the forest sector when drawing up a relevant agenda for action. Given that an expanding agricultural frontier (especially in existing crop lands and in lands cultivated at the forest margins) is the primary agent of deforestation in Sub-Sahara countries, an improvement in the performance of agriculture stands out as an indispensable precondition for the conservation and sustainable use of forest resources here. Increasing agricultural production and productivity through improved inputs, credit, infrastructure, marketing, and research and extension is essential to relieving population pressure on forest lands left intact.

Forestry and agroforestry (including the domestication of trees for high value/low volume products such as indigenous fruit trees and medicinal plants), can also enhance agricultural production through watershed protection, and through the introduction of appropriate tree species in farming systems. Separate but related policies involve land use planning and natural resource management. Countries in Sub-Sahara countries must give priority to revising their land use policies (access to land, tenure security, and tree tenure). Through improved land use policy and zoning, countries can allocate forest lands for different purposes (conservation of biological resources, wildlife protection, stabilization of watersheds, timber production, extractive reserves, conservation of areas for agriculture, recreation, etc.). Population, energy, and industrial policies also have a strong influence on forest sector performance. Energy policies should give special attention to alternative sources of energy and conservation measures to ease the high dependency on fuelwood and charcoal.

Conclusion

The paper has emphasized that that all forest reserves in each state should be jointly by an agency through Public Private Participation (PPP) as is being done in other countries of the world may be an ideal innovation yet to be fully tapped into in Nigeria. The promotion of social and environmental forestry ideology was also suggested in Land tenure and land use have remained major issues in national planning and development. Most of the growth and development over the years has been at the expense of forests and forestry. Sadly, the extant land laws do not encourage private/non-governmental investment in forestry, yet non-governmental

involvement can shape forestry development positively. Several models have been advocated for private/non-governmental forestry. Private Forestry, though not institutionalized has gained some measure of popularity, borne mainly out of individual/corporate interests and passion for tree growing. Governments should provide an enabling environment for economically efficient and environmentally sound forest sector activity; ensure better pricing to reflect the full scarcity of forest resources, and tax resource users accordingly to internalize externalities. For sub-Sahara Africa (SSA) in general, the existing institutional and policy framework will need to be re-ordered to strike the right balance between economic development and conservation aims. African governments will also need to change the perception of their role in sector development to become more effective custodians of society's interests.

Recommendations

Key actions that Nigerian communities need to take within the social and environmental forestry sector are as follows:

Forest policy and legislative reform

In many African countries including Nigeria, the existing policy environment encourages deforestation by undervaluing and underpricing forest resources. To change this situation, it is essential to make markets for forest products work better, and to take account of non-marketed benefits in decisions regarding the use of forests. Market and policy failures should be corrected through a process of dialogue among various stakeholders. New policies and laws will need to be based on the fundamental principles of transparency and public accountability. New policies should be translated into appropriate legislation and implemented effectively.

Capacity building and human resources development

Strengthening forestry institutions should be part of a systemic civil service reform process for improved governance, with emphasis on accountability, rule of law, improved financial management and budgetary process, and transparency. The mandates of government forestry agencies should be reoriented by granting rights and devolving responsibilities for forest sector activity to farmers, local communities, and the private sector, as appropriate.

Capacity building initiatives within state forestry departments will also need to respond to the capacity building requirements of these important forest sector agents. Furthermore, capacity building should also be targeted to institutions at the regional, district, and local levels, involving all the major stakeholders.

Involving farmers and local communities in forestry activities through policy and legal change (e.g., land tenure and incentives). Training in participatory planning will also enable forestry agencies to develop partnerships for forest management and reforestation with local communities and NGOs. In addition, government support for participatory negotiation processes among forest users will greatly facilitate sustainable forest management by local people and help resolve local conflicts.

Enhancing private sector involvement in forestry and forest industry

Governments must shift their role from direct involvement in production toward an enabling function, providing a policy and legal environment, and information services that stimulate private investment in forestry as well as a more efficient wood industry. Private sector involvement in planning and policy making can help towards this end.

Improving and disseminating forest-related knowledge and technology

Governments need to conduct national forest inventories which will serve as a basic framework for planning, implementing, monitoring, and evaluating forest sector activities. Lessons learned from pilot field activities need to be disseminated more widely, and the relevance and efficiency of forestry research needs to be improved by closer cooperation between researchers and the potential users of their results. More emphasis should also be placed on educating people about the social and environmental considerations associated with forest utilization. In addition, a more integrated, participatory approach for developing and disseminating knowledge on forest sector management and use is needed to optimize results.

The Role of the World Bank: A New Strategy for Lending in Sub-Sahara Africa

Bank lending to the forest sector in SSA started in fiscal year 1969. Since then, it has evolved considerably, moving from an initial focus on industrial forestry to social and agroforestry and, more recently, to operations supporting national programs with multiple objectives as well as increased emphasis on forest resource conservation. *Past projects, however, systematically failed to address the pervasive policy and institutional constraints to improved sector performance and neglected local participation in the development process*. The experience with these projects further underlines the importance of a holistic approach to the social and environmental forestry sector; one encompassing other forms of land use and economic activity, as well as the prevailing policy and institutional environment.

Guiding Principles for Sustainable Management of Forest Resources

* Forests and trees should be treated as economic, social, and environmental goods. Forest utilization should rely on market and pricing mechanisms.

* A comprehensive, more ecosystem-based approach, recognizing the interrelationship between forests and land use, should be adopted for sustainable management of forest resources.

* Management of forest resources requires local and national actions as well as international cooperation.

* Forest management should be decentralized based on the principle of "shared responsibility," including local people, private sector, and the government at appropriate levels.

* The management of intact TMFs should follow the "precautionary principle"; the burden of proof falls on countries to demonstrate that use of TMFs is ecologically, economically, and socially sound. This also implies that sound practice should be demonstrated, and adequate provision for monitoring and assessment of implementation assured.

* Expanded investments in the forest sector should be preceded by comprehensive sector work, including cross-sectoral considerations, and adoption of a long-term forest development plan.

* Environment and social assessments should precede all major investments in the forest sector.

*A sensitivity to gender issues is required, as women play a major role in forest resource utilization and regeneration in SSA.

A strategy for Bank lending is proposed that focuses on four areas where the Bank has considerable comparative advantage, and where it can complement government and other donor activity. The four key areas for future Bank lending are:

(a) Promotion of policy reforms

(b) Support to capacity building and human resources development

(c) Support to investments in critical areas via promotion of better donor coordination in the forest sector.

This approach incorporates the nexus of interactions among forestry, agriculture, poverty, population, and technology advocated in the build-up to the new lending strategy, which are accommodated through the National Environmental Action Plan (NEAP) process.

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Crown Width Modelfor Hardwood Tree Species Found in Nnamdi Azikiwe University Awka, Nigeria

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ABSTRACT

Models are true tools for actual and inventive forest management. Crown width models predict the reliable dimensions of tree crowns in forest stands and have many applications in sustainable forest management. Measurement of tree crown remains one of the most laborious and uninteresting tasks in forestry. This study aimed to develop crown width-diameter model for hardwood tree species found in Nnamdi Azikiwe University Awka Nigeria. Fifteen sample plots of 50 m × 50 m using systematic techniques were alternately laid at 50 m an interval on 3 transects of 500 m long each. Trees with diameter at Breast Height (Dbh, cm) ≥ 10 cm were identified to species level and enumerated. The Dbh, Diameter at base (Db, cm), Crown width (CW, m) was measured. Five models (Linear, growth, square, semi and double logarithmic using Dbh as independent variable) were fitted and examined using Adjusted coefficient of determination (Adj.R^2), Akaike's information criterion (AIC), and Relative standard error of estimate (RSE). Descriptive statistics, Pearson's correlation and regression analyses were used for data analysis. Double logarithmic model (M5) showed best performance for predicting crown width for the hardwood tree species found within the study area with Adj.R^2 value of 0.88, lowest RSE and AIC values of 11% and -539.05 respectively. The study concluded that, the crown width for hardwood tree species could be appropriately predicted using diameter at breast height. Therefore, recommends that this model be used by the University management for the sustainable management of hardwood tree species found in Nnamdi Azikiwe University, Nigeria

Keyword: Hardwood, crown width, Nnamdi Azikwe, model prediction, diameter at breast height.

INTRODUCTION

Hardwood is wood from dicot trees which are usually found in broad-leaved temperate and tropical forests. Hardwood trees are mostly deciduous in temperate and boreal latitudes but mostly evergreen in tropics and subtropics (Nix, 2021). Hardwoods are produced by angiosperm trees that reproduce by flowers and have broad leaves. Many species are deciduous. Hardwoods are used in a huge diversity of applications which include firewood, building, furniture making, flooring, boat building, musical instruments, manufacture of charcoal and so on. In the past, tropical hardwoods were easily available, but indiscriminate felling and over exploitation of forests has affected the supply of some species, such as Burma teak and mahogany (Nix, 2021). Most of furniture and musical instruments are produced from hardwood tree species due to their density and durability, appearance, and performance. Some are mostly used in construction due to the diversity of characteristics apparent in different timbers which include density, grain, pore size, growth and fiber pattern, flexibility, and ability to be steam bent (Gunnar *et al,* 2009). Most of hardwood tree species produce large crown and have broad leaves.

The part of a tree bearing live branches and foliage is defined as tree crown. A tree's crown thus, represents the aboveground spatial requirements needed for a tree to survive, grow, and

reproduce (Kramer and Kozlowski, 1979). Tree crown represents its potential for growth and development, but crown measurements are difficult to obtain (Bechtold *et al*., 2002) especially in a closed forest. The relationship between a tree crown width and diameter at breast height (DBH) has a variety of uses including forest competition studies, tree crown densities, spacing and stocking relationships, wildlife habitat suitability models, and tree volume estimations (Lockhart *et al*., 2005). Estimating Crown width (CW) from diameter at breast height (DBH) is of interest to natural resource managers because diameter at breast height is a common tree dimensional characteristic that is used to quantify tree and stand structure and is easier to obtain (Sonmez, 2009).

The ability to predict crown diameter from diameter at breast height provides an efficient method of obtaining its estimate (Adesoye and Ezenwnyi, 2014). Crowns of trees have been subjected to much less study than their stems, primarily due to their lower marketable value (Elmugheira and Elmamoun, 2014). However, crown size, being closely related to the photosynthetic capacity of a tree, is an important variable in studies of the growth of individual trees. It is also very relevant in studies of the growth of stands due to the close correlation between crown size and stem diameter, and the density of trees in a stand. Some variables such as diameter or age are easy to obtain with simple instruments and it is widely used by forest inventories (Ibrahim, 2014). Nevertheless, various studies have revealed that other difficult measurable growth variables are also good predictors of forest dynamics, and they can improve the consistency of tools like growth and yield models (Kalliovirta and Tokola, 2005, Adesoye and Ezenwenyi, 2014). Tree crown dimension has received increasing attention to estimate tree growth. Measurement of tree crown width is more difficult and more time consuming than that of Diameter at Breast Height (Dbh).

Crown width is used in tree and crown level growth-modelling systems, where simple competition indices are not available to adequately predict recovery from competition when a competitor is removed (Brag, 2001; Raptis *et al*, 2018). In forest stands, crown width models can forecast the actual magnitude of tree crowns and be applied in various areas including crown surface area and volume estimations for the assessment of forest health, tree-crown profiles and canopy architecture and forest canopy cover. Crown width models can be formulated from mixed tree species (natural stands), open-grown trees or from stand grown trees. High cost of inventory operations compared with its outcome value of harvested timber represented the main problem in forest estimation. To reduce the inventory cost and time, modelling of crown width-diameter at breast height can be used as proposed method to overcome the problem of higher inventory cost (Elmugheira and Elmamoun, 2014).

There are few models available for predicting tree crown diameter of hardwood species in a forest. Knowing the tree crown can provide information on health of the forest, the state of the soil in the forest as well as providing indices for decision making concerning the forest (Adesoye and Ezenwenyi, 2014). As a result of difficult and strenuous circumstances involved in taking crown readings, most forest do not have readings in their forests. Therefore, the aim of this study is to develop crown width models for hardwood tree species in the study area which will help in envisaging the site productivity and in the proper management of the forest.

MATERIALS AND METHODS

Study Area

This study was conducted in a Restricted Forest in Nnamdi Azikiwe University, Awka campus, which is in Awka south local government area, Anambra state. NAU lies between latitude 6° 14' 48"N and longitudes7° 6' 56" E situated in Anambra state Nigeria. With the land area of 260 hectares and with an altitude of 96 m above sea level. The study area covers a total surface of 19 km². The vegetation of the study area is a tropical rainforest. It is dominated by broad leaved hardwood and softwood trees that forms dense layered stands with large crown cover. Tree canopy cover closure of the forest varies from 80% to 93%. The soil cover is claying sandy formation and waterlogged peat soil from the entrance and impoverished sandy loam as one progress deeper into the forest. The climate of the study area is of equatorial type, mean annual rainfall is about 1828 mm and the rainy season lasts for 8 to 9 months between March and November with a dry season from December to March. The indigenous wildlife animal found in the study are includes – Grass cutter, monkeys, snakes, fishes, and antelopes. The forest host more than 10 tree species which include: *Terminalia superba, Ceiba pentandra, Daniella oliverii, Gmelina arborea, Vitex doniana, Terminalia catapa, Tectonia grandis, Dalbergia peniculata, Milicia excelsa, Newbouldia laevis* etc. (Ekwealor *et al.,* 2020). The topography of the Forest is generally flat or semi-flat. The forest soils are dominantly ferralitic and highly weathered. The texture of the forest soil is usually loamy and sandy becoming heavier at greater depth with cracky clay soil in northern-part and sandy soil in southern-part of the forest. The forest soils are dominantly ferralitic and highly weathered. The soils tend to be acidic with low cations exchange capacity. If the soils are not maintained under forest cover surface soil erosion would set in. (Ekwealor *et al,* 2020). Figure 1 displayed the map of Awka South showing the location of the study area.

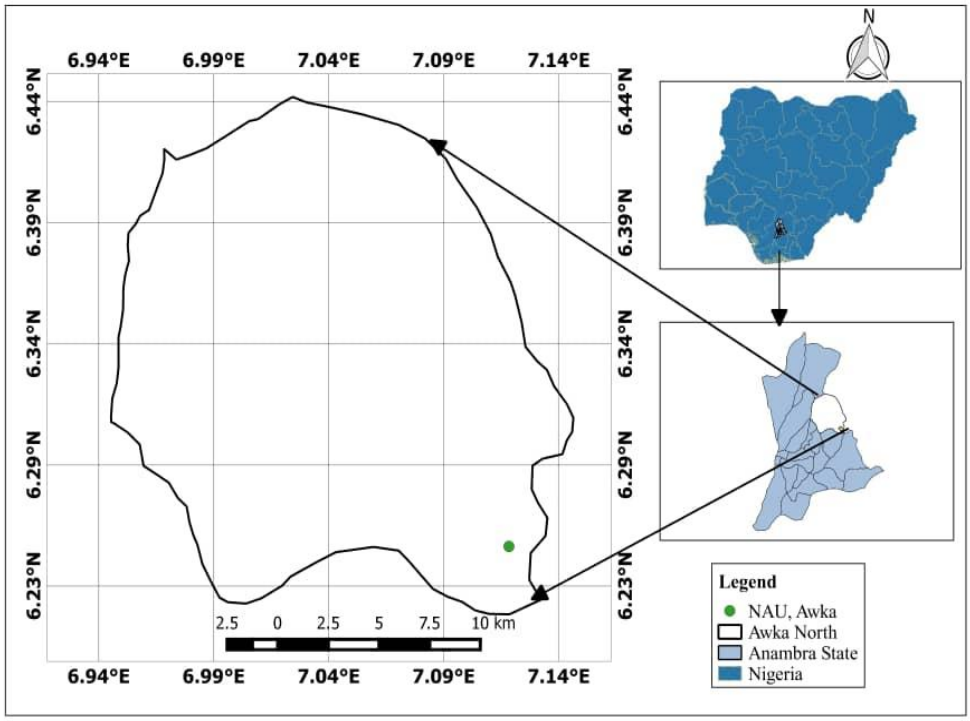

Figure 1: Map of Awka showing NAU.

Source: Ezenwenyi *et al.* (2020)

DATA COLLECTION

The sampling technique used for this study is a systematic random sampling technique (line transect). It is a probability sampling method which involves the random selection of trees of the same population at a regular interval. It helps to minimize biased samples and poor inventory results. Systematic (line transect) sampling technique was used for plot locations. For the location or selection of plots, a base line was made for easier and more accurate laying of transects. A global positioning system (GPS) was used to determine the starting point of each transect. At the study location, three (3) transects of 500 m long were laid, 50 m apart from each other, five sample plots of 50 m × 50 m was laid alternately alongside the other at 50 m interval on each transect. A total number of 15 sample plots used for this study. The reason for the alternate selection of trees is to cover variation that is existing in the forest.

Hardwood tree species in the study area were identified and measurement of the growth characteristics was carried out. Data were collected for the living hardwood trees in the stand whose Dbh is ≥ 10 cm. Crown width (CW), diameter at base (Db) and diameter at breast height (Dbh) of the selected trees were measured. Diameter at base was measured at 0.3 m and Diameter at the breast height (Dbh) was measured at 1.3 m above the ground level using the diameter tape. Crown width was measured by projecting the diameter of the crown width ranging poles on the ground at four different directions and taking the distance between the ranging poles using meter tape. The crown diameter was obtained by taking the average of the two readings recorded from the four directions for each tree. Basal area (m^2) and crown projection area (m^2) were computed.

Data Processing and Analysis

The data obtained from the field inventory were cautiously processed and analyzed. Descriptive statistics was used to summarize the growth variables data collected and Pearson's correlation analysis (rectangular matrix) was done to investigate the nature of association between the dependent (Crown width) and selected tree size variable (Dbh).

Model description and fitting procedure.

The available fitting data set consists of measurements taken from hardwood tree species located within different plots in the study area. Eight equations for predicting crown width (CW) using Dbh were selected as candidate functions to model the diameter at breast height – crown width relationship. The Dbh was taken as the independent variable, while the crown width was taken as the dependent variable. Ordinary least square method was used to fit data using the various candidate functions. The following crown width functions as presented in Table 1 were used as candidate models for the crown width prediction of the hardwood tree species in the study area.

Table 1: Models Examined for Crown width Prediction using Dbh.

Model	Designation	Function form	
1	Linear	$CW = b_0 + b_1 Dbh$	1
2	Growth	$CW = b_0 + b_1^{Dbh}$	2
3	Square	$CW = b_0 \times Dbh^{b1}$	3
4	Semi log	$\ln CW = b_0 + b_1 Dbh$	4
5	Double log	$\ln CW = b_0 + b_1 \ln Dbh$	5

Dbh= Diameter at breast height (cm), Cd = Crown width (m), b_0 and are parameters to be estimated.

Models Evaluation

The models fitted were evaluated using the following fit statistics namely; Akaike's Information Criterion (AIC), adjusted coefficient of determination (Adj.R^2), relative standard error of estimate (RSE). Model resulting in the largest value of Adj.R^2, lowest RSE, and smallest value of AIC was selected as the best model for the hardwood tree species. RSE was used to enable the comparison of transformed and untransformed dependent variable.

These fits statistics are mathematically expressed as:

$$Adj.R^2 = 1 - \frac{(1-R^2)(n-1)}{n-p} \quad (6)$$

$$RSE = \frac{SEE}{Estimate} \times 100 \quad (7)$$

$$AIC = n \ln(RSS/n) + 2p \quad (8)$$

Where:

n = Number of observations

ln = Natural logarithm

RSS = Residual sums of squares

P = Number of parameters in the model

R^2 =coefficient of determination

SEE= Standard error of estimate.

RESULTS

A total of one hundred and thirty-two (132) hardwood tree species were identified in the study area and the results are presented in Table 2. The result revealed that a total number of twenty (20) species distributed in twelve (12) families were identified. The *Ceiba pentandra* had the highest number of trees (13) distributed in the study area. This was followed by *Crescentia cujete* and *Vitex doniana* having the tree frequency of 12 and 11 respectively. *Spondias mombin* and *Tectonia grandis* had the lowest number (2) of trees identified in the study area. The highest number of species (3) was observed in the family Euphorbiaceae. Most of the families had one (1) species identified in the study area. See Table 2 for more details. The result of the descriptive statistics which showed the growth patterns of the hardwood tree species observed within the study location is presented in Table 3. The results revealed that the distribution of diameter at base (Db) ranged from 13.4 cm – 115.2 cm with the mean and standard deviation of 50.26±25.45. The distribution of diameter at breast height (Dbh) varied from 10 cm –102.2 cm with the mean and standard deviation of 38.03±21.97. Crown width ranged from 2.5 m – 19.5 m with the mean and standard of 10.28 ± 3.21. The BA had the minimum and maximum of 0.007 m^2 and 0.82 m^2 respectively with mean and standard deviation of 0.151±0.191 while the CPA varied from 4.91 m^2 – 298.65 m^2 with the mean and standard deviation of 91.03 ± 60.28.

Table 2: Hardwood species identified in the study area.

S/N	**Family**	Tree **species**	**Frequency**
1	Anacardiaceae	*Spondias mombin* Linn.	2
2	Asparagaceae	*Dracaena fragrans* (L.) Ker Gawl	5
3	Bignoniaceae	*Crescentia cujete* L.	12
4		*Newbouldia laevis* Seem.	9
5	Combretaceae	*Terminalia superba* Engl. & Diels	9
6	Ebenaceae	*Diospyros digyna* Jacq	7
7	Euphorbiaceae	*Alchornea cordifolia* Schumach. & Thonn.	5
8		*Mallotus oppositifolius* (Geiseler) Mull. Arg.	3
9		*Ricinodendron heudelotii* (Baill.) Heckel.	4
10	Fabaceae	*Daniellia oliveri (*Rolfe) Hutch. & Dalziel	6
11		*Millettia thonningii* Schum. & Thonn.	4
12		*Dalbergia paniculata* (Roxb.) Thoth.	8
13	Lamiaceae	*Tectonia grandis* L.f	2
14		*Vitex doniana* Sweet	11
15	Malvaceae	*Ceiba pentandra (*L.)(Gaertn)	13
16	Meliaceae	*Azadirachta indica* A. Juss	6
17		*Azadirachta indica* A. Juss	6
18	Moraceae	*Ficus sycomorus* L.	8
19		*Milicia excelsa* (Welw.) CC. Berg	6
20	Oxalidaceae	*Averrhoa carambola* L.	6

Table 3: Summary statistics for hardwood tree species characteristics

Growth variables	Minimum	Maximum	Mean	Std. Dev.
Db (cm)	13.4	115.2	50.26	25.45
Dbh (cm)	10.0	102.2	38.03	21.97
BA (m^2)	0.007	0.82	0.151	0.191
CW (m)	2.5	19.5	10.28	3.21
CPA (m^2)	4.91	298.65	91.03	60.28

Dbh=Diameter at breast height, Db=diameter at base, BA=basal area, CW=Crown width, CPA= crown projection area.

The results of Pearson's rectangular correlation matrix analysis which investigated the nature of linear association between the dependent variable (crown width) and the other selected tree variables are presented in Table 4. The results showed that the relationship between crown width (CW) and CPA had the highest and significant positive correlation (r) of 0.984. This was followed by the relationship between CW and Dbh which had the significant positive correlation 0.957. Then, the relationship between CW and Db which had the high significant and positive correlation of 0.920. This implies that increase in CW brings about increase in Db and Dbh which are hypothetically all-encompassing and biologically realistic.

Table 4: Rectangular correlation matrix

Growth variables	Db (cm)	Dbh (cm)	BA (m^2)	CPA (m^2)
Crown (m)	0.920*	0.957*	0.918*	0.984*

*Correlation is significant at the 0.05 level (2 tailed)
Where Dbh- diameter at breast height (independent variable),
Db= diameter at base, BA= basal area, crown width (dependent variable) and CPA= crown projection area

Models for predicting Crown width for Hardwood tree species

The results of the parameters estimated and fit statistics for crown width models developed using five (5) different models for hardwood tree species found in the study area are presented in Table 5. Dbh was used as the independent variable while the crown width was used as dependent variable. Generally, all fitted models gave acceptable results with Adj.R^2 ranging from 0.77 - 0.93, RSE values ranging from 11 – 94%. The AIC values range from -593.05 to 497.35. From the results (Table 5) obtained, it revealed that model 3 had the highest Adj.R^2 value of 0.93 with high RSE and low AIC values of 84% and -42.83 respectively. Among all models, model 5 showed higher performance for predicting crown width for the hardwood tree species found within the study area having the Adj.R^2 value of 0.88 with lowest RSE and AIC values of 11% and -539.05 respectively. Model 5 despite not having the highest value of Adj.R^2, had the lowest values of RSE and AIC with also a higher value of Adj.R^2 which made it the best predictor model for the hardwood tree species found in the study area. See Table 5 for more details. Generally, all parameters were statistically significant ($p < 0.005$). This result imply that double logarithmic (model 5) regression model is more consistent for modelling the CW-DBH relationship for hardwood tree species found in the study area.

Table 6 showed the results of the validation of the best model (double log., M5). The results of test revealed that observed values of crown width was not significantly different from the predicted values of natural logarithm of crown width at probability level of 0.05.

Table 5: Crown width models for Hardwood tree species

M.No	Model	Parameters estimated		Fit statistics		
		b_0	b_1	Adj.R^2	RSE(%)	AIC
1	$CW = b_0 + b_1 Dbh$	4.973	0.14	0.91	90	-15.46
2	$CW = b_0 + b_1^{Dbh}$	6.983	1.026	0.8	94	96.31
3	$CW = b_0 \times Dbh^{b1}$	1.414	0.555	0.93	84	-42.83
4	$\ln CW = b_0 + b_1 Dbh$	1.813	0.012	0.77	23	-397.8
5	$\ln CW = b_0 + b_1 \ln Dbh$	0.219	0.589	0.88	11	-593.05

Table 6: Result of validation of double log. (M5) using t-test for paired sample.

Variable	Mean	SD	N	Diff	T	Df	p	Remark
Observed LnCW	2.496	0.223	50	0.2071	1.0561	49	0.2403	**
Predicted LnCW	2.288	0.213						

SD = standard deviation, Diff = hypothesized mean difference, df = degree of freedom, p = probability value, ** = not significant at 0.05.

DISCUSSION

The results of this study showed the number of hardwood tree species identified in the study area and their various families. A total of 20 hardwood tree species distributed into 12 families was obtained in the study area. This is lower than what was reported by Haastrup *et al.* (2019) in their study on tree diversity in Owo forest reserve, Ondo state where a total number of 112 species and 42 families were encountered. The discrepancy may be since only hardwood tree species were considered and also as a result of the size of the study area. The low number of species might also be because of infrastructural development and other anthropogenic activities causing encroachments in the study area. Similar findings have been reported by Dimitrios *et al.* (2018) on forest that have been anthropogenically disturbed.

In this study, information on tree growth characteristics (Db, Dbh, and CW) was obtained. From the result of this study, the minimum, maximum and mean diameter at base for the trees measured were higher than the diameter at breast height, which is biologically realistic. This is like the reports of Ezenwenyi and Chukwu (2017) for *Tectona grandis* Linn. f. species in Omo Forest Reserve, Ogun State and Chukwu *et al.* (2017) for *Parkia biglobosa* Benth. species in Makurdi, Benue State in Nigeria. The knowledge of these tree and stand variables is fundamental in predicting growth and yield models, determining tree stability, health status and condition in any forest stands (Ezenwenyi *et al.*, 2020).

The study also showed that there is significant and positive relationship between crown width (CW) and other selected tree variables. The Crown width (CW) and Crown projection area (CPA) had the highest and significant positive relationship. This was followed by the

relationship between Crown width (CW) and diameter at breast (DBH). This implies that these tree variables significantly affect the crown width, that is, trees with larger diameter will likely have wider crown width. This association is of importance to the trees because crown width contributes enormously to a tree total weight. This result is in line with the reports of Bragg (2001) and Adesoye and Ezenwenyi (2014) who reported in their studies that a strong relationship between crown width and tree diameters. Crown width can be used to calculate stand canopy closure, which is important for assessing wildlife habitat suitability, fire risk, stability, and competition for regeneration (Crookston and Stage, 1999; Adesoye and Ezenwenyi, 2014; Ezenwenyi *et al.*, 2020). Avery and Burkhart (2002) stated that forest management decisions are predicated on information about current and future resource conditions.

In this study five models for predicting crown width were tested for the hardwood tree species found in the study area. In fitting these regression models, simple linear, non-linear, semi- and double logarithm were examined. Dbh was used as explanatory variable while crown width was used as independent variable. All parameters were found to be significant at 0.05 level (5%) probability. The models fitted in this study were evaluated using adjusted coefficient of determination (Adj.R^2), Akaike Information Criterion (AIC), and relative standard error of estimate (RSE) which are considered as the standard way for evaluating models' predictive ability as indicated by Shamaki and Akindele (2013) and Adesoye and Ezenwenyi (2014). The model which had high value of Adj.R^2, lowest RSE, and smallest value of AIC was selected as the best predictor model for the hardwood tree species.

Among the five crown width models fitted and examined, model 5 (double logarithmic function) gave the best fit and predictive ability for crown width for the hardwood tree species found within the study area with Adj.R^2 = 0.88, RSE =11 and AIC= -539.05 respectively. Model 5 despite not having the highest value of Adj.R^2, had the lowest values of RMSE and AIC with also a high value of Adj.R^2 which made it the best predictor model for the hardwood tree species found in the study area. This study revealed that double logarithmic regression model is more consistent for modelling the CW-Dbh relationship for hardwood tree species. This result is similar to the report of Adesoye and Ezenwenyi (2014) who reported in their study that double logarithmic model performed best for crown diameter prediction for *Tectona grandis* stands in Omo Forest reserve. This result is not in agreement with the findings of Avsar and Ayyildiz (2005) who observed that crown diameter-Dbh relationships can be described by the Power model. This may be because of the use of only different hardwood tree species instead of single species.

Table 5 results showed that there is no significant difference ($p > 0.05$) between predicted and observed values of crown width. The study showed that diameter at breast height is suitable for tree crown width prediction once both crown width and diameter at breast height are logarithmically transformed. Overall, the results obtained can help in the current silviculture and management of the hardwood tree species in the study area.

CONCLUSION

Information on tree growth characteristics is a vital part of appraising trees in the forest stand. Hardwood tree species remain one of the economic tree species that require global attention. Unbiassed and dependable procedures for obtaining these growth characteristics measurements are needed from the results of this study. This study therefore concluded that crown width could be estimated by the mean of diameter at breast height as it is easy to measure for ground-based inventory and stand structure determination. The crown width model examined in this study produced reasonably precise estimates for crown width and could be used to predict the crown width of the hardwood tree species found in the study area which are under consideration. This study concluded that, the crown width can easily be predicted from diameter at breast height with high accuracy and precision using double logarithmic model (M5).

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SUB-THEME:

TRENDS IN AGROFRESTRY RESEARCH, FOOD SECURITY AND BIODIVERSITY CONSERVATION

In vitro rooting of *Milicia excelsa* (Welw.) C.C. Berg. towards mass propagation

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Abstract

The development of *in vitro* propagation protocol is incomplete without efficient rooting method for the generated plantlets. Hence, the root induction of *Milicia excelsa* micro-cuttings were assessed in five treatments [(control), 0.25, 0.5, 1.0 and 1.5 mg/L NAA] experiment, laid in CRD with five replicates. Murashige and Skoog medium basally supplemented with 0.5 mg/L BAP was used, while explants inoculated were excised from a culture of *M. excelsa* in growth room. Data collected on number of roots, root length and shoot length were subjected to analysis of variance using GenStat and means separated with fisher's protected least significant deference. The results indicated that all the NAA concentrations induced roots on the plantlets compared with control which had no roots at 8 Weeks After Inoculation (WAI). Moreover, treatment 0.5 mg/L NAA elicited highest average number of roots and longest root length (5.2 cm and 1.7 cm, respectively) though, not significantly different ($p > 0.05$) from results (5.2 and 1.54 cm) observed for 1.0 mg/L NAA at 8 WAI. Treatment 0.25 mg/L NAA stimulated the longest shoot length (4.0 cm), which similar to shoot length produced by 0.5 mg/L NAA (3.16 cm) at 8 WAI. These results indicated that NAA was an effective rooting hormone for *M. excelsa in vitro*, while 0.5 mg/L was the optimum concentration for best results.

Keywords: Plantlets, Micro-cuttings, Root induction, Explants

Introduction

Climate change remains a global threat to ecosystems and biodiversity, while trees play crucial roles in combating its impacts through carbon sequestration, conservation of forest ecosystems and livelihoods support (Weiskopf et al., 2020; Cherinet and Lemi, 2023). Native to tropical Africa, *Milicia excelsa*, commonly known as African teak or Iroko, is renowned for its high-quality timber, dense wood properties and ecological importance in the region (Mugabi et al., 2005; Cunha et al., 2021). However, due to deforestation and habitat degradation, its population is declining, while the species becomes threatened, necessitating its plantation establishment for conservation program (Quinsavi and Sokpon, 2010). Notably, successful plantation establishment relies on the adequate supply of healthy seedlings (Ugwu and Omoloye, 2015). Propagation of *M. excelsa* is not without challenges which include low seed germination potential and disease attacks in the nursery (Olajuyigbe and Adegeye, 2014). These factors continue to limit its seedling production, while creating gaps for efficient alternative methods of propagating the species, to continue harnessing its full potentials. Micropropagation offers unique opportunities for the mass propagation and conservation of endangered and economically valuable tree species in a controlled environment (Yadav et al., 2012; Gautam and Harshal, 2014). The technique is pivotal in *in-vitro* plant tissue culture, and it relies on the successful development of efficient protocols across different stages which include but not limited to root

induction (Sharma et al., 2015). Efficient *in vitro* rooting protocols remain crucial to the success of the whole *in vitro* micropropagation, as the induced roots enables better adaptation of plantlets to the changing environmental conditions (Shekhar et al., 2019; Calleja-Cabrera et al., 2020). Auxin hormones play crucial role during root formation in micropropagation. Moreover, exogenous auxin such as NAA, can induce de novo root primordia in preformed xylem pole of pericycle cell of plantlets (Pasternak and Steinmacher, 2024). Past efforts to achieve regeneration of *M. excelsa* whole plantlets stopped at shoot multiplication stage (Afolabi et al., 2022). Whereas the chances of survival of the young, generated plantlets without root is relatively low (Leite et al., 2021). Consequently, the present study sought to assess the effects of different NAA concentrations on root induction of *M. excelsa*, to enhance effectiveness of its propagation efforts.

Materials and Methods

This experiment was conducted at the Biotechnology Department of Forestry Research Institute of Nigeria (FRIN), Ibadan, located on longitude 07°23'18″ N to 07°23'43″N and latitude 03°51'20″E to 03°23'43″E. The treatment consists of a control [Murashige and Skoog (MS) medium, (Murashige and Skoog, 1962)] and four concentrations of NAA [0.25, 0.5, 1.0 and 1.5 mg/L], added to the medium and laid in completely randomised design with five replicates. The growth medium was prepared by dissolving 34.43 g of MS powder in 800 ml of distilled water and was basally supplemented with 0.5 mg/L BAP (Afolabi et al. 2022). The volume was divided into five and NAA was added accordingly. The pH of each medium was adjusted to 5.8, made up to 200 ml and solidified with 9.5 g/L of agar. The media were dispensed at 20 ml per tube and sterilised in autoclave for 15 minutes at 121° C and 15 *psi*. Plantlets of *M. excelsa* were taken from growth room. The shoots and nodal segments (about 1.5 cm size) of the plantlets were exercised and inoculated into the media. The inoculated tubes were sealed with parafilm and kept in the growth room under 16-hour light and eight hours dark.

Data were collected on number of roots, length of roots, stem height and number of leaves at interval of four weeks, starting from fourth to eight weeks after inoculation. The data were subjected to analysis of variance using GenStat, edition fourth while significantly different means were separated with fisher's protected least significant deference.

Results and Discussions

The results of analysis of variance conducted on number of roots, roots length, shoot length and number of leaves of *M. excelsa* as influenced by NAA concentrations indicated that there were significant differences ($p \leq 0.05$) between the treatment means for the variables except for number of leaves at successive growth weeks (Table 1). Results showed that all the NAA concentrations induced roots on the plantlets compared with control which had no roots at 8 Weeks After Inoculation (WAI). Highest average number of roots (4.4 and 5.2) were produced by 0.5 mg/L NAA which were not significantly different ($p > 0.05$) from the roots (4.2 and 5.2) induced by addition of 1.0 mg/L NAA at each period of investigation, respectively (Figures 2 and 3). However, each of these treatments produced significantly higher number of roots than control and other treatments at the same periods. Similarly, the number of roots induced by addition of 1.5 mg/L NAA and 0.25 mg/L NAA were comparable at 4 and 8 WAI.

Results for root length followed similar trend as numbers of roots at each period of observation (Table 1). There was no significant difference between the average root lengths produced from media supplemented with 0.5 mg/L NAA (1.14 and 1.7 cm) and 1.0 mg/L NAA (1.26 and 1.54 cm) at 4 and 8 WAI, respectively. Nonetheless, each of these treatments produced significantly longer root lengths than what was observed for control and other NAA levels at the same periods (Figures 2 and 3). On the other hands, treatment 0.25 mg/L NAA stimulated the longest shoot length (2.98 cm and 4.0 cm) at 4 and 8 WAI respectively. These results were parallel to shoot length elicited by 0.5 mg/L NAA (2.64 cm and 3.16 cm, respectively) while significantly higher than values for control and other NAA applications at each periods of observations. The results of analysis of variance indicated that there was no significance difference ($p > 0.05$) in the effects of NAA levels for number of leaves of the plantlets at successive growth weeks. Average number of leaves ranged from the highest (3.2) produced by treatment 0.25 mg/L NAA to the lowest (1.8) produced by treatment 1.5 mg/L NAA at 8 WAI (Figure 1).

Table 1. **Effects of NAA on average number of roots, root and shoot length of *Milicia excelsa* at successive weeks of growth.**

NAA (mg/L)	Number of roots		Root length (cm)		Shoot length (cm)	
	4WAI	8WAI	4WAI	8WAI	4WAI	8WAI
0.0 (Control)	0	0	0.0	0.0	1.52	1.6
0.25	0.8	0.8	0.14	0.36	2.98	4.0
0.5	4.4	5.2	1.14	1.7	2.64	3.16
1.0	4.2	5.2	1.26	1.54	1.56	2.84
1.5	1	2.4	0.36	0.84	2.08	2.66
L.S.D at $p \leq 0.05$	2.05*	2.16*	0.30*	0.61*	0.88*	1.34*

*****indicates means in the same column are significantly different at $p \leq 0.05$ by Fisher's L.S.D

WAI: weeks after inoculation

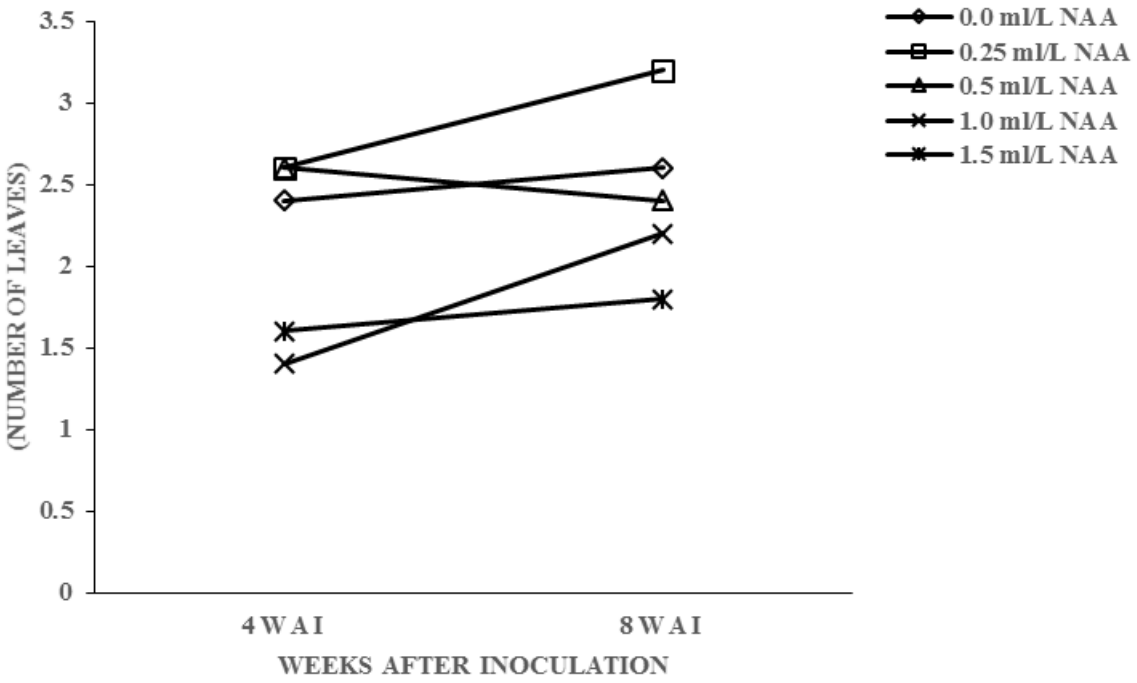

Figure 1. Effects of NAA on number of leaves of *Milicia excelsa* micro-cuttings at successive weeks of growth.

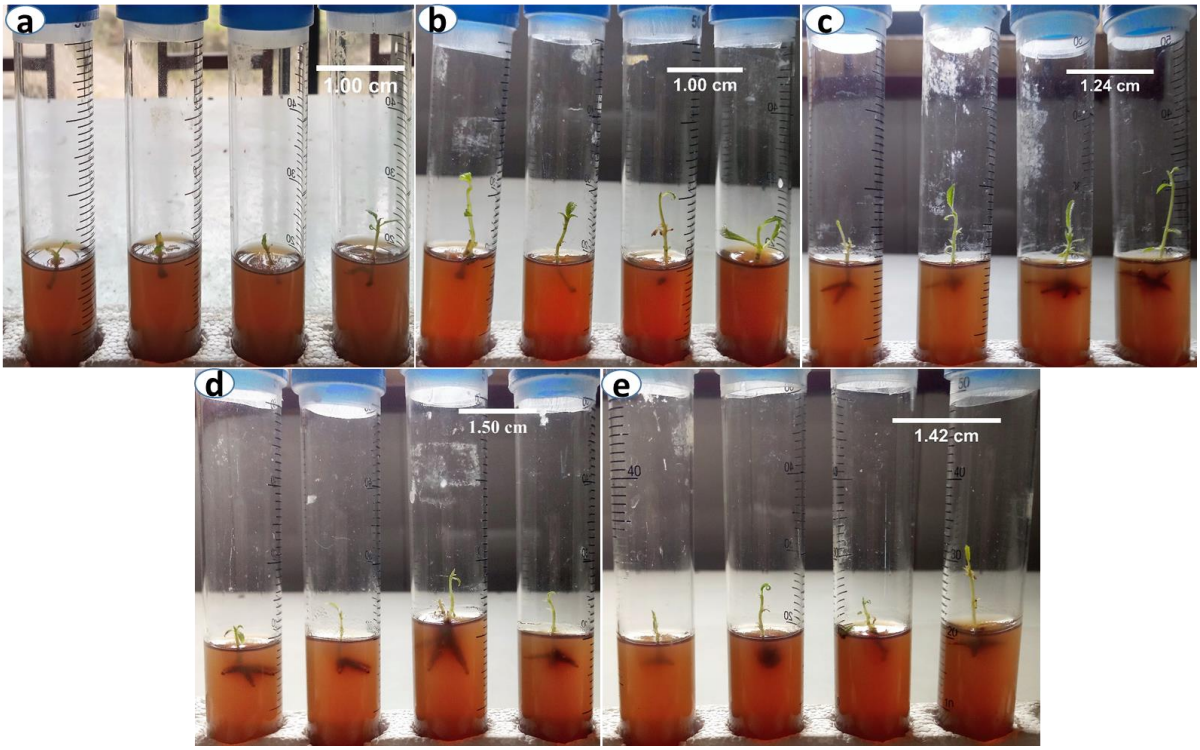

Figure 2. Effects of NAA on growth of *Milicia excelsa* micro-cuttings at 4 weeks after inoculation

a: Control, b: 0.25 mg/L NAA, c: 0.5 mg/L NAA, d: 1.0 mg/L NAA and e: 1.5 mg/L NAA

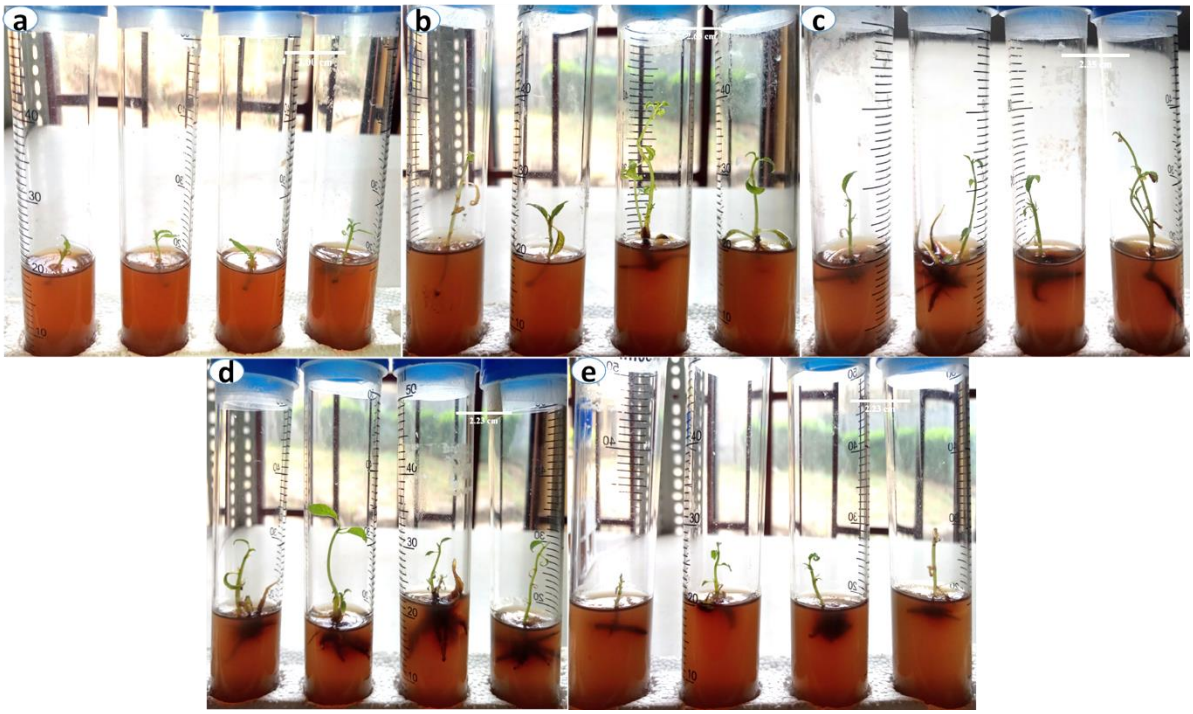

Figure 3. Effects of NAA on growth of *Milicia excelsa* micro-cuttings at 8 weeks after inoculation

a: Control, b: 0.25 mg/L NAA, c: 0.5 mg/L NAA, d: 1.0 mg/L NAA and e: 1.5 mg/L NAA

The observed better growth response of *Milicia excelsa* micro-cuttings (Shoot tips and nodal segments) from the media supplemented with NAA compared with control at successive growth weeks indicated that the concentration of endogenous rooting hormone available in the plantlets was not enough to induce roots except when externally added. These results also underlined NAA as an effective rooting hormone for the species *in vitro* (Table 1 and Figure 3). NAA is a synthetic auxin hormone which acts by promoting root differentiation and formation, cell growth and elongation (Rehman et al., 2023). These functions were expressed in the micro-cuttings inoculated on media supplemented with NAA, leading to root formations compared with control.

The observed better results elicited by the addition of 0.5 mg/L NAA in terms of average number of roots induced at 8 WAI, indicated that the concentration was the optimum for *in vitro* rooting of *M. excelsa*. Though, this result was closely related to the number of roots observed for 1.0 mg/L NAA however, the longest root and shoot length observed for 0.5 mg/L NAA validated the treatment as the best performing hormone concentration. The results observed for 0.25 mg/L and 1.5 mg/L NAA indicated that these rates were at extreme low and high respectively, for optimum root induction in *Milicia excelsa*. This was evident in the suppressed growth of the aerial parts of the plantlets at concentration above 1.0 mg/L NAA and reduced roots formation at concentration below 0.5 mg/L NAA, giving room for longest shoot length observed for 0.25 mg/L NAA. These

results supported the report of Yan et al. (2014), that NAA is used relatively at low dose to elicit responses in cell growth. Moreover, these results relate to previous findings, when 0.5 mg/L NAA induced highest number of roots on *Eucalyptus camaldulensis* micro-cuttings (Afolabi et al., 2021).

Conclusions

The efficacy of NAA at different concentrations were accessed on root induction of *Milicia excelsa* micro-cuttings. Murashige and Skoog media supplemented with NAA induced roots compared with control medium. Application of 0.5 mg/L NAA elicited the highest number of roots and root length at 8 weeks after initiation. Hence, for good root formation and survival of *Milicia excelsa* plantlets, MS medium supplemented with 0.5 mg/L NAA in the presence of low level of BAP (0.5mg/L) should be used for best results.

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Effects of garlic extract on growth performance of Sheep Fed on a Concentrated Diet in the Semi-Arid Zone of Borno State.

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Abstract

The study was carried out to determine the influence of garlic extract on the growth performance of sheep fed on a concentrate diet in the semi-arid zone of Borno state; sixteen (16) sheep of mixed breed weighing an average of 21.56kg were used for the experiment. The animals were divided into four (4) groups with four (4) animals per treatment and assigned to treatment in a complete randomized design (CRD). The animals were given 0, 2.5, 5.0 and 7.5ml of garlic extract for T1 (control), T2, T3 and T4, respectively. The animals were fed with a concentrated diet and water ad-libitum. The result of the growth performance showed no significant (P>0.05) differences in feed intake between the treatment groups. While the daily weight gain and feed conversion ratio differ significantly (P>0.05) between the treatment groups. In conclusion, sheep drenched with 7.5ml of garlic extract had the best growth performance.

Introduction

Nigeria has about 22.1 million sheep. They thrive in various environments in the tropics and subtropics. They require less capital as they can be maintained entirely on pastures, browse and agricultural waste products. The economic importance of sheep in developing nations cannot be over-emphasized. Sheep have a small body size, high productive capacity, and rapid growth rate and are ideally suited to production by resource-poor smallholders. In sub-Saharan Africa, sheep account for almost 30% of the meat consumed and around 16% of the milk produced. Sheep contribute about 50% of Nigeria's total domestically produced meat (Citation needed). One of the significant problems of sheep production is nutrition, which accounts for more than 60% of the cost of production. However, crop residues have been estimated to account for more than 25% of the total feed energy suitable for ruminant's livestock in developed and developing countries (Benchaar et al. 2007). The nutritional value of crop residue varies according to species, variety, environmental conditions, stage of maturity and method of harvest, storage and feeding, among others (Subands and Said,1993). In general, crop residue, especially for cereals type, is characterized by low levels of nutrients, which limits utilization. The nutritional value of this residue can be upgraded using various methods to meet the animal's requirements. The farmers are mainly ignorant of the principles of feeding, although the nutrition plan is a significant factor that determines the growth and development of small ruminants (Ekumanka, 1999). Also, natural pastures support only satisfactory performance of small ruminants for a relatively short period, and agro-industrial products and crop residues such as corn cob are readily available. When sheep are fed with cowpea husk, maize cob or low-quality roughages,

supplementation with feeds containing protein or energy sources such as bran, maize corn cob, sorghum bran, and urea is required to improve both roughage utilization and growth performance. Sampong et al., (2007) reported that garlic as feed additive, improve sheep's properties.

Garlic (*Allium sativum*) is widely distributed and used in all parts of the world as a spice and herbal medicine for the prevention and treatment of various diseases, ranging from microbial pharmacologic infections to respiratory diseases. Garlic is thought to have various growth and feed conversion ratios (FCR) and decreased mortality rates in sheep. Similarly, Demir et al. (2003) reported that garlic may be used as an alternative antibiotic growth promoter for broiler production. Javandel et al. (2008) also reported that the use of natural feed additives garlic has made it possible for one to avoid the harmful effects of synthetic antibiotics.

Materials and methods

Experimental site
The experiment was carried out at the Livestock Teaching and Research Farm, Department of Animal Science, Faculty of Agriculture, University of Maiduguri. The study area is situated at a latitude of 11.050" N, a longitude of 13.009" E, and an altitude of 354m above sea level. The area falls within the Sahelian region of West Africa, which is noted for its significant climatic and seasonal variation. It has a very short period (3-4 months) of rainfall of 645.9mm/annum with a long dry season of about 8-9 months, and the relative humidity is 45% in August, which usually lowers to about 5% in December and January (Raji et al. 2014).

Experimental animals and their management

Sixteen (16) sheep of mixed breed with an average body weight of 21.5kg were used for the study. All the animals were obtained from the Department of Animal Science Livestock Teaching and Research Farm at the University of Maiduguri. The animals were weighed and identified using plastic ear tags and assigned to four (4) different treatments using a complete randomized design (CRD). The animals were given prophylactic treatments against external and internal parasites. The animals were housed in pens with expansive windows for adequate ventilation. The animals were fed for 7 days as an adaptation period before the commencement of data measurement.

Sources and preparation of feed

The feed ingredients, namely cotton seed cake and wheat offal, were purchased from a local market in Maiduguri. The corn cob was purchased from a local farmer and was ground into coarse form; the poultry litter was collected from the poultry units of the teaching and research farm, animal science department of the university of Maiduguri. The poultry litter, after collection, was sun-dried and ground into fine particles. A concentrated diet was formulated using the feed ingredients.

Treatments

The sheep were divided into four (4) groups of four animals per group and assigned to treatments in a complete randomized design (CRD). T1 (control) had no garlic extract, while T2, T3, and T4 were given 2.5, 5.0 and 7.5ml weekly of garlic extract, respectively. The sheep were fed the concentrated diet and fresh drinking water ad-libitum.

Preparation of garlic extract

About 200g of dried garlic cloves were soaked overnight in 200ml of distilled water to allow easy removal of cuticles and extraction of juice. The cloves immersed in water were pounded until they were completely mushy. The crushed material was left to stand for 2 hours and later filtered. The garlic juice is used as soon as possible because the active compound Allicin is prone to rapid decomposition. The garlic juice is then diluted with water at the ratio of 8:2, making a concentration of 80%, according to Masamhaet al. (2010).

Table 1: composition of the experiment diet.

Ingredient	T1	T2	T3	T4
Maize cob	40	40	40	40
Wheat Bran	30	30	30	30
Cotton seed cake	15	15	15	15
Poultry litter	15	15	15	15
Total	100	100	100	100
Level of garlic extract	0ml	2.5ml	5.0ml	7.5ml

Parameters measured.

The parameters determined in this experiment include, feed intake, weight gained and feed conversion ratio (FCR)

Feed intake

A weighed amount of the experimental diet (2kg) was given to each treatment group. The daily feed intake was obtained by subtracting the left-over feed from the feed given to each treatment.

Weight gained

The animals were initially weighed before assigning them to different treatment diets. These served as the initial weight and subsequently weighing was carried out on a weekly basis, throughout the experimental period of eight weeks (56 days).

Feed conversion ratio.

This was calculated as the ratio daily feed intake to that of weight gained.
Feed conversion ratio (FCR) = daily feed intake/daily weight gained

Statistical analysis

All data collected were subjected to analysis of variance (ANOVA) using the complete randomized design (CRD) (Steel and Torrie, 1980) means were separated where applicable using Duncan's multiple range test (Duncan, 1955), a computer package (statistic-9.0), was used for the analysis.

Result and Discussion

The proximate composition of the feed ingredients is presented in Table 2; the percentage of dry matter recorded in poultry litter is 95.2% and it is higher than the average value of 35.3% reported by Abeke et al. (2005). This probably could be due to weather condition of the environment. The crude protein content was 10.11%, within the range value of 5-10%. As reported by Mohammed (2007), the crude fibre content of 25% recorded in conformity with the work of Abeke et al. (2000), who reported an average value of 24.28%. The ether extract recorded 3%, was similar to the value 2.70% reported by Pond and Pond (2000) the value of ash (4%) was not in conformity with the value 14.20% reported by Pond and Pond (2000).

The dry matter content (96.3%) of cotton seed cake was higher than the range value 85-90% reported by NDDB (2012) and Mc George (2000). The crude protein content is similar to the value of 15%, reported byNDDB, (2012). The crude fiber value recorded in this study is similarto the value 22,88% reported by Bonsiet al., (1999).
The dry matter content (94.3%) recorded in wheat bran is comparable with the value of Olumo (1993). Ether extract value 3% is lower than 5% reported by Alawa and umunna (1986). The nitrogen free extract (5.07%) recorded and the crude fiber (21%), are in line with the work of Akinfemi et al., (2009). Ether extract value (4%) recorded it is within the range value of 3.6-6%.

Table:2 proximate composition of feed ingredient

Ingredient	DM%	CP%	CF%	EE%	ASH%	NFE%	ME
Poultry litter	95.20	10.11	25.00	3.00	4.00	57.89	249.90
Cotton seed cake	96.30	15.10	23.00	8.00	5.00	49.90	2810.06
Wheat offals	94.30	8.31	19.00	3.00	5.00	64.69	2644.62
Corn cob	96.10	5.07	21.00	3.00	4.00	66.93	2668.16
Experimental diets	95.20	18.25	16.00	5.00	4.00	51.95	2922.63

DM (Dry matter), CP(Crude protein), CF(Crude fibre), EE(Ether extract), Ash and NFE(Nitrogen free extract), ME=Metabolizable energy=(37%CP)+(81%EE)+(35.5%NFE)

The result of growth performance of sheep fed concentrate diet shown in table 3. The result of initial weight, final weight and feed intake were not significantly ($p>0.05$) different among the treatment groups. Also, daily weight gain and feed conversion ratio were not significantly($p>0.05$) different between the treatments. The initial live weight of the sheep fed the concentrate diet drenched with garlic extract range from 20.675-23.275kg. The final live weight ranged from 25.275-26.9750kg. The sheep are increasing weight by increasing volume of garlic extracts administration according to Bampidis et al., (2005).

Treatment T3and T4 recorded the highest feed intake. The daily weight gained of sheep fed concentrate diet drenched with garlic extract ranged from 0.0975 to 0.850kg. The daily weight gained recorded in this study was similar to the value reported by Alawa and Ummuna (2004) who fed various concentrate diet to sheep. Odeyinka et al., (2014) reported daily weight gain of 0.0800 to 0.850kg/day. The weight gained of sheep in this study was higher than the range value of 0.100-0.200kg/day, reported by Cheeke (1987) for sheep reared in tropical countries. The feed conversion ratio of sheep fed the concentrate drenched with garlic extract, value ranges between 13.7325 -24.8975. the value recorded in this study were higher than the value 10.5467-12.2387 reported by Odeyinkaet al., (2014), who fed corn cob-based diet drenched with garlic extract. The variations observed in the treatment groups may be due to the varying levels of garlic extract used in drenching the animals.

Table 3: Growth performance of sheep fed concentrate diet supplemented with garlic extracts

Parameter	T1	T2	T3	T4	SEM
Initial weight	22.2750	21.3500	20.6750	23.2750	4.2^{NS}
Final weight	25.2750	25.7750	26.1250	26.1250	4.33^{NS}
Dailyfeed intake	1.0400	1.0500	1.0900	1.0900	0.000^{NS}
Daily weight gain	0.0550^{ab}	0.800^{ab}	0.0975^{b}	0.850^{a}	0.03^{*}
Feed conversion ratio	24.8975^{a}	13.7325^{ab}	16.4625^{b}	15.2150^{ab}	8.22^{*}

SEM=standard error of mean
NS=not significant (p>0.05)
*= significant (p>0.05)
a,b= mean in the same row with different superscripts differ significantly(p>0.05)

Conclusion

The results of the experiment showed that drenching rams with garlic extract feed with concentrate diet had no adverse effects on growth performance of sheep. The highest growth rate was recorded in sheep fed T4 while the lowest was recorded in sheep fed on T1(control). This implied that there was an increase in growth performance as the quantity of garlic extract is being increase across the treatment.

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Comparative evaluation of some Physico-chemical properties of Soil under *Parkia biglobosa*, Plantation in Kabba, Kogi State, Nigeria.

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Abstracts

The study was carried out to investigate the physicochemical properties of soils under ***Parkia biglobosa*, (**African locust bean) plantations located in Kabba, Kogi State, Nigeria, to maintain its optimum growth conditions and establish the fertility status of the plantation. A matured plantation of approximately five hectares was selected for this study, which was delineated into eight strata and 3 points and sampled randomly at the surface and subsurface (0-15 and 15 - 30 cm) per stratum yearly from 2017 to 2019 with the use of soil augur. Soils collected from each stratum were bulked, bagged, and taken to the laboratory for analysis. The study was a 3 X 2 factorial experiment set in a completely randomized design having 24 replicates. The collected soil samples were air-dried and sieved with a 2mm diameter sieve before the laboratory analysis. Standard analytical methods were employed to determine the physicochemical properties. The results across the years under investigation revealed that the soils were slightly acidic to slightly alkaline with pH values that ranged from 5.48 – 8.0, and the organic matter content of the soils ranged from 0.57 -4.41. This indicates that the soil under investigation has a high organic matter content. Similarly, the exchangeable cations are moderate to high across the sampled area with the Ca that ranged from19.70-76.26, Mg from 1.71- 6.96, Na from 0.52- 2.21 and K contents from 0.05- 1.36. All these values indicate a non-saline nature of the soils, suitable for plant growth and soil microbial processes. This study inferred that these forest surfaces and subsoils are considered good quality due to their non-saline, non-acidic nature and have proven to contain significant quantities of SOM and exchangeable cations. Also, the soils were predominantly sandy loam and loamy sand and possess suitable pH for typical forest ecosystems.

Keywords: Physicochemical, *Parkia biglobosa*, Delineated, Stratum and soil pH

INTRODUCTION:

In Nigeria, particularly in the southwestern zone, continuous cropping with intercropping intensified has significantly reduced agricultural lands' fertility to the extent that it could no longer supply the nutrients crops require for average growth. Most of the soils in the tropics are dominated by soil with low-activity clay. These soils have low buffering capacity and water retention and are susceptible to soil erosion and compaction. Thus, soils suffer from multiple nutrient deficiencies, nutrient imbalances, and degradation of vital chemical properties (Lawrence *et al*., 2013). The destruction of vegetation through forest clearing for cropping purposes further reduces the vegetation cover, thereby leading to erosion, especially in sloppy areas. Leaching nutrients below the rooting zone of crops due to waterlogging, the volatilization of Nitrogen (N) and the deficiency of phosphorus are common. Recent research has shown that

crucial chemical soil characteristics can change in less than a decade due to broad environmental changes driven by the consequences of human activities (Lawrence *et al*., 2013). Ogunkunle and Awotoye (2011) reported that trees are acknowledged to convey changes in micro-climate, floral, faunal, and other mechanisms of the ecosystem via bio-recycling of mineral elements.

However, there is no doubt that trees have played an essential role in soil conservation and management throughout the tropics. The selection of tree species for use in agroforestry is significant and not just to select super species but should include promoting genetic diversity and matching intra-specific diversity to the needs of farmers, markets, and the diversity of the environment (Atta-Krah *et al.,* 2004). Therefore, the need to use *Parkia biglobosa,* owing to its numerous importance in the southwestern agro-ecological zone's economy was necessitated. *Parkia biglobosa* is a perennial deciduous tree with a height ranging from 7 to 20 m, although it can reach 30 m under exceptional conditions. Crown large, spreads wide with branches low down on a stout bole; amber gum exudes from wounds; bark dark grey-brown, thick, fissured. *P. biglobosa* occurs in a wide range of natural and semi-natural communities, such as open savannah woodlands. Still, it is most conspicuous and abundant in anthropic communities, principally bush fallow, and wooded farmland where cultivation is semi-permanent. The tree can also grow on rocky slopes, stony ridges, or sandstone hills. It is a fire-resistant heliophyte. This tree also occurs in diverse agro-ecological zones, ranging from tropical forests with high and well-distributed rainfall to arid zones where mean annual rainfall may be less than 400 mm. It can withstand drought conditions because of its deep taproot system and its ability to restrict transpiration. It prefers well-drained, deep, cultivated soils but is also found on shallow, skeletal soils and thick laterites (Orwa *et al*., 2009). Therefore, the objective of this study is to evaluate the physic-chemical properties and nutrient status of the soils under Parkia biglobosa and establish the fertility status of the plantation to recommend the importance of tree species for agroforestry practice.

MATERIALS AND METHODS

Description of the study area

This study was carried out in the forest vegetative zone of Kogi State, Nigeria, on a *parkia biglobosa* plantation in Kabba, a prominent town within the state adjudged to play a vital role in agricultural production. The study area lies on Latitude 6° 44' N and Longitude 7° 44' E. Going by the present composition of the state, Kogi State is quintessentially Nigeria, with three dominant ethnic groups, namely Igala, Ebira and Okun (Yoruba) and several minorities (Omotola, 2008). Kogi state has a total land area of 28,313.53 square kilometres. The Nigeria national population census of 1991 estimated an average population figure of 2,141,756 for the state, with most of the population involved in one form of agricultural practice or another (Ali *et al*., 2012). The state, like many other states in Nigeria, is blessed with vast natural resources and fertile lands that support agricultural production; among the natural resources that Kogi State can bold of are coal at Okobo, Ankpa, extensive deposits of iron ore at Ajaokuta, limestone at Obajana and tantalite in Kabba, the studied area, to mention just a few. The climate is a tropical climate with two distinct seasons' rainy season (March – October) and dry season (November – March)]. The rainfall regime shows double peaks separated by a comparatively low rainfall period (dry period) in August called August Break. The mean annual rainfall ranges from 1,560

mm at Kabba in the West to 1,808mm at Anyigba in the East. The average monthly temperature varies from 17 to 36.2^{o}C. The temperature shows some variation throughout the years. The state is known for cultivating arable crops such as yam, cassava, maize, groundnut, cowpea e. etc. c, which are also abundant at the study site (Omotola, 2008).

Sample collection and preparation.

A matured plantation of approximately five hectares was selected for this study. The entire plantation was delineated into 8 strata and 3 points and sampled randomly at the 2 depths (0-15 and 15 - 30 cm) per stratum yearly from 2017 to 2019 using soil augur. The soil samples collected at the top and subsoil were bulked and composited. A subsample was collected from the bulked samples and stored in a labelled sample bag for transportation to the laboratory for analysis. The study was a 3 X 2 factorial experiment set in a completely randomized design having 24 replicates. The subsamples collected were air-dried in the laboratory. They were made to pass through a 2 mm diameter sieve; particles less than 2mm were used for the laboratory analysis of the soil physicochemical properties using international standard methods.

The modified Bouyoucos hydrometer method evaluated the particle size distribution, as reported by (Gee and Or, 2002), using 5% w/v sodium hexametaphosphate (Calgon) as the dispersing agent. The soil pH was determined in 1.0 M KCl (1:1 soil: solution ratio) using a glass electrode pH meter (Kent model 720) after equilibration for 30 minutes (Thomas, 1996). The exchangeable cations (Ca, Mg, K and Na) were extracted with 1.0 M ammonium acetate (NH_40AC) solution at pH 7.0 (Thomas and Throp, 1985). Calcium, sodium, and potassium ions in the extract were determined using a flame photometer (Gallenkamp Model FH 500), while magnesium ion in the extract was determined by titration. Bray determined the available phosphorous One method as reported by (Kuo, 1996). The Walkley Black method determined organic carbon, and the soil organic matter was determined by multiplying organic carbon by 1.724 (Nelson and Sommers, 1982).

Statistical analysis.

The generated data was subjected to analysis of variance using the Genstat statistical software package. Means were separated using the Duncan multiple range test (DMRT) at a 5% significance level.

Results and Discussion

Soil physical properties play a significant role in soil fertility because the amount and sizes of soil particles control the porosity and bulk density, which account for the retention or leaching of nutrients (Unanaonwi and Chinevu 2013). The result of the study in Table 1 shows that sand has the highest particle size distribution, which ranged from 81.50 % to 88.50 %, while silt particles ranged from 2.50 % to 11.00 %) of soil and clay particles ranged from 7.5% to 9.00 %) of soil. The examined plantations' soils are light, with a more significant percentage of sand. The size distribution has a direct influence on porosity, which is highest in sand, as expected, given its inability to retain water except for the plant canopy cover and the litter falls within the plantation that has reduced the rate of water and mineral loss through leaching and evapotranspiration. This finding is corroborated by Adugna and Abegaz's (2016) findings, which indicated that forestland

soils had the highest sand content. The results showed that the soil samples had primarily sandy loam and loamy sand textures. It aligns with what Uquetan *et al*. (2017) and Umeri *et al*. (2017) reported. The pH values ranged from 5.48 to 8.0 across the years under consideration.

Generally, the pH fluctuated across the sampled area but ranged between slightly acidic and slightly alkaline. This is in line with the previous research carried out by Smyth and Montgomery (1962) on soils in Southwestern Nigeria and Okenmuo *et al.* (2020) on the soils of the lower Niger floodplain of Atani, southeastern Nigeria. The slightly acidic nature of the soil can be ascribed to the leaching rate of bases prevalent in the humid tropics and probably the acidic nature of the parent rock. The higher pH values observed at the soil surface, according to Fasina *et al.* (2007), might be due to the liming nature of the plantation litter and the bio-cycling of nutrients. Generally, the soils were between medium and high organic matter content, with values ranging from 1.27 to 4.41%. The surface soils had the highest amounts of organic matter. However, with the level of organic matter content of the soils, one of the management problems agronomists would have to contend with is the maintenance of organic matter in the soil over a long period under continuous cultivation across the area. This is because these soils would become markedly depleted in organic matter once they are put under constant cultivation due to the rapid humidification of organic matter that promotes activities of microorganisms, ants, and termites, hence lead the disruption of the natural built-up of organic matter.

Table 1: Laboratory result of physical and chemical properties of the forest surface soils under investigation

S/N	location	soil depth (cm)	Rep	OM %	TN %	pH	Ca	Mg	Na	K	P	Cu	Mn	Zn	Fe	Particle Size Analysis %			Texture class
							cmol kg-1				mg/kg					Sand	Silt	Clay	
1	A	0-15	1	3.47	0.17	6.50	34.21	2.94	1.11	0.2	0.14	3.4	49.6	30	660	84.50	6.50	9.00	Loamy Sand
2	A	15-30	2	3.06	0.14	5.70	31.99	2.86	0.88	0.35	0.12	3.2	45.3	28	597	84.50	6.70	8.80	Loamy Sand
3	A	0-15	3	3.88	0.2	7.30	36.43	3.02	1.34	0.05	0.16	3.6	53.9	32	723	83.50	7.90	8.60	Loamy Sand
4	A	15-30	1	2.44	0.12	6.50	33.21	2.84	0.78	0.18	1.68	4.4	50.0	56	1780	86.50	4.70	8.80	Loamy Sand
5	A	0-15	2	2.39	0.09	6.30	37.29	2.9	0.61	0.09	2.01	3.7	52.6	65	1687	88.50	2.70	8.80	Loamy Sand
6	A	15-30	3	2.49	0.15	6.70	29.13	2.78	0.95	0.27	1.35	5.1	47.4	47	1873	88.50	2.90	8.60	Loamy Sand
7	B	0-15	1	1.82	0.09	6.59	27.82	2.19	0.59	0.18	1.40	3.1	49.5	38	420	86.50	4.70	8.80	Loamy Sand
8	B	15-30	2	1.53	0.07	6.36	29.02	2.11	0.52	0.16	1.60	3.3	48.8	35	402	84.50	6.50	9.00	Loamy Sand
9	B	0-15	3	2.11	0.11	6.82	26.62	2.27	0.66	0.2	1.20	2.9	50.2	41	438	83.50	7.90	8.60	Loamy Sand
10	B	15-30	1	1.65	0.08	6.78	33.65	2.25	0.78	0.15	1.19	6.5	50.1	48	680	82.50	8.50	9.00	Loamy Sand
11	B	0-15	2	1.38	0.10	6.57	32.87	2.26	1.01	0.14	1.42	6.4	49.9	47	654	81.50	11.00	7.50	Sandy Loam
12	B	15-30	3	1.92	0.06	6.99	34.43	2.24	0.55	0.16	0.96	6.6	50.3	49	706	81.50	9.70	8.80	Sandy Loam
13	C	0-15	1	2.15	0.13	6.50	19.76	2.74	0.74	0.16	3.01	3	49.0	34	300	88.50	2.50	9.00	Loamy Sand
14	C	15-30	2	2.01	0.17	6.90	19.70	2.97	0.76	0.17	3.08	2.4	43.0	38	292	88.50	5.50	9.00	Loamy Sand
15	C	0-15	3	2.29	0.09	6.10	19.82	2.51	0.72	0.15	2.94	3.6	55.0	30	308	82.50	8.70	8.80	Sandy Loam
16	C	15-30	1	2.13	0.11	6.33	31.21	2.64	0.72	0.13	0.70	2.4	47.5	36	540	84.50	6.50	9.00	Loamy Sand
17	C	0-15	2	2.21	0.13	6.30	32.09	2.78	0.71	0.18	0.60	2.0	49.3	32	556	86.50	4.70	8.80	Loamy Sand
18	C	15-30	3	2.05	0.09	6.36	30.33	2.5	0.73	0.08	0.80	2.8	45.7	40	524	82.50	8.50	9.00	Loamy Sand
19	D	0-15	1	1.38	0.07	7.10	46.77	4.29	0.74	0.23	2.80	6.1	47.3	58	1240	86.50	4.70	8.80	Loamy Sand
20	D	15-30	2	1.27	0.06	6.20	46.45	4.67	0.70	0.22	2.40	5.8	49.4	56	1470	83.50	7.90	8.60	Loamy Sand
21	D	0-15	3	1.49	0.08	8.00	47.09	3.91	0.78	0.24	3.20	6.4	45.2	60	1010	86.50	4.70	8.80	Loamy Sand
22	D	15-30	1	2.06	0.10	7.19	60.92	2.44	1.06	0.09	0.42	3.9	42.8	62	2180	88.50	2.50	9.00	Loamy Sand
23	D	0-15	2	2.02	0.09	6.84	60.26	2.74	1.11	0.07	0.38	4.6	40.7	65	2120	84.50	6.50	9.00	Loamy Sand
24	D	15-30	3	2.10	0.11	7.54	61.58	2.14	1.01	0.11	0.46	3.2	44.9	59	2240	88.5	2.50	9.00	Loamy Sand

The values of the available P are shallow. The values vary from 0.12 to 6.55 ppm. The values of the available P obtained across the area showed that it is inadequate for the maximum yield of most phosphorous-dependent crops. This is because the moderate value of available P required for crops' optimum yield is 10 to 20 ppm (Loganathan, 1987). The number of exchangeable cations (K, Mg, Na, and Ca) varies across the area as some increase while others decrease as depth increases (Table 1). In the study area, the value of K ranged from 0.05 to 1.36 cmol/kg. According to Loganathan (1987), these values were classified as moderate to high for crop production in the area. The Na, Ca and Mg values varied in all the regions sampled. The values of Na ranged from 0.52 to 2.21 cmol/kg, the values of Mg varied from 1.71 to 6.96 cmol/kg, and the values of Ca were much higher and ranged from 19.70 to 76.26 cmol/kg. Generally, the total exchangeable bases fluctuated with soil depth owing to nutrient biocycling. This could also be due to differential weathering that had taken place or because of plant uptake and leaching losses. Like in most tropical soils, the exchangeable sites of the soils studied were dominated by exchangeable calcium.

The soil total nitrogen level ranged from low to high according to Sobulo and Adepetu (1987), which classified the percentage of total Nitrogen into low (<0.10%), medium (0.10 - 0.20%) and high (>0.20%). The total Nitrogen of the soils across the location was from 0.05 to 2.00%. The probable reasons for the high value of Nitrogen in the soils may be due to reduced leaching activities in the area because of the canopy cover, and the low value of Nitrogen, as observed in some instances in the region, could be ascribed to the rapid rate of soil organic matter decomposition, high rate of leaching and loss to soil erosion where the canopy cover is skeletal (Solarin and Ayolagha, 2006). The Extractable micronutrient contents of the soils indicated that Copper (Cu) was 2.0 to 20.79 mg/kg, Iron (Fe) was 300.0 to 4800.0 mg/kg, Zinc (Zn) was 30.0 to 142.0 mg/kg, and Manganese (Mn) was 39.01 to 66.34 mg/kg in soils at the studied area. The distribution of these elements across the soil sampled was irregular, as observed from the sampling locations. The concentration of Fe was found to be higher in all the areas examined; this could either be due to the mineral composition of the underlying rock and the transported materials, uptake of essential nutrients by plants, leaching of exchangeable cations through heavy rainfall or by erosion or a combination of these factors. The higher values observed could be responsible for the occlusion of some of the plants' nutrients, like phosphorus, making it unavailable for plant uptake. They could also be responsible for the lower exchangeable cations recorded in some sampled areas from the soils under examination. This can be handled with an an adequate soil management system under continuous crop production. Apart from this element, the soil is presumed to have adequate other micronutrients for plant growth.

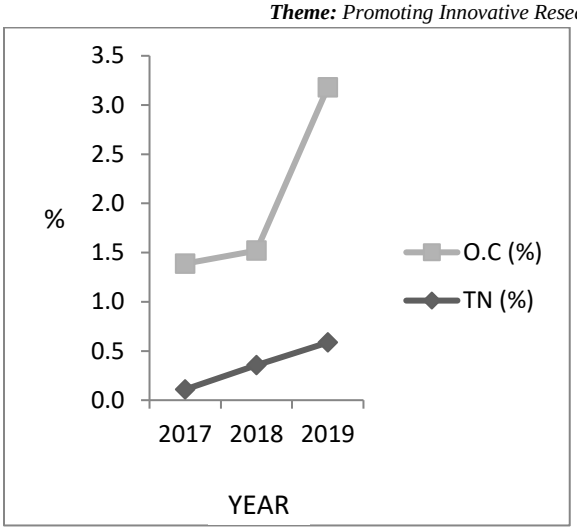

Figure 1: Yearly mean conc. of O.C and T.N in %

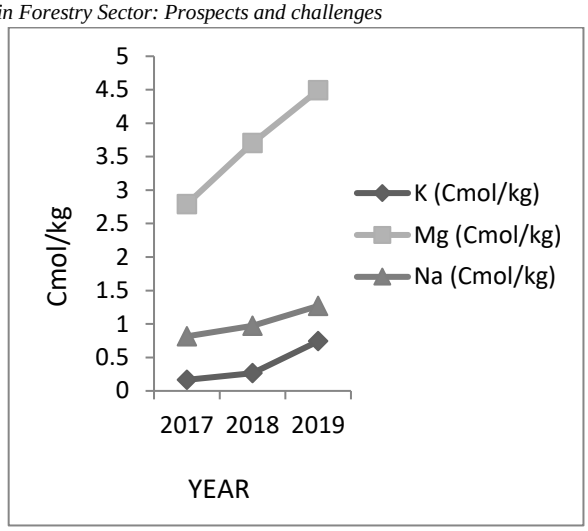

Figure 2: Yearly mean conc. of K, Mg and Na in Cmol/kg

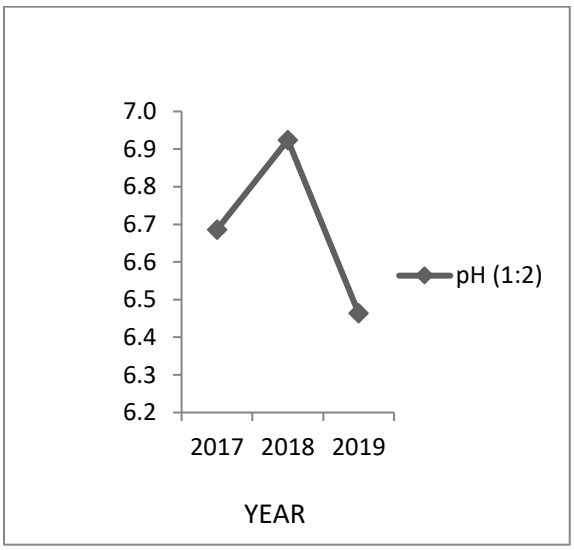

Figure 3: Yearly mean soil pH values

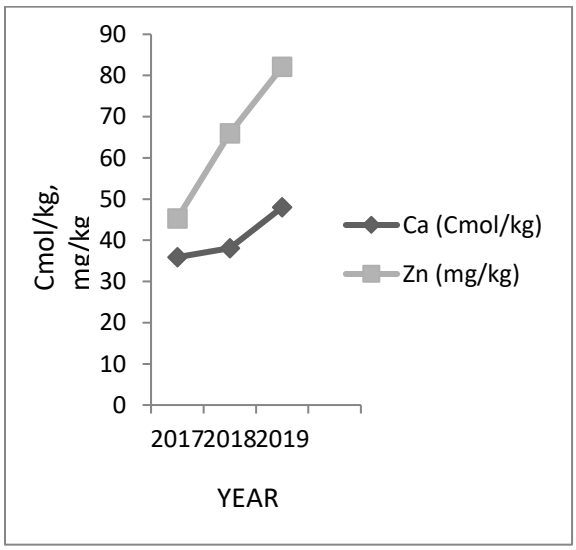

Figure 4: Yearly mean conc. of Ca and Zn in Cmol/kg and mg/kg, respectively

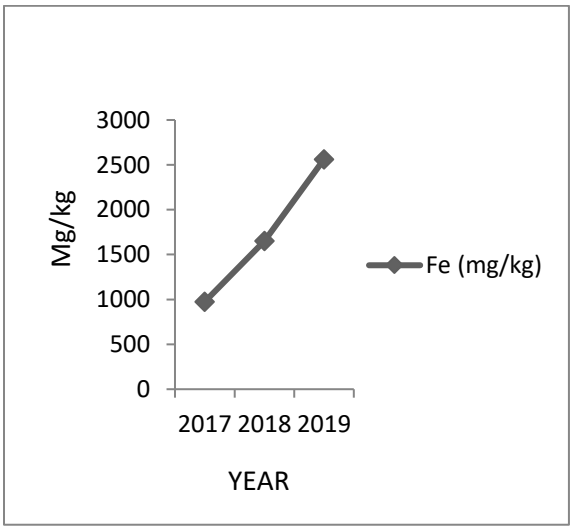

Figure 5: Yearly mean conc. of Fe mg/kg

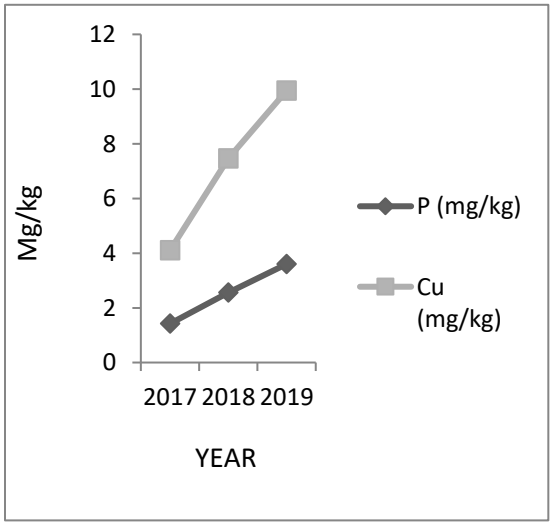

Figure 6: Yearly mean conc. of P and Cu in mg/kg

Figure 1 revealed that the soil organic carbon and total nitrogen contents of the soils studied increased within the years under investigation (2017-2019), although it does not follow any pattern; this could be a result of more decomposable plant materials on the surface soil (Lal, 1991; Akinbola *et al*., 2006), and that the surface horizons are the points where decomposition and humification of organic materials take place. Figure 2 also depicts a yearly increase in the soils' Potassium, Magnesium, and Sodium content within the period under investigation. The higher values obtained could be attributed to higher organic matter content (Ano, 1991). Meanwhile, the values fluctuated irregularly down the period. Exchangeable Ca dominated the exchange site. Similar results have been reported by Fasina *et al*. (2007) and Noma *et al*. (2004).

However, as shown in Figure 3 above, the pH shows an upward increase between 2017 and 2018 and decreased irregularly in 2019. Similar trends have been observed and reported by Sharu *et al*. (2013) and Fasina *et al*. (2007). Landon (1991) states that a pH range of 5.5-7.0 is preferred for most crops. Factors suggested to be responsible for the level of acidity in soils in the study area may include heavy rainfall, the nature of some of the parent rock within the region and crop removal around the study area. The higher pH values observed at the soil surface horizons, according to Fasina *et al.* (2007), might also be due to the liming effect of bush burning and bio cycling of nutrients. Figures 4, 5 and 6 show an increase in the contents of Calcium, Zinc, Iron, phosphorus, and Copper within the period under investigation and do not follow any specific pattern. The reason could not be farfetched from one or two of the abovementioned reasons.

Conclusion and recommendations

In conclusion, the soil samples collected in this study area are presumed to contain significant quantities of all the nutrients analyzed. These soils are proven to contain high SOM and possess suitable pH for typical forest ecosystems. The statistical analysis revealed interactions between these physicochemical properties, which seem essential in supplying the soil with available nutrients. It is therefore recommended that the conservation of these forests in Kogi state is an urgent need for the proper management practices of the forests, which will, in turn, increase the quality of soils and the forest under agroforestry practices and reduce indiscriminate destruction of forest cover and maintenance of the surface soils.

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ASSESSMENT OF KNOWLEDGE, CONSERVATION STATUS AND SILVICULTURAL PRACTICES OF THREE INDIGENOUS TREE SPECIES IN ABIA STATE, NIGERIA

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ABSTRACT

Nigeria has a range of indigenous tree species. Many rural communities depend on these forest species for their livelihood. Such a community's perception of forest and forest resources provides managers with relevant tools for sustainable forest management. Respondents selected via a stratified randomly sampling technique from three communities in each of the three agricultural zones in Abia State, Nigeria, provided primary data on three indigenous tree species (*Afzelia africana, Brachystegia eurycoma* and *Milicia excelsa*) and forest conservation status in the state. Data was collected by distributing a pretested semi-structured questionnaire and focal group discussions. The data collected were subjected to descriptive statistical analysis of frequencies, percentages and means using SPSS 20.0. The result indicated variations in the species' perception and usefulness in the three agro-ecological zones in Abia State. There is more excellent knowledge and use of *B. euricoma* and *M. excelsa* than *A. africana* in the state. The level of knowledge and use of the species in the agricultural zones correlated positively with the species abundance, indicating that public understanding of the uses of the species enhances their ecological/conservation status. The findings supported a global paradigm shift and growing interest in the principles of community forest management, which is also a recommendation of this study to the State Forestry Department.

Keywords: Indigenous tree species, Forest management, community participation and conservation.

INTRODUCTION

Nigeria has a range of indigenous tree species. A tree species is considered native or indigenous to a given region or ecosystem if its presence in that region results from natural processes, with no human intervention (Onefeli and Adesoye, 2014). It grows naturally in the country concerned, and with such species, no political or quarantine problems obstruct its use in a plantation programme. Some advantages of using indigenous species over exotic species also include the following: i) the species is adapted to the environment and is already filling an ecological niche. As such, they are less susceptible to severe damage from pests and diseases since controlling agents (predators, viruses and climatic factors) are already present. ii) they are generally considered more ecologically valuable than exotics for conserving native fauna and flora. The growth of the natural stand provides some indicators of possible performance in the plantation. iii) Timber is likely well-known and preferred by local wood-using industries.

The Nigeria Fifth National Biodiversity Report (FGN, 2015) extensively describes the importance of indigenous trees under the key subheadings. For all these reasons, if an indigenous species

grows well on the site for plantation or afforestation purposes, there is no compelling reason to widen the choice. However, amongst factors such as population explosion, high rate of deforestation, poor land use planning, industrialization and oil spillage, open grazing, and bush burning that have continued to affect the survival of Indigenous trees in Nigeria is the extinction of traditional knowledge of their usefulness and silvicultural requirements for their management. *Afzelia africana, Brachystegia eurycoma,* and *Milicia excelsa,* known respectively by their Igbo names of Akparata, Achi and Oji (Keay *et al*., 1964), are amongst the Indigenous forest species so affected, despite their enormous importance for the production of high-quality timber and other raw materials used by various industries, human medicine, edible fruits used as food condiments and soup thickeners, forage for livestock, browse plant for wild animals, and carbon sink for greenhouse gasses (Nwajiobi *et al.,* 2021). The people of Nigeria have an extensive history, and based on archaeological evidence, human habitation in the area dates to at least 9000 BC. (Okunomo and Egho, 2010). According to this Author, the people of Nigeria have been planting trees for thousands of years for food, shelter, ceremonial, or religious purposes. These ancient people devised a way of harnessing forest resources sustainably to survive long before the arrival of the colonialists. Their knowledge of the forest and forest species should have been found to be increasing in relevance with the advent of community-based forest management. However, this traditional knowledge seems to have been lost in most places mainly because of a lack of documentation or modernization (Wanjohi *et al.,* 2020).

Incorporating the principles of community participation in forest management has become widely acceptable. There has been a change in the last few years in many parts of the world towards this new forest management system based on the participation of the local people. This concept has various names (Suharti, 2001; Borokini *et al*., 2012). It primarily entails involving the local communities in the conservation of the forests around them, enlightening them on the value of the forest, training them on tree plantation and management, integrating tree planting with food crop cultivation (agroforestry), employing some of the local people as staff of the protected area, and involving the people in the formulation of conservation policies. In return, knowledge, or perception of the community about the forest and forest species provides valuable information for the effective management of forest and forest species (Atiku *et al*., 2015). This study aims to assess the community's knowledge and perception of the three Indigenous tree species and the silvicultural practices associated with them to enhance the management and conservation of the species in Abia State.

MATERIALS AND METHOD

Abia State is located between longitude 04° 45^{1} and 06° 17^{1} North and latitude 07° 00^{1} and 08° 10^{1} East, within the lowland rainforest area of southeast Nigeria, with a land mass of about 5,833.77 square kilometres (Keay, 1989; Abia State Government, 2005). The ambient temperature ranges between 20°C and 36^{0}C and is characterized by the rainy and dry seasons. The dry dust-laden northeasterly winds, which blow across the country, bring the dry season (November to March), while the rainy period is from April to October, during which period the moisture-laden Southwesterly winds blow, bringing with it the rains (Abia State Government, 2005; Onyemaobi, 2010; Peter *et al.,* 2017). The state is comprised of 17 LGA and shares boundaries with Imo State on the West, Anambra, and Enugu States on the North and North-east directions, respectively, the Cross River and the Akwa Ibom States in the East and Southeast ends, while Rivers State is at the Southern part of the State (Onyemaobi, 2010, Abia State Government, 2005). It has a population of 2,833,999 people, made up of 1,434,193 males and 1,399,806 females, a population density of 580 per square km, a growth rate of 2.83%, and a male-to-female ratio of 49:51(Abia State

Government, 2005; NBS, 2008). Agriculture is the primary occupation of the people, especially in rural areas, which involve over 70% of the population. The state also boasts several industries, including Nigeria Breweries Plc Aba, Aba Textile Mills Plc Aba, and International Glass Industries Plc (IGI), to mention a few. The industrial activities and impact of Aba (one of the largest cities in the state) small-scale artisans have earned it the name Japan of Africa (Abia State Government, 2005). For ease of agricultural administration and the advancement of scientific research in agriculture and socio-economic development, Abia State is divided into three (3) agricultural zones, namely Abia South, Abia Central, and Abia North (Abia State Government, 2005). This is not without the consequent loss of large areas of the State Forest land and species (Nwajiobi *et al.*, 2021).

Structured Questionnaire Approach

Three communities were selected for random sampling of 40 households in each agro-ecological zone of the state (Fig. 1). The communities for Abia North are Acharra, Bende, and Abiah. For Abia Central: Itunta, Ubakala, Nkalunta, and for Abia South: Akwaete, Oke-Ikpe, Oburu. Respondents completed a structured questionnaire for the study. A total of 360 questionnaires were used in the nine communities across the three agro-ecological zones of the state. The questionnaire elicited information on the species' existence/abundance and uses, factors responsible for forest loss, and silvicultural practices for managing the three indigenous tree species in the study area. The questionnaire was pretested for validity and reliability. The face and content validity was assessed following the Bamgbade et al. (2011) method by experts and professionals representing authority in agricultural and forest management research at Michael Okpara University of Agriculture, Umudike (MOUAU). The questionnaire was thoroughly edited and reviewed so that only items that satisfied the selection criteria based on the study's nature and object were used. The questionnaire was then pilot-tested for reliability with the Amawom community in Ikwuano LGA, Abia State, using the test-retest reliability testing style according to SPSS (2008). The result showed a reliability coefficient Cronbach Alpha of 0.78 (a = 0.78).

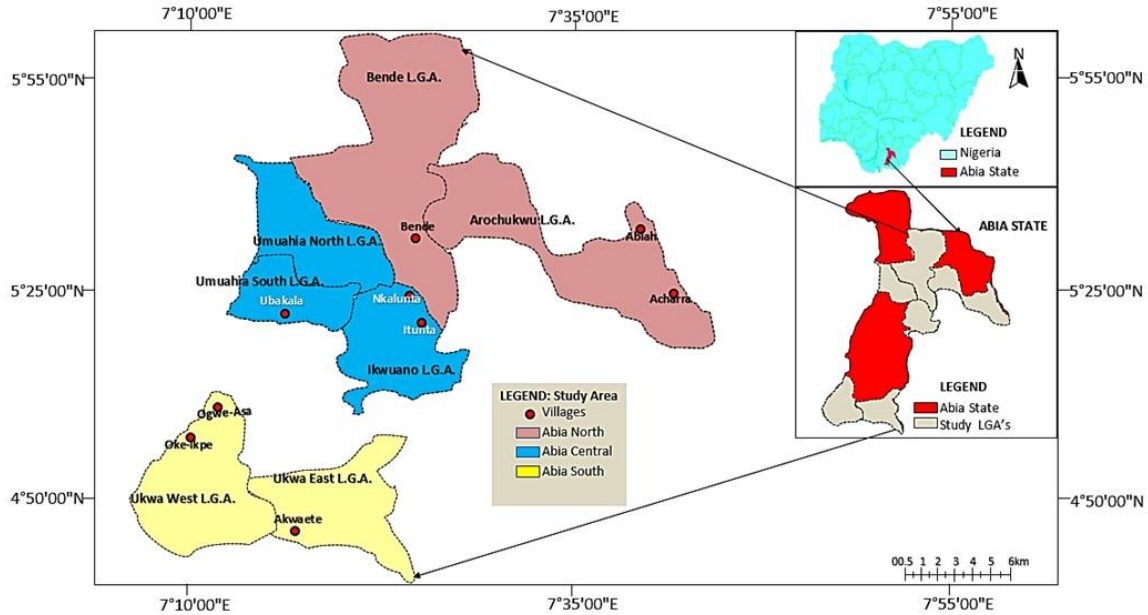

Figure 1: Map of Abia State showing selected communities/villages for questionnaire and focal group discussion

Interviews and Focal Group Discussion (FDG) Approach

Focal Group Discussions (FDG) and in-depth interviews were also organized with Staff of the State Department of Forestry, Community leaders, Youth leaders, elderly members who have been residents in the communities for at least 30 years, and timber dealers. The FGD and interviews were to generate further information about forestry and the study area's species (Plate 1 to 4).

RESULTS AND DISCUSSION

Socio-economic characteristics of respondents

The results in Table 1 show that a majority of the respondents in all three agro-ecological zones, Abia South (54.17 %), Abia Central (55.00 %) and Abia North (59.17 %), were between the age group 31 to 50 years. This is probably because this age group was the most confident and assertive in making themselves available to complete our questionnaire. The findings support Odoemelam and Nwachukwu (2012), who reported a high percentage (27.5%) of respondents within the age range of 31-40 in a study to evaluate farmer's use of Agricultural television broadcast in Abia State, Nigeria. According to the authors, age has been assumed by most studies as a significant variable to the extent that young farmers are deemed more willing to take risks and are, therefore, more open to change. There were more male respondents than female respondents in all three zones of Abia State, 68.33% and 31.67%, respectively, in Abia South, 72.50% and 27.50% in Abia Central, 73.33% and 26.67% in Abia North. The result is consistent with our field experience that the males were less apprehensive of strangers in their community. Another reason for fewer female respondents could be that since data were collected at the household level, it was usual for males to speak for the household (Odoemelam and Nwachukwu, 2012). Abia North has the highest percentage of respondents (42.50% with B.Sc/HND and 3.33% with MSc). This could indicate a higher adoption rate of new ideas and technologies in Abia North than in the other zones since education broadens horizons and makes people willing to test new grounds. The implication is that respondents in Abia North will be willing to seek more information to enhance their living. The marital status of the respondents indicates that a greater percentage of the respondents in all three agricultural zones, 62.50%, 74.17%, and 79.17% in Abia South, Abia Central and Abia North, respectively, were married. These findings show that respondents were responsible family men and women who may be desirous of information to improve their livelihood. It corresponded with the findings of Odoemelam and Nwachukwu (2012), who remarked that married are likely to seek more information on innovative practices and positively influence adoption because they have more family labour at their disposal.

Table 1. Socio-Economic Characteristics of Respondents

	Abia South		Abia Central		Abia North	
Variable	**Freq.**	**Per cent.**	**Freq.**	**Per cent**	**Freq.**	**Per cent.**
Age						
21-30 (1)	15.00	12.50	15.00	12.50	10.00	8.33
31-50 (2)	65.00	54.17	66.00	55.00	71.00	59.17
41-70 (3)	40.00	33.33	39.00	32.50	39.00	32.50
Total	**120.00**	**100.00**	**120.00**	**100.00**	**120.00**	**100.00**
Sex						
Male	92.00	76.67	87.00	72.50	88.00	73.33
Female	28.00	23.33	33.00	27.50	32.00	26.67
Total	**120.00**	**100.00**	**120.00**	**100.00**	**120.00**	**100.00**
Education Level						
Non-formal (0)						
Primary (1)	15.00	12.50	15.00	12.50	9.00	7.50
SSc/GCE (2-4)	60.00	50.00	50.00	41.67	56.00	46.67
BSc/HND (5-7)	44.00	36.67	53.00	44.17	51.00	42.50
MSc (8-9)	1.00	0.83	2.00	1.67	4.00	3.33
PhD (10)	0.00	0.00	0.00	0.00	0.00	0.00
Total	**120.00**	**100.00**	**120.00**	**100.00**	**120.00**	**100.00**
Marital Status						
Married	75.00	62.50	89.00	74.17	95.00	79.17
Single	45.00	37.50	30.00	25.00	22.00	18.33
Widowed	0.00	0.00	1.00	0.83	3.00	2.50
Total	**120.00**	**100.00**	**120.00**	**100.00**	**120.00**	**100.00**

Knowledge and Conservation Status of *A. africana, B. eurycoma* and *M. excelsa* in Abia State
Table 2 shows that *B. eurycoma* is the most known species in all three agro-ecological zones. It is more known to communities in Abia Central (85.83%) than Abia North (84.443%) and Abia South (81.50%) in the state. The least known species is *A. africana* in all three zones- Abia South (35.43%), Abia Central (41.67%), and Abia North (40.87%). The findings corresponded with the report of a population survey of the species by Nwajiobi *et al.* (2021), which indicated a more significant population of *B. eurycoma* than *M. excelsa* and *A. africana* in all three agro-ecological zones of Abia State. The use of *M. excelsa* as timber is better known to a more significant percentage of respondents than other range of uses of the species. In contrast, the use of *B. eurycoma* as a food/soup condiment is most known in all three agro-ecological zones-Abia South (87.50%), Abia Central (89.83%), and Abia North (85.00%) than its use for other purposes in the

three agro-ecological zone. A more significant percentage of respondents in all three zones of Abia South (49.48%), Abia Central (51.24%), and Abia North (47.74%) are familiar with the use of *B. eurycoma* than *M. excelsa* and *A. africana*. The use of *A. africana* is the least known among the three species in all three zones: Abia South (25.36%), Abia Central (21.38%), and Abia North (21.09%). The level of knowledge about the usefulness of the species in the various corresponded with the respective reported by Nwajiobi et al. (2021). In other words, the level of understanding of and use of the species affected their conservation status in the state, thereby supporting advocates of the conservation model of enhancing the use of valuable genetic resources as a means of conserving them (the 'use it or lose it' model) (Kjaer and Nathan, 2000; Lillesø *et al.*, 2001; Agbogidi and Avwevughware, 2011). The result also shows that the degree of threats to the three species is high. Only a few respondents in all three zones indicated that *B. eurycoma, A. africana* and *M. excelsa* were Abundant 28.42%, 15.00%, and 24.42%, respectively, Abia Central had 31.59%, 14.17%, and 18.05% and Abia North has 22.83%, 11.00% and 24.17% respectively, while the majority of the respondents indicated that the species are scarce in Abia South (41.67%, 67.50%, and 58.33% respectively), Abia Central (52.50%, 74.17%, and 60.00% respectively), and Abia North (44.17%, 85.00%. and 59.17% respectively), while many indicated that they threatened/endangered Abia South (52.50%, 68.33%, and 65.00% respectively), Abia Central (54.17%, 80.00%, and 57.50% respectively), and Abia North (53.33%, 84.83%. and 77.50% respectively). The findings supported reports of the high rate of deforestation in Nigeria as reported by (Meregini, 2005, Akachuku, 2006; Nzegbule, 2008; Molinos, 2013) that many of Nigeria's tree species are endangered or at risk of extinction (Mbakwe, 1986; Okojie, 1997; Akachuku, 2006, Borokini *et al.*, 2012).

Table 4.15 Status of the Three Forest Tree Species in Abia State

	Abia South			**Abia Central**			**Abia North**		
Variable	*B. eurico ma* %	*A. africa na* %	*M. excels a* %	*B. eurico ma* %	*A. africa n*a %	*M. excels a* %	*B. eurico ma* %	*A. africa n*a %	*M. excels a* %
Do you know the species?	81.50	35.43	82.50	85.83	41.67	80.55	84.44	40.87	84.50
Uses of *the species*									
Timber	76.17	24.17	80.83	84.5	15.83	86.67	72.5	20.81	85.83
Foods/food condiments	82.5	28.39	1.67	89.83	21.83	2.67	85	25	2.5
Fodder/forage	28.33	43.33	70.83	35.83	33.33	45	26.67	35.39	62.5
Fuelwood	58.33	38.33	21.67	57.5	37.5	26.67	57.5	27.5	55
Vegetable/spices	17.5	17.50	10.83	12.55	11.5	13.33	14.5	10.2	11.67
Cultural uses	27.50	12.50	37.50	34.17	17.5	28.33	35	18.33	30.83
Medicine	56.03	13.33	37.50	44.30	12.17	45.53	43	10.4	36.4
Average	49.48	25.36	37.26	51.24	21.38	35.46	47.74	21.09	40.68
Degree of threat to *the species*									
Safe/ Abundant	28.42	15.00	24.42	31.59	14.17	18.05	22.83	11.00	24.17

Scarce/Rare	41.67	67.50	58.33	52.50	74.17	60.00	44.17	85.00	59.17
Threatened/ Endangered	52.50	68.33	65.00	54.17	80.00	57.50	53.33	84.83	77.50
Extinct	25.83	19.17	11.67	23.33	31.67	7.50	21.67	49.17	9.17
Individual/communal Conservation effort	51.33	15.00	31.67	63.33	31.00	36.67	58.33	30.00	36.67

Silvicultural Practices for Enhancing Growth of *A. africana, B. eurycoma* and *M. excelsa in Abia State*

The result presented in Table 3 shows that a more significant percentage of the people in all three zones of the State Abia South (28.73%), Abia Central (42.77%), and Abia North (38.78%) have planted *B, eurycoma*. In comparison, the lowest percentage of the people in all three zones of Abia State, Abia South (3.54%), Abia Central (5.12%), and Abia North (1.81%) have planted *A. africana*. The findings agreed with the report of the population survey by Nwajiobi *et al*. (2021), which reported a more significant population of *B. eurycoma* in the three zones than *A. africana* and *M. excelsa*. A more significant number of people planting *B. eurycoma* could be due to greater knowledge of use of the species in all three agro-ecological zones Abia South (8.66%), Abia Central (16.60%), and Abia North (12.11%) than *A. africana* (3.14%, 2.45% and 2.59%) and *M. excelsa* (8.13%, 11.58% and 9.00%) correspondingly. However, the poor population of the species in Abia State could be attributed to the low percentage of the respondents who apply appropriate silvicultural practices for the germination, growth, and establishment of the species. A high dieback, for instance, could discourage crop production and negatively impact a community's species population. Thus, these findings support that the lack of adequate knowledge of the silvicultural requirements of the diverse forest species is among the reasons for poor tropical forest management systems in Nigeria (Umeh, 1992; Laird, 1995; Okojie, 1997). It also supported FORMECU (1999), Borokini *et al.* (2012) and Babalola (2009), who reported limited practice of community-based forest management in Nigeria and associated it with the poor management status of Nigerian forest and tree species.

Table 3 Silvicultural Practices for the Species in Abia State

	Abia South			**Abia Central**			**Abia North**		
Variable	***B. eurycoma***	***A. africana***	***M. excelsa***	***B. eurycoma***	***A. africana***	***M. excelsa***	***B. eurycoma***	***A. africana***	***M. excelsa***
	%	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
Have you planted/ grown the species?	28.73	3.54	16.33	42.77	5.12	20.00	38.78	1.81	17.95
Silvicultural Practices									
Seed germination pre-treatment	11.67	1.67	10.33	18.67	2.50	13.11	15.12	3.67	16.39
Nursery	7.17	2.41	8.63	20.57	1.83	14.17	14.13	1.50	11.11

establishment									
Manure/fertilizer application	18.52	1.67	11.67	27.83	2.5	15.15	16.15	1.28	13.67
Pruning	4.66	5.00	3.17	1.17	3.33	2.17	2.87	3.73	2.51
Thinning	5.67	7.50	7.5	11.5	2.67	5.83	5.83	4.76	5.83
Pest/Disease Control	4.17	2.50	8.33	15.00	2.33	17.33	17.33	2.13	1.33
Weed Control/Management	8.79	1.25	7.31	21.43	2.02	13.33	13.33	1.11	12.13
Average	**8.66**	**3.14**	**8.13**	**16.60**	**2.45**	**11.58**	**12.11**	**2.59**	**9.00**

B = *B.eurycoma*, A = *A africana*, and M = *M. excelsa*.

Conclusion and Recommendation

Indigenous species have excellent advantages and benefits over exotic species even though several factors militate against their conservation. They also sequester significant amounts of carbon in their biomass at varying rates, which helps in climate change mitigation. However, poor knowledge of the species and their usefulness/services-including their role in environmental protection, indicated a negation/departure from the global best practice of forest management by community participation, and it is antithetical to sustainable forest management and the conservation of the species. The abundance of exotic species (*Gmelina arborea* and *Tectona grandis*) in most of Abia State Forest reserves and accessible forest areas demonstrated a high level of knowledge of the indigenous species such that the characteristics and composition of the forest have been modified to suit the perceived needs of the people, based on their knowledge of the usefulness of the forest tree species. In the face of the current global climate change regime, opportunities exist for the indigenous tropical tree species whose adaptability to the natural environment and ecological value gave significant advantages for diverse goods and services, broadening the socio-economic benefits derivable by communities from forests and consequently enhancing their conservation status.

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EFFECT OF STORAGE MEDIA ON THE GERMINATION OF *Annona muricata* Linnaeus (SOURSOP).

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ABSTRACT

Annona muricata (Soursop) are high in vitamins B1, B2 and C and are commonly grown from seed. There is a lack of sufficient information on the storage media that can be used to obtain optimum germination. This study aimed to assess the effect of storage media and time on the germination of *Annona muricata* seeds. This study was conducted at the Prof. E.L.C Nnabuife Screenhouse in the Department of Forestry and Wildlife, Nnamdi Azikiwe University, Awka, Nigeria. *Annona muricata* fruits were sourced from Ukuorji Market in Awka. The seeds were then stored in the four media (Treatments (T)) viz: Foil (T1), polythene bag (T2), glass jar (T3) and open-air storage (T4) and for four different time intervals: 3 days (t1), seven days (t2), 14 days (t3), and 31 days (t4). The germination percentage was calculated, transformed using square root, and subjected to Analysis of Variance (ANOVA). The result showed that the highest germination (75%) was recorded in seeds sown in T3, T4 and T2 at t2, t3 and t4 times, respectively. The ANOVA results showed no significant difference in the storage media ($p=0.821$) and storage time ($p=0.231$). The study concluded that viable seeds of soursop stored between 0 to 31 days would germinate irrespective of the media used for storage and storage time, provided they were sown on healthy soil. However, the seed storage using polythene bags (T2) for 31 days (t4) gave the highest mean germination and, hence, recommended for optimum production.

Keywords: storage, germination, *Annona muricata*, unizik.

INTRODUCTION

Annona muricata Linnaeus is a small (7.5-9 m), evergreen, quick-growing tree that may be slender and upright or low branching and bushy; it often becomes straggly and untidy with age. The highly nutritious fruits are consumed fresh or processed as juice and purées or made into jams, jellies, candies and desserts. Fruits are well suited for processing due to the pulp's flavour and high recovery rate from the large fruit. A short shelf life means that trade in fresh fruit is very low (Litz, 2004; Janick and Paull, 2008). The white edible pulp corresponds to about 67.5% of the whole soursop fruit, which is composed of water (~82.8% fw), protein (~1.0% fw, N × 6.25) that is biologically incomplete, lipid (~1.0% fw), carbohydrate (~14.6% fw) that has a high content of sugars (12%) such as sucrose, glucose, and fructose, as well as pectin, fibre (~0.8% fw), ash (~0.9% fw) rich in potassium and sodium, and vitamins such as A, B-complex, and C (Badrie and Schauss, 2010).

Annona muricata is a beneficial crop; however, despite its usefulness, there is a dearth of information on the effect of storage media on its seeds. That is, to preserve the seed for quite a period before planting and to evaluate the viability of the seed after storage through germination (germination is a process whose essential purpose is to produce the energy required for protein synthesis in plant growth). Although many studies have been done on *Annona muricata*, there is a gap in knowledge on its seed storage. Hence, this study aimed to assess the effect of storage media on the germination of *Annona muricata* seeds. This study aimed to access the storage of soursop seeds and their effect on the seeds using experimental design to provide adequate information on the impact of storage media on the germination of *Annona muricata* seeds.

MATERIALS AND METHODS

This study was conducted at Prof. E.L.C Nnabuife's screen house in the Department of Forestry and Wildlife, Faculty of Agriculture, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria. The University lies between latitude 6° 10' to 6° 17'N longitude of 7° 2.4' to 7° 7.2' E situated in Awka (Chukwu *et al.,* 2020).

The materials used for the storage of *Annona muricata* seeds were as follows:

a) Polythene bag
b) Foil pouches
c) Glass jar
d) Through open storage

Other materials include topsoil, polypot, freshly extracted *Annona muricata seeds*, greenhouse, and water. Since it was the same soil used for all the storage apparatus, it was believed that, if they were affected, it was at the same rate because the same soil was collected from the same place. Therefore, the only difference was in the storage.

Seed source

Annona muricata seeds were obtained from the ripened fruit of soursop, which was bought from a fruit market at Ukuorji in Awka, Anambra State.

Viability test

The seeds were tested for viability by soaking them in water for forty-eight hours (48 hours) before storing them in their respective media in their respective time intervals.

$$\text{Viability (\%)} = \frac{\text{Number of sinkers}}{\text{Total number of seeds}} \times \frac{100}{1} = \text{ Equation (1)}$$

Procedure

Seeds of *Annona muricata* were divided into four groups and then stored in the four media (Treatments (T)) viz: Foil (T1), polythene bag (T2), glass jar (T3) and open-air storage (T4). The seeds were stored in the four media at different time intervals: three days (3 days), seven days (7 days), 14 days (2 weeks), and thirty-one days (one month) after air drying for forty-eight hours (2 days). Then, it was sown into black polythene bags filled with topsoil: the seeds were planted at the end of each storage period (for example, at the end of storing the seed in foil paper for seven days, it was sown into the soil). Seeds planted immediately after extraction from its fruit (soursop) were used as controls. Each medium has a total population of sixteen polypots and was subdivided into four polypots, each based on the storage period. The total polypots used for all four media stored at four different time intervals was sixty-four (64). Four seeds were sown in each pot,

making sixty-four (64) seeds for each medium. These were monitored daily until epicotyls emerged from the soil when seedling assessment commenced. Germination initiation was observed for four weeks (4 weeks) when the total emergence was counted and recorded. Evaluation of growth variables commenced twenty-five days (25 days) after epicotyls emerged and was done every seven days (7 days) for fifty-three days (53 days). The parameter assessed was seedling germination.

Statistical analysis

The data collected were subjected to descriptive statistics and one-way analysis of variance (ANOVA), and the means were separated.

RESULTS

Table 1 displays the impact of storage media on the percentage of *Annona muricata* germination. The highest mean germination rate of 75% was observed in seeds sown from polythene bag medium, followed by glass jar medium with a mean germination rate of 68.8%. According to the results, seeds sown from foil, open-air storage and glass jar had an identical average germination rate of 43.8%. Open-air storage and glass jars exhibited similar rates at 56.3%. Similarly, foil and polythene bags demonstrated comparable averages at 50%, while glass jar and open-air storage displayed equivalent figures at 62.5%. Polythene bags and foil reported the lowest percentage germination rates recorded during different storage stages, with a similar average rate of only 25%.

The y-axis of the graph displays germination frequency, while the x-axis denotes storage time (Figure 1). The colour sky blue on the graph signifies seeds stored in a polythene bag, red represents those stored in foil paper, lemon green indicates open-air storage and purple stands for glass jar storage. Seeds from each category, as mentioned earlier, had two germinants after three days of storage, except for the glass jar, which yielded three seedlings. Furthermore, under seven days of storage, open-air storage, foil paper, and polythene bags all produced a total of two germinants, each with glass jars that yielded three seedlings. After being stored using polythene bags for fourteen days, one seedling emerged, whereas two were observed in foil paper and three in open-air and glass jar storages, respectively. Polythene bags and glass jars demonstrated the highest germination rate at four, followed by seeds that were stored openly, producing only two after thirty-one days. Conversely, seeds kept in foil paper showed the lowest germination rate, with only one sprouting recorded, as depicted on the graph above.

Table 1: Effects of different storage media on percentage germination of seeds of *Annona muricata*

Storage media	3 days Germination (%)	7 days Germination (%)	14 days Germination (%)	31 days Germination (%)
Polythene bag	50	37.5	25	75
Foil pouch	50	43.8	43.8	25
Glass jar	56.3	43.8	62.5	43.8
Open-air	43.8	56.3	68.8	62.5

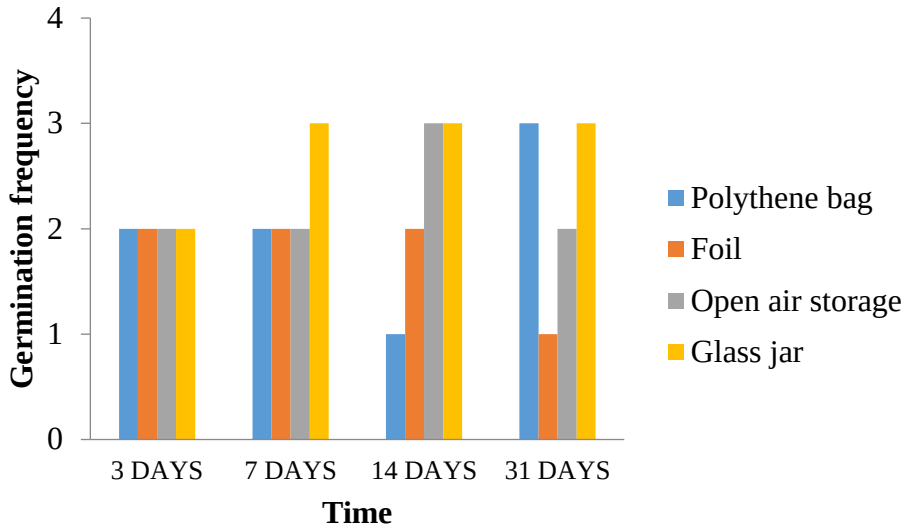

Figure 1: Germination Frequency

The data collected is counted data, and then the data was transformed using square root transformation to satisfy the variance analysis assumptions (ANOVA). Table 2. shows the descriptive statistics of both storage and time. The Polythene bag recorded the highest mean (1.41) for media and 31 days (1.50) for time. Foil recorded the lowest mean (1.28) for media and the 3 and 7 days (1.30 each) for time (Table 2).

Table 2. Descriptive statistics for storage media and time

Storage	Treatments	Number of seed	Mean	Standard Deviation	Standard Error
Media	Polythene bag	16	1.41	0.13	0.03
	Foil	16	1.28	0.44	0.11
	Open air storage	16	1.34	0.45	0.11
	Glass jar	16	1.36	0.46	0.11
	Total	**64**	**1.35**	**0.39**	**0.05**
Time	3 days	16	1.30	0.45	0.11
	7 days	16	1.30	0. 37	0.09
	14 days	16	1.37	0. 43	0.11
	31 days	16	1.50	0. 27	0.07
	Total	**64**	**1.35**	**0. 39**	**0.05**

The ANOVA results for the different media and time for storing the seeds *(Annona muricata)* were presented in Table 3. The result showed no significant difference between storage media and time (p=0.821 and p=0.231, respectively). Due to this result, there was no need for a follow-up test.

Table 3. Analysis of variance for storage media and time

Source of variation		Degree of freedom	Sum of square	Mean square	F	p
Storage media	Treatment	3	0.146	0.049	0.306	0.821
	Error	60	9.532	0.159		
	Total	63	9.678			
Storage time	Treatment	3	0.664	0.221	1.473	0.231
	Error	60	9.014	0.150		
	Total	63	9.678			

DISCUSSION

The study indicates no significant disparity in utilising different techniques or media for storing *Annona muricata* seeds and storage time. The seed preservation period varied according to the medium used for storage, such as foil paper, glass jar, open-air storage, and polythene bag. As per Trade Winds Fruit's report, soursop seeds can be stored for several months before planting; however, germination may be delayed up to 2-3 months under sub-optimal conditions. Many researchers have reported seed treatment to enhance the germination of recalcitrant seeds (Aduradola et al., 2005; Aduradola and Adejumo, 2005; Agbogodi et al., 2007). According to the results obtained from this research work, it is evident that seven days of storage in a glass jar before planting had produced the maximum number of germinations (3 seedlings).

Further analysis revealed that fourteen days of preservation in a glass jar resulted in three seedlings followed by two when stored using foil paper. Seeds kept inside polythene bags and glass jars yielded the highest germinants following thirty-one days of storage with four seedlings each. All four mediums employed during these experiments gave equal levels of germination within three days. At the same time, both foil and polythene bags demonstrated the lowest level of germinal activity after thirty-one and fourteen days, respectively.

The problem of storing the seeds of *Annona muricata* for some time to cultivate them at the convince of farmers discouraged farmers from cultivating the tree crop. However, as a way of working in line with the Global Forum on Agricultural Research (GFAR) of 1999, which emphasized the role of underutilized species in raising the income of the rural poor (Frison et al., 2000) vis-a-vis the current moves towards poverty alleviation, ability to get vigorous and uniform seedlings, will go a long way in the achievement of cultivation or planting of this fruit tree which is of great potential through sustainable production and bring economic gain and growth to the sower. Therefore, none of the methods, including foil paper, glass jar, or even storing soursop seeds, openly had any adverse effects on *Annona muricata*'s ability to sprout when preserved through any one among these four techniques discussed earlier - an outcome consistent with Trade Winds Fruit's claim regarding "soursop can be stored for several months before planting."Furthermore, their reports state that these seeds usually take almost three weeks to mature under optimal conditions but may experience delays up to 2-3 months otherwise.

CONCLUSION

The study concluded that the seeds of soursop, when stored between 0 to 31 days, so long as it is not moulded, not attacked by insects and pests and as long as it was viable (viability test) after extraction properly dried and if the soil is healthy, watered daily and weeded, the seed will

germinate irrespective of the media used for storage and time of storage. However, storing the seed using polythene bags for 31 days gave the highest mean germination and, hence, recommended for optimum production. Furthermore, the study suggested that further research be conducted for this experiment, "effect of storage media on the germination of *Annona muricata* (Soursop)" for more than one month.

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EARLY GROWTH RESPONSES OF *TECTONA GRANDIS* L. f. TO LOCALLY MANUFACTURED LEGUME-BASED ORGANIC FERTILIZER

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ABSTRACT

A field trial was conducted to evaluate the growth responses of *Tectona grandis* seedlings to a locally manufactured legume-based organic fertilizer at Umudike, Abia State, Nigeria. Three (3 weeks) vigorous seedlings of T. grandis raised in the nursery of the Department of Forestry and Environmental Management, Michael Okpara University of Agriculture Umudike (MOUAU), were used for the experiment. There were four treatments consisting of legume-based organic fertilizer 15 t/ha, N.P.K 15:15:15 2500 kg/ha, complimentary application of organic manure 7.5t/ha and NPK 1250 kg/ha (i.e. 1/2 OM + 1/2NPK) and a control (no fertilizer). The experiment was laid out in a randomized block design in 3 replications and monitored for 10 weeks. Data was collected weekly on growth variables of plant height, collar diameter and number of leaves for six weeks (from four weeks after germination (4 W.A.G.) to ten weeks after germination (10 W.A.G.)). Collected data were subjected to descriptive and inferential statistics such as analysis of variance (ANOVA). Mean separation was conducted using $LSD_{0.5}$. At the end of the experiment, nine weeks after planting (9wap), the seedlings treated solely with legume-based organic fertilizer recorded significantly highest seedlings height (10.2cm), Collar diameter (1.4cm), and number of leaves (10) than the other treatments. The control treatment had correspondingly lowest values for the various parameters (7, 0.8 and 9 cm), respectively. The use of the fortified organic fertilizer significantly ($P<0.5$) favoured the early growth of *T. grandis* and, therefore, is recommended for the management of forest nurseries for healthy growth and production.

Keywords: *Tectona grandis*, soil fertility and legume-based organic fertilizers, growth

Introduction

Tectona grandis, commonly known as Teak, is a deciduous tree found in mixed hardwood or deciduous forests. It is used for soil conservation and improvement (Agbogidi and Onomeregbor, 2007). The tree makes an essential contribution to the economy by providing timber, poles, wood, etc. and helps regulate degraded land and environmental pollution (Etukudo, 2000; Agbogidi *et al.*, 2008). The tree crop became essential to forestry due to the multiple socioeconomic and ecological benefits to man and the high demand for the species. Hence, there are continuing searches for methods of enhancing their growth and productivity. Soil degradation has led to the disappearance of some indigenous species and caused difficulty in growing some seedlings (Nwoboshi, 1985; Etukudo, 2000). With deforestation and population pressure, the low germination rate and lack of knowledge of silvicultural requirements for germination and growth have remained a problem for indigenous trees in Nigeria.

Seed germination and early seedling growth phases are considered critical for raising a successful crop as they directly determine the crop stand density and, yield of the the resultant crop. It is

indicated that the seed germination, seedling growth, and survival percentage in the nursery are governed by many intrinsic and extrinsic factors, including the nutrient component of the soil. Organic manure has played a significant role in the growth of some forest and agricultural species. Organic fertilizers: rice mill waste manure (R.M.M.), swine waste manure (SWM), poultry manure (PM), and compost, among others, have been used for crop production for centuries. These forms of fertilizers certainly pre-date chemical (mineral) fertilizers and are currently being encouraged. In contrast to chemical fertilizer, it adds organic matter to soil, which improves soil structures, nutrient retention, aeration, soil moisture holding capacity and water infiltration (Deksissa *et al.*, 2008), and they are more environmentally friendly since they are of organic source.

Despite the numerous economic uses of *T. grandis*, they documented reports on cultivation and seedling growth of this multipurpose tree, known commonly as African mahogany, are scarce. In addition, the high demand for *T. grandis* leaves, seeds, roots and barks for various uses has resulted in a corresponding increase in the exploitation at such a rate that the sustainability of this natural resource cannot be guaranteed. Suppose the benefits derivable from T. grandis must continue especially to the future generations. In that case, there is a need to stimulate farmers' interest in the cultivation of *T. grandis*, including techniques for successful nursery management practices for enhanced species growth. This will help to reduce poverty,

MATERIALS AND METHOD

Study Area

The experiment was carried out at the Nursery Unit of the Department of Forestry and Environmental Management (FOREM), Michael Okpara University of Agriculture Umudike (MOUAU), Abia State. Umudike is located between latitude 5^0 31'N to $6^0$17' N and longitude $7^0$11'Eto $8^0$10' East in the lowland rainforest zone of southeast Nigeria, at an elevation of 122 meters above sea level (Nwosu *et al.*, 2011) (Fig. 1).

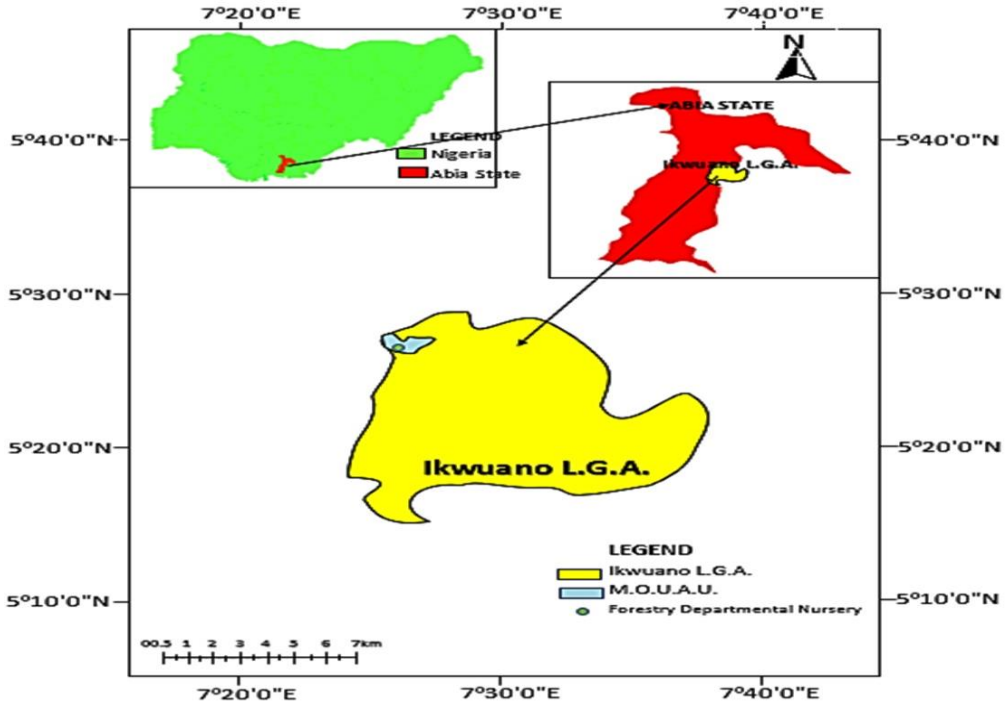

Fig. 1. Map of Ikwuano L.G.A. showing the location of FOREM Nursery in MOUAU, Abia State.

Climate is essentially humid tropical. Though the vegetation is typical rainforest, much of the forest estate has been destroyed, leaving behind a few patches of forest stands (Akachuku, 2006). The zone is characterized by two distinct seasons: the rainy season from March/April to October with bimodal peaks (June and September) with a short break in August and a dry season from November to March (Audu *et al*., 2008). Annual rainfall ranges from 1800mm to 2200mm, with the intensity reaching up to 100mmhr^{-1} (Audu *et al*., 2008; Nwosu *et al.*, 2011). Temperature is high throughout the year, with a range of 33^{0}C -35^{0}C as the maximum and 28^{0}C to 29^{0}C as a minimum (Nwosu *et al.*, 2011), while relative humidity varies from 51% to 87%. The soil is acid sandy loam in the ultisoland haplicacrisol group (Enweozor *et al*., 1990; Omenihu *et al*., 2011). Agriculture is the people's major occupation, especially in the rural areas, and involves over 70% of the population.

***Tectona grandis* Seeds:** The seeds of *Tectona grandis* were collected from a Teak parent plant at the back of the department of Forestry and Environmental Management. After picking the fallen seeds, the chaff was sieved off, and the seed viability was tested using the floatation method. Viable seeds were soaked in water for seven days before being planted.

Fertilizers: N.P.K. 15:15:15 and locally manufactured organic fertilizers were used. The organic fertilizer was produced from composting a mixture of the vegetal matter of *Lablab purpureus*, a leguminous plant with rice husk, poultry manure and swine dung in the ratio 5:4:4:4. The mineral element composition of the organic fertilizer has been determined at the laboratory of the National Root Crops Research Institute (NRCRI) Umudike, Abia State and reported by Nwajiobi *et al.*, 2020).

Topsoil and poly pots: Topsoil collected from fallow farmland beside the Nursery Unit of FOREM were bulked, adequately mixed, and sieved to remove large particles, roots and debris. The composite soil sample was analyzed for physico-chemical properties at the Soil Laboratory of the National Root Crop Research Institute (NRCRI), Umudike, using standard methods of soil analysis according to Udo *et al.* (2001). Eight grams (8g) of the soil was collected into poly pots measuring 35cm × 30cmfor the experiment. A total of ninety-eight (98) poly pots measuring 35cm × 30cm were used for planting for the experiment.

Experimental Layout: The experimental site was cleared manually. Poly pots measuring 17cm x 8cm containing appropriate treatment growth media were subsequently arranged on the plot in a Randomized Complete Block Design in three replications. With a sample size of nine (9) plants per treatment, 108 polypots were used for the experiment (Table 1 and Plate 1).

Table 1. Experimental treatments

Treatment	Description
1.	15t/ha Organic Fertilizer
2.	7.5t/ha NPK+12.5kg/ha of Organic Fertilizer
3.	2500kg/ha NPK 15 15 15
4.	Control (No Fertilizer Application)

Plate 1. Teak seedlings in the experimental plot.

Seed Sowing: Three Teak seeds were planted per poly pot at 2-3cm depth and 5cm apart, which were thinned to one seedling 14 days after planting (D.A.P.).

Cultural Practices: Watering was done once, in the evenings, daily. Weeds were hand-picked from the pots, while the space between the blocks and treatments was weeded with hoe.

Data Analysis: Data collected in the growth parameters will be subjected to Analysis of Variance (ANOVA) at a 0.05 level of significance ($P<0.05$). Mean Separation will be done using the Fishers' Least Significance Difference.

RESULT AND DISCUSSION

Effects of organic manure and N.P.K. on the height (cm) of *Tectona grandis*

The result (Fig. 1) shows that the height growth of *T. grandis* significantly varied with the treatments from the 4th week to the 9th week. In all the weeks, the sole organic fertiliser treatment recorded significantly higher growth in height than all the other treatments except at week 4. At week 4, plant height of *T. grandis* treated with N.K.P. fertilizer recorded the highest value of 4.2±0.05. Though it was not significantly different from the sole organic manure treatment (4.2±0.05), it was considerably higher than the N.P.K. and Organic manure combination (3.4±0.02) as well as the control treatment (3.6±0.03). From the 5th week, however, the organic fertilizer treatment grew significantly higher in height (5.7±0.01) than the N.P.K. treatment (5.0±0.01), and this continued to the last (week 9) of data collection. By week 6, the height of N.P.K. - organic fertilizer combination treatments (5.8±0.05) was no longer less than the N.P.K. treatment (5.7±0.03). In fact, from the 7th week, the height of plants treated with the NPK-organic fertilizer combination became significantly higher than the N.P.K. treatment, and this continued to the last week of data collection. The higher plant height of the N.P.K. treatment than the organic fertilizer treatment and the NPK-Organic fertilizer treatment in the early week of data collection indicated a slow nutrient release to the plants with the organic fertilizer treatment and the NPK-Organic fertilizer treatment. This could be why the plants treated with the organic fertilizer treatment and the NPK-Organic fertilizer treatment later grew to higher heights than the N.P.K. treatment. The findings agree with Basso and Ritchie (2005), Akanbi *et al. (*2010), Quattara *et al*. (2008), Louisa and Taguiling (2013) and Chukwuka *et al.* (2014) that organic fertilizers supply the essential plant nutrients that enhance growth, development and optimum productivity of crops. It

also supported Roy *et al*. (2006), who noted that concentrated organic manures are comparatively richer in N.P.K.

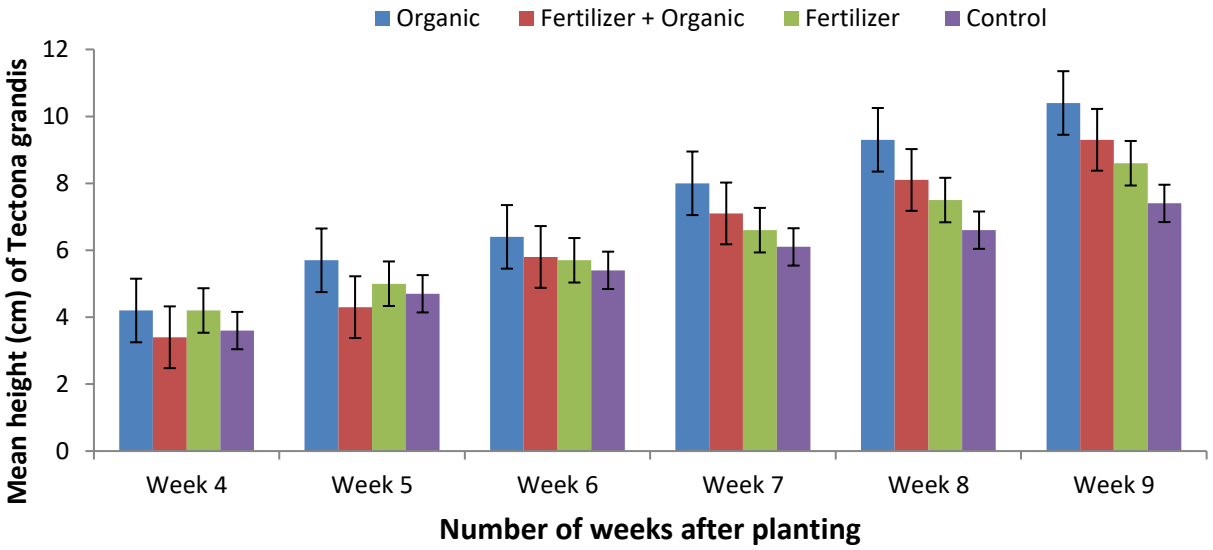

Fig. 1: Effects of organic manure and N.P.K. on the height (cm) of *Tectonagrandis*

Effects of organic manure and N.P.K. on stem diameter (r) of *Tectonagrandis*

The result showss no significant diference in the colar diameters of all the treatments in the fourth and fifth weeks after germination. In the 6th week, only the organic fertilizer treatment had a sigfinicatly higher colar diameter (0.8±0.05 cm) than all the other treatments. By the last week of data collection (week 9), the organic fertilizer treatment had the significantly highest collar diameter (1.5±0.05cm) than all other treatments and was followed by the NKP-organic fertilizer combination treatment (1.3±0.01cm). Plant colar diameter was least in the control (0.9±0.28). However, there was no significant difference in the N.P.K. and control treatments. The findings also support Basso and Ritchie (2005), Akanbi *et al.* (2010), Quattara *et al*. (2008), Louisa and Taguiling (2013), and Ibrahim and Fadni (2013) that organic fertilizers supply the essential plant nutrients that enhance growth, development and optimum productivity of crops; and that concentrated organic manures are comparatively richer in N.P.K. (Roy *et al*., 2006).

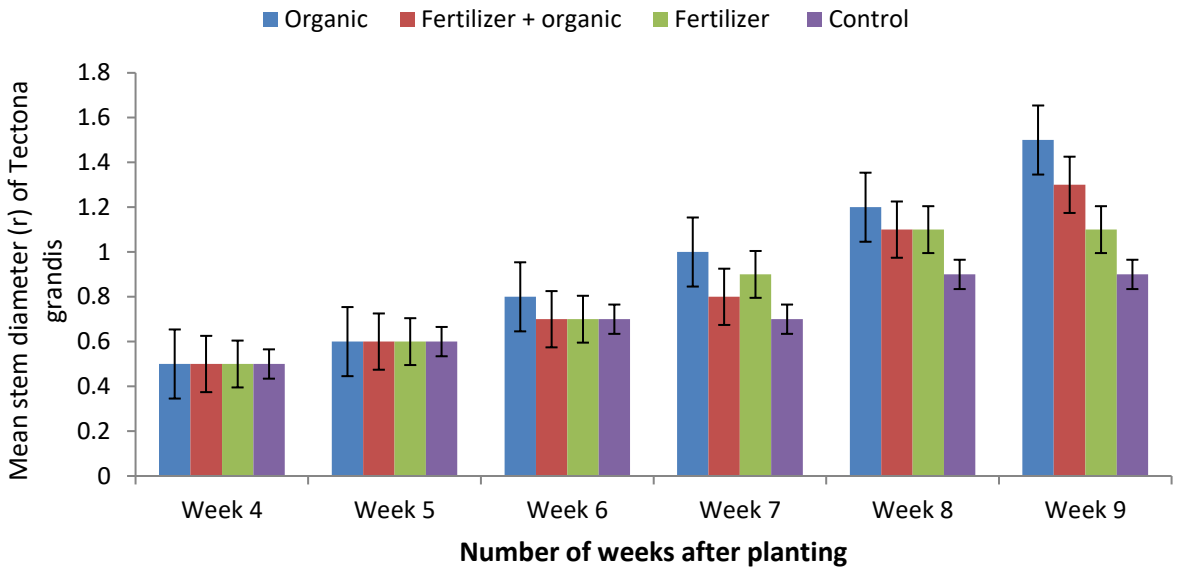

Fig. 2. Effects of organic manure and N.P.K. on stem diameter (r) of *Tectona grandis*

Effects of the fertilizers on the number of leaves of *Tecton agrandis*

The control treatment recorded the least number of leaves throughout data collection (Fig. 2). The organic fertilizer the N.P.K. + organic fertilizer, and the N.P.K. treatments were not significantly different in the first three months of data collection. From the seventh month, however, the organic fertilizer treatment recorded a significantly greater number of leaves than the N.P.K. and the control treatments, respectively. Only until the 8th and 9th week was the number of leaves of the organic fertilizer treatment (9.7±0.02 and 10.8±0.05) significantly greater than that of the N.P.K. + organic fertilizer treatment (9.0±0.06 and 10.1±0.05 correspondingly), the slow release of nutrients by the organic fertilizers (Nwosu *et al.*, 2011; Adeniyan *et al.*, 2011; Uka *et al.*, 2013) could be the reason for the differences in the number of leaves of the organic fertilizer treatment from all other treatments at the later periods of data collection. Nevertheless, the result supported that Basso and Ritchie (2005), Akanbi *et al. (*2010), Quattara *et al*. (2008), Louisa and Taguiling (2013) and Chukwuka *et al.* (2014) that organic fertilizers supply the essential plant nutrients that enhance growth, development and optimum productivity of crops.

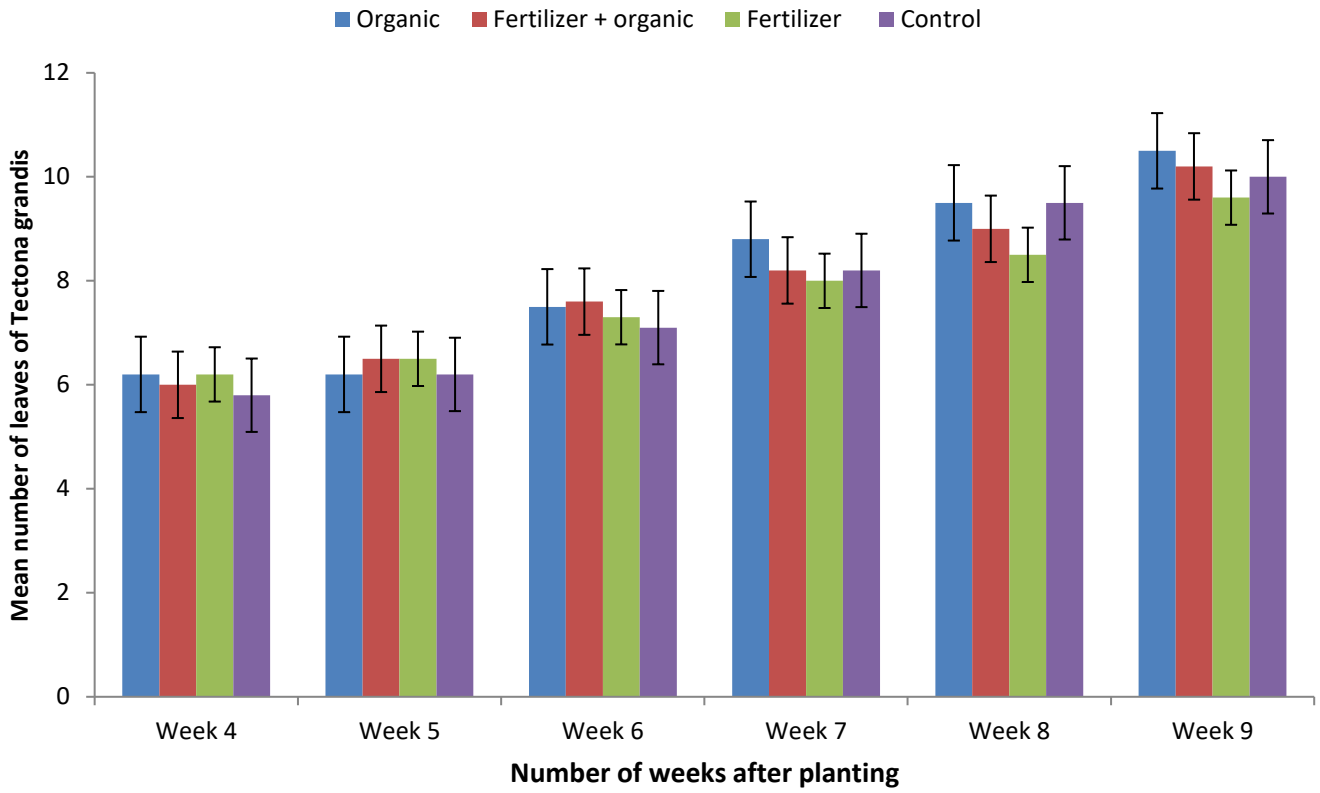

Fig. 3. Effects of the fertilizers on number of leaves of *T. grandis*

Conclusion and Recommendations

Leguminous species are increasingly appreciated for their roles in animal nutrition, soil amendment and soil fertility enhancement. Nigeria is endowed with numerous underutilized leguminous species, many growing in the wild as weeds. A few of these are only used to cover crops and for green manuring in improved fallow technologies. The vegetal matter of the legumes, as well as other agricultural wastes, are rich in minerals and plant nutrients in varying compositions. Using these relatively abundant organic materials for organic fertilizer production has potential for soil management, biodiversity conservation and agro-ecosystem stabilization in Nigeria. The legume-based organic fertilizer significantly improved Teak seedlings' growth in the field trials. Hence, legume-based organic fertilizer should be recommended to foresters to improve forest crop production significantly. Forest practitioners are encouraged to identify and use locally available organic materials to enhance soil fertility rather than overdependence on inorganic fertilization. Further studies are required, especially with many other legume species which are abundantly growing in the wild but whose usefulness is not well known, to enhance the conservation status of these species based on the conservation theory of use enhances conservation.

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The Role of Human Activities on Tree Regeneration in tTe Agricultural Parklands of Northern Nigeria

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Abstract

The research assessed the role of human activities on tree regeneration in the agricultural parklands of northern Nigeria. 540 structured questionnaires were purposively distributed across the sampled States (Bauchi, Jigawa and Kano) to respondents to assess their roles in tree regeneration in the parklands. Descriptive statistics was used to analyze the data using SPSS software. Most of the respondents (94.50%) were male, among which 82.28% are married, and 80% of the respondents have farming as their primary occupation with experience of over ten years in agriculture. Thirty-four percent (34.83%) of the respondents have never planted a tree on their farm. Regeneration is primarily natural and aided through vegetative propagation. Land is the major problem facing farmers in terms of tree regeneration. The parkland had poor regeneration potential due to little or no intervention by the farmers. Intervention is also needed by the government at all levels, including NGOs and CBOs, for proper development, conservation, and sustainable use of tree species on farms for improved livelihood and biodiversity conservation.

Introduction

Human activities and global climate change are the most critical issues in the conservation of forest ecosystems in developing and advanced countries. The fast population growth in developing countries has raised demand for forest products in the tropics. Urban immigrants, unlike the traditional people, have no indigenous knowledge or skill in the sustainable use of natural forest resources, leading to severe damage to forest ecosystems. Natural and manufactured threats, and direct and indirect consequences of socio-economic development, have contributed to the erosion of biodiversity at all levels in the country. It is believed that within the last 25 years, about 43% of the forest ecosystem has been lost through human activities in Nigeria (Abdulhakim *et al*., 2017). The agricultural parklands of Northern Nigeria are characterized by a unique landscape where trees are interspersed within farmland, creating a mosaic of trees, crops, and livestock. This agroforestry system is crucial in sustaining livelihoods, biodiversity, and ecosystem services in the region. However, human activities within these parklands can significantly influence tree regeneration processes, impacting tree populations' composition, structure, and dynamics (Larwanou and Assoumane, 2017; Adesina and Agbaje, 2018). This paper assessed the various roles of human activities on tree regeneration in the agricultural parklands of Northern Nigeria

Methodology

The study was conducted in the Sudano-Sahelianregion, located at latitudes 10°N to 14°N and longitudes 4°E to 11°E, encompassing the northern parts of Nigeria. This region has an extensively varied climate; with an average annual precipitation of around 610 mm, this part of Nigeria receives the least amount of rainfall overall. The region is characterized by hot, semi-arid weather and savannah vegetation, with patches of savannah shrubs interspersed with cultivated

parkland. Since agriculture and the rearing of animals are the primary industries in this area, rainfall is crucial, and fluctuations in its features are concerning (Bako *et al*., 2020).

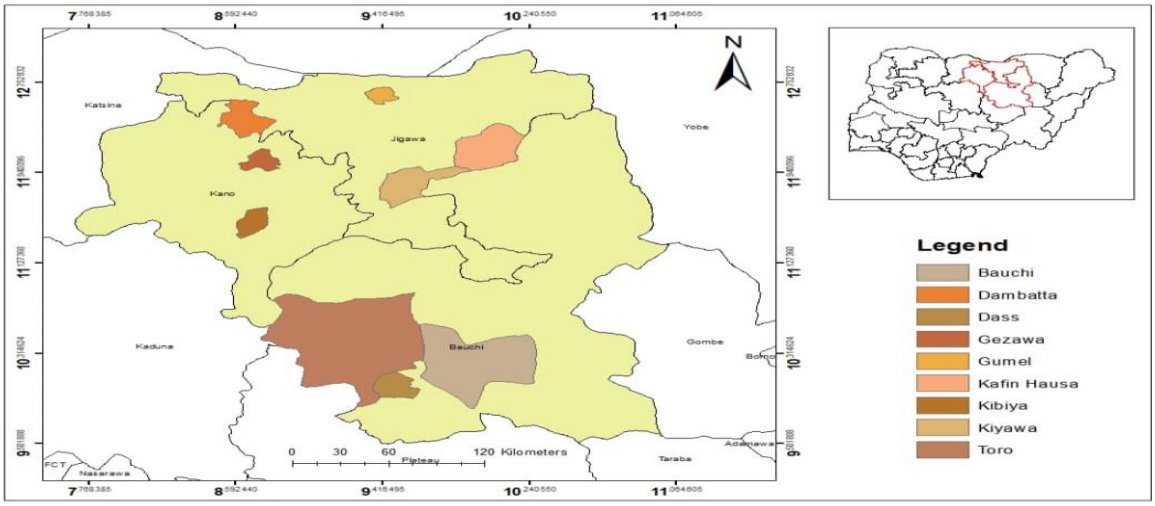

Figure 1: Map showing all the study locations in the region (Source: CDA GIS LAB, BUK, 2023)

Respondents Sampling

The selection of respondents for this research was conducted using a purposive sampling technique. Data for this study was collected through the interview using a semi-structured questionnaire administered to farmers. Because accurate data on the actual population of small-scale farmers (who oversee almost all the parklands) were unavailable, a total of 540 farmers were conveniently selected across the States, i.e. 20 respondents from each village and one hundred and eighty (180) respondents from each State; this makes a total of 540 respondents in the study area.

Data analysis

The data obtained from parkland respondents were processed and analyzed based on their questionnaire responses. Descriptive statistical methods were used to analyse the collected data, including frequency counts, percentages, and mean scores. SPSS software v16 was used for this study.

Results

Demographic characteristics of the respondents

Table 1 displays the demographic profile of the respondents, including gender, marital status, and educational qualifications. According to the findings, 94.50% of the respondents were male, with only 5.50% female indicating a substantial gender disparity. Furthermore, the results reveal that 4.49% of respondents were aged between 31-40 years, while 40.94% fell within the 41-50 years age bracket, 48.07% were above 50 years of age, and 6.11% of the respondents were less than 30 years old. Most of the respondents about (82.28%) were married, and 14.46% were single. The educational status of the respondents indicates that 2.85% had no formal education, 5% had adult education, 19.35% had primary education, 26.48% had secondary education and 23.83% had tertiary education. Hausa is the most spoken language among the respondents in the region, and it was 65.17%, followed by English (20.98%) and Fulfulde (13.85%). Farming is predominantly the primary occupation of the respondents (80.04%), followed by civil servants (7.74%) and trading/business (5.50%).

Table 1: Demographic characteristics of the respondents

Variables	Frequency	Percentage
Gender		
Male	464	94.50
Female	27	5.50
Total	491	100
Age (Years)		
Below 30	30	6.11
31-40	24	4.89
41-50	201	40.94
Above 50	236	48.07
Total	491	100
Marital status		
Single	71	14.46
Married	404	82.28
Divorced	3	0.61
Widowed	14	2.65
Total	491	100
Educational Status		
Primary education	95	19.35
Secondary education	130	26.48
Qur'anic education	130	26.48
Tertiary education	117	23.83
Vocational education	5	1.02
I didn't attend any such	14	2.85
Total	491	100
Language spoken		
English	103	20.98
Hausa	320	65.17
Fulani	68	13.85
Total	491	100
Occupation		
Farming	393	80.04
Civil servant	38	7.74
Ranching	3	0.61
Cap weaving	8	1.63
Fishing	3	0.61
Business	27	5.50
Student	5	1.02
Not employed	4	0.81
Rope weaving	5	1.02
Driver	5	1.02
Total	491	100

Sources: Field Survey, 2022

Information on tree regeneration practices in the study area

The result of Table 2 revealed information on tree regeneration practices in the region's parklands. It shows that 244 respondents (49.69%) are aware of the yearly tree planting campaigned by the government at different levels, 34.83% of the farmers have never planted a single tree on the farms, while 35.44% have planted more than 5tree on the farms before. Seedlings are privately sourced. Fuel wood exploitation is the primary reason for tree planting (45.82%), while 16.50% and 11.61% were for wind barrier and fodder production, respectively. Mature trees constitute most tree classes (68%) of the classes followed by saplings (22.61%) and seedlings (8.96%), respectively. Farmers play minimal roles in helping the trees regenerate as 27.09% of the trees grow naturally on the farmed parklands, while 22.20% helped with pruning and 14.87% helped with watering, respectively.

Table 3: Information on Tree Regeneration Practices

Variables	Frequency	Percentages
Tree planting campaign awareness		
Yes	244	49.69
No	247	50.31
Total	491	100
Number of trees planted		
None	171	34.83
<5	146	29.74
>5	174	35.44
Total	491	100
Source of Seedling		
ADP	54	11.00
Private nursery	225	45.82
Government nursery	57	11.61
State forest nursery	36	7.33
Others	119	24.24
Total	491	100
Purpose for tree planting		
Fuelwood	225	45.82
Soil fertility	30	6.11
Wind barrier	81	16.50
Fodder	57	11.61
Erosion control	33	6.72
Pole production	46	9.37
Others	19	3.87
Total	491	100
Tree class status		
Seedling	44	8.96
Sapling	111	22.61
Trees	336	68.43
Total	491	100
Method of regeneration		
Seeds	73	14.87
Coppicing	136	27.70
Vegetative propagation	282	57.43

Total	491	100.00
Farmers' roles in tree Regeneration		
Natural	133	27.09
Watering	73	14.87
Fencing	54	11.00
Pruning	109	22.20
Other tending operations	122	24.85
Total	491	100.00

Source: Field Survey, 2022

Constraints and Recommendations for Tree Regeneration Practices

The findings provided insights into the obstacles hindering the adoption of tree regeneration practices, along with recommendations to enhance tree regeneration in the parklands. The results show that landoccupied (33.60%), lack of adequate seedlings (21.59%), shortage of labor (12.63%), and lack of incentives (11.00%) constitute the major constrain to the adoption of tree regeneration practices in the region. Halting indiscriminate tree felling (51.73%), provision of more land (11.61%), provision of cheaper energy alternatives (9.98%), and planting more trees (8.35%) were highly recommended by the respondents (farmers) for better tree regeneration practices in the parklands of the region.

Table 4: Constraints and Recommendations for Tree Regeneration Practices

Variables	Frequency	Percentages
Constraints to Tree Regeneration Practices		
Lack of adequate seedlings	106	21.59
Lack of protective basket	29	5.91
Fencing materials	11	2.24
Transportation	22	4.48
Land	165	33.60
Lack of incentives	54	11.00
Termite and insects attack	14	2.85
Scanty rainfall	14	2.85
Shortage of labour	62	12.63
Inadequate extension agent	14	2.85
Total	491	100
Recommendations for Better Regeneration Practices		
Increased Awareness	38	7.74
Stop indiscriminate tree felling	254	51.73
Planting more tree	41	8.35
Provision of more seedlings	27	5.50
Provision of more land	57	11.61
Provision of more extension agents	11	2.24
Youth involvement	14	2.85
Cheaper energy alternative	49	9.98
Total	491	100

Source: Field Survey, 2022

Discussion

In demographic terms, most respondents were male (94.5%), while females made up only 5.5% of the total. The highest proportion of respondents was over 50, followed by those aged 40-50, with individuals under 30 being the least represented group in this study. This corroborates the outcomes of many authors who revealed that older people appeared to know more about tree uses than young ones (Jamala, 2017). This showed that the result obtained in this study was reliable as to the maturity of the respondents of whom the majority were above 50 years of age. This also aligned with the long-standing belief that only older people possess knowledge of their environment and tend to keep this knowledge secrets. Most of the respondents (82%) are in a marital relationship. The respondent's distribution shows that 23.83% have obtained tertiary level certificates, 26.48% have a secondary school and qur'anic education, and only 2.85% of the respondents didn't attend any school. As indicated by Amaza and Tashikalma (2003), the literacy level of farmers plays a crucial role in determining their uptake of enhanced technology to boost productivity in the parklands.

Additionally, Adekunle (2009) suggests that farmers' educational attainment directly influences their capacity to embrace changes and new ideas. Hausa is the predominant language in these regions, followed by Fulani and other indigenous dialects. Agriculture is the primary occupation of most respondents in these states. This trend could be attributed to the culture and traditions of the people, which allows men to perform all the farming activities and the women to take care of the home front. Most of the younger ones consider farming not lucrative anymore; this informed their decisions to engage in other businesses that will quickly bring them money. This agrees with the findings of Bayisa and Kotolo (2020) in southern Ethiopia, but Abdullahi (2019) observed a contrasting pattern in the agroecological regions of northern Nigeria.

Concerning the farmers' knowledge of tree regeneration efforts, half (50%) of the respondents indicated that they were unaware of any tree planting initiatives conducted by the respective State governments in their areas; only 35.4% of the farmers planted over five trees in their farms, and 29.74% less than five, but 34.83% never planted a single tree in their farms. The majority of farmers in the study area obtain seedlings from private sources. Fuel wood exploitation, wind barriers, and fodder were the main reasons farmers planted trees. Moreover, around 68.44% of regenerating stands in the respondents' farms were trees, followed by saplings and seedlings, which indicates inferior regeneration potential. This also conforms to the findings of Abdullahi (2021) at different agroecological zones of northern Nigeria. The result also revealed that regeneration is mainly natural. Land, lack of adequate seedlings, lack of incentives, and shortage of labour were the main constraints to tree regeneration in the parklands. Stopping/discouraging indiscriminate tree felling, land availability, and increased awareness regarding the significance of regenerating tree species in the parklands, coupled with the availability of more affordable energy sources, have been identified as the best ways of improving tree regeneration practices in the parklands (Mbah and Adugbo, 2018). This contradicts what Okonkwo (2010) reported in the Agroforestry farms in Jos, Plateau State, Nigeria, and this discrepancy may be attributed to the climatic variations among the ecological zones

Conclusion

Human activities significantly influence tree regeneration processes in the agricultural parklands of Northern Nigeria. Sustainable land management practices that promote tree conservation,

agroforestry, and community-based natural resource management are essential for maintaining and enhancing tree regeneration in these landscapes. Policy interventions, community engagement, and capacity-building initiatives are needed to address the challenges and opportunities associated with human-induced impacts on tree regeneration in agricultural parklands. Collaborative efforts involving government agencies, research institutions, non-governmental organizations, and local communities are crucial for promoting sustainable land use practices and conserving the biodiversity and ecosystem services provided by parkland trees in Northern Nigeria.

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Antimicrobial Potentials of *Parkia biglobosa* Jacq, *Boswellia dalzielli* Hutch and *Carica papaya* L. Ethanolic Extract on Multi- drug Resistant Diarrheal *salmonallae* and *shigellae* Bacteria.

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ABSTRACT

Medicinal plants constitute the major component of traditional medicine practised worldwide due to their economic viability, accessibility, and ancestral experience. Three medicinal plants (*Boswelllia dalzielli* Hutch, *Carica papaya* L. and *Parkia biglobosa* Jacq) used locally in diarrheal treatment were investigated. This study was carried out on isolated and confirmed strains of multidrug resistant isolates of *salmonellae* and *shigellae* bacteria isolated from diarrheal patients in Kaduna metropolis, Nigeria. The antidiarrheal activity of the three plant extracts against multidrug resistant strains of *Shigella* and *Salmonella* was performed using the agar well diffusion method using standard guidelines. The results were statistically analyzed using Duncan's multiple range test ($P<0.05$). The findings indicated that *Boswelllia dalzielli*, *Carica papaya* and *Parkia biglobosa* had growth-inhibitory effects against the tested bacteria. Ethanolic extract of *Boswelllia dalzielli* exhibited the highest inhibitory effect at 100mg/ml concentration on both *Salmonella* and *Shigella* isolates. The highest efficacy was recorded with the ethanol extracts of *Boswelllia dalzielli* (26.00 ± 1.00). Based on these findings, it can be assumed that ethanol extracts of *Boswelllia dalzielli*, *Carica papaya* and *Parkia biglobosa* could be potential sources for antidiarrheal drugs.

Keywords: Diarrhea, multidrug resistance, medicinal plants.

INTRODUCTION

Diarrheal diseases are the leading cause of mortality and morbidity, especially in children in developing countries, including Nigeria and other Sub-Saharan countries, resulting in a significant healthcare problem (Bangar, 2011). Infections due to a variety of bacterial etiologic agents, such as pathogenic *Escherichia coli, Vibrio cholerae, Areomonas* spp., *Shigella* spp., *Salmonella* spp., *Pseudomonas* spp., *Klebsiella* spp., *Campylobacter* spp., *and Staphylococcus aureus* are most common. Infectious diseases are the world's significant danger to human health and account for approximately 550,000 deaths/day (Ahmad and Beg, 2011). Most of the severe conditions are caused by pathogenic bacteria. Antibacterial drugs are one of the most essential tools in combating bacterial infections and saving human life from severe invasion of many infectious diseases. However, these health opportunities are at risk from the past few decades as many frequently used antibiotics have become less effective against certain illnesses. This is not only due to the toxic reactions but also to the emergence of multi-drug-resistant strains of bacteria and the recent appearance of strains with reduced susceptibility to antibiotics (Hancock *et al.*, 2012).

Multiple drug resistance (MDR), or multi-resistance, is a condition enabling disease-causing microorganisms (bacteria, viruses, fungi or parasites) to resist distinct antimicrobials, first and foremost antibiotics, but also antifungal drugs, antiviral medications, anti-parasitic drugs, chemicals of a wide variety of structure and function targeted at eradicating the organism. Therefore, alternative antimicrobial sources are urgently needed, and this has led to a re-evaluation of the therapeutic relevance of ancient remedies, such as plants (Mandal *et al.,* 2010). Medicinal plants have been acknowledged as potential sources of new compounds of therapeutic value and as sources of lead compounds for drug design and development (Newman *et al.,*2003). Medicinal plants generally exhibit multiple non-specific effects, which are usually complementary or synergistic. In most cases, a plant is often used for a variety of ailments, which may suggest a concerted or wholesome therapy. These therapeutic agents can have antispasmodic effects, delay intestinal transit, suppress gut motility, inhibit intestinal motility, stimulate water adsorption, or reduce electrolyte secretion (Palombo, 2006), and some of these effects have been attributed to the presence of numerous phytochemicals (such as alkaloids, tannins, flavonoids, and terpenes). Considering the vast potentiality of plants as sources for antimicrobial drugs, this study aimed at detecting the antibacterial activities of some natural plant extracts and investigating their effects on some multidrug resistant human clinical bacterial isolates to common commercial antibiotics.

METHODOLOGY

Collection, identification, and treatment of plant materials

Fresh plant parts were collected at Trial Afforestation Research Station, Forestry Research Institute of Nigeria, Afaka, Kaduna. The plants were authenticated by a taxonomist in the Department of Biological Sciences Nigerian Defence Academy, Kaduna, to confirm their identities with voucher numbers NDA BIO 1529, 1530 and 1531 for *Carica papaya, Parkia biglobosa* and *Boswellia dalzielli* spp, respectively. The samples were then dried at room temperature and milled into coarse powder with an electric blender; the milled samples were kept in tight bottles.

Extraction procedure

Ethanolic extracts of the plants were prepared using the method described by Barry and Thornsberry (1991). One hundred grams of the blended samples each were separately measured into a conical flask, and 1000 ml of ethanol was added, ered with a cork, and left on a shaker at 100 revolutions per minute for 24 hours, after which the extract was filtered and squeezed through four layers of muslin cloth. The filtrate was concentrated under reduced pressure in a rotavapor at 40°C to recover the solvent. The extracts obtained were stored in sterile McCartney plastic bottles, kept in the refrigerator at 4°C and, later used for antimicrobial tests.

Phytochemical screening of the plant extracts.

Chemical constituents of the extracts were analyzed to detect the presence of compounds using standard procedures according to the methods of Odebiyi and Sofowora (1990) and Trease and Evans (1983).

Collection and maintenance of test organisms

Pure cultures of bacteria *(Salmonella* spp. and *Shigella* spp) isolated from clinical specimens were obtained from the Microbiology Department of Ahmadu Bello University Teaching Hospital Zaria,

Yusuf Dan-tsoho Memorial Hospital, Kaduna National Institute for Trypanosomiasis Research (NITR), Kaduna and Gold Bond Medical Laboratories, Kaduna. The organisms were maintained on Nutrient agar slants at 4°C and were routinely sub-cultured during storage.

Morphological and Biochemical Characterization of Isolates
Isolates were characterized and identified based on morphological and biochemical characterization using standard techniques by Aneja (2007).

Antibiotic susceptibility screening
The sensitivity/resistance of the bacterial strains to antibiotics was carried out using the Kirby-Bauer disc diffusion method. A multi-disc containing Augmentin (30 µg), Ciprofloxacin (10micrograms), Septrin (30micrgramms), Chloramphenicol (30microgramms), Sparfloxacin (10microgramms), Amoxicillin (30microgramms), Gentamycin (10microgramms), Pefloxacin (30microgramms), Tarivid (10micrgramms) and Streptomycin (30microgramms) was employed.

Antibacterial properties of plant extracts
The antibacterial properties of ethanolic plant extracts were determined using the agar well diffusion method of (Bauer *et al.*, 1966). Twenty-four (24) hour-old broth cultures of each test organism (standardized inoculum) were swabbed onto sterile Mueller Hinton agar in Petri dishes using sterile cotton swab. A sterile stainless steel cork borer of size 5mm diameter was used to make wells on the plates. The holes were filled with 10mg/ml, 20mg/ml, 30mg/ml, 50mg/ml and 100 mg/ml of the extracts, and each was labelled appropriately. The control experiment was also set up where the holes were filled with sterile distilled water using sterile 2 ml syringes. The plates were incubated at 37°C for 24 hours, after which the result was read and recorded by measuring the diameter of zones of inhibition around the wells with the aid of a ruler. The antimicrobial readings were done in triplicates, and diameters of zones of inhibition (mm) were expressed as means.

Minimum Inhibitory Concentration (MIC)
The extracts' Minimum Inhibitory Concentration (MIC) was determined for each of the test organisms in triplicates in test tubes. To 0.5 ml of varying concentrations of the extracts (5, 25, 50, 75, 100, 125, 150, 175 and 200 mg/ml) in test tubes, Nutrient broth (2 ml) was added and then a loopful of the test organism, previously diluted to 0.5 McFarland turbidity standard, was introduced. A tube containing nutrient broth only was seeded with the test organisms, as described above, to serve as controls. The culture tubes were then incubated at 37°C for 24 h. After incubation, the tubes were examined for microbial growth by observing turbidity.

Minimum bactericidal concentration (MBC)
Visual observation of growth inhibition on a solid medium was used to determine MBC as described by Mitscher *et al.*, 1972. To determine the MBC, for each set of test tubes in the MIC determination, a loopful of broth was collected from those tubes that showed no growth and inoculated onto sterile Nutrient agar by streaking. Nutrient agar plates only were streaked with the respective test organisms to serve as controls. All the plates were then incubated for 37°C 24 h. After incubation, the concertation at which no visible growth was seen was noted as the Minimum Bactericidal Concentration (MBC).

RESULTS

Identification of Organisms

Salmonella and *Shigella* were the two enteric bacteria studied. Isolates collected from the different healthcare institutions were subjected to biochemical tests (their ability to utilize or oxidize certain chemical substances to produce a specific colour). They were identified based on their morphological and biochemical reactions (Table 1).

Table 1: characterization and Biochemical reaction of *Salmonella spp* and *Shigella spp* isolates from diarrhoea.

Phenotypic Traits and Tests	Appearances and Responses of Bacterial Isolates	
	Salmonella spp.	*Shigella spp.*
Morphology	smooth, colourless, colonies. 2-4mm	smooth, colourless colonies.2-3mm
Shape	Rod	Rod
Gram reaction	-ve	-ve
Glucose	+ve	+ve
Sucrose	+ve	+ve
lactose	-ve	-ve
Oxidase	-ve	-ve
Indole	-ve	-ve
Hydrogen Sulphide	+ve	-ve
Gas production	+ve	+ve
Ornithine	+ve	+ve
Urea	-ve	-ve
Citrate	+ve	-ve
Motility	motile	non-motile
Triple sugar iron(butt)	A	A
Triple sugar iron (slant)	K	K

Key: +ve Positive, -ve Negative, A: Acid, K: Alkaline A/A; utilize glucose, lactose, and sucrose

Phytochemical Screening

Phytochemical screening of the plant extracts showed the presence of some Phyto compounds (Table 2).

Table 2: Qualitative analysis of the phytochemicals of the ethanolic extracts of *Boswellia dalzielli, Parkia biglobosa* and *Carica papaya.*

Plant	Alkaloids	Glycoside	Flavonoid	Saponin	Tannin	Steroids	Phenols	Protein
BDL	+	_	+	+	+	+	+	_
BDB	+	+	+	+	+	+	_	_
CPL	+	+	_	+	+	+	+	_
CPB	+	+	+	+	+	+	_	_
PBL	+	+	+	+	+	_	_	_
PBB	+	+	_	+	+	+	+	_

KEY: BDL= *Boswellia dalzielli* leaf, *BDB= Boswellia dalzielli* bark, *CPL= Carica papaya* leaf, CPB = *Carica papaya* bark, PBL= *Parkia biglobosa* leaf PBB= *Parkia biglobosa* bark.

Susceptibility Testing of Conventional Antibiotics against *Salmonella* and *Shigella* species.

Susceptibility testing of conventional antibiotics against *Salmonella* and *Shigella* species shows that Augmentin, Amoxicillin and Streptomycin were the most resisted antibiotics, not affect any of the isolates exposed to them (Table 3); Chloramphenicol was the most effective with 25±1.00 and 23±1.00 against *Salmonella* and *Shigella* respectively. They were followed by Sparfloxacin (15.33±0.58) for *Shigella* and *Salmonella* at 21.00±1.00. Drug resistance was also observed for Gentamycin, perfloxacin and Tarivid. The result of the susceptibility of antibiotics presented a varying degree of resistance to the different drugs used against the different organisms, but in all, from the result of antibiotics susceptibility tests, all isolates were sensitive to at least one of the Ten antibiotics and resistant to more than three they were tested against. The result was labelled Resistant (R), Intermediate (I) and Susceptible (S) after being compared to the approved performance standards for antimicrobial susceptibility testing.

Table 3: Zones of inhibition of Antibiotics with *Salmonella spp.* and *Shigella spp.*

	← Zones of inhibitions →	
Antibiotics	*Shigella*	*Salmonella*
Chloramphenicol	23.00 ± 1.00(S)	25.00 ± 1.00(S)
Sparfloxacin	15.33 ± 0.58(I)	21.00 ± 1.00(S)
Septrin	7.17 ± 0.29(R)	14.67 ± 0.58(I)
Ciproflaxacin	20.50 ± 3.04(S)	21.00 ± 1.00(S)
Amoxicillin	0.00 ± 0.00(R)	0.00 ± 0.00(R)
Augmentin	0.00 ± 0.00(R)	0.00 ± 0.00(R)
Gentamycin	0.00 ± 0.00(R)	8.33 ± 0.58(R)
Pefloxacin	0.33 ± 0.58(R)	0.00 ± 0.00(R)
Tarivid	4.83 ±0.29(R)	7.00 ± 1.00(R)
Streptomycin	0.00 ± 0.00(R)	0.00 ± 0.00(R)

KEY: R= Resistant, I=Intermediate, S= Susceptible
Values are means ± standard deviation of three replicates

Susceptibility Testing of *Boswellia dalzielli, Parkia biglobosa* and *Carica papaya* extracts on *Salmonella* and *Shigella* species

The results showed that the plant extracts had activity on on all the test organisms at varying degrees (Tables 4 and 5)—the absence of zones of inhibition around each well-signified resistance. The zone of inhibition against the isolates increased with an increase in the concentration of the plant extracts. Against *Salmonella* isolate, the highest zone of inhibition was observed at 100mg /ml with an inhibition of 26±1.00 (Table 4) by ethanol extract of *Boswellia dalzielli* stem bark followed by the leave extract with 25.50±0.50 (Table 4). No zone of inhibition was observed at 10mg/ml by ethanol extracts of *Carica papaya* and *Parkia biglobosa* (Table 4). Table 5 showed that at 100mg/ml the highest inhibition was observed against *Shigella* at 26 ±1.00 by *Boswellia dalzielli* ethanol leave extract.

Table 4: Zones of Inhibition of Ethanolic Extracts of *Boswellia dalzielli, Parkia biglobosa* and Carica *papaya* with *Salmonella spp*

Plant extract	→ concentration (mg/ml) ←				
	10	20	30	50	100
BDL	$8.00^{c} \pm 1.00$	$14.60^{d} \pm 0.85$	$15.00^{c} \pm 1.00$	$21.00^{d} \pm 1.00$	$25.50^{d} \pm 0.50$
BDB	$4.17^{b} \pm 1.04$	$6.30^{c} \pm 0.92$	$11.20^{b} \pm 1.57$	$17.40^{c} \pm 2.42$	$26.00^{d} \pm 1.00$
CPL	$0.00^{a} \pm 0.00$	$2.50^{ab} \pm 0.50$	$8.33^{ab} \pm 0.58$	$13.03^{b} \pm 0.58$	$16.00^{b} \pm 2.00$
CPB	$0.00^{a} \pm 0.00$	$1.67^{a} \pm 2.87$	$4.90^{a} \pm 4.25$	$7.93^{a} \pm 2.50$	$12.33^{a} \pm 4.16$
PBL	$0.00^{a} \pm 0.00$	$1.00^{a} \pm 1.00$	$11.13^{b} \pm 1.79$	$12.73^{b} \pm 0.64$	$17.00^{bc} \pm 1.00$
PBB	$0.00^{a} \pm 0.00$	$4.33^{bc} \pm 0.58$	$10.50^{b} \pm 0.50$	$15.23^{bc} \pm c2.08$	$19.77^{c} \pm 0.56$

a,b,c,d means within a column in each plant part with different superscripts are significantly different (P<0.05). Values are means ± standard deviation of three replicates.

BDL= *Boswellia dalzielli* leaf *BDB= Boswellia dalzielli* bark, *CPL= Carica papaya* leaf CPB = *Carica papaya* bark, PBL= *Parkia biglobosa* leaf PBB= *Parkia biglobosa* bark.

Table 5: Zones of Inhibition of Ethanolic Extracts of *Boswellia dalzielli, Parkia biglobosa* and *Carica papaya* with *Shigella spp.*

Plant extract	← concentration (mg/ml) →				
	10	20	30	50	100
BDL	$8.83^{d} \pm 0.29$	$10.83^{c} \pm 0.29$	$19.40^{e} \pm 0.53$	$23.33^{e} \pm 0.58$	$26.00^{d} \pm 1.00$
BDB	$0.00^{a} \pm 0.00$	$5.00^{b} \pm 1.00$	$8.50^{c} \pm 0.50$	$12.00^{c} \pm 1.00$	$15.67^{b} \pm 0.58$
CPL	$0.00^{a} \pm 0.00$	$4.67^{b} \pm 0.58$	$6.67^{b} \pm 0.58$	$10.33^{b} \pm 0.58$	$14.67^{b} \pm 0.58$
CPB	$0.00^{a} \pm 0.00$	$0.67^{a} \pm 0.58$	$3.33^{a} \pm 0.58$	$7.00^{a} \pm 1.00$	$11.00^{a} \pm 1.00$
PBL	$1.33^{b} \pm 0.58$	$5.67^{b} \pm 0.58$	$8.83^{c} \pm 0.29$	$11.67^{bc} \pm 0.58$	$15.33^{b} \pm 0.58$
PBB	$2.33^{c} \pm 0.58$	$5.33^{b} \pm 0.58$	$10.00^{d} \pm 0.00$	$15.33^{d} \pm 1.15$	$20.00^{c} \pm 1.00$

a,b,c,d means within a column in each plant part with different superscripts are significantly different (P<0.05). Values are means ± standard deviation of three replicates.

BDL= *Boswellia dalzielli* leaf *BDB= Boswellia dalzielli* bark, *CPL= Carica papaya* leaf, CPB = *Carica papaya* bark, PBL= *Parkia biglobosa* leaf PBB= *Parkia biglobosa* bark.

Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC)

The minimum inhibitory concentration (MIC) was observed by lack of turbidity in each test tube used for the minimum inhibitory concentration test after 24 hours at 37°C (Figures 1 and 2). The appearance of turbidity indicated the growth of the test organism, and the effects of the extracts were also observed.

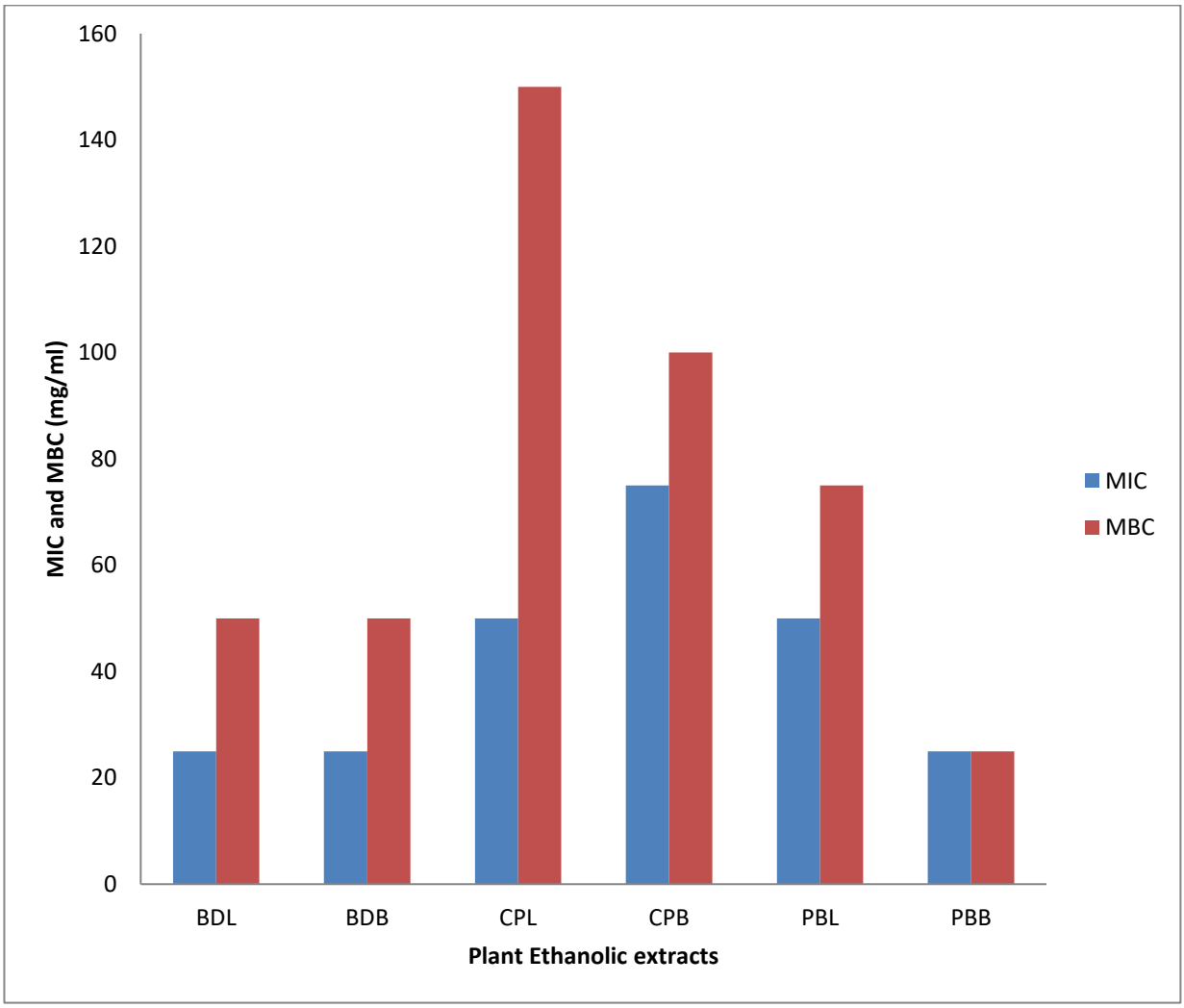

Figure 1: Minimum Inhibitory Concentration MIC (mg/ml) and Minimum Bactericidal Concentration MBC (mg/ml) of *Boswellia dalzielli*, *Parkia biglobosa* and *Carica papaya* ethanolic extract for *Salmonella* spp .

BDL= *Boswellia dalzielli* leaf *BDB= Boswellia dalzielli* bark, *CPL= Carica papaya* leaf, CPB = *Carica papaya* bark, PBL= *Parkia biglobosa* leaf PBB= *Parkia biglobosa* bark.

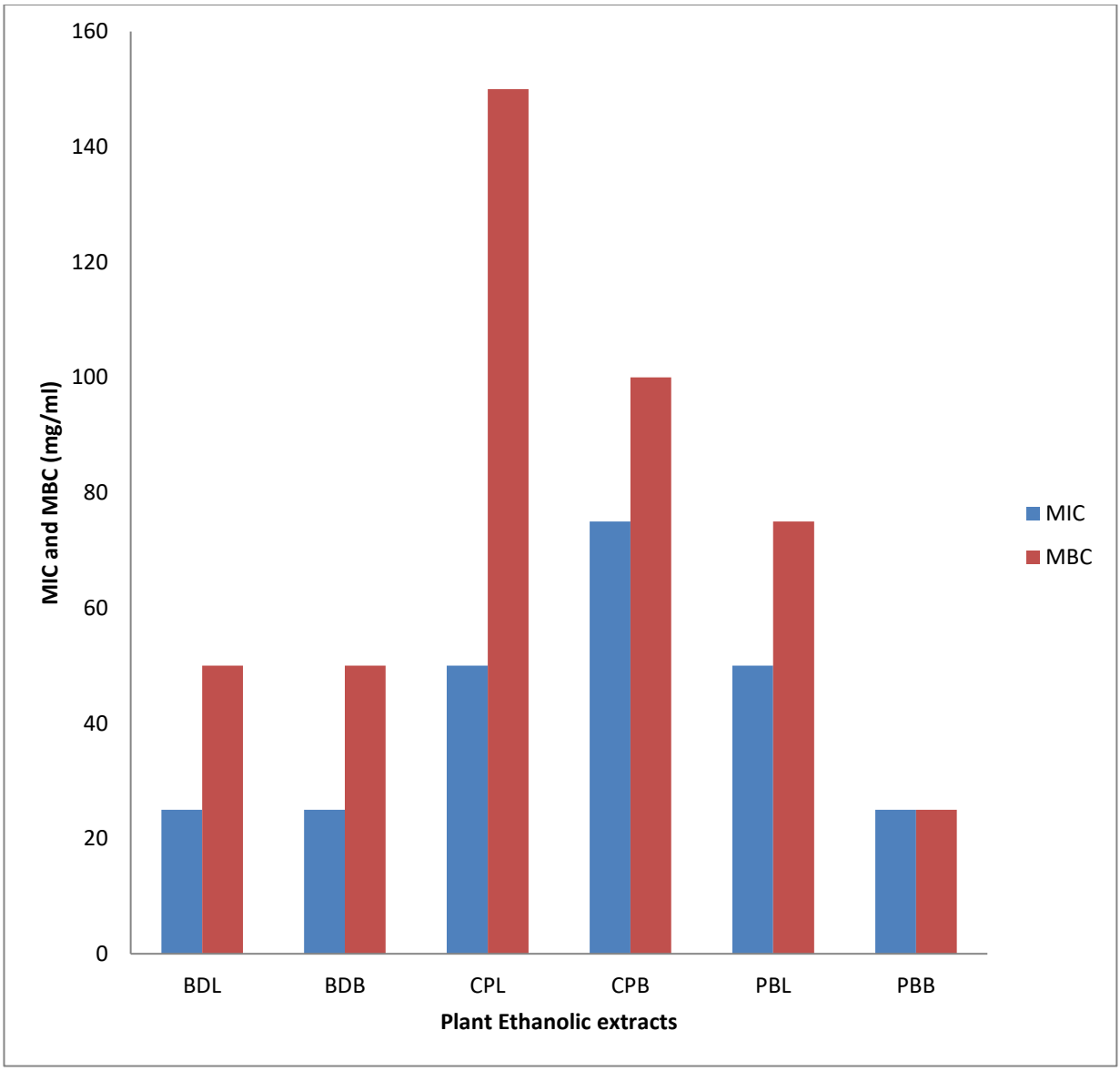

Figure 2: Minimum Inhibitory Concentration MIC (mg/ml) and Minumum Bactericidal Concentration MBC (mg/ml) of *Boswellia dalzielli*, *Parkia biglobosa* and *Carica papaya* ethanolic extract for *Shigella spp*

KEY: BDL= *Boswellia dalzielli* leaf *BDB*= *Boswellia dalzielli* bark, *CPL*= *Carica papaya* leaf, CPB = *Carica papaya* bark, PBL= *Parkia biglobosa* leaf PBB= *Parkia biglobosa* bark.

DISCUSSION

The emergence of multidrug resistance in human and animal pathogenic bacteria, and undesirable side effects of certain antibiotics, has triggered immense interest in the search for new antimicrobial drugs of plant origin. The study was conducted to investigating the antimicrobial properties of some medicinal plant extracts against some human clinical bacterial isolates. In this study, the isolated *salmonellae* and *shigella* bacteria were observed to be resistant to most (70%) of the commonly used antibiotics (Table 3). Drug resistance of bacteria to antibiotics has been attributed to the misuse and overuse of antibiotics and the possession of drug resistance plasmids (DubMandal, 2005). There seemed to be complete resistance to Augmentin, Pefloxacin, Tarivid and Amoxicillin by both *Salmonella* and *Shigella* isolates (Table 3) in this study, which disagrees with reports from Mache *et al.* (1997) and Asrat (2008). Resistance is a natural biological response of microbes to antimicrobials and is currently a worrisome scenario affecting many parts of the world (Sharma *et al.*, 2005; Khatun, 2011). Apart from intrinsic resistance, gene transfer and mutation are among the underlying mechanisms involved in developing antimicrobial resistance by microbes (Sharma *et al.*, 2005). Ethanolic extract of the bark and leaves of *Boswellia dalzielli* showed high potency in their bactericidal action against the test bacteria. This might be due to the ability of the solvent to extract active ingredients (bioactive compounds) from the plant materials. This research suggests that ethanolic extracts of screened plants would help treat diseases in man caused by enterotoxin-producing bacteria like *Salmonella* and *Shigella*. The antibacterial activities of the extracts increased as the concentration increased, as found in this work (Table 4 and 5). This does not differ from the research findings of Banso and Adeyemo (2007), who reported that the tannins isolated from medicinal plants possess remarkable toxic activity against bacteria and fungi and may assume pharmacological importance in future.

The demonstration of activity against the test bacteria provides a scientific basis for the local usage of these plants in treating various bacterial-related ailments. This observation is very significant because of the possibility of developing therapeutic substances that will be active against multidrug-resistant bacteria. The low MIC value observed in our study (Figures 1 and 2) using some of the extracts is a good indication of high efficacy against these bacteria, as was observed in a survey by Doughari (2007). This outcome is good considering that diarrhoea is rising and becoming recalcitrant to first-line antibiotics for its treatment in developing countries, including Nigeria. Other extracts, notably Carica papaya with high Minimum Inhibitory Concentration (MIC), may indicate low efficacy or that the organisms have the potential for developing resistance to the bioactive compounds (Doughari, 2007).

CONCLUSION

Except for Chloramphenicol, ciprofloxacin and Sparfloxacin for which both *Salmonella* and *Shigella* isolates were susceptible, a high level of multidrug resistance was detected. Notably, the bacteria seemed to have developed complete resistance to Augmentin, Streptomycin, Pefloxacin and Amoxicillin. Therefore, traditional medicinal methods, especially medicinal plants, still play a vital role in covering the basic health needs in developing countries.

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Allelopathic Effects of *Eucalyptus camaldulensis* DEHNH and *Azadirachta indica* AJUSS Leaf Powder on The Growth of Millet and Sorghum (POLACEA)

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ABSTRACT

Allelopathic effects of some trees thriving in northern Nigeria, especially the exotic species such as *Eucalyptus camaldulensis* and *Azadirachta indica* have been a topic of discourse among the Agroforesters and farmers. However, it was observed to have an influence on the Growth and yield of Sorghum and Millet. Hence, the research aimed to assess the allelopathic effect of neem and Eucalyptus of leaf powered on the seedling's Growth of Millet and Sorghum. Four levels of neem and eucalyptus leaf powder (1.0, 1.5, 2.0 and 2.5g respectively) were mixed with 1kg of topsoil while the last dosage was controlled. The study was conducted using a completely randomized design (CRD), using nine treatments and three replicates. Data collected was subjected to analysis of variance while means were separated using Duncan's Multiple Range Test. The experiment was terminated three months after sowing, and morphological features of the crop seedlings were measured. The results showed a significant reduction in the growth pattern of the examined crops when treated with eucalyptus leaf powder. Additionally, are direct negative relationship between the concentration of the powder and the growth-yield. This information could be important for further research in crop cultivation and management. Control actively supported the Growth of Millet and Sorghum followed by NIM and NIS. E4M and E4S had the most negative effect on the polacea crops. *Eucalyptus camaldulensis* had the highest allelopathic effects on seed germination, seedling growth and yield of poaceous crops and it recommended that planting seeds too close to the eucalyptus hot spot should be avoided.

Keywords: Allelopathic, Neem, Eucalyptus, Leaf powder, Growth, Yield, Sorghum and Millet

INTRODUCTION

Allelopathic describes the different of effects of plants caused by the environmental discharge of certain chemicals (Delabays *et al.,* 2004). This biochemical is identified as allelochemicals (Singh and Chaundhary, 2011). Yuvraj *et al.* (2022) described Allelopatic as the process by which plants directly release phytochemicals into their surroundings, preventing established neighbouring species' seeds from germinating and growing. In agricultural and natural systems, allelochemicals are liberated from plant components by various processes such as residue breakdown, volatilization, root exudation, and leaching (Chou, 1990). Allelochemicals can inhibit cell division or auxin, which promotes the Growth of roots and shoots (Gholami *et al.,* 2011). Allelochemicals that limit root and shoot length include phenolic compounds (Hussain and

Reigosa, 2011). These allelochemicals may have inhibited development because they interfered with the mechanisms involved in plant growth. Allelochemicals emitted into the environment can disrupt a plant's natural symbiotic relationship or hinder shoot/root growth and nutrient uptake (Salami and Lawal, 2018b; Salami *et al.,* 2019; Gholami *et al.,* 2011). In determining species diversity, vegetation dynamics, and vegetation patterns, allelopathy plays a significant role. Allelopathic methods involve using fewer chemical herbicides or replacing them with natural products (plant and microbial products) to lessen environmental pollution and preserve ecological balance, particularly regarding soil fauna and flora. Using allelopathy in agricultural operations to suppress weeds is a good idea. Many plants and organs, such as leaves, flowers, fruits, and buds, contain compounds that exhibit allelopathy action (Ashrafi *et al.,* 2007; May and Ash, 1990; Inderjit, 1996). When activated charcoal was added to the soil, the Growth of bulrush did not decrease, indicating that allelopathy phenolics hindered bulrush growth.

Additionally, Phragmites manufactures compounds known as allelopathy, which prevent other species' seeds from germinating and growing (Uddin *et al.,* 2014). Allelopathy was noted by Uddin *et al.* (2012) in the extracts of the leaves, rhizome, roots, and stems. The most potent inhibitors were rhizome and leaf extracts, which slowed the Growth of *Juncus pallidus* roots by 75%. In a dose-dependent way, extracts from *E camadulensis* and *A. indica* considerably suppressed the germination and Growth of the Poaceae crops that were examined (Ashrafi *et al.,* 2007). Regarding radicle (root) growth as opposed to shoot Growth, the inhibitory effects were more noticeable. To reduce the adverse impact of these plants on the Growth and development of their crops, farmers and gardeners may need to take the necessary precautions. Eucalyptus can also alter the pH of the soil (Kubmarawa *et al.,* 2008; Mubarak *et al.,* 2011) or compete with crops for underlying light, water, and soil nutrients (Onyewotu *et al.,* 1994; Pérez Bidegain *et al.,* 2001).

Furthermore, there is an ongoing debate on the ecological roles of Eucalyptus, as it decreases the productivity of understory crops and the diversity of understory species (Moradshahi *et al.,* 2003). Other plant species are affected by allelopathy caused by its allelochemicals (Turnbull, 1999). Numerous compounds found in neem trees include queceretin (anti-protozoal), azadirachtin (repellent, anti-feedant, and antihormonal), nimbin, nimbidin, nimbidol, gaduin, and sodium nimbinate (Sankaram, 1987). According to the study's findings, secondary metabolites, including phenolic compounds and terpenoids in the leaves of *E camadulensis* and *A. indica,* may be responsible for their allelopathy effects on the Poaceae crops under investigation. It's critical to take neem and Eucalyptus allelopathy into account when choosing which crops to plant nearby. To recommend appropriate management practices, the study described in the proceeding set out to ascertain the impact of the allelopathy properties of *Eucalyptus camaldulensis* Dehnh and *A. indica* Ajuss leaf powder on the Growth of Sorghum and Millet.

Plate 1: Neem leave

Plate 2: Eucalyptus leave

Plate 3: Neem leave powder

Plate 4: Eucalyptus leave powder

Plate 5: Eucalyptus tree

Plate 6: Neem Tree – Forestry.com

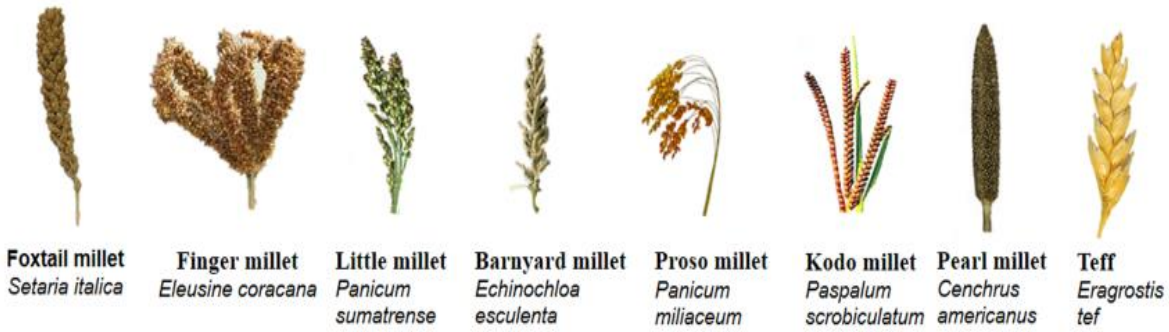

Plate 7: Flower morphology of millets with their common and botanical names

Plate 8: Sorghum plant

MATERIALS AND METHODS

Description of the Study Area

Dutse is a city located in northern Nigeria. The study area has coordinates of latitude 11°42′ 04″ N, 9.2^{0}31"E and Longitude 11^{0}70'11" N, 9.3^{0}41'94 "E and elevation of 435m above the sea level. With an average yearly rainfall of between 600 and 100 mm and high temperatures typically observed during April and September, the rainy season spans from May to September (Salami and Lawal, 2018a). As reported by Salami and Lawal. (2018a); Jibo *et al.* (2018) found that it is covered by Sudan savannah and is distinguished by hot, humid summers and cold, dry winters with an average rainy season of three to five months (644 mm). The majority of the population is farmers who raise cattle and farms (Richard *et al.,* 1997). With a population estimated at 153,000, Hausa and Fulani make up most of the population of Dutse (National Population Commission, 2006). A nearly 750-meter-high land region typifies the geography. Most soil types, from sandy to loamy, are fertile (Salami *et al.,* 2019).

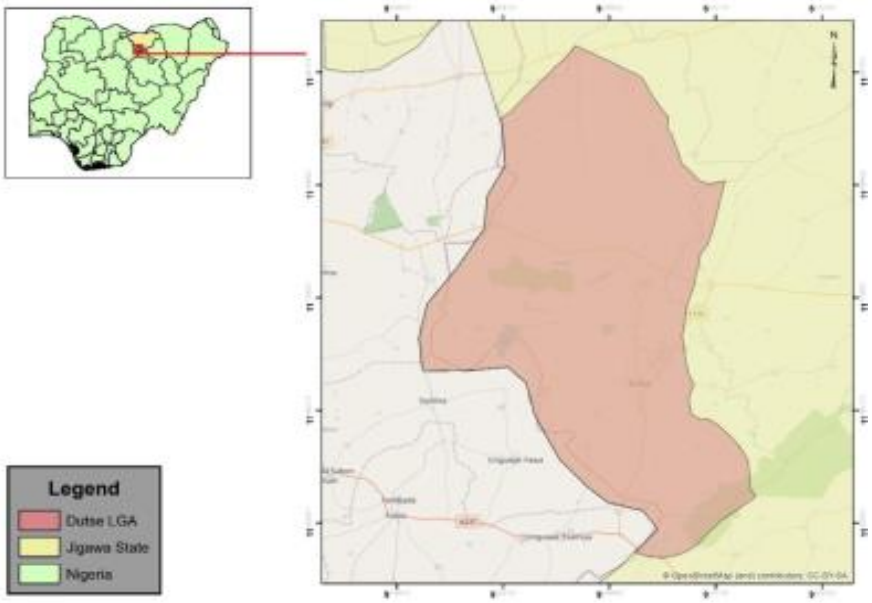

Fig. 1. Map of the study area

Adapted from: Garba *et al.*, (2021)

Data Collection

Mature leaves of Eucalyptus and neem tree were collected from an experimental farm in Federal University, Dutse, Jigawa state. Certified seeds of Sorghum and Millet with a germination percentage of 95-100% and purity of 100% were obtained from International Crops Research Institute for Semi-Arid Tropics (ICRISAT)

Method

Procedure

After being cleaned with sterilized distilled water, the leaves were allowed to air dry for 15 days at room temperature in a dark area, away from direct sunlight, which could have caused unwanted reactions (Awadallah and Eman, 2017). Once dried, the leaves were ground into a powder and stored in brown bottles until needed. To lessen fungal infection, the seeds were surface sterilized with a 1% (v/v) sodium hypochlorite solution for three minutes while constantly stirring (Awadallah and Eman, 2017). Successively, the seeds were washed with treated distil water several times and stored at room temperature until used. Four levels of neem and eucalyptus leaf powder (1, 1.5, 2.0 and 2.5g, respectively) were mixed with 1kg of topsoil. Furthermore, a treatment without any dosage was included (control). Morphological characteristics which were assessed are: Plant height with the aid of linear tape, stem diameter with the help of vernier calliper, leaf production by counting, dry matter with the aid of a sensitive weighing machine and leaf area with the help of the formula, expressed below (Jibo *et al*., 2021; Yisau, 2018; Ugese, 2017)

Leaf Area: Length x Width $(4 + 4.411)$…….eqn 1

Sampling Design and Experimental Layout
Sampling design

A complete Randomized Design was applied. One (1) kg of topsoil was filled in each polythene bag, and the experiment contained nine treatments and three replicates, making twenty - seven (27) for each study.

Experimental Layout

Experimental layout for the Growth and yield of Millet with the impacts of leaving powder

	E_1	**E_2**	**E_3**	**E_4**	**N_1**	**N_2**	**N_3**	**N_4**	**C_0**
M	E_1M	E_2M	E_3M	E_4M	N_1M	N_2M	N_3M	N_4M	C_0M

Experimental layout for the Growth and yield of Sorghum with the impacts of leaving powder

	E_1	**E_2**	**E_3**	**E_4**	**N_1**	**N_2**	**N_3**	**N_4**	**C_0**
S	E_1S	E_2S	E_3S	E_4S	N_1S	N_2S	N_3S	N_4S	C_0S

C_0 means control, which is plain soil with no treatment applied
M: means Millet
S: Means Sorghum
E: means *Eucalyptus camdulensis* leaf powder
N means *Azadiratcha indica* leaf powder
1, 2, 3, 4 means treatment levels
Where: 1 = 1.0g, 2 = 1.5g 3 = 2.0, 4 = 2.5g neem and eucalyptus powder.

The study had nine (9) treatments with three (3) replicates each for the study, making twenty - seven (27) for each sampling pot.

Data analysis

The objectives of the study were accomplished with the aid of descriptive and inferential statistics. The influence of neem and eucalyptus leaf powder on Growth of Millet and Sorghum was analyzed by a descriptive statistics like frequency and inferential statistics such as one-way Analysis of Variance (ANOVA) using computer software statistics-8.0. Mean differences were compared using the Duncan Multiple Range Test (DMRT) (Duncan, 1955)

Results and Discussion

Results

Effect of Neem leaf powder and Eucalyptus leaf powder on the Growth of Millet and Sorghum

The Growth of the Millet plant, as shown in Table 3, revealed its response to the effect of Neem and Eucalyptus leaf powder. Results from Table 3 showed that the untreated plant CO, N1M, N2M, N3M and N4M exhibited higher shoot heights (70.5 cm, 68.5 cm, 68.1 cm, 66.0 cm and 65.5 cm, respectively). The effects were not significantly different ($p>0.05$) from each other, with the least effect (50.0 cm) reflected in E4M seedlings. Similarly, C0 and N1M had the highest number of leaves produced (12), while N2M, N3M and N4M were consistent (11) and not significantly different ($p>0.05$) from E4M with the most minor effect on the number of produced leaves (9). A similar trend was recorded for stem diameter and dry weight, with C0 exhibiting the highest impact (4.0 mm and 4.0 g, respectively) with no significant difference ($p>0.05$) from the E4M, which had the most minor impact 3.0 mm and 2.0 g on stem diameter and dry weight respectively. However, C0 demonstrated a higher leaf area of 965.1 cm^2 with a significance difference ($p<0.05$) from N1M (942.9 cm^2), N2M (941.2 cm^2), N3M (938.5 cm^2) and N4M (901.3 cm^2). The least significant effect of 714.0 cm^2 was shown in E4M. Furthermore, the Millet root of length 35.05 cm was prominent in CO with significant difference ($P<0.05$) from the effect of N1M, N2M, N3M and N4M (33.05 cm, 32.50 cm, 31.06 cm and 30.01 cm respectively) on root length. The leaf powder's least effect (25.05 cm) was shown in E4M seedlings.

The growth parameters of the Sorghum plant are shown in Table 4. The shoot height (71.0 cm) was significantly ($p<0.05$) higher in the control treatment, which was followed by 1.0g and 1.5g of Neem leaf powder, which is (N1S), (N2S) at 66.0 and 65.0 cm. Treatments N3S, N4S, E1S, E2S, E3S, and E4S showed relatively lower shoot heights ranging from 60.1 cm to 55.5 cm with no significant differences ($p>0.05$) among the shoot heights. Similarly, C0 had the highest leaf area recorded (982.9 cm) with a significant difference ($p<0.05$) from N1S (954.5 cm), while the most minor effect (700.9 cm) on the leaf area of Sorghum was found in 2.5 g of Eucalyptus leaf powder (E4S). However, the highest number of leaves produced in the C0 and N1S (12) were not significantly different ($p>0.05$) from N2S, N3S and N4S (11), while the least effect (9) was recorded in E3S and E4S, respectively. Similarly, with the C0 treatment, stem diameter (3.8 mm), Root length (38.01 cm) and Dry weight (3.5 g) and were not significantly different ($p>0.05$) from other treatments but least effect 3.0 mm, 23.00 cm and 2.5 g were established in E4S for stem diameter, root length and dry weight respectively.

Table 1: Analysis of Variance for the influence of leaf powder on the Growth of Millet

	The sum of Mean Square						
Source of variation	**Degree of freedom**	**Shoot height**	**Number of leave**	**Leaf area**	**Stem diameter**	**Root length**	**Dry weight**
Treatment	8	2682.14*	4.27^{ns}	35589.24*	0.66^{ns}	34.11^{ns}	1.37^{ns}
Error	16						
Total	26						

Note: ** =significant at 5% probability level; ns= non-significant at 5% probability level

Table 2: Analysis of Variance for the influence of leaf powder on the Growth of Sorghum

		The sum of Mean Square					
Source of variation	**Degree of freedom**	**Shoot height**	**Number of leave**	**Leaf area**	**Stem diameter**	**Root height**	**Dry weight**
Treatment	8	76.17^{ns}	3.75^{ns}	30255.38**	0.29^{ns}	93.16**	0.28^{ns}
Error	16						
Total	26						

Note: ** =significant at 5% probability level; ns= non-significant at 5% probability level

Table 3 Discriptive Statistic for the influence of control and leave powders on the Growth of Millet at maturity period (12 weeks), (Mean ± standard error)

SN	**Treats Code**	**Shoot height**	**Leave number**	**Leaf area** cm^2	**Stem diameter (cm)**	**Root length (cm)**	**Fresh weight (gm)**	**Dry weight (gm)**
i.	**C0M**	70.5 ± 0.13^{a}	12 ± 0.75^{a}	965.1 ± 0.009^{a}	4.0 ± 0.45^{a}	35.05 ± 0.26^{a}	28.7 ± 0.31^{a}	4.0±0.45a
ii.	**N1M**	68.5 ± 0.13^{b}	12 ± 0.75^{a}	942.9 ± 0.01^{b}	4.0 ± 0.4^{a}	33.05 ± 0.27^{b}	27.8 ± 0.32^{a}	3.80 ± 0.42^{a}
iii.	**N2M**	68.1 ± 0.13^{b}	11 ± 0.81^{b}	941.2 ± 0.01^{b}	3.8 ± 0.42^{a}	32.50 ± 0.27^{b}	26.8 ± 0.33^{a}	3.6±0.4b
iv.	**N3M**	66 ± 0.14^{c}	11 ± 0.81^{b}	938.5 ± 0.01^{b}	3.8 ± 0.42^{a}	31.06 ± 0.29^{b}	25.5 ± 0.35^{b}	3.1 ± 0.34^{b}
v.	**N4M**	65.5 ± 0.01^{c}	11 ± 0.81^{b}	901.3 ± 0.01^{c}	3.8 ± 0.42^{a}	30.01 ± 0.29^{c}	24.5 ± 0.37^{b}	2.5 ± 0.27^{c}
vi.	**E1M**	60.1 ± 0.15^{c}	10 ± 0.9^{bc}	761.7 ± 0.01^{d}	3 ± 0.33^{b}	28.06 ± 0.32^{c}	22.0 ± 0.41^{c}	3.5 ± 0.39^{b}
vii	**E2M**	55.5 ± 0.16^{c}	9.5 ± 0.95^{bc}	761.7 ± 0.01^{d}	3 ± 0.33^{b}	27.05 ± 0.33^{c}	21.50 ± 0.42^{c}	3.0 ± 0.33^{b}
vii	**E3M**	51.2 ± 0.18^{d}	9 ± 1.0^{c}	717.9 ± 0.01^{e}	3 ± 0.33^{b}	26.01 ± 0.35^{d}	26.01 ± 0.35^{a}	2.5 ± 0.28^{c}
ix.	**E4M**	50.0 ± 0.18^{d}	9 ± 1.0^{c}	714.0 ± 0.01^{e}	3 ± 0.33^{b}	25.05 ± 0.36^{d}	25.05 ± 0.36^{b}	2.0 ± 0.22^{c}

Note: Means followed by the same letter(s) along the row were not significantly different at a 5% significance level using Duncan's Multiples Range test. CO control (0g), N1M= Neem leaf powder (1g), N2M= Neem leaf powder (1.5g), N3M= Neem leaf powder (2g). N4M= Neem leaf powder (2.5g), E1M= Eucalyptus leaf powder (1g), E2M= Eucalyptus leaf powder (1.5g), E3M= Eucalyptus leaf (2g)E4M= Eucalyptus leaf powder (2.5g)

Table 4 Mean separation for the influence of control and leave powders on the Growth of Sorghum at maturity period (12 weeks), Mean ± standard error

SN	Treats Code	Shoot height	Leave number	Leaf area cm^2	Stem diameter (cm)	Root length (cm)	Fresh weight (gm)	Dry weight (gm)
•	**COS**	71±0.13^{a}	12±0.75^{a}	982.9±0.009^{a}	3.8±0.42^{a}	38.01±0.24^{a}	29.2±0.31^{a}	3.5±0.39^{a}
•	**N1S**	66±0.15^{c}	12±0.75^{a}	954.5±0.09^{ab}	3.7±0.41^{a}	35.09±0.26^{a} b	28.5±0.31^{a}	3.1±0.34^{b}
•	**N2S**	65±0.14^{b}	11±0.75^{a}	913.5±0.01^{b}	3.7±0.41^{a}	33.05±0.27^{b}	28.0±0.32^{a}	2.9±0.32^{b}
•	**N3S**	60±0.15^{c}	11±0.75^{a}	869.1±0.01^{c}	3.7±0.41^{a}	32.07±0.28^{b}	27.05±0.33 b	2.6±0.29^{c}
•	**N4S**	60.1±0.15 c	11±0.75^{a}	828.6±0.01^{c}	3.6±0.4^{a}	32±0.28^{b}	26±0.35^{b}	2.6±0.29^{c}
•	**E1S**	59±0.15^{c}	11±0.75^{a}	761.7±0.01^{d}	3.5±0.38^{a}	25.01±0.36^{c}	25.05±0.35 b	3.0±0.33^{b}
•	**E2S**	58.5±0.15 c	10±0.90^{a}	755.1±0.01^{d}	3.5±0.38^{a}	24.09±0.37^{c}	24.09±0.37 c	2.9±0.32^{b}
•	**E3S**	56.9±0.16 c	9±1.0^{b}	749±0.01^{d}	3±0.33^{a}	24.05±0.37^{c}	24±0.38^{c}	2.8±0.31^{ab}
•	**E4S**	55.5±0.16 d	9±1.0^{b}	700.9±0.01^{e}	3±0.33^{a}	23.00±0.39^{c}	20±0.45^{d}	2.5±0.28^{c}

Note: Means followed by the same letter(s) along the row are not significantly different at the 5% level using Duncan's Multiples Range test. CO control (0g), N1S= Neem leaf powder (1g), N2S= Neem leaf powder (1.5g), N3S= Neem leaf powder (2g). N4S= Neem leaf powder (2.5g), E1S= Eucalyptus leaf powder (1g), E2S=Eucalyptus leaf powder (1.5g), E3S= Eucalyptus leaf powder (2.0g), E4S= Eucalyptus leaf powder (2.5g).

Discussion

Effect of the Leaf Power on Growth

It is interesting to learn about the impact of neem and eucalyptus leaf powders on the Growth of grain crops. The study revealed a negative relationship between concentration and early Growth, with higher application rates leading to lower plant growth for Millet and Sorghum. It's noteworthy that integrating these leaf powders into the soil at different rates had a direct impact on the Growth of the crops. The finding you mentioned contradicts Patil's (2002) study on the allelopathic influence of eucalyptus powder on grain crops. In Patil's study, the parameters examined were strongly influenced by the soil at the site, and the dry weights of the shoots and roots of the plants were significantly increased by soil obtained from 3 and 6 meters away. The soil taken from three meters had the most significant impact on the shoot length and root dry weights of wheat in polybags. Maize comparatively tolerated the allelopathic effect of the soil in the eucalyptus site. In line with Mohamadi and Rajaie. (2009), the study investigated the allelopathic impact of eucalyptus leaf on the morphological, physiological, and germination parameters of kidney beans (*Phaseolus vulgaris*) and Sorghum (*Sorghum bicolour*). A control

group of sterilized distilled water was employed, while leaf leachate was investigated at 5, 10, and 20% concentrations. In both species, the 0/05 level significantly reduced seed germination, seedling dry matter, and shoot/root length at all concentrations. In both species, an increase in the quantity of leaf leachate is correlated with a decrease in the amounts of soluble sugar, chlorophyll, and protein. Khan et al. (2007) investigated the allelopathic effect of eucalyptus extracts soaked, crushed, and cooked in tap water on maize var. 'Kissan' seed germination and Growth, they found similar results.

Based on the results, it was found that all the extracts drastically decreased the fresh and dry weight, root and shoot length, and germination of maize seeds. Gurmu. (2015) concurred that the leaf powders of *E. grandis* and *camaldulensis* significantly inhibited the germination, Growth, and change in soil reaction of haricot bean and maize seedlings. Additionally, this study concurs with Awadallah *et al.* (2017), who investigated the allelopathic effect of eucalypt leaf powder on Seed germination and seedling Growth of a few Poaceous crops. There appears to be a negative correlation between concentration and germination, and the investigation revealed that the aqueous extract of Eucalyptus camaldulensis significantly reduced seed germination of the tested poaceous crops. Understandably, a study found that adding eucalyptus leaf powder to the soil at different rates significantly restricted the Growth of seedlings and that the higher the amount of powder in the soil, the more the seedling Growth decreased. Additionally, Aleem *et al*. (2014) reported that *Parkia biglobosa* and *Vitelaria paradoxa* exhibit stronger inhibitory properties on cowpeas than *A. indica*.

Conclusion and Recommendations

Conclusion

Leaf powder of Eucalyptus significantly reduced seed germination, growth, and yield of the examined crops (millet and Sorghum). There was a direct negative relationship between concentration and responses to morphological features. The higher the weight (gram) of leaf power applied the higher the negative reactions. Application of the leaf powder of Eucalyptus into the topsoil at 2.0 and 2.5g had a negative influence on the growth, development, and yield of the plant. Furthermore, the decrease in seedlings' growth was improved as leaf powder increased in the soil, even though both neem and Eucalyptus are exotic plant species. They will greatly impact national economic, industrial development and ecological influence if they are put to positive use. However, *Azardiratcha indica* should be controlledled because of its invasive nature and alleloparthic properties which negatively impacted the yield of arable crops.

Recommendations

This study, therefore, recommends the following:

- **B.** Large quantities of the seeds must be sown to achieve substantive germination.
- **C.** The wide spacing of neem trees should be encouraged since the species is pretty supported by the Growth of Millet and sorghum.
- **D.** Planting of seeds too close to the eucalyptus hot spot must be avoided.
- **E.** Chosen of supportive tree species for shelterbelt, tree planting, and plantation should be encouraged for agroforestry.
- **F.** Promotion and planting of Indigenous trees; and avoiding invasive, exotic and allelopathic tree species.
- **G.** In cluster planting, the number of stands in the plots should be reduced to achieve better yield.

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SUSTAINABLE LAND CONSERVATION AMONG SMALLHOLDER AGROFORESTRY FARMERS IN OYO STATE, NIGERIA

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ABSTRACT

Over a long period, one of the main concerns of many Nigerian farmers has been the issue of sustainable land conservation and agricultural production. This study used cross-sectional data. One hundred seventy-six (176) farmers provided the data, which was then analyzed using the Cobb Douglass production function and Tobit regression analysis. Results showed that farm size (r = 0.0572), years of farming experience (r = 0.172), farmers' age (r = 0.240), income (r = 0.187), and farming experience (r = -0.204) were significant ($p<0.01$), except irrigation (r = 0.048) with a different level of significance ($p<0.10$). According to Tobit regression, farm size (β = 0.0193, p=0.05), organic manure (β = 0.0347, p=0.10), fertilizer (β = 0.1707, p=0.01), continuous cropping (β = -0.0494, p=0.05), pesticide (β = 0.0807, p=0.01), income (β = 0.0094, p=0.05), and cultivation type (β = -0.0524, p=0.05) were the significant factors influencing sustainable land conservation management techniques. To have a sustainable rise in agricultural production in the research region, it was advised, among other things, that better agronomic practices should be supported and that informal training through extension services should be performed to educate farmers on better practices of sustainable land conservation management.

Keywords: Effects, Land, Conservation, Smallholder, Cassava, Production, Nigeria

INTRODUCTION

Nigeria has had meager yields per hectare over the past few years due to soil and land degradation, which has been one of the main issues with agricultural sustainability in the nation's agricultural industry. Several environmental issues plagues Nigeria's land, especially those brought on by human activity. A few examples include land destruction due to agricultural practices that are inappropriate for the climate, slope, and soil, the extinction of animal and plant species due to hunting, fishing, and habitat disturbance, and the impediment to forest regeneration due to unplanned deforestation practices (Oyewo, 2018). Various governments in Nigeria have tried several ways and initiated policies and programs aimed at restoring the country's agricultural sector to its pride (Adama, 2016). Agribusiness sustainability and issues such as diminishing soil fertility, land degradation, poor farm productivity, low farm income, low outputs, and food security are often negatively impacted by the ongoing loss of farmland due to land degradation and soil erosion (MoFA, 2016).

Given that these resources serve as both the foundation for Nigerian agriculture's productivity and the means of subsistence for numerous rural and urban households, the extent of land degradation in the country is worrying, and the management of these resources cannot be taken

for granted (Oyekale, 2012). More importantly, smallholder crop production has recently increased in herbicide use (Gazali and Awudu, 2020). As part of measures to reduce the drudgery associated with manual land preparation and weeding, many farmers are increasingly employing herbicides (Watkins *et al*., 2018). However, it is widely accepted among farmers who practice sustainable agriculture that "healthy" soil is a crucial element of farm sustainability, i.e., healthy soil will result in healthy crop plants. Farmers who practice agroforestry have typically evolved their own unique soil conservation and land management techniques throughout time. Since they have maintained their production with these methods for centuries, the effects of resource exploitation have spread widely.

There is a rising understanding that fewer and less productive lands are available, that land resources are finite, and that the already-used land requires better care. There is a progressive loss of land for food production due to competition for land from other non-agricultural activities brought on by the rise in the global population. It was confirmed that the demand for food and other agricultural goods is rising with time, necessitating more land, which is not feasible given the finite amount of land on Earth. Sustainable land management (S.L.M.) is 'the adoption of appropriate land management practice that enables land users to maximize the economic and social benefits from the land while maintaining or enhancing the ecological support functions of the land resources' (F.A.O., 2009). Therefore, there is a need for an average farmer to operate various farmland management practices to enhance sustainable agriculture through soil and land conservation practices. Hence, this raises the research objectives to examine the determinants of crop production and determine the status of sustainable land conservation management techniques (SLCM) among agroforestry farmers in the study area.

METHODOLOGY

The study area

This research was conducted in Oyo state, Nigeria. Oyo State, which is in the country's southwest, is made up of thirty-three (33) L.G.A.s that are organized into four (4) agricultural zones by the Oyo State Agricultural Development Program (OYSADEP). Ibadan-Ibarapa, Oyo, Saki, and Ogbomoso Zones are the zones. According to the National Population Commission (2006), Oyo State has a total land area of around 27,249,000 square kilometres and roughly 5.6 million people. According to population projections made public by the National Bureau of Statistics in 2017, Oyo State's population as of 2016 was predicted to be 7,840 864 million. It is located between Longitude 2.5^{o}E and 5°E of the meridian and Latitude 7°N and 19°N. The State is primarily agrarian, with an annual mean rainfall of over 1000 mm and an average wet season of eight months per year. In Oyo State, rain begins in the first week of March with storms. The daily minimum temperature is 18.9^{0}C, while the daily maximum is 35^{0}C. Oyo State has a high relative humidity of 70%, with a maximum of around 60% in the evening and a maximum of around 80% during the day.

Sampling technique and sampling size

This study used well-structured questionnaires to obtain data using a multi-stage approach sampling strategy. Due to the presence of agroforestry farmers, the first stage involved selecting the four Agricultural Development Program (A.D.P.) zones already in place in the State: Ibadan-Ibarapa, Oyo, Saki, and Ogbomoso. In the second stage, one Local Government was purposefully

chosen from each zone with the highest concentration of agroforestry farmers. The third stage involved selecting the agroforestry farmers proportionately from the chosen local governments; this included 50, 46, 40, and 40 respondents from the Oyo, Ogbomoso, Ibadan / Ibarapa, and Saki zones, respectively. Finally, a sample of 176 agroforestry farmers from the study areas were given structured questionnaires to fill out for the data collection.

Analytical techniques

Using a multiple linear regression model, the Cobb Douglass production function was utilized to assess the factors influencing agricultural yield in the research area. A derivative of production function analysis was used to determine how land conservation approaches affect agricultural yield. The drivers of sustainable land conservation techniques employed by agroforestry farmers were identified using Tobit regression analysis.

Model specification.

$Y = b_0 + b_1X_1 + b_2 X_2 + b_3X_3 + b_4X_4 + b_5X_5 \ldots\ldots\ldots\ldots X_{11} + \mu$

$Yi = f(Xij, \alpha j) \ldots$ **(**implicit form)

$Y = f(Xs)$

$Y = (X_1, X_2, X_3, \ldots X_n)$

Linear

$Y = a+b_1X_1+b_2X_2+b3X_3+b_4X_4+b_5X_5+b_6X_6+b_7X_7+b_8X_8+b_9X_9+b_{10}X_{10}+ b_{11}X_{11}+b_{11}X_{11} +e$

Double log

$LnY = a+ b_1\ln X_1 + b_2\ln X_2 + b_3\ln X_3 + b_4\ln X_4 + b_5\ln X_5 + b_6\ln X_6 \ldots\ldots\ldots\ldots b_{11}\ln X_{11} +e$

Semi-log

$Y = a+ b_1\ln X_1 + b_2\ln X_2 + b_3\ln X_3 + b_4\ln X_4 + b_5\ln X_5 + b_6\ln X_6 \ldots\ldots\ldots\ldots b_{11}\ln X_{11} +e$

Exponential

$LnY= a+b_1X_1+b_2X_2+b_3X_3+b_4X_4+b_5X_5+b_6X_6 \ldots\ldots\ldots\ldots b_{11}X_{11} +e$

Where,

Where Y = Crop output (kg)

X_1 = Farming experience (years)

X_2 = Farm size (ha)

X_3 = Educational level (dummy)

X_4 = Credit source (dummy)

X_5= Land ownerships (dummy)

X_6 = farmland use duration (years)

X_7 = Respondents age (years)

X_8 = Income (Naira)

X_9 = Conservation management experience (years)

X_{10} = Cultivation mode (dummy: local/manual = 0, mechanized = 1)

X_{11} = Irrigation source (dummy)

e = error term

b = Parameter estimated

a = Constant

Tobit analysis

The model used for the estimation was given as:

$$SLMIi = A + \beta i \sum_{j=1}^{12} Zi + \mu$$ MIiA+βi_j=1 ^12Zi+ μ …….. (1)

$$SLMIi = \beta o + \beta 1Z1 + \beta 2Z2 + \beta 3Z3 + \beta 4Z4 + \beta 5Z5 \ldots . \beta 12Z12 + \mu i$$ …… (2)

Where SLCM = (Sustainable Land Conservation Management)

Z_1= Age (Years), Z_2 = Farming experience (years), Z_3 = Income (Naira), Z_4 = Farm size (ha),

Z_5 = Organic manure application (dummy), Z_6 = Fertilizer application (dummy),

Z_7 = Continuous cropping (dummy), Z_8 = Erosion runoff (dummy), Z_9 = Pesticide (litre), Z_{10} = Organic matter (dummy), Z_{11} = Cultivation mode (dummy), Z_{12} = Educational level (years), μ = Error term, β = Parameter estimated, β_o= Constant

RESULTS AND DISCUSSION

The factors affecting agroforestry farmers' production in the study area

Different functional models were fixed from Table 1 for the factors affecting farmers' crop output. The double log was chosen from the four functional forms (linear, semi-log, exponential, and double log). The selection of the line as the function is based on its agreement with a priori expectations in terms of coefficient signs and magnitude, the number of significant variables, the coefficient of multiple determinations, and the significance of the overall profitability as determined by the t-value (Olayemi and Olayide, 1981). The findings show that, among the alternatives, double-log was the most appropriate way to explain the analyses of the findings. The size of the farm and the number of years were revealed to be positive and significant except for farm management experience, which has a negative coefficient to the level of crop outputs but is also significant at 1%, farming experience, age of farmers, and income were positively significant

at 1% level. At a 10% level, the source of irrigation was also positively significant. According to these, an increase in any of these factors will result in a proportionate rise in the level of crop outputs (Babalola *et al*., 2013; Oyewo *et al*., 2014), except conservation management experience, which could result in a decrease in the level of output due to the low level of years of experience with farmland management techniques and low level of education by the farmers, which is consistent with the work of Oyekale, (2012). R^2 was 0.740, indicating 74% of the variance in output level, which can be attributed to the explanatory variables listed in the model. In comparison, 26% of the variance may be attributed to the variables not included in the model.

Table 1: Analysis of the factors of crop production in the study area

Variables	Linear	Double log	Exponential	Semi-log
a = Constant	7.106	-0.054	1.084	-76.377
X1 = Farming experience	0.428***	0.172***	0.005***	13.911***
	(3.114)	(3.800)	(3.128)	(3.197)
X2 = Farm size	4.293***	0.0572***	0.045***	48.150***
	(4.764)	(8.875)	(4.266)	(7.768)
X3 = Educational level	-1.148	-0.058	-0.015	-2.499
	(-0.856)	(-0.933)	(-0.936)	(-0.419)
X4 = source of credit	-0.647	-0.005	-0.002	-2.541
	(-0.629)	(-0.075)	(-0.196)	(-0.421)
X5= Types of Land	1.275	0.088	0.011	11.594*
	(1.027)	(1.289)	(0.742)	(1.766)
X6 = land use duration	0.046	-0.063	-0.002	-5.060
	(0.227)	(-1-155)	(0.011)	(-0.961)
X7 = Age of respondent	0.144	0.240***	0.003**	10.155
	(1.474)	(2.013)	(2.321)	(0.883)
X8 = farm income	0.003***	0.187***	-0.000***	15.584**
	(1.474)	(2.647)	(3.760)	(2.292)
X9 = conservation mgt exper	-0.605***	-0.204***	-0.007***	-16.757***
	(-3.014)	(-3.682)	(-2.785)	(-3.146)
X10 = mode of cultivation	3.772	0.036	0.054*	2.489
	(1.474)	(1.460)	(1.815)	(-0.872)
X11 = source of irrigation	4.758*	0.048*	0.040	5-216**
	(1.661)	(1.746)	(1.179)	(1.059)
R^2	0.622	0.740	0.611	0.678
F Statistics	22.316	38.570	21.336	28.613

Source: author regression. (*) mean 10%; (**), mean 5%; (***) mean 1% significant.

Note: figures in parenthesis are t-values

Tobit Analysis

According to the results in Table 2, which illustrate the marginal effects of the variables employed on the factors affecting sustainable land conservation techniques (SLCT), farm size is positively correlated with SLCT (p= 0.05). It suggests the likelihood of an increase in SLCT with a larger application of this variable (farm size) exists. Farm size is one of the elements determining land use intensity; according to Yusuf *et al*. (2011), an increase in farmland by one hectare very slightly increases land usage. Gross revenue for farmers is significantly more

significant (p = 0.05) than (SLCM). This suggests that SLCM will likely be improved as the income of agroforestry farmers rises. This aligns with the a priori expectation that farmers will be encouraged to adopt sustainable land management techniques as their income increases. It may also be the case that farmers increased gross farm income will encourage them to operate a comprehensive land management system that can improve the sustainability of their farmland. This supports the findings of Ogbonna *et al*. (2007) and Ikechukwu and Nwakwo (2013) that an increase in income will result in a rise in the usage of sustainable farmland management strategies. A higher income will also give farmers more money for potentially adopting farmland management techniques. Agboola *et al*. (2015) research on farm income supports this finding, finding that the higher the money made, the greater the level of application of a given technology and the less of a capital constraint needed for investments in soil conservation.

Continuous cropping and this kind of agriculture exhibited a significant negative link with sustainable land conservation management (p=0.05). This suggests that there is a chance that sustainable land management won't be improved if farmers continue to cultivate (manually). This might be because farmers cannot adopt mechanized farming methods, which would improve sustainable farming due to their cultural customs. The sustainability of agroforestry farmers is also negatively impacted by continuous cropping since crop production on the same plot of land without fallow (allowing the land to rest) may result in soil nutrient loss, limiting sustainable management and harming the crop produced. Organic manure is also significant (p=0.10), along with fertilizer and pesticide (p=0.01). As these have a favourable relationship with SLCM and improve the sustainability of agroforestry farmers, an increase in any of these variables will increase the level of sustainable land conservation management of the agroforestry farmers. A significant Chi^2 score of 61.99 (p=0.01) indicated an excellent fit for the study's model.

Table 2: Tobit Analysis of the Determinants of Sustainable Land Conservation Management

Variable	Coefficient	dy/dx	Standard error	T-statistic
Constant	0.2022		0.0614	3.29
Z_1= Age	0.0009	0.0009	0.0092	0.10
Z_2 = Farming experience	0.0009	0.0009	0.0012	0.77
Z_3 = Income	0.0094**	00094**	0.0038	2.48
Z_4 = Farm size	0.0193**	0.0193**	0.0079	2.45
Z_5 = Organic manure	0.0347*	0.0347*	0.0208	1.67
Z_6 = Fertilizer application	0.1707***	0.1707***	0.0273	6.25
Z_7 = Continuous cropping	-0.0494**	-0.0494**	0.0222	-2.22
Z_8 = Erosion runoff	0.0188	0.0188	0.0220	0.85
Z_9 = Pesticide application	0.0807***	0.0807***	0.0253	3.20
Z_{10} = Organic matter	0.0473	0.0473	0.0319	1.48

Z_{11} = Mode of cultivation	-0.0524**	-0.0524**	0.0217	-2.41
Z_{12} = Educational level	0.0033	0.0033	0.0116	0.28
Sigma	0.1223			
Chi^2 (12)	61.9900***			

Source: Authors Data Analysis. (*) =, p<0.10; (**) =, p<0.05; (***) p<0.01.

CONCLUSION AND RECOMMENDATION

Conclusion

The study considered several productive goals in farmers' sustainable agricultural practices. Tobit regression and Cobb-Douglas production function were employed to examine the study's objectives. As a result, it was determined that the primary determinants of crop production were farming experience, farm size, respondents' ages, the source of irrigation, and farm management experience. The study shows that farmers' income, farm size, organic manure, fertilizer and pesticide application and mode of cultivation were the significant determinants of farmers' sustainable land conservation management; this will, however, enhance environmental quality and the natural resource base upon which agricultural sustainability depends.

Recommendations

It is therefore recommended that agroforestry farmers should be sensitized on the need to be discouraged on manual cultivation and embrace mechanized mode of cultivation which may enhance farmers sustainable agricultural practices, in increase farmer's productivity and enhance the quality of life for farmers and the households. Also, continuous cropping could be encouraged if the present land is properly managed with the present combination of sustainable land conservation techniques and better agronomic practices since the available land is competing with other non-agricultural activities such as land tenure system. It was further suggested that this research work could be carried out among other food crops in western and Sub-Sahara Africa.

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Role of *Xylopia aethiopica,* Rice husk and biocontrol agents on germination and vigour index of Sorghum (*Sorghum bicolour* L. Moench) infected with *Fusarium verticillioides.*

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Abstract

Fusarium verticillioides is an important pathogen of sorghum affecting grain production, leading to reduced seed weight, germination and marketability. The menace of this pathogen could be curbed using a single or combined control approach. This study investigated the effect of *Xylopia aethiopica*, rice husk and biocontrol agents on germination and vigour index of sorghum infected with *Fusarium verticillioides.* Sorghum panicles were inoculated with *F. verticillioides* at 1×10^6 spores/ml concentration and later treated with biocontrol agents (*Trichoderma asperellum, T. harziaum, T. longibrachiatum* and *Streptomyces* sp.) singly, biocontrol agents combined *X. aethiopica*, biocontrol agents combined rice husk, biocontrol agents combined mancozeb, *X. aethiopica* singly, rice husk singly, mancozeb singly and sterilized distilled water (control). Results revealed that seeds from panicles treated with *Trichoderma longibrachiatum* combined with mancozeb, *Streptomyces* sp. combined with mancozeb and *X. aethiopica* singly enhanced germination. However, *Streptomyces* sp. combined with mancozeb was more effective in promoting the vigour index than other treatments. Identification of bioactive substances and their functional properties that promote germination in *X. aethiopica,* which would be a valuable tool for crop production.

Keywords: Sorghum panicles**,** mancozeb, germination, *X. aethiopica*

Introduction

Sorghum bicolor (L.) Moench is a versatile cereal crop grown in different parts of the world for food, feed, brewing, biofuel, and construction uses (Werle *et al.,* 2016). Sorghum is affected by phytopathogens that reduce its productivity. *Fusarium verticillioides* Sheld is a predominant pathogen of sorghum in humid tropical, subtropical, and temperate regions (Tesso *et al.,* 2004; Deepa and Screenivasa, 2017). *Fusarium verticillioides* cause severe symptomatic infections such as grain mould disease, stalk, and root rot (Adeyanju *et al.,* 2015). Grain mould disease caused by *Fusarium verticillioides* infects sorghum flower tissues during the early phases of grain development, resulting in seed weight losses, decreased grain production and premature seed rot, which affect the germinability and marketability of the grain (Das *et al.,* 2012; Audilakshmi *et al.,* 2007). It is also associated with mycotoxin contamination (fumonisin) that threatens sorghum grain quality and safety (Ackerman *et al.,* 2021). Efforts to mitigate the pathogenic activities of *F. verticillioides* using chemical fungicides contributed to pathogen resistance and human and environmental damage (Goswani *et al.,* 2018). There is a need to adopt a sustainable strategy to

control the detrimental influence of *F. verticillioides* using biopesticides to improve sorghum productivity. Biopesticides are naturally occurring biological substances that control pests by non-toxic mechanisms and eco-friendly manner (Chakraborty *et al.,* 2023). Biopesticides are known for low mammalian toxicity, biodegradability, easy accessibility, and acceptability (Ugwuja *et al.,* 2023); they are derived from plants, animals and microorganisms that serve as biocontrol agents.

Xylopia aethiopica (Dunal) A. rich in the family Annonaceae is a tree with bioactive substances promoting its antimicrobial potential. Fleischer *et al.* (2008) indicated that *X. aethiopica* contains phytochemicals promoting different antimicrobial activity degrees. Extracts of *X. aethiopica* showed antibacterial, antifungal and antiplasmodial activities (Ijeh *et al.*, 2004). *Xylopia aethiopica* can be mixed with diverse plant components to produce desired outcomes (Ogunkunle and Ladejobi, 2006). Some ailments cured by *X. aethiopica* include cough, bronchitis, dysentery, sores and biliousness (Famuyiwa *et al.*, 2018; Soladoye *et al.*, 2012). Aqueous extracts of rice husk showed antibacterial efficiency against *Escherichia coli* and *Pseudomonas aeruginosa* (Firdous and Bharathi, 2014). Abiala *et al.* (2011) found an inhibitory effect of rice husk extract on *Mycosphaerella fijiensis*. *Trichoderma* sp. and *Streptomyces* sp. are soil-inhabiting microorganisms capable of protecting plants from pests and diseases (Ayaz *et al.,* 2023). These microorganisms promote plant health and nutrient availability due to their ability to synthesize different types of bioactive organic compounds (Qui *et al.,* 2019). Previous works focused on the management of plant diseases using biological substances, but there is limited information on the residual influence of biological substances on germination and vigour index of seeds harvested from treated plants. Hence, in the present study, we investigated the effect of *Xylopia aethiopica,* rice husk and biocontrol agents on germination and vigour index of sorghum (*Sorghum bicolor* L. Moench) infected with *Fusarium verticillioides.*

Materials and Methods

Sources of materials

Rice husk was obtained from the International Institute of Tropical Agriculture (IITA), while *Xylopia aethiopica* was purchased from Bode market, Ibadan. The biocontrol agents (*Trichoderma asperellum, T. harzianum, T. longibrachiatum, Streptomyces* sp.) and *F. verticillioides*) were sourced from the Pathology Laboratory of Crop Protection and Environmental Biology, University of Ibadan, Nigeria.

Preparation of spore suspension

Fusarium verticillioides spore was prepared by weighing 50 g of white sorghum and soaked with distilled water for 4 hours and autoclave at 121°C (1.05 kg/cm^2) for 15 minutes in a 250 millilitres conical flask. *Fusarium verticillioides* was inoculated aseptically using a 5-mm diameter mycelial disc and incubated for 10 days. Every alternate day, the flasks were shaken to ensure consistent growth. The infested grains were rinsed and swirled in sterile water for two to three minutes to dislodge the spore from the grains. *Trichoderma asperellum, T. harzianum* and *T. longibrachiatum* on Potato dextrose agar plates and *Streptomyces* sp. streaked on International Streptomyces Project 2 (ISP 2) plates were washed with sterile distilled water. The double layer of cheesecloth placed in a sterile funnel was used to remove mycelia and media fragments. The

spore suspension of *F. verticillioides* and biocontrol agents was adjusted to l.0 x $l0^6$ spores /ml. Thereafter, a drop of polysorbate 20 (Tween 20) was added to 1000 millilitres spore suspension.

Preparation of plant extracts and synthetic fungicide

Rice husk and seeds of *X. aethiopica* were blended separately for three to five minutes using a warring blender. Weights of powder samples 0.05 g, 25 g of *X. aethiopica*, 0.05 g and 2 g of rice husk were dissolved in 100 millilitres of distilled water to produce 0.05 % and 25 %, 0.05 % and 2% (single treatment) of *X. aethiopica* and rice husk respectively. The suspension was placed in hot water at 100°C for 15 minutes, then filtered using Whatman No. 1 filter paper and the filtrate was used within twenty-four hours of preparation (Olabiyi *et al.*, 1992). The synthetic fungicide, mancozeb 80 % W.P. (commonly known as Z-force), was prepared by dissolving 0.01g and 0.5 g into 100 millilitres of sterile distilled water to produce 0.01 % and 0.5 % mancozeb.

Effect of *Xylopia aethiopica,* rice husk and biocontrol *X. aethiopica* agents on germination and vigour index of sorghum infected with *Fusarium verticillioides.*

Twenty kilogrammes of sterilized soil were poured into polythene bags in a completely randomized design, and two to three seeds of Samsorg- 14 variety were planted per pot with four replications. Thinning was done two weeks after planting. Sorghum panicles were tagged on uniformly- flowering plants at full anthesis (> 80%) and inoculated with *F. verticillioides* at 1× 10^6 spores/ml concentration was sprayed on the panicles from all angles. The following treatments were sprayed 12 days after inoculation with *F. verticillioides*; biocontrol agents (*Trichoderma asperellum, T. harzianum, T. longibrachiatum Streptomyces* sp.) singly (1× 10^6 spores/ml), biocontrol agents combined *X. aethiopica* (1× 10^6 spores/ml + 0.05 % *X. aethiopica*), biocontrol agents combined rice husk (1× 10^6 spores/ml + 0.05 % rice husk), biocontrol agents combined mancozeb (1× 10^6 spores/ml + 0.01% mancozeb), *X. aethiopica* singly (25 %), rice husk singly (2%), mancozeb singly (0.5 %) and control (sterilized distilled water). All treatments were covered with pollinating bags for 48 hours. Panicles were harvested 40 days after flowering, and seeds obtained after threshing were assessed for germination and vigour index. Ten seeds from each treated panicle were rinsed with sterile distilled water and placed in 9 cm Petri dishes lined with sterilized wet Whatman No 1 filter paper. They were incubated at 28±2°C for 7 days for percentage germination. The Petri dishes were arranged in a complete randomized design with three replications. The Vigour index was determined by multiplying the germination rate by (mean of plumule + radicle lengths) (Zucconi *et al.*, 1981). Data obtained were subjected to analysis of variance (ANOVA) at a probability level of 5 %, and means were separated using the Duncan Multiple Range Test (DMRT).

Result

Trichoderma longibrachiatum combined with mancozeb, *Streptomyces* sp. combined with mancozeb, *Streptomyces* sp. combined with rice husk and *X. aethiopica* showed high germinability (95 %) (Table 1). Germinability was lowest in *T. harzianum* (42.5%) compared to untreated (55.0 %). There was no significant difference in germination of *T. asperellum, T. longibrachiatum, Streptomyces* sp., *T. asperellum* combined with mancozeb and *T. longibrachiatum* combined with mancozeb. *Trichoderma harzianum* was significantly lower (p= 0.05) than *Streptomyces* sp. combined with mancozeb, *T. asperellum* combined with rice husk, *T.*

harzianum combined with rice husk and *T. longibrachiatum* combined with rice husk. Also, *Streptomyces* sp. combined with rice husk, *T. harzianum* combined with *X. aethiopica, T. `longibrachiatum* combined with *X. aethiopica, Streptomyces* sp. combined with *X. aethiopica* and *X. aethiopica* were significantly higher (p= 0.05) than the control. *Trichoderma harzianum, T. harzianum* combined with mancozeb, *T. asperellum* combined with *X. aethiopica,* mancozeb and rice husk were not significantly different (p= 0.05) from the control.

Table 1. Germination of seed from panicles infected with *Fusarium verticillioides* and treated with *Xylopia aethiopica,* rice husk and biocontrol agents

Treatment	Percentage germination (%)
Trichoderma asperellum	80.00^{abcd}
Trichoderma harzianum	42.50^{f}
Trichoderma longibrachiatum	77.50^{abcde}
Streptomyces sp.	90.00^{ab}
Trichoderma asperellum + mancozeb	87.50^{abc}
Trichoderma harzianum + mancozeb	62.50^{cdef}
Trichoderma longibrachiatum + mancozeb	95.00^{a}
Streptomyces sp.+ mancozeb	95.00^{a}
Trichoderma asperellum + rice husk	87.50^{abc}
Trichoderma harzianum + rice husk	70.00^{abcde}
Trichoderma longibrachiatum + rice husk	87.50^{abc}
Streptomyces sp.+ rice husk	95.00^{a}
Trichoderma asperellum+ X. aethiopica	54.17^{ef}
Trichoderma harzianum+ X. aethiopica	80.00^{abcd}
Trichoderma longibrachiatum+ X. aethiopica	85.00^{abc}
Streptomyces sp.+ *X. aethiopica*	75.36^{abcde}
Mancozeb	65.00^{bcdef}
Rice husk	67.50^{bcdef}
Xylopia aethiopica	95.00^{a}
Control	55.00^{def}

Duncan Multiple Range Test was used to differentiate between the means, values with similar letter (s) in the column do not differ significantly (p = 0.05).

The vigour index of *Streptomyces* sp. combined with mancozeb was significantly different (p= 0.05) from *T. harzianum*, *T. asperellum* combined with *X. aethiopica*, *T. longibrachiatum* combined with *X. aethiopica,* rice husk and control (Table 2). *Streptomyces* sp. combined with mancozeb was not significantly different (p= 0.05) from *T. longibrachiatum* and *T. asperellum* combined with rice husk. The control was not significantly different (p= 0.05) from *T. asperellum, T. harzianum, Streptomyces* sp., *T. asperellum* combined with mancozeb and *T.*

harzianum combined with mancozeb. *Trichoderma longibrachiatum* combined with mancozeb, *T. harzianum* combined with rice husk, *T. longibrachiatum* combined with rice husk and *Streptomyces* sp. combined with rice husk were significantly higher (p= 0.05) than the control (Table 2).

Although *T. asperellum* with *X. aethiopica, T. longibrachiatum* with *X. aethiopica* and *Streptomyces* sp. with *X. aethiopica,* rice husk were not significantly different (p= 0.05) from untreated (control) in vigour index.

Table 2 Vigour index of seed from panicles infected with *Fusarium verticillioides* and treated with *Xylopia aethiopica,* rice husk and biocontrol agents

Treatment	Vigour index
Trichoderma asperellum	497.10^{abcd}
Trichoderma harzianum	255.43^{d}
Trichoderma longibrachiatum	607.33^{ab}
Streptomyces sp.	313.67^{bcd}
Trichoderma asperellum + mancozeb	454.03^{abcd}
Trichoderma harzianum + mancozeb	311.60^{bcd}
Trichoderma longibrachiatum +mancozeb	383.07^{abcd}
Streptomyces sp. + mancozeb	667.00^{a}
Trichoderma asperellum + rice husk	591.93^{abcd}
Trichoderma harzianum + rice husk	400.27^{abcd}
Trichoderma longibrachiatum + rice husk	487.77^{abcd}
Streptomyces sp. + rice husk	382.80^{abcd}
Trichoderma asperellum + *X. aethiopica*	259.56^{d}
Trichoderma harzianum + *X. aethiopica*	391.43^{abcd}
Trichoderma longibrachiatum + *X. aethiopica*	262.77^{d}
Streptomyces sp+ *X. aethiopica*	242.94^{d}
Mancozeb	491.00^{abcd}
Rice husk	256.53^{d}
Xylopia aethiopica	357.87^{abcd}
Control	221.40^{d}

Duncan Multiple Range Test was used to differentiate between the means, values with similar letter (s) in the column do not differ significantly (p = 0.05).

Discussion

Fusarium verticillioides reduced germination and vigour index of untreated seeds. Seeds from panicles treated with *T. longibrachiatum* combined with mancozeb, *Streptomyces* sp. combined with mancozeb and *X. aethiopica* had high germination rate. Gopalakrishnan *et al.* (2014) reported some bacteria such as *Streptomyces* strains can produce siderophores, indole acetic acid (IAA) and glucanase have been found to stimulate plant performance. Bacteria producing IAA influence seed germination, root development allowing the host plant to have more access to available water and nutrients in the soil (Ahemad and Kibret, 2014). Zhang *et al.* (2022) confirmed that *Streptomyces* sp. RP1A-12 increased seed germination and peanut seed vigour. *Trichoderma longibrachiatum* T6 enhanced wheat growth and tolerance to parasitic nematodes (*Zhang et al., 2016). Metalaxyl and mancozeb are pre-sowing fungicides that promote maize germination and seedling vigour (Taye et al., 2012). Antra, mancozeb and daconil increased seed germination of chickpeas under pot conditions (Jayale et al., 2015). Trichoderma longibrachiatum* combined with mancozeb and *Streptomyces* sp. combined with mancozeb have synergistic effects on the germination of sorghum. *Xylopia aethiopica* may contain plant health-promoting substances that enhance plant germination. Seed treatment with botanicals synergistically influences early and uniform germination and tolerance to pests and diseases (Girase *et al.,* 2019).

Seed from panicles treated with *Streptomyces* sp. combined with mancozeb had highest vigour index which can help them to perform better under environmentally stressed seedbed conditions than *T. harzianum* singly, *T. asperellum* combined with *X. aethiopica, T. longibrachiatum* combined with *X. aethiopica, Streptomyces* sp. combined with *X. aethiopica*, rice husk singly and control. *Xylopia aethiopica* promoted germination without substantial influence on vigour index of infected sorghum seed.

Conclusion

Trichoderma longibrachiatum combined with mancozeb, *Streptomyces* sp. combined with mancozeb and *X. aethiopica* promoted the germination of infected seeds. Seeds from panicles treated *Streptomyces* sp. combined with mancozeb was effective in promoting vigour index in comparison to other treatment. Identification of bioactive substances and functional properties that promote germination in *X. aethiopica* would be valuable tool for crop production.

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EFFECT OF SUBSTITUTING *MORINGA OLEIFERA* LEAVES AS NATURAL SOURCES OF METHIONINE AND LYSINE ON NUTRIENT DIGESTIBILITY OF BROILER CHICKENS IN SEMI-ARID ZONE OF NIGERIA.

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ABSTRACT

The effect of replacing ground and ground Moringa Oleifera leaf (powder) in place of synthetic Methionine and Lysine on nutrient digestibility by broiler chickens was investigated in eight weeks feeding trial. One hundred and twenty (120) Marshal Broiler chicks were randomly assigned to four experimental diets in a completely randomized design (CRD). Each treatment consisted of thirty (30) birds and was replicated three (3) times with ten (10) birds per replicate. The treatments were T1 (control), 0% Moringa oleifera, T2 0.2% Moringa oleifera replacing Methionine, T3 Moringa oleifera replacing lysine, and T4 Moringa oleifera replacing both Methionine and Lysine. Feed and water were given ad-libitum. The results reveal that there were no significant (P>0.05) differences among the treatment groups compared to T1 (control), which were fed a diet containing synthetic Methionine and Lysine. This means that birds utilize Moringa Oleifera leaves powder without adverse effects on the chicken. In conclusion, Moringa Oleifera leaf powder can be used to replace synthetic Methionine and Lysine completely in a broiler chicken diet without any adverse effect on the nutrient digestibility of the chicken.

KEYWORDS: Nutrient, *Moringa oleifera*, Proteins, Methionne, Lysine

INTRODUCTION

Protein is the most essential component of feed ingredients. Twenty-two different amino acids are the building block of protein among them, 10 are indispensable for Monogastric animal production. The amino acids which chicken does not synthesize are called indispensable (essential) where, whereas those synthesized from other amino acids are called dispensable (non-essential) amino acids. Amino acid obtained from protein are used by chicken to fulfill a diversity of function, protein are primary constituent of structural and protective tissue such as skin, feathers, bone matrix, ligament, soft tissue, including organ and muscle. Methionine and lysine are the first and second most limiting amino acids (Gill. 2003). In most plant protein sources, except soybeans, which contain a relatively high amount of lysine, all other plant sources are very low as required in the the chicken diet. Methionine is needed for protein synthesis. When there is no Methionine, protein synthesis does not occur because Methionine is the initiator of protein

synthesis. Lysine is also essential for growing birds, and inadequacy of lysine causes productive activities. Deficiency of lysine manifested depigmentation in birds (Vohra and krazler, 1959) and causes reduced haemoglobin and haematocrit in chickens (Brahma et al., 1961). National Research Council (NRC, 1994) recommended that 24% crude protein is needed in the starter (0-4 weeks) and 20% for the finisher diet (4-7weeks).

For any nation to meet the millennium development goal in technological advance and natural development there is a a need to have optimum food security. However, there is a problem of severe food crises in developing countries due to the aggravated increase in human population. The world population has grown exponentially, almost doubling in less than a century. It has grown from 2.5 billion in 1950 to about 6 billion or more by 2000. (Cole and Wilson, 1980). According to the United States of America Census Bureau (2010), the population of Nigeria will reach 402 million by the year 2050, and then it will be the 4th most populous nation in the world. For this population to survive, there must be adequate provision of food because the fundamental factor underlying the behaviour of human and animals is their need for food. Ekumankama (2000) observed that despite all efforts to improve livestock production in Nigeria, animal protein is still in short supply and has become prohibitively expensive for the average Nigerian. It becomes necessary therefore, to search for cheaper sources of animal protein to counter the downward trend in its consumption in Nigeria. Poultry, which is raised by a considerable number of Nigerians, mainly rural dwellers (who keep backyard poultry), contributes to the protein of the nation among livestock. Despite this contribution, backyard poultry cannot improve the protein need. This therefore calls to produce commercial birds which have high production potential.

However, the poultry industry, which possesses immense potentialities in offsetting the huge animal protein deficit of Nigerians is being constrained by high cost of feed. It was observed by Adamu and Ubosi (2000) that feed is the top among factors militating against the emergence and development of the poultry industry in Nigeria. In another word, feeding birds is the most expensive aspect of poultry production, accounting for over 70% of the total cost of production (Jones. 1988: Oruseibio and Smile, 2001). Poultry feed is formulated with a wide range of ingredient-ranging from energy-protein, mineral, vitamin and synthetic amino acid sources. The high cost of poultry feed is attributed mainly to the scarcity attributed and exorbitant price of the Conventional ingredient such as synthetic amino acids, maize, groundnut cake, fish meal and soybean meal (Apata and Ojo, 2000).

In view of the above, it is necessary to try ingredient that will replace any of the above conventional feed. But the choice here is synthetic amino acids with leaf powder without compromising poultry performance and nutrient digestibility of the chickens' feed. According to Marker and Bekcker (1997) being a highly protentous source, belongs to the moringaceae family and is considered to have its origin in the North-West region of India, South of the Himalayan mountains. It is now widely cultivated and has become naturalized in many locations in the Tropics (Faheyat et al., 2001). According to Fuglie (1999), being a portentous source and a high content of oil in its seed, it has a high content of Methionine, lysine and other amino acids, and all its parts are being consumed by humans for various uses such as medicinal, food, animal forages, etc. The objective of this study is to evaluate the effect of substituting synthetic Methionine and lysine with leave powder on nutrient digestibility of the broiler chickens.

MATERIAL AND METHOD

Study Site

The study was conducted at the University of Maiduguri, animal science Department poultry unit of teaching and research farm. Maiduguri, the Borno state capital, is situated on latitude 11° 5N, longitude 13°009°E and at an altitude of 354m above sea level. The area falls within the semi-arid region of West Africa, which is noted for its great climate and seasonal variation. It has a short period of rainfall of 3-4 months given 645.9mm per annum, with a long dry season of about 8-9 months. The ambient temperature could be as low as 20C during the dry cold (October-January) season and as high as 44°C during the dry hot (February - may) season. The relative humidity is 5% in April and May. Day length varies from 11 - 12 hours (Raji et al.: 2009)

Experimental Stock and Management

Eighty-four (84) Mashal broilers chicks were purchased from reportable hatcheries for the study. Before the arrival of chicks, the brooding house was cleaned and disinfected. The feeders and drinkers were also washed and disinfected. Wood shaving was used as a source of litter material throughout the brooding period, and stoves and charcoal served as sources of heat in the brooding house. After brooding, the birds were transferred to deep litter pens in open-sided poultry houses for the rest of the experimental period. Flat feeding trays were spread on the litter materials for young chicks, and plastic drinkers were also provided in the brooding house for the chicks.

Routine Husbandry Practice

The birds were vaccinated strictly based on the vaccination program recommended for the North-East zone. At the age of two weeks, they were given a dose of the gumboro disease vaccine. At three weeks a dose of new castle disease (lasota) was given and at the age of five weeks a second dose of gumboro disease vaccine (boster) was given. All vaccines were administered in clean drinking water. Proper sanitation was carried out strictly in the morning and evening from the beginning of the experiment to the end; the birds were switched over from the commercial broiler starter mash to the formulated experimental diets. This marked the start of the experiment.

Experimental Diets

The experimental die was formulated using leaves (ground) as a natural source of Methionine and lysine. There are four different treatments. T1 (control) contains synthetic Methionine and lysine, T2 replaces Methionine, T3 replaces lysine and T4 replaces both Methionine and lysine.

Experimental Design

Eighty-four (84) marshal broiler chicks were used for the study. The birds were allocated into four treatment groups in a completely randomized design. Each treatment consisted of 21 birds and was replicated three (3) times with 7 birds per replicate. The experiment lasted for 8 weeks.

Processing of Leaves

Matured leaves were collected, clean, and sun-dried. The dried leaves were ground thoroughly into fine particles and incorporated into the diet at a measured quantity in different levels.

Table 1: Composition of Experimental Diet (Broiler Starter)

Ingredient	T1 (0%)	T2 (0.25%)	T3 (0.20%)	T4 (0.45%)
Maize	43.10	43.10	43.10	43.10
Wheat offal	10.77	10.77	10.77	10.77
Groundnut cake	41.11	41.11	41.11	41.11
Bone meal	3.00	3.00	3.00	3.00
Limestone	1.00	1.00	1.00	1.00
Salt	0.30	0.30	0.30	0.30
Premix	0.25	0.25	0.25	0.25
Methionine	0.20	-	0.20	-
Lysine	0.25	0.25	-	-
Moringa	-	0.20	0.25	0.45
Total	100	100	100	100
Calculated analysis				
Crude protein	24.49	24.64	24.66	24.72
Crude fibre	4.27	4.30	4.31	4.36
Calcium	1.12	1.14	1.15	1.17
Methionine	0.25	0.25	0.25	0.25
Phosphorus	0.89	1.30	0.39	0.89
Lysine	0.89	0.89	0.89	0.89
Metabolizable energy	2985	2980	2978	2978

Each 2.5kg of Bio premix contains Starter

Vitamin A, 10,000,000.00 IU, Vitamin D3, 2,000,000.00 IU, Vitamin E, 23,000.00mg, Vitamin K3, 2.000.00 mg, Vitamin B1, 1,800.00 mg, Vitamin B2, 5,500.00 mg, Niacin 27,500.00 mg, Pantothenic 7,500.00 mg, Vitamin B6 3,000.00 mg, Vitamin B12 15.00 mg, Folic acid 750.00 mg, Biotin H2 60.00 mg, Choline chloride 300,000.00 mg, Cobalt 200.00 mg, Copper 3,000.00, mg, lodine 1,000.00 mg, Iron 20,000.00 mg. Manganese is 40,000.00 mg, selenium is 200.00 mg, zinc is 30.000.00 mg, and an antioxidant is 1.250.00 mg.

Table 2: Composition of Experimental Diet (Broiler Starter)

Ingredient	T1 (0%)	T2 (0.25%)	T3 (0.20%)	T4 (0.45%)
Maize	52.87	52.87	52.87.10	52.87
Wheat offal	13.22	13.22	13.22	13.22
Groundnut cake	29.47	29.47	29.47	29.47
Bone meal	2.50	2.50	2.50	2.50
Limestone	1.00	1.00	1.00	1.00
Salt	0.30	0.30	0.30	0.30
Premix	0.25	0.25	0.25	0.25
Methionine	0.20	-	0.20	-
Lysine	0.25	0.25	-	-
Moringa	-	0.20	0.25	0.45
Total	100	100	100	100

Calculated analysis				
Crude protein	20.44	20.44	20.44	20.44
Crude fibre	4.31	4.31	4.31	4.31
Calcium	1.12	1.12	1.12	1.12
Methionine	0.25	0.25	0.25	0.25
Phosphorus	0.89	1.30	1.39	1.39
Lysine	0.89	0.89	0.89	0.89
Metabolizable energy	2978.50	2978.50	2978.50	2978.50

Each 2.5kg of Bio premix contains Starter
Vitamin A, 10,000,000.00 IU, Vitamin D3, 2,000,000.00 IU, Vitamin E, 23,000.00mg, Vitamin K3, 2.000.00 mg, Vitamin B1, 1,800.00 mg, Vitamin B2, 5,500.00 mg, Niacin 27,500.00 mg, Pantothenic 7,500.00 mg, Vitamin B6 3,000.00 mg, Vitamin B12 15.00 mg, Folic acid 750.00 mg, Biotin H2 60.00 mg, Choline chloride 300,000.00 mg, Cobalt 200.00 mg, Copper 3,000.00, mg, lodine 1,000.00 mg, Iron 20,000.00 mg. Manganese is 40,000.00 mg, selenium is 200.00 mg, zinc is 30.000.00 mg, and an antioxidant is 1,250.00 mg.

DATA COLLECTION

During the experiment, the following data were collected: at the beginning of 8 weeks, three (3) birds were selected randomly from each treatment, which means one (1) from each replication for the digestibility study. The birds were put into metabolism cages according to the treatment group and fed with known quantities of the experimental diet. Feed left over was weighed every morning, and faecal output was collected each morning. The feed intake and faecal output are then determined after drying the faeces.

The metabolism cage was made so that trays were inserted underneath to trap all droppings and facilitate the collection of the daily excreta. Three (3) days faecal collection was carried out for the digestibility study. The faeces were all dried and bulked from each treatment for laboratory analysis.

Chemical Analysis of Feed

Sample of each treatment diet and faeces were analyzed for dry matter (D.M), Crude protein (C.P), crude fibre (C.F), Ether extract (E.E), and Mineral and ash according to A. O. A. C (1990).

Dry Matter (DM)

The dry matter of the sample was determined by drying 10g of each sample in an oven at 105°C for 24 hours. The samples were removed and cooled in desiccators reweighed. The process was repeated until constant weight was obtained, and it was calculated as

$$DM = \frac{\text{Final Wt}}{\text{Initial Wt}} \times 100$$

Crude Protein (CP)

The kjeldah procedure determined this (NOAC 1990), which involved three stages, which are digestion, distillation, and filtration. About 2g of the sample was placed in a dry digestion tube; one digestion tablet was added, which acted as a catalyst and 20mls of concentrated H_2SO4 was added and heated on a digestion block at 420°C. For seven hours. This was done for all samples

until the solution turned colourless. The solution was diluted with 80mls of distilled water to make it up 100mls. Then 10ml of the diluted solution was transferred with a pipette into another digestion tube, and the distillation was carried out at the distillation unit of the system. 20mls of saturated boric acid solution containing bromocresol green methyl indicator was measured into a 250ml conical flask, and 10ml of sodium hydrochloride (NaOH) was added to the digestion tube by tilting it and was connected to the system with the conical flask. After the 20-25 minutes of steam distillation. The ammonia was released and collected in the boric acid. The green distillate was titrated against 0.1NHL until a neutral grey end point was obtained. The volume of acid used was recorded, and the crude protein was calculated (A.0.A.C) as

% CP = 14.001x (A-B) x 6.25/ weight of sample x 100

Where A = mole of acid for titrating sample

B=mole of acid for titrating a blank sample

C normal of acid used, crude protein (%)

=Nx6.25 (factor of feed).

Crude Fibre (CF)

This was determined using the trichloroacetic acid method (TCA). About 2g of sample was weighed into a 500ml conical flask, and 100ml of digestion reagent was added and prepared by mixing 450ml of glacial acetic acid, 500mls of distilled water, and 50ml of concentrated nitric acid and 20g of trichloroacetic acid salt. The flask containing the sample and the digestion reagent was boiled and refluxed for about 40 minutes starting from the time heating commenced; the flask was removed from the heater and cooled. The solution was filtered through an ashless filter paper, the filter paper was opened out, and the residue poured in and was air dried overnight at 105°C; the residue was cooled in desicators and weighed. It was ashed at 6000 ^{o}C, allowed to cool and weighed. The CF was calculated as (A.O.A.C 1990)

CF= Wt after oven drying- Wt of ash/ Ft of sample x 100

Ether Extract (EE)

Soxhlet apparatus was used for this, and 2g of the sample was weighed from the previously dried samples into a thimble; the mouth of the thimble was corked with cotton wool and inserted into the extraction chamber. About 250mls of petroleum ether was measured into a collection flask to known weight. The apparatus was placed in a water bath at 60°C and fixed by clamps in the condenser. It was turned on and allowed to continuously reflux until oil was extracted and settled in the collecting flask, the flask which contained only the crude fat or either extract was disconnected, dried in a hot air oven at 100°C fọr an hour. It was then cooled in desiccators and weighed (A.O.A.C 1990).

The either extracted was calculated as:

$$EE\ (\%) = \frac{\text{Wt of flask containing oil- Wt of empty flask x100}}{\text{Wt of a dried sample taken}}$$

Ash

About 2g of the sample was weighed into a crucible of known weight and burnt In the furnace for four hours. This residue or ash was removed, cooled in desiccators and reweighed.

$$\%ASH = \frac{\text{Wt of residue x100}}{\text{Wt of sample}}$$

Nitrogen-Free Extract
This was calculated for each sample by subtraction the percentage of dry matter, crude protein, crude fibre, ether extract and ash from 100 with the formula
% NFE=100-%(EE + CP +CF + Ash)

Statistical Analysis
All data collected were subjected to analysis of variance (ANOVA) using a completely randomized design (Steel and Terie 1980) where necessary means were Separated using the least significant difference (LSD)

RESULT AND DISCUSION
The Proximate Composition of the Experimental Broiler Starter Diet.
The proximate composition of the experimental broiler starter diet is presented in Table 1. The crude protein and metabolisable energy ranged from 24.59-24.72 and 2975-2980, respectively, which was in line with the range of 22-24% crude protein by Olumo (1995), and the metabolisable energy too was in line with Olumu 1995 that is 2800-3000MEkcal/kg respectively. So, the protein and metabolisable energy were all sufficient in a broiler starter diet. The crude fibre level was found to be 4.36% in T4, and it was the highest, but the result of the proximate composition was all in line with the recommended level of 3.49%-6.24% by Smith (1990) and Igwebuke (2001). Thus, fibre levels were adequate in the broiler starter diet. The calcium and phosphorus in the diet were changing with the quantity across the treatment, with the lowest value in the basal diet T1 control (feed without) and recorded high in T4 for both the calcium and phosphorus that is fed without synthetic Methionine and lysine, i.e. complete. The variation in this mineral may be due to the quantity of this mineral in the leaf. The amount of Methionine and lysine were all the same throughout the experimental diet without variation among the treatments; the Methionine in the treatment is (0.25%) and lysine is (0.89%) respectively.

Table 3: Proximate Composition of the diet (Broiler Starter)

Constituents	T1 (0%)	T2 (0.20%)	T3 (0.25%)	T4 (0.45%)
dry matter (DM)	93.8	94.1	94.0	94.0
Crude fibre (CF)	4.27	4.30	4.31	4.36
Crude protein (CP)	24.59	24.65	24.66	24.72
Phosphorus	0.89	1.30	1.39	1.89
Calcium	1.12	1.14	1.15	1.17
Methionine	0.25	0.25	0.25	0.25
Lysine	0.89	0.89	0.89	0.89
M.E(Kcal/kg)	2985	2980	2979	2978

4.3 Proximate Composition of the Experimental Diet (Broiler Finisher)
The proximate composition of the experimental broiler finisher diet is presented in Table 2. The crude protein and Metabolisable energy levels were 20.44% and 2978.5kcal/kg for the four treatments, without variation in the treatments (T1, T2, 13 and T4), respectively. The crude protein level was in-line with the recommendation level of 20% by (Oluyumi and Robert, 1995) and NRC (1984), but the Metabolisable energy was slightly below the recommendation level of

3000kcal/kg (Olumo, 1995) with slight variation in the recommended energy was very little and has not shown any sign of deficiency. The crude fibre level was found to be 4.31, which was also in the range recommended level of 3.39-6.24% by Smith (1990), Igwebuike (2001), and Adamu and Bulus (2004). Thus, fibre level was adequate in the broiler finisher diet. The calcium and phosphorus levels in the diet changed with the quantity across the treatment, with the lowest value in T1 (control) (free diet) and increasing with the replacement of leaf powder replacing Methionine in T2, followed by T3, with the replacement of lysine with the highest level in T4 (with complete replacing both Methionine and lysine) for both calcium and Phosphorus. The reason for variation in this mineral was due to the presence of in the diet (T2, T3, and T4).
The quantity of Methionine and lysine were all the same throughout the experimental diet without variation among treatments, Methionine (0.26%) and lysine (0.89%), respectively.

TABLE 4: Proximate Composition of the Experimental Diet (Broiler Finisher)

Constituents	T1 (0%)	T2 (0.20%)	T3 (0.25%)	T4 (0.45%)
Dry matter(dm)	93.6	93.5	93.9	96.1
Crude fibre(cf)	4.31	4.31	4.31	4.31
Crude protein(cp)	20.44	20.44	20.44	20.44
phosphorus	0.89	1.30	1.39	1.39
Calcium	1.12	1.12	1.12	1.12
Methionine	0.26	0.26	0.26	0.26
Lysine	0.89	0.89	0.89	0.89
M.E(Kcal/kg)	2975.50	2978.50	2978.50	2978.50

APPARENT DIGESTABILITY

The percentage nutrient digestibility of broiler chicken diet fed with complete Synthetic Methionine and lysine without based diet T1 (control), and those fed with replacing Methionine in T2, replacing lysine in T3 and replacing both Methionine and lysine in T4, is shown in Table 4. The result of the nutrient digestibility on (DMD, CPD, EED CFD, AND ASH) showed that there were no significant (P>0.05) differences in the nutrient digestibility among the treatment group when compared to the T1 (control) group that were fed synthetic Methionine and lysine. This means that the chickens utilize synthetic and natural Methionine and lysine without adversely affecting their nutrient digestibility.
The observation was in line with (Faheyat et al, 2001), which indicated that the inclusion level of seed meal in broiler finisher diet improves digestibility of the diet, hence increased intake and subsequent digestibility.

Nutrient Digestibility

Based on the result obtained and presented in Table 6, there was no significant (P>0.05) difference among the treatment groups which contained natural sources of Methionine and lysine did not significantly (P>0.05) differ from T1 (control), which contain synthetic Methionine and lysine in all the parameters recorded, i.e. (Crude protein, crude fibre, ether extract, dry matter, and Ash digestibility). This finding agreed with the earlier faheyat et al, (2001) report.

Table 5: The Apparent and Nutrient Digestibility

Constituent	T1 (0%)	T2 (0.20%)	T3 (0.25%)	T4 (0.45%)	SEMs
D M D (%)	53.82	60.65	53.36	61.63	6.81
C P D (%)	48.35	49.87	21.96	32.27	9.10
C F D (%)	19.36	30.05	15.88	27.14	9.78
E E D (%)	90.58	86.60	92.21	90.54	2.43
ASH (%)	21.59	28.55	54.25	45.22	17.08

Standard error of the mean
DMD=Dry matter digestibility
CPD=Crude protein digestibility
CFD=crude fibre digestibility
EED=Ether Extract digestibility
ASHD=Ash Digestibility

CONCLUSION AND RECOMMENDATION

This research has contributed additional valuable information on the Nutritional value of. This study has become a plat form and reference for future researchers to build on. In this study, it was discovered that these unconventional protein sources (leaf) are palatable and digestible for poultry feeding, and it did not show any negative sign on nutrient digestibility when compared with the basal diet; therefore, leaf powder can be used as a natural source of lysine and Methionine in broiler diet without any adverse effect on any nutrient digestibility. I, therefore, recommend that leaf powder should be dried ground and be used as a natural Methionine and lysine in a broiler diet, but further research should be geared toward evaluating the effect of leaf, pods, and the seed on nutrient digestibility in layers and other Monogastric animals.

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Optimizing Rooting Potentials of *Tetrapleura tetraptera* (Schum. & Thonn.) Taub. Through Stem Cuttings

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Abstract

An experiment was conducted to explore the rooting response of juvenile stem cuttings of *Tetrapleura tetraptera* (Schum. & Thonn.) Taub. to synthetic and non-synthetic growth stimulants in the screen house. Four hundred double-node stem cuttings were obtained from six-month-old *T. tetraptera* seedlings with their leaves reduced to half. The study tests the effect of synthetic auxins (Indole butyric acid (IBA), naphthalene acetic acid (NAA) and their combination (IBA/NAA)) on stem cuttings at three levels (100, 150, 200 ppm), coconut water (25, 50 and 100% coconut water, CW) and a control (no stimulant). The experiment was laid out in a completely randomized design with three replicates. Cuttings were assessed for percentage of survived and rooted cuttings, number of roots and length of root. Data was analyzed using descriptive and inferential statistics such as Analysis of Variance (ANOVA). The highest percentage of survived (50.9±5.9%) and rooted cuttings (44.7±9.2%) was obtained in cuttings treated with 50% CW, while the lowest rate of survived (31±2.2%) and rooted cuttings (23.3±4.9%) was obtained in untreated cuttings, although not significant. Growth stimulants had a substantial effect on root growth. Number of roots was significantly highest (5.5±0.3) in IBA (150ppm), however comparable with 25% CW (5±0.3). Cuttings treated with 25% CW produced the highest length (5.0±0.9cm) of root while the lowest (1.7±0.3cm) was obtained in NAA 200ppm. Rooting of *T. tetraptera* stem cuttings can be significantly enhanced by treating the cuttings with 25% CW or IBA (150ppm). Coconut water is a suitable alternative to auxins for stimulating root formation in *T. tetraptera* stem cuttings.

Keywords: Auxins, non-synthetic growth regulators, rooting, stem cuttings, *Tetrapleura tetraptera*

Introduction

Non-timber forest products (NTFPs) besides timber provide raw materials (animal parts, leaves, sticks, local building materials, chewing sticks, sponges, fibres, gums, rattan canes and medicinal plants, among others) and services of subsistence and commercial value which sustain rural economies (Suleiman et al., 2017). Today, most forest people in developing countries use NTFPs daily. *Tetrapleura tetraptera* (Thonn and Schum.) Taub. (Fabaceae) commonly known as Aidan, is a tree species in the humid forest zone of Africa. The species is among the NTFPs of enormous domestic importance to rural and urban dwellers. It is distributed mainly in West Africa, and it's exploited for its nutritional and ethno-medicinal values (Orwa et al. 2009). In Nigeria, fruit pulp is widely consumed for its aromatic properties and as spices for food preparations. The medicinal properties of *T. tetraptera* fruits range from anti-inflammatory (Ojewole and Adewumi, 2004), antibacterial (Achi, 2006; Ekwenye & Okorie, 2010), anti-malaria (Okokon et al., 2007)). The sales of *T. tetraptera* fruits contribute largely to rural household economies. The increasing demand for *T. tetraptera* fruits for multipurpose use has led to unsustainable exploitation of the species. In addition, massive habitat loss and fragmentation in the tropics pose a conservation

threat to the species in future. Given this, it becomes imperative to develop macro propagation techniques, especially rooting of stem cuttings, to ensure conservation of the species' genetic resources and production of high-quality seedlings. Several thousand plants have been propagated through rooting of stem cuttings in various fields like agriculture, landscaping, and forestry. However, the rooting of cuttings varies from species to species. Previous research on cutting propagation has shown that the physiological state of stock plants, prevailing environmental conditions in the nursery, rooting medium and exogenous use of growth hormones, among others, play valuable roles in propagation success (Topacoglu et al., 2016).

Generally, applying plant growth hormones (auxins) to cutting as a pre-treatment has been reported to significantly enhance the rooting rate in stem cuttings of most tropical trees (Chen et al., 2023). Conventionally, the most frequently used synthetic auxins are Indole-3-butyric acid (IBA), Indole Acetic acid (IAA) and naphthalene acetic acid (NAA) (Hartmann et al., 2002). However, accessibility and the high cost of procuring these synthetic auxins tend to limit their usage by low-income farmers. On the other hand, non-synthetic growth hormones like coconut water are promising alternatives to synthetic auxins for stimulating root growth in stem cuttings (Usman & Akinyele, 2015; Okunlola, 2016). Moreover, the non-synthetic growth regulators are cheap and readily available. Therefore, this study aims to evaluate the rooting capacity of T. tetraptera stem cuttings using synthetic and non-synthetic growth regulators to determine the most effective growth regulators for optimizing rooting rates of the species.

Materials and methods

Leafy stem cuttings (Single node) of 6.5 cm in length were prepared from eight-month-old seedlings of *Tetrapleura tetraptera* in the Departmental Nursery of Forest Production and Products, University of Ibadan. Four hundred cuttings were obtained from the seedlings, and all cuttings had their leaves reduced to half to minimize transpiration. The basal end of the cuttings was treated with coconut water (0, 25 and 50% water dilution), IBA, NAA, a combination of IBA and NAA at 100, 150 and 200 ppm and a control (no hormone). Ten cuttings were set per treatment in a germination tray filled with sterilized river sand. The treatment was replicated thrice, and the germination trays were arranged in a completely randomized design under the high humidity propagator. Watering was done daily, and assessment was done on the cuttings after 60 days for the following variables: survived cuttings (%), rooted cuttings (%), number of roots, root length (cm) and length of longest root (cm).

Statistical analysis

Analysis of variance was performed on the data collected for the different variables and the Duncan Multiple Range Test at 5% was used to compare significantly different means using the STATISTICA software package.

Results

Percentage of survived and rooted cuttings

Growth hormones had no significant effect (P>0.05) on the percentage of survived and rooted cuttings (Table 1). Percentage of survived cuttings was highest (50.9±5.9%) in cuttings treated with 50% coconut water. In comparison, the untreated cuttings (control) had the lowest (31 ± 2.2%) after sixty days (Fig. 1). Similarly, percentage of rooted cuttings was highest (44.7±9.2%) in 50% coconut water and lowest (23.3±4.9%) in untreated (control) cuttings (Fig. 2).

Table 1: Summary of analysis of variance for the effect of growth hormones on rooting variables of *Tetrapleura tetraptera* after 60 days

Source of variation	Df	Mean squares			
		Survived cuttings (%)	Rooted cuttings (%)	Number of roots	Length of root (cm)
Treatment	12	92.76^{ns}	111.65^{ns}	3.26*	1.89*
Error	26	46.60	95.35	0.39	1.093
Total	38				

***Significant (P<0.05), ns- not significant (P>0.05)**

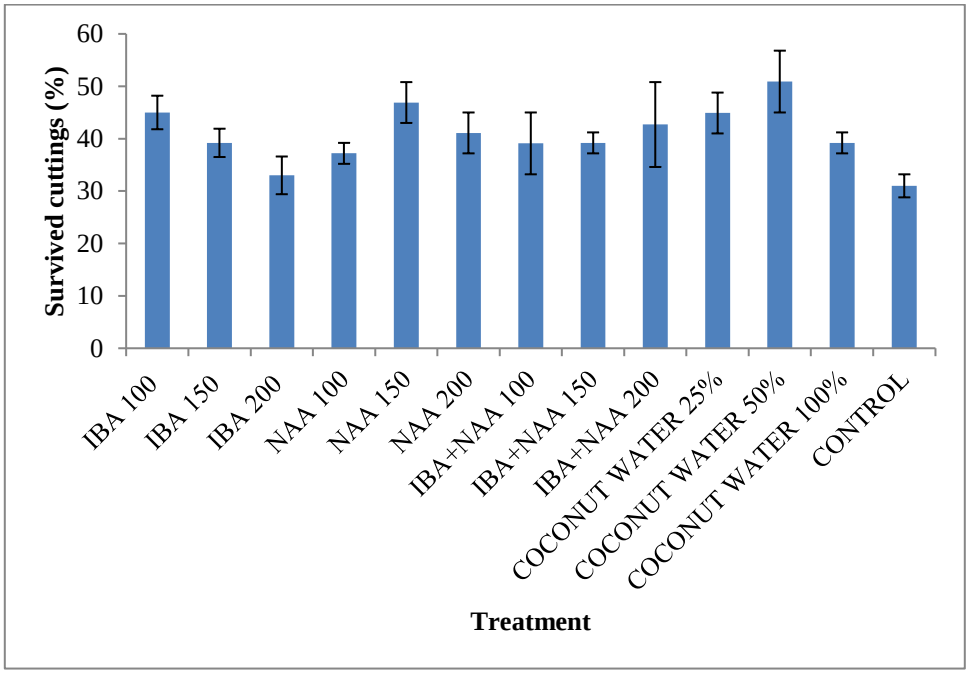

Figure 1: Percentage of survived *Tetrapleura tetraptera* stem cuttings after 60 days (Mean±SE)

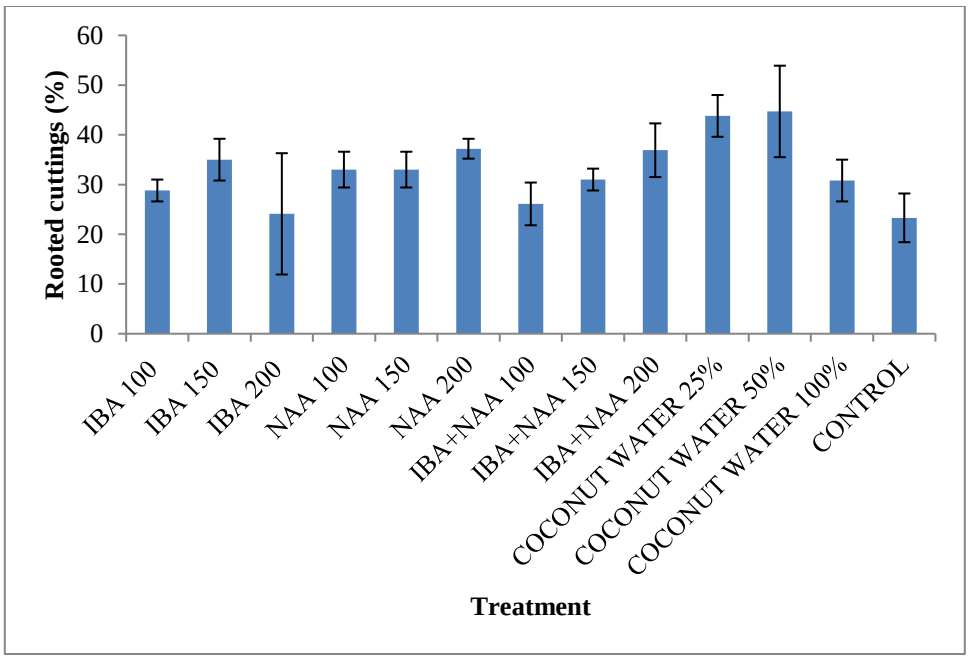

Figure 2: Percentage of rooted *Tetrapleura tetraptera* stem cuttings after 60 days (Mean±SE)

Number of roots per rooted cutting

The number of roots formed on stem cuttings of *T. tetraptera* was significantly affected (P<0.05) by hormone application (Table 1). Cuttings treated with IBA 150 ppm had the highest (5.5±0.3) while the lowest (1.6±0.4) was 100% coconut water (Fig. 3). Cuttings treated with 25 % coconut water had comparable results with IBA 150 ppm, however, they are significantly different from all other treatment (Fig. 3). Combination of IBA and NAA at the three levels were not significantly different (P>0.05).

Length of root per cutting

Growth hormones had a significant influence (P<0.05) on the length of the root of *T. tetraptera* cuttings (Table 1). Cuttings treated with 25% coconut water had the longest (5.0±0.9 cm) roots while the lowest (1.7±0.3 cm) was NAA 200 ppm treated cuttings (Fig. 4). Cuttings treated with 25% coconut water are significantly different than other treatment. In cuttings treated with non-synthetic growth hormones (coconut water), the root length decreased significantly with increasing concentration.

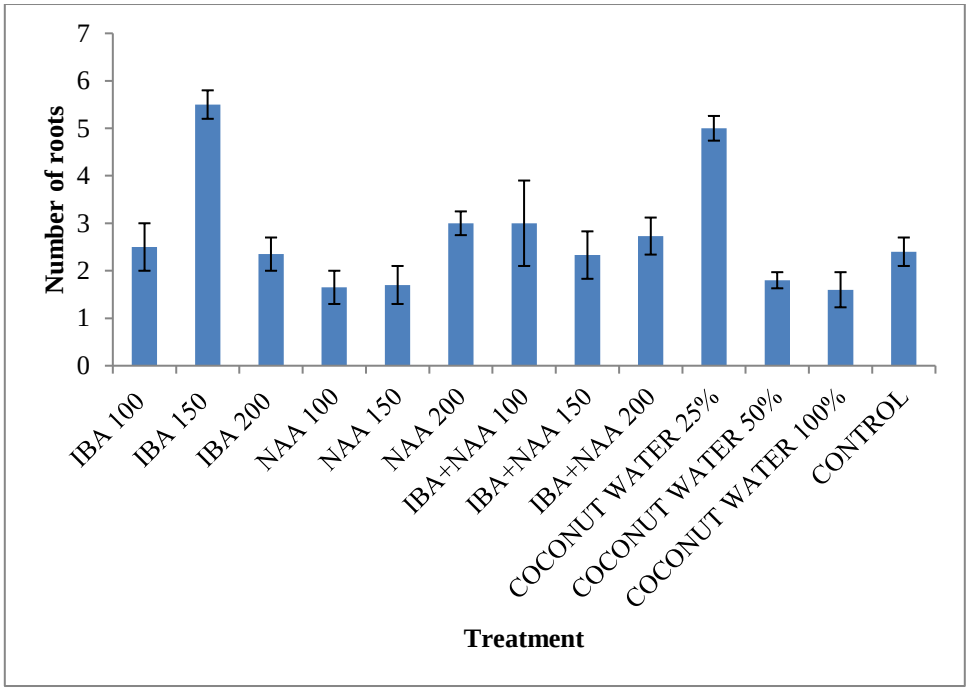

Figure 3: Number of roots per *Tetrapleura tetraptera* stem cuttings after 60 days (Mean±SE)

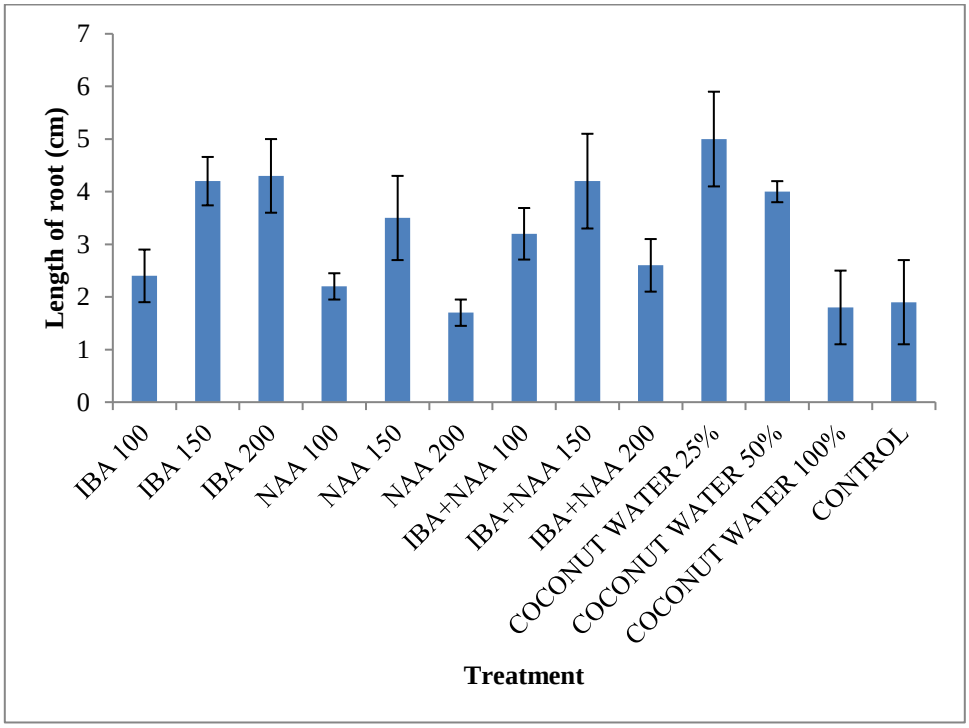

Figure 4: Length of root per *Tetrapleura tetraptera* stem cuttings after 60 days (Mean±SE)

Discussion

The ability of stem cuttings to produce long and massive roots is essential for plant establishment in the nursery. Generally, growth hormones are applied to stem cuttings to enhance the rooting potential of plant species. The results of this study indicated that the rooting capacity of *T. tetraptera* was sensitive to growth hormone treatment, particularly the non-synthetic growth stimulant (coconut water). In this study, coconut water resulted in higher percentages of both survived and rooted cuttings in the present study, although not significant. The lack of significant differences in the rate of survived and rooted cuttings in both treated and untreated cuttings in this study is an indication that *T. tetraptera* stem cuttings is an easy-to-root species, which may be due to the presence of a substantial amount of endogenous growth regulatory substances. In this study, applying IBA 150 ppm and 25% coconut water significantly enhanced the number of roots formed and the length of the root of *T. tetraptera* compared to other treatments. However, the lack of significant difference between cuttings treated with IBA ppm and cuttings treated with 25% coconut water in the present study has proven coconut water to be a suitable alternative for auxins (IBA) in stimulating root growth and number of roots formed on stem cuttings of *T. tetraptera.* This observation agreed with the findings of Dunsin et al. (2016), who reported that coconut water greatly enhanced the number of rooted cuttings in *Parkia biglobosa.* Previous research on using coconut water as a growth stimulant for treating stem cuttings has also reported similar observations (Bamigboye et al., 2016; Okunlola, 2016). Studies on vegetative propagation have reported the importance of coconut water in stem elongation and plant development in fruit species (Trevisan, 2005). Natural growth-regulating substances such as indole acetic acid (IAA), cytokinin, abscisic acid and salicylic acid in coconut water have made it a promising alternative to synthetic growth hormones.

Further, the concentration of growth regulators can be varied to ascertain the optimum level. In this study, the concentration of growth regulators tends to affect elongation and formation of roots. For instance, root formation was retarded in *T. tetraptera* cuttings treated with 100% (undiluted) coconut water. This is similar to what was observed in the auxins (IBA and NAA) treated cuttings, particularly when applied individually in this study, as the number of roots formed on cuttings reduced significantly in cuttings treated at 200ppm concentration. This observation conforms with the work of Memon et al. (2013), who reported that higher concentrations of NAA had inhibitory effects on the number of roots. A similar observation was also reported in the rooting of *Enantia chlorantia* stem cuttings, where cuttings treated with a high concentration of IBA inhibit root formation (Gbadamosi & Oni, 2005). A comparable result (for the percentage of survived and rooted cuttings), for the cuttings treated with 25% coconut water with those treated with 150 ppm IBA implies that *T. tetrapera* can be macro-propagated at a reduced cost, thus ensuring that this technology can be adopted with minimum capital to produce expected results.

Conclusion

Regeneration of *T. tetrapera* can be done using stem cuttings with or without hormone treatment. Coconut water (non-synthetic growth stimulant) is a suitable alternative for auxins (IBA) to enhance the rooting performance of *T. tetrapera* stem cuttings because it is cheap, easy to use and readily available. A low concentration of coconut water (25%) or IBA (150 ppm) is recommended in *T. tetrapera* stem cuttings pre-treatment for optimum results.

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Microscopic Structure and Proximate Analysis of Zanthoxylum gilletti (De wild.) Waterman and Zanthoxylum zanthoxyloides Lam leaves

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Abstract

Zanthoxylum species belonging to the family Rutaceae are widely used in many countries as food and in trado-medicinal practice. This is due to their wide geographical distribution and medicinal properties. Much research has been carried out on the phytochemical, antiplasmodium and antimicrobial activities of *Zanthoxylum zanthoxyloides* and *Zanthoxylum gilletti* stem bark and leaves. However, a detailed examination of micromorphology and proximate analysis is yet lacking. Therefore, This study aimed to evaluate the micromorphology of the leaves of *Zanthoxylum zanthoxyloides* and *Zanthoxylum gilletti* using chemoscopic analysis and epidermal and transverse layer micrographs. The standard micro Kjeldahl technique was used to determine the proximate analysis of the plant samples. The paraffin micro technique was used to characterize the morphology of the plant material. The chemoscopic analysis of the powdered leaves sample of both species showed that both leaves do not contain calcium oxalate crystals but rather calcium carbonate. Lignin and mucilage were absent in the leaves of *Z. zanthoxyloides* but present in *Zanthoxylum gilletti.* Furthermore, starch granules and fat deposits were present in both leaves. The epidermal layer micrograph showed that both leaves are hypostomatic. This study established the similarities and differences in the morphology and proximate content of the leaves of both *Zanthoxylum zanthoxyloides* and *Zanthoxylum gilletti.*

Keywords: Medicinal plants, Micromorphology, Proximate analysis, *Zanthoxylum gilletti, Zanthoxylum zanthoxyloide*

Introduction:

Alternative medicine embraces the practice of medicine that does not usually involve conventional methods. Commonly cited examples include naturopathy, chiropractic, herbalism, traditional Chinese medicine, ayurveda, meditation, yoga, biofeedback, hypnosis, homoeopathy, acupuncture, diet-based therapies, and a range of other practices. The World Health Organization (WHO) estimates that as many as 80% of the world's more than six billion people rely primarily on animal and plant-based medicines (Alves and Rosa, 2005). Phytochemistry is the art of resolving plants into chemically pure distinct constituents. Since they have numerous components that exhibit potent therapeutic effects, medicinal plants have been employed for thousands of years to cure a wide range of human disorders. Using these medicinal herbs more often can reduce the adverse effects of anecdotics associated with conventional medical systems (Akinyemi et al. 2018). Most of the trace elements participate in numerous metabolic activities as cofactors, catalysts, and centres for creating stabilizing structures (Prashanth et al. 2015; Proma et al. 2020).

It is well known that many medicinal plants with similar morphology and the same folk name among species within the same genus can be misidentified and intentionally or accidentally be substituted in commercial products during the manufacturing process which may result in losing efficacy and safety. Experienced taxonomists usually perform the authentication of biological species. However, morphological identification can be limited by the absence of different phenotypic characteristics. Furthermore, herbal products are available in the market in processed form, such as herbs (i.e., leaf powder and crushed material), herbal material (i.e. essential oils), herbal preparations (i.e. extracts) and finished herbal products (i.e. capsules and tablets). Consequently, morphological identification is quite challenging (Rivera-Mondragón et al. 2019). The epidermis of most plants also contains hairs that are functionally classified as glandular or non-glandular trichomes. Glandular trichomes are specialized secretory structures that vary in size, form, location, and function in different plant species (Robles-Zepeda et al., 2009). Stomata, glandular trichomes, and non-glandular trichomes are secretory structures of scientific interest due to their functional attributes and economic importance in the production or secretion of phytochemicals. Glandular trichomes have been reported to possess higher levels of secondary metabolites than those produced from other plant organs (Badmus and Afolayan, 2010).

Zanthoxylum gilletii (De Wild Waterm), commonly known as African satinwoodis, is an indigenous deciduous tree growing 10-35m high belonging to the family Rutaceae (Gaya et al. 2013). This plant is traditionally used to treat toothaches, nausea and urinogenital complaints and infections. *Z. gilletii* is a monoecious species distributed between tropical rainforest and wooded savannah (Mukeba et al. 2020). *Zanthoxylum zanthoxyloïdes* (Lam.) Zepernick, family Rutaceae is commonly called 'toothache bark' or 'candle wood' (English); Orin ata (Yoruba) is widespread in West Tropical Africa, occurring in Savanna and dry forest areas (Raphael et al. 2023). This species has been used to treat other diseases, including infections causing stomach-aches, toothaches, coughs, urinary infections, rheumatism, leprosy ulcerations, and venereal diseases (Masinde, 2014). The food and fragrance industries have extensively used the essential oils of *Zanthoxylum species*; the most utilized species are *Z. zanthoxyloides*, *Z. gillettii*, and *Z. simulans* (Patino et al. 2012). Some researches have been reported on the two species of *Zanthoxylum*. These include cytotoxicity, antimicrobial and phytochemical analysis (Guetchueng et al. 2018; Olushola-Siedoks et al. 2020; Okagu et al. 2021; Raphael et al. 2023).

However, little or no research has been done on their micromorphology and proximate analysis. There is also the problem of misidentification between *Zanthoxylum zanthoxyloides* and *Zanthoxylum gilletti* species. The local users tend to mistake them for each other as they are locally called *Orin-ata*. Micromorphology should provide tools for differentiating between the leaves of *Zanthoxylum zanthoxyloides* and *Zanthoxylum gilletti*. To ascertain if a plant successfully treats human diseases, it is crucial to study the proximate analysis found in various medicinal plants.

The foliar micro-morphological characteristics of medicinal plants offer complete and extensive evidence to help in their appropriate identification, as Chandaz (2014) emphasized. These helpful taxonomic traits can minimize the distortion and misidentification. Therefore, instruments for standardizing and authenticating medicinal plants include micro-morphological assessments, microchemistry, and phytochemistry. Chemoscopic analysis and epidermal and transverse layer

micrographs were used in the current work to assess the micromorphology of the leaves of *Z. zanthoxyloides* and *Z. gilletti*.

Methods

Sample selection and collection.

Fresh stem bark and leaves of *Zanthoxylum zanthoxyloides* were collected from a forest at Oni Gambari, Oluyole Local Government area of Ibadan, Oyo state, Nigeria, while *Zanthoxylum gilletti* was collected from the herbal garden in Forestry Research Institutes of Nigeria (FRIN), Jericho hills, Ibadan, Nigeria. Identification was carried out at Forest Herbarium, Ibadan, Nigeria, and the chemical analysis was carried out at the Biomedicinal Research Centre Laboratory, FRIN, Nigeria. The samples were cleaned and oven dried. The leaves were oven-dried at 50^0C and the bark at 100^0C for a week. They were after that blended into fine and coarse powder separately and then kept in an airtight container for further analysis.

Micromorphological characterization

A pinch of the powder samples was mounted and stained with phloroglucinol, concentrated hydrochloric acid (HCl), diluted iodine solution, Ruthenium Red, Sudan Red and diluted HCl (Odewale et al. 2021).

The morphological characterization of the plant sample was carried out using the paraffin micro technique. The analysis of leaf structure was carried out using freshly collected material. The leaf located in the nodes of the middle part of the newest branchlets (one leaf per node along the stem) was used to carry out the morphological study.

Each leaf sample's transverse section (TS) was cut at micron thickness using the sledge microtone. The leaves were sliced using a sledge microtome machine (Reichert Austria model). Samples were stained in Safranin O for 2 min, after which they were dehydrated in increasing ethanol concentrations (30%, 50%, 70%, and 90%). Clove oil was used for clearing, while Canada balsam was used as a mounting agent before being observed under a light microscope.

Epidermal sections of leaf samples were obtained by soaking fresh leaf samples of *Z. zanthoxyloides* and *Z. gilletti* in covered glass petri dishes containing concentrated nitric acid (HNO_3) for four h. As soon as the disintegration of tissues and formation of bubbles was observed, the specimen was carefully transferred into clean Petri dishes and rinsed with distilled water before the epidermises were separated with forceps. The mesophylls were also removed with a camel brush. The obtained epidermises were then stained in Safranin O for 2 min. The excess stain was then removed in distilled water. The stained tissues were carefully mounted in 25% glycerol onto clear microscopic glass slides with coverslip and rinsed with nail varnish to preserve the specimen for subsequent observation. The slides were then studied under an Olympus light microscope at different magnifications (x10). Twenty observations were taken from the fields of view for each epidermal surface (abaxial and adaxial) of the *Z. zanthoxyloides* and *Z. gilletti* studied (Olaniyi et al. 2020).

Proximate analysis

The proximate analysis for the leaves and stem bark of *Z. zanthoxyloides* and *Z. gilletti* was determined by routine micro Kjeldahl procedure/technique. This consists of three analysis techniques, namely, digestion, distillation, and titration (AOAC International, 2005).

Statistical analysis

The obtained data were computed as means ± SD and calculated using Analysis of Variance. Values were presented as mean ± SD at 95 % confidence level.

Results

Chemoscopic examination of the leaf-powdered samples of *Zanthoxylum zanthoxyloides* and *Zanthoxylum gilletti*

The result of the chemoscopic examination of the leaf-powdered samples of *Z. zanthoxyloides* and *Z. gilletti* is shown in Table 1. This study has revealed specific quantitative and chemoscopic analytical features that can be employed to verify its authenticity and purity. From this study, the powdered microscopic examination of leaves of *Z. zanthoxyloides* and *Z. gilletti* revealed that both leaves do not contain calcium oxalate crystals but contain calcium carbonate as polygonal to circular crystals inside the adaxial layer's epidermal veins.

Lignin and mucilage were absent in the leaves of *Z. zanthoxyloides* but present in the leaves of *Z. gilletti*. Furthermore, starch granules and fat deposits were seen to be present because of abundant prisms of micro-crystals in both the abaxial and adaxial layers of the two leaves.

Table 1: Chemoscopic examination of the leaves powdered samples of *Z. zanthoxyloides* and *Z. gilletti*

S/N	Components	Reagents	*Z. zanthoxyloides*	*Z. gilletti*
1	Calcium oxalate	Chlorohydrate + Dilute HCl	-	-
2	Calcium carbonate	Chlorohydrate + Dilute HCl	+	+
3	Lignin	Phloroglucinol + Conc. HCl	-	+
4	Starches	Dilute iodine	+	+
5	Mucilage	Ruthenium red	-	+
6	Fat deposits	Sudan III Red	+	+

Footnote
Z. zanthoxyloides: *Zanthoxylum zanthoxyloides*
Z. gilletti: *Zanthoxylum gilletti*

Proximate analysis of *Zanthoxylum zanthoxyloides* and *Zanthoxylum gilletti*

The proximate analysis result is shown in Table 2. Comparing the proximate composition of the two species, the moisture content, ash content, crude fat, and protein contents are similar. However, *Z. zanthoxyloides* possess higher crude fiber and lesser Nitrogen-free extract than *Z. gilletti.*

Table 2: Proximate analysis result

Analysis	Z.GB	Z.GL	Z.ZB	Z.ZL	Extract
Moisture Content (MC)	8.93	9.18	9.36	9.57	3.18
Ash Content (AC)	6.87	7.17	6.24	6.87	2.18
Crude Protein (CP)	9.62	10.18	9.81	10.16	5.67
Crude Fiber (CF)	7.91	8.08	12.87	13.25	1.74
Crude Fat (CF)	5.68	7.08	6.36	6.87	1.23
Nitrogen Free Extract (NFE)	60. 99	58.31	55.36	53.28	82.82

Footnote

Z.GL: *Zanthoxylum gilletti* leaf

Z.GB: *Zanthoxylum gilletti* bark

Z.ZL: *Zanthoxylum zanthoxyloides* leaf

Z.ZB: *Zanthoxylum zanthoxyloides* bark

The result of a transverse section of the leaves sample confirms the presence of trichomes in the abaxial parts (Figure 1; A1 and A2). Figure 2; B1 and B2 show the photomicrographs of abaxial surfaces of the epidermal layer of *Z. zanthoxyloides* and *Z. gilletti*. The photomicrographs of adaxial surfaces of the epidermal layer of *Z. zanthoxyloides* and *Z. gilletti* are presented in Figure 3; C1 and C2.

The epidermal section of the leaves sample of *Z. zanthoxyloides* and *Z. gilletti* shows numerous epidermal cells on both adaxial and abaxial layers of both leaves, with the highest number from *Z. gilletti*. The epidermal cells of *Z. zanthoxyloides* are large with the thin anticlinal wallss while *Z. gilletti* is smaller with the thicker anticlinal wallss. Non-glandular, simple multicerate trichomes, micro-crystals and starch granules are present in the abaxial layers of *Z. zanthoxyloides.* Trichomes were not observed in the abaxial layers of *Z. gilletti.* The adaxial layer of both leaves possesses epidermal cells and anticlinal walls but does not contain trichomes and stomates. The type of stomata present in both leaves is called the diacytic stomata. Both leaves can be said to be hypostomatic due to the presence of stomata in their abaxial layers and the absence of stomata in their adaxial layers.

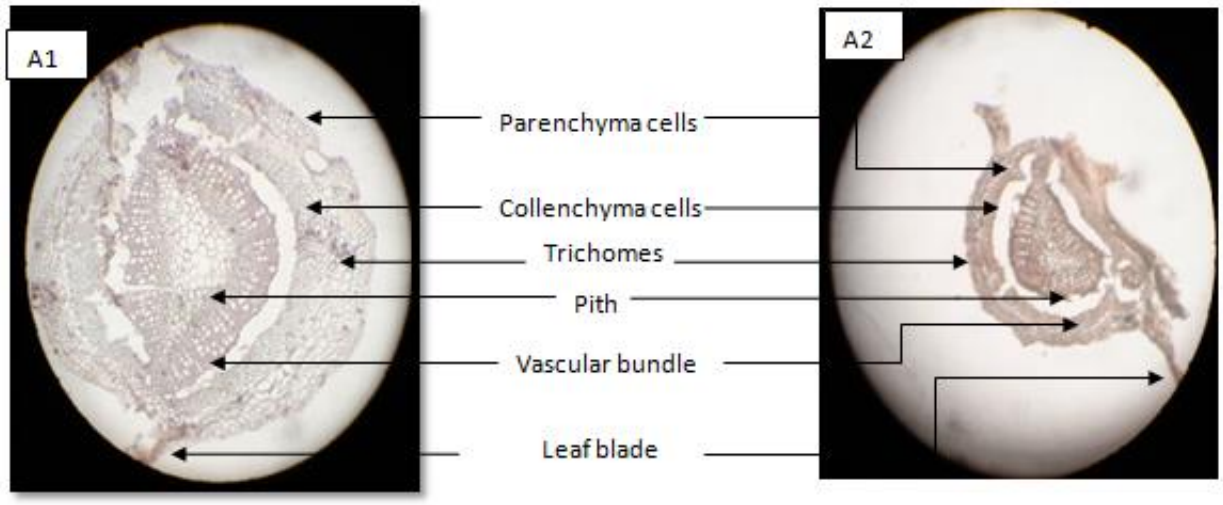

Figure 1: A1 and A2, Photomicrographs of transverse section of *Z. zanthoxyloides* and *Z. gilletti* leaves

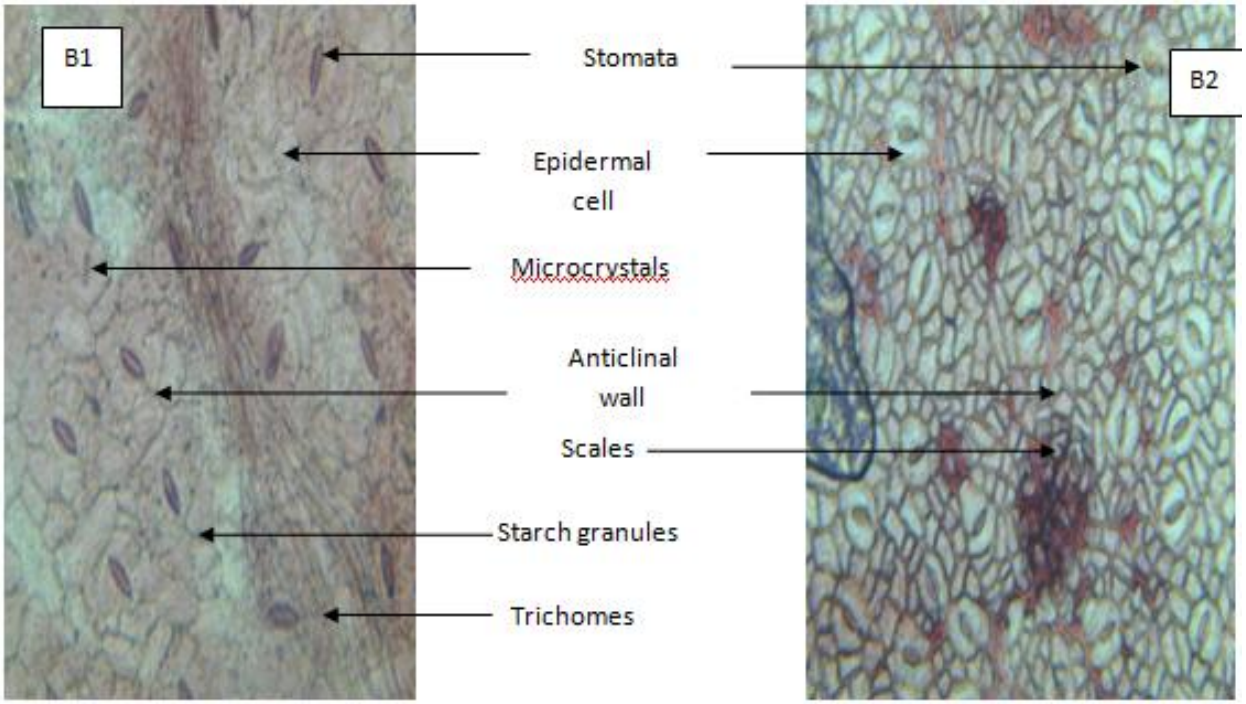

Figure 2: B1 and B2, Photomicrographs of Abaxial surfaces of the epidermal layer of *Z. zanthoxyloides* and *Z. gilletti*

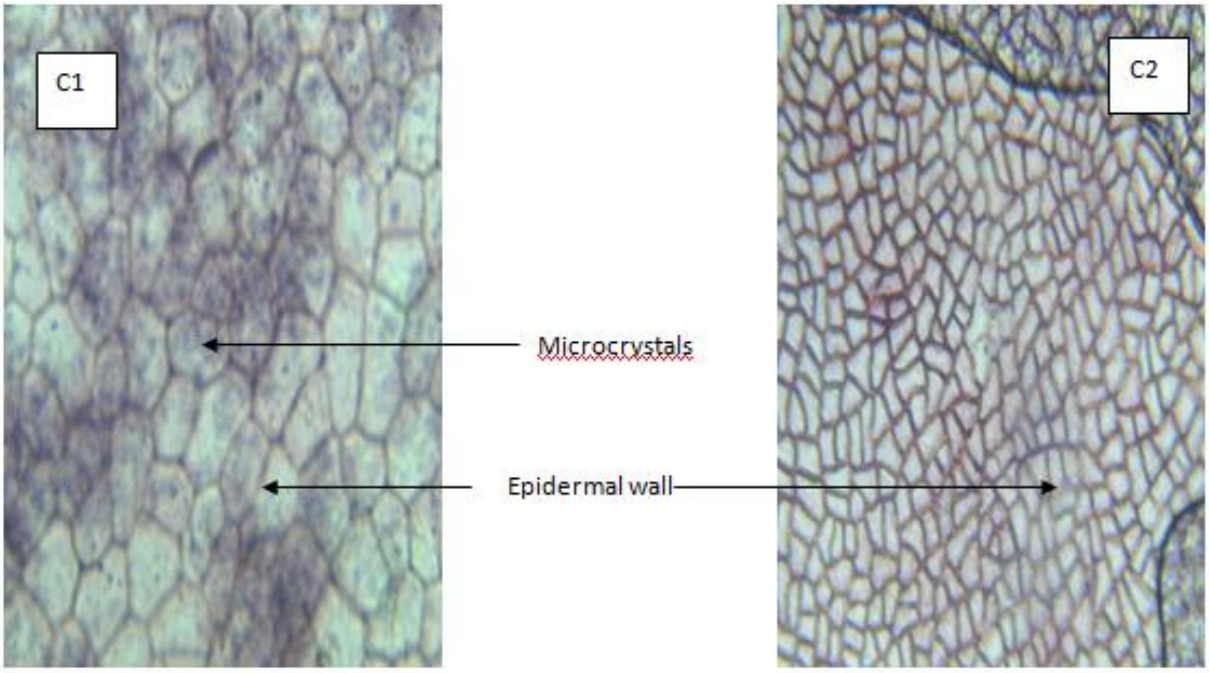

Figure 3: C1 and C2, Photomicrographs of Adaxial surfaces of the epidermal layer of *Z. zanthoxyloides* and *Z. gilletti*

Discussion

About 20 traces of vascular bundles were arranged circularly within the midrib of *Z. zanthoxyloides* and *Z. gilletti*. The ground tissues were mainly composed of parenchyma and collenchyma cells, which formed a sheath around the vascular bundles. This is contrary to Olaniyi et al. (2018), where the trichomes were found on the adaxial layer of *Crescentia cujete* L. leaves. It is pertinent to note that the epidermal cell sizes, anticlinal cell wall thickness and stomata sizes of *Z. zanthoxyloides* and *Z. gilletti* leaves are features that may be useful in the characterization of the studied species. The transverse section, and epidermal sections, provided ample variable characteristics such as stomata types, trichomes, presence of crystals, and vascular bundles that can be used to distinguish plants.

This is the first known report of the proximate composition of *Z. gilletti*. A previous report of the proximate composition of *Z. zanthoxyloides* by Olushola-Siedoks (2020) gave the moisture content, ash, crude protein, crude fibre, and crude fat to be 9.47 g/100g, 4.29 g/100g, 11.00 g/100g, 18.75 g/100g, and 6.36 g/100g respectively. However, the proximate composition of *Zanthoxylum alatum* Roxb., family Rutaceae gave the moisture, fat, protein, ash, and fibre contents to be 12.6 g/100g, 11.3 g/100g, 2.9 g/100g, 7.0 g/100g, and 1.4 g/100g respectively (Joshi et al. 2016). Protein is a necessary component of the human diet for the replacement of dead tissues, as well as the delivery of energy and the essential amino acids (Igile et al., 2013). According to the World Health Organization, all the moisture content, ash, crude protein, crude fibre, and crude fat values obtained in this study are within the acceptable limit of 18%. While "mineral content" measures the quantity of inorganic components, such as Ca, Na, K, and Cl, present in a food, "ash content" measures the total amount of minerals contained in a sample.

Moisture content is a significant quality factor in the stability and preservation of crude drugs. The plants are high in crude fibre, which can help lower blood cholesterol, heart disease, and hypertension. Crude fibre also relieves constipation and treats diabetes and breast cancer when taken in sufficient amounts (Ishida et al. 2000). The chemomicroscopic and quantitative leaf microscopic determinations revealed parameters that are distinctive to the plant studied, which are of great importance in its standardization (Olaniyi et al. 2020).

Conclusion

Micromorphology provides a tool for elaborating hidden features in a plant, which are essential for character assessment in plant taxonomy. Studies on the foliar micromorphology of medicinal plants are also crucial in establishing standards for identifying adulterated medicinal plants. This study showcased several features that differentiate the leaves of *Zanthoxylum zanthoxyloides* from those of *Zanthoxylum gilletti.* Despite the beneficial effect of herbal plants in traditional medicine, one major drawback is the misidentification and mistaken substitution of the medicinal plant with closely related species, which may lead to the problem of adulteration of the herbal product. Apart from the critical roles of micromorphological character assessment in plant taxonomy, studies on the foliar micromorphology of medicinal plants are also crucial in establishing standards for identifying adulterated medicinal plants. Consequently, evaluating the leaf powdered sample's micromorphology provides a cost-effective means in identifying, safely assessing and retrieving the original medicinal plant from crude drug materials.

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Therapeutic Potential of *Parquetina nigrescens (Afzel.)* Bullock: Bridging Ethnobotany and Modern Pharmacology

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Abstract

The importance of medicinal plants as food supplements and in treating diseases cannot be overemphasized. A wide range of ethnomedicinal use and pharmacological activities has been ascribed to *Parquetina nigrescnens*. Many studies have attempted to justify the ethnobotanical use of this plant species in the treatment of haematological disorders, diabetes, ulcers, and antibiotics, especially in Africa. This paper presents documented evidence on ethno-medicinal use, phytochemistry, and pharmacological activities based on a literature search from an online academic database using various search engines such as Google Scholar, Science Direct, and other relevant online sources. The commonly reported pharmacological activities include antioxidant, antisickling, antidiabetes, gastroprotective effect, antimalarial properties, anti-inflammatory and antiproliferative activities, and the ability to improve blood parameters and modulate sexual dysfunction. This plant's extract does not show any significant acute toxicity in experimental rats. Therefore, the existing body of evidence supports its folkloric uses.

Keywords: *Parquetina nigrescent*, Ethnobotany, Pharmacological activity, Medicinal Plants

Introduction

Medicinal plants constitute an important class of valuable plants that are important to the health of individuals and communities. Many rural communities in developing countries rely significantly on medicinal plants for their therapeutic needs against various ailments. Since time immemorial, these plant classes have been found helpful in the treatment and management of different health problems, as they have been found to contain an array of biologically active compounds that play active roles as therapeutic agents and have made significant contributions to maintaining human health (Oluwafemi and Debiri, 2008; Roshan *et al.*,2012). These plants are known to be cheaper, readily available, and widely used in non-industrialized/developing societies. It is commonly reported that more than 80% of the populations living in less developed countries rely almost exclusively on traditional medicine for their primary health care needs. The medicinal value of plants is attributed to some chemical substances that produce definite physiological actions in the human body (WHO, 2008). Several plants have been reported to have

medicinal effects across different regions due to bioactive chemical compounds. Some of these have been demonstrated to be significant in treating diabetes and its complications. One such is *Parquetina nigrescens*, which has a long and wide history of medicinal use. This review, therefore, attempts to collate the available scientific information on the plant's ethnobotanical, phytochemistry and pharmacological importance.

Methodology

Literature searches from online academic databases using various search engines such as Google Scholar, Science Direct, and other relevant online sources were accessed using the keywords *Parquetina nigrescens*, ethnobotanical survey, ethnopharmacology, pharmacology, toxicology, and other necessary words.

Description

Parquetina nigrescens is an herbaceous, perennial twine belonging to the family Asclepiadaceae. However, some authors have placed it in the family Apocynaceae, which may be because both families have close relationship and, therefore unified (Sennblad and Bremer, 1996; Endress, 2001). The plant is woody at the base, measures between 7-8 m in length, and is commonly found growing on anthills across African regions, from Senegal to Nigeria over the Congo basin and down to south tropical Africa (Saba *et al.*, 2010; Ayoola *et al.*, 2011; Okunrobo *et al.*, 2014).

It has relatively large and coriaceous leaves 10-15 cm long and 6-8 cm broad. The leaf arrangement is opposite, with both surfaces glabrous. Other features include cordate leaf shape and pinnate leaf venation with a distinct color on both surfaces, where the adaxial surface has a darker green shade than the abaxial surface (Sopeyin and Ajayi, 2016). It has fleshy coriaceous corolla with inside pink, maroon, or deep crimson to black-violet and pubescent or hirsute stamens with pollen in tetrads. The fruits come in horizontal follicles (Figure 1), with each narrowly ellipsoid to narrowly ovoid, 2–21 cm × 12–20 mm, 2-ridged apex slightly curved, many-seeded. The seeds are narrowly elliptical, brown to dark brown, warty, and have tufts of white hair (Alvarez-Cruz, 2012). Microscopic evaluation reveals hypostomatic leaves with paracytic stomata, presence of non-glandular trichomes (multicellular and possibly stellate) in the abaxial epidermal layer, prismatic calcium oxalate crystal, and polygonal epidermal cells with straight anticlinal walls (Sopeyin and Ajayi, 2016).

The common name for *P. nigrescens* is African parqueting, Nigerian local names attributed to this plant include "Ewe Ogbo" (Erinoso and Aworinde, 2012; Gbadamosi *et al.*,2012) Ogbo Ewidun, Inuwu elepe among the Yoruba ethnic group, kwankwanin in Hausa (Awobajo and Olatunji-Bello, 2010; Okunrobo *et al.*, 2014; Gbadamosi, 2015), Mgbidim gbe (Okunrobo *et al.*, 2013), and otonta in Igbo (Gbadamosi, 2015), as well as Olilia Or Ovieukpakoma in Avianwu

(Etsako) languages (Okunrobo *et al.*, 2014). The leaves are the part commonly used for medicinal purposes. *P. nigrescens* is a critical component of Jubi Formula, a herbal formulation used in the treatment of anaemia in Nigeria (Erah *et al.*, 2003), while in Ghana, it is a significant component of Tina-A, an anti-asthmatic medicine developed for research purposes (Nsiah *et al.*, 2006).

Figure 1: Different Parts of *P. nigrescens* plant (Source: Original)

Ethnobotanical uses

The plants used by man for therapeutic purposes came about from observation of their definite physiological effect after ingestion. *P. nigrescens* has been used since time immemorial for specific medicinal purposes. It is essential one of the plants commonly used as heamatinics in Yoruba, (Nigeria) ethnomedicine to boost the blood; the leaves are squeezed with water and then filtered, and the filtrate is taken to increase blood (Gbadamosi *et al.*, 2012). The leaves of *P. nigrescens* are used by traditional birth attendants in antenatal care in the Southwestern states of Nigeria for the treatment of gestational diabetes and the improvement of haematological parameters (Awobajo and Olatunji-Bello, 2010). The leaves have also been reportedly used to treat fever and pain (a decoction of the leaves taken twice daily is specifically prescribed traditionally for the treatment of fever) by traditional medical practitioners in Ilorin, Nigeria

(Owoyele *et al.,* 2009) while it is also a component the decoction used in the treatment of malaria in Ilorin (Adetutu, 2015) and in Issia, Côte d'Ivoire (Guede *et al.,* 2010).

In Oyo state, Nigeria, the leaf of Parquetina is reputed to be used for treating intestinal worms and the roots for treating rheumatism (Adeyemi, 1993). It is also said to be an ingredient used in the treatment of insanity as well as an aphrodisiac in East Africa (Oloyede *et al.,* 2017). Other ethnobotanical uses of *P. nigrescens* include the treatment of gastrointestinal disorders in Nigeria (Odetola *et al.,* 2006); in Cote d'Ivoire, freshly crushed whole plant is used as an abortifacient (Nsiah *et al.,* 2006), while a mixture of the leave juice with capsicum extract is used for the treatment of menstrual disorder; and facilitate deliveries in pregnant women (Datte *et al.,* 1996). The plant is also used to manage and treat gonorrhoea, skin diseases, dysentery, and as a cardiac tonic. In central Africa, the latex is considered very toxic and widely used as an ingredient of arrow poison (Alvarez-Cruz, 2012), while in Ghana, *P. nigrescens* leaves and root poultices are used in the treatment of wounds such as boils, carbuncles, snakebites, new and old wounds (Agyare *et al.,* 2009).

Pharmacological Activities

Several studies have reported/demonstrated a wide range of pharmacological activities of *P. nigrescens*, some of which are summarized in this section.

Hematological and Antisickling activity

P. nigrescens is one of the medicinal plants reportedly used to manage sickle cell anaemia either through the modulation of blood parameters or reversal of the sickling process. The effects of the aqueous leaf extract of *P. nigrescens* on haematological parameters were studied in hemorrhagic anaemic rats, where a significantly progressive and dose-related increase was observed in red blood cell count, packed cell volume, haemoglobin concentration. In contrast, a decrease in white blood cell count was observed in test rats (Agbor and Odetola, 2001).

Furthermore, the erythropoietic potential of *P. nigrescens* was investigated by Agbor and Odetola (2005), where the effect of two weeks of administration of graded doses of aqueous leaf extract on erythrocyte indices and serum electrolytes following acute blood loss resulted in a significant increase in the measured indices which were initially reduced following blood loss. Crude ethanol and chloroform extracts of *P.nigrescens* leaves were also shown to significantly increase the Packed Cell Volume (PCV), Red Blood Cell (R.B.C.), haemoglobin, lymphocyte, neutrophil, and eosinophil concentration at doses of 50 and 100 mg/kg body weight (b.wt) in albino rats compared with the rats in the control group (Omoboyowa *et al.,* 2016). This observation was similarly reported for aqueous root extract of *P. nigrescnes* (Owoyele *et al.,* 2011); also, Adu-

Amoah *et al.* (2014) showed that rats treated with methanolic leaf and aerial part extracts of *P. nigrescens* at a concentration of 100, 300 and 1000mg/kg resulted in a lower white blood cell count compared to the untreated group; while most of the hematological parameters measured including the red blood cell, hemoglobin, and the haematocrits concentrations were found to be higher in the treated group compared to the untreated group.

In Nigeria, *P. nigrescens* is one of the components of Jubi Formula®, an herbal formulation prepared to treat anaemic conditions. The formula was shown to significantly cause the restoration of haematological parameters to normal levels in anaemic rabbits. At the same time, those not treated with the herbal preparation were reported to show a progressive decline in their PCV and haemoglobin concentrations, where the majority of them died before the end of the study (Erah *et al.*, 2003) however, a similar study by Nsiah *et al.,* (2006) shows *P. nigrescens* extract did not affect blood parameters of Sprague Dawley rats. This variation could be because of the extract's preparation method, where the powdered material was extracted under reflux condensation for 1h using water as a solvent in the latter's study.The synergistic effect of aqueous extracts of *P. nigrescens* alongside *Camellia sinensis* and *Telfaria occidentalis* on the proliferation of haemopoietic stem cells was reported by Olatunbosun *et al.* (2014), where it was observed that the three plants have synergistic proliferative inhibition. However, *P. nigrescens* in the sole application was shown to have moderate proliferation haemopoietic stem cell action when compared with the control without extracts. This implied that the plant may improve beneficial cell proliferation in cancer patients undergoing irradiation treatments.

The sickling process describes the polymerization of sickle cell haemoglobin (HbS) in the red blood cells of patients who have sickle cell disease during the deoxygenating (low oxygen tension) state into a gel or further into fibres, leading to a drastic decrease in the red cell deformities (Mehanna, 2001; Dash *et al.,* 2013). The anti-sickling testing of plant extracts aims to interfere with three stages of the sickling process: modification at the sickle gene level, HbS polymerization level, and the red cell membrane level (Dash *et al.*, 2013). Thus, a drug or therapeutic agent that prolongs the polymerization time of HbS is said to possess anti-sickling properties (Imaga *et al*., 2010a; Imaga, 2013). Image *et al.* (2010a) reported that *P. nigrescens* has significant anti-sickling activity as measured by the osmotic fragility testing, which shows the ability of the aqueous leaf extract to cause a reduction in osmotic fragility and its inhibitory action on haemolysis of Red Blood Cells (R.B.C.); as well as the *in vitro* anti-sickling activity as determined by inhibition of polymerization testing which shows that pre-treatment of sickle cell suspensions with extracts of parquetina inhibits the formation of sickle cells under severe hypoxia. The osmotic fragility test stems from the fact that a normal red blood cell is flexible and elastic, which enables it to move through narrow blood vessels. In contrast, the sickle cell (formed because of the polymerization of HbS under hypoxic conditions), on the other hand, is rigid and therefore, prone to lysis (Nurain *et al.,* 2017). Earlier studies by Kade *et al.* (2003) also reported the anti-sickling properties of the root extracts of *P. nigrescens*, this body of evidence

suggests that *P. nigrescens* could indeed be used in the management and treatment of anaemia and thus supports its use in the treatment of anaemic conditions.

Antioxidant Activity

The medical implications of free radicals have been the subject of interest for the past decades. Living organisms must continuously deal with generating reactive oxygen species, which are by-products of metabolism, and thus, defend themselves from the harm these radicals can do to cellular biomolecules. Antioxidants prevent the oxidative actions of reactive oxygen species/free radicals in living organisms. Plants that possess antioxidant activity have free radical scavenging activity. Several studies have recognized the antioxidant activity of *P. nigrescens* extracts using different *in-vitro* and *in-vivo* assays to demonstrate the antioxidant activity of diverse plants. Some of *the in-vitro* models that have been used include 2, 2- Diphenyl- 1 –picrylhydrazyl (DPPH), reducing power which describes the reduction of Fe^{3+}/ferricyanide complex to the ferrous form Fe^{2+}, ferric thiocyanate assays and many others.

The DPPH assay was used to test the free radical scavenging activity of ethanol leaf extract of P. nigrescens based on the positive influence of antioxidants on wound healing. Strong antioxidant potential was reported with an IC_{50} value of 10 µg/ml (Agyare *et al.,* 2009). The antioxidant activity of methanolic leaf extract of *P. nigrescens,* as determined using DPPH assay and ferric thiocyanate (F.T.C.) assay, showed appreciable concentration-dependent antioxidant activity, which compares favourably with standard antioxidant ascorbic acid (Imaga *et al.,* 2010b). Ayoola *et al.* (2011) also reported the in-vitro antioxidant activity of aqueous, methanol extract, and flavonoids extracted from the leaves and stems of *P. nigrescens.* Regarding DPPH scavenging activity, the reducing power assay results indicated that the flavonoid extract had the highest antioxidant activity, closely followed by the methanol and aqueous extracts in both assays. In an in-vivo study by the same authors, the effect of 50 mg/kg crude flavonoids extract from *P. nigrescens* on both serum and liver antioxidant enzymes of experimental rats after induction of oxidative stress with carbon tetrachloride (CCl_4) revealed that, while superoxide dismutase was not changed after oxidative stress in serum, catalase activity was significantly modulated; At the same time, lipid peroxidation and glutathione that were increased were also considerably reduced by the crude flavonoid extract, thus proving the antioxidant properties of the plant. Similarly, Edoge *et al.* (2017) reported that the crude, methanolic, and ethyl acetate/methanolic fractions of the seed extracts showed significant concentration-dependent DPPH radical scavenging activity and ferric reducing antioxidant power (FRAP) activities comparable to ascorbic acid at the studied concentration range of 25-100 µg/ml.

Nigrescigenin, one of the cardenolides isolated from *P. nigrescens* leaves, possessed free DPPH radical scavenging activity comparable with the standard antioxidant butylated hydroxyanisole (Oloyede *et al.,* 2018). Conditions such as gastric ulcers are associated with oxidative stress. Thus, the protective role of methanol extract of *P. nigrescens* against ischemia-reperfusion injury in the intestine of rats was demonstrated by Akinrinmade *et al.* (2016), where the extract

provided considerable alleviation of intestinal injury produced by ischemia-reperfusion injury. Certain substances and disease states, such as diabetes, ulcer, myocardial infarction, microbial infections, etc., cause oxidative stress, which the antioxidant defence system mitigates. For instance, the polyphenol rich fraction of *P. nigrescens* was shown to mitigate dichlorvos-induced cardio-renal toxicity where the reduced activity of common non-enzymic and enzymic antioxidants, as well as other oxidative stress markers (such as cardiac tissue superoxide dismutase, glutathione peroxidase, reduced glutathione, and elevated levels of malondialdehyde and myeloperoxidase) in the cardiac and renal tissues, was observed in experimental rats (Oyagbemi *et al.,* 2018). Studies by Adeyomoye and Adewoye (2018) reported that common oxidative stress markers such as glucose-6-phosphate dehydrogenase, lactate dehydrogenase, superoxide dismutase, glutathione peroxidase, and catalase enzyme activity, some of which are endogenous enzyme antioxidant defence system were found to be drastically reduced in alloxan-induced diabetic rats. Consequently, administration of the methanolic extract of *P. nigrescens* was found to increase the activity of the enzymes, especially at the higher dosage of 200 mg/kg. In comparison, superoxide dismutase activity was increased at 100 mg/kg.

Antimalarial Activity

Malaria remains an acute public health issue in many developing countries. Despite the advances in medical research on antimalarial drugs, many people in rural areas still rely on medicinal plants for the management and treatment of malaria. Some ethnobotanical studies have shown that some localities used *P. nigrescens* to treat malaria. However, studies by Guede *et al.* (2010) concluded that the ethanol leaf extract of *P. nigrescens* had weak antiplasmodial activity with an IC_{50} value of 20.3 µg/ml among other studied plants, while Adetutu (2015) reported that the aqueous leaf extract of *P. nigrescens* showed significant antimalarial activity. Nafiu *et al.* (2014) examined the antimalarial activities of aqueous leaf extracts of *P. nigrescens* and its synergistic effect with *Tithonia diversifolia* in mice infected with chloroquine-sensitive *Plasmodium berghei*. The aqueous extract of *P. nigrescens* displayed good activity against the malaria parasite, significantly reducing percentage parasitemia, 86% chemo-suppression after 5 days, and 18 days mean survival time. The combination of parquetina with *T. diversifolia* also gave 90% chemo-suppression at day 5, thus supporting its inclusion in traditional herbal preparations for the treatment of malaria.

Antidiabetic Activity

According to the World Health Organization, diabetes is a condition whereby enough insulin is either not produced or the body cannot use the insulin made, leading to excess glucose in the blood (WHO, 2023). The extracts of *P. nigrescens* have been shown to have antidiabetic effect. Studies by Awobajo and Olatunji-Bello (2010) revealed that in normoglycaemic rats, the hypoglycaemic action of the leaf extracts of *P. nigrescens* was shown to be dose-dependent where the aqueous extracts expressed its hypoglycemic effect at lower concentrations while the

methanolic extract showed hypoglycaemic activities at higher concentration. A similar study by Saba *et al.* (2010) also indicated that diabetic rats treated with aqueous extracts of *P. nigrescens* showed a significant reduction in their blood sugar levels, which is comparable to those of non-diabetic control rats and those treated with standard drug (chlorpropamide). Some management techniques for diabetes require diets that release sugar slowly; the enzyme α-Glucosidase helps break down carbohydrates; thus, inhibiting this enzyme delays the breaking down of carbohydrates in the small intestines and consequently prevents hyperglycemia. Enzyme inhibition studies revealed that 17α-strophadogenin and nigrescigenin, two compounds isolated from the leaves of *P. nigrescens,* demonstrated significant activity in inhibiting α-glucosidase in-vitro (Oloyede *et al.,* 2018).

Antibacterial activity

Drug resistance is a common problem with the treatment of bacterial infections, researchers have shown that the causative agent of some bacterial infections have developed resistance to most conventional antibiotics used to treat them. Consequently, research is currently focused on plant based therapeutic substance with antimicrobial activity that will solve this problem (Chowdhury *et al.*, 2021; Arip *et al.,* 2022). Aqueous extract of *P. nigrescens* was shown to be active against a wide range of bacteria including *Staphylococcus aureus, Salmonella typhi, Proteus mirabilis* and *Pseudomonas aeruginosa* while the ethanol leaf extract was reported to be active against *P. aeruginosa* and *S. typhi* only (Odetola *et al.,* 2006). At the concentration of 100, 250 and 300 mg/ml, Makanjuola *et al.,* (2010) tested the aqueous and ethanol extracts of *P. nigrescens* against clinical bacterial isolates such as *Pseudomonas aeruginosa, Staphylococcus aureus, Klebsiella pneumoniae, Enterococcus feacalis, Escherichia coli* and *Salmonella typhi.* These researchers revealed that *S. aureus, P. mirabilis* and *S. typhi* were inhibited effectively by both the aqueous and ethanol extracts at all concentrations and *P. aeruginosa* to a lesser extent, with the ethanol extract exhibiting more significant inhibitory potential on the tested organisms except *E. coli* which was resistant to the highest concentration used in the study.

Using the agar cup diffusion method, Oluwafemi and Debiri, (2008) tested the hot water, cold water and ethanolic extracts of *P. nigrescens* leaves on *S. typhi* the causative organism for typhoid fever, and revealed that the extracts exhibited appreciable activity comparable with some standard drugs. In a related study, the sensitivity of *S. typhi* to the ethanol, hot water and cold water extracts of *P. nigrescens* was reported by Akinyemi and Dada (2013) using the disc diffusion method and the determination of minimum inhibitory concentration and minimum bactericidal concentration. The ethanolic extract produced the highest zone of inhibition at a dose of 300 mg/ml, which is significantly higher than that of some of the standard drugs tested. Silver nanoparticles made from hot water extract of *P. nigrescens* was shown to have activity against certain pathogenic microorganisms such as *E. coli, S. aureus, B. subtilis,* and *S. typhi* (Ogunsile *et al.,* 2016). Aqueous extract of *P.* nigrescens was reported to be inactive against multidrug resistant strains of *Escherichia coli,* Salmonella *gallinarum, Acinetobacter* species,

Staphylococcus aureus and *Pseudomonas diminuta* isolated from dog and poultry with the only activity observed against *Corynebacterium diphtheria* (Oyagbemi *et al.*, 2013). The activity of *P. nigrescens* extract on gastrointestinal microflora flora of rats was investigated using both in-vitro and animal models by Oloyede *et al.,* (2017). The authors reported that extracts of *P. nigrescens* reduced the microbial count of some beneficial microbes inhabiting the gastrointestinal tracts of Wistar rats, thus highlighting the need for standardization of the plant extract for appropriate dosage recommendation.

Analgesic and Anti-inflammatory

The analgesic and anti-inflammatory activity of aqueous leaf extract of *P. nigrescens* was demonstrated on experimental rats using the formalin paw licking and hot plate latency test for the analgesic test and cotton pellet granuloma, carrageenan test and arthritis model for the anti-inflammatory studies where the extract was shown to possess analgesic and positive anti-inflammatory activity (Owoyele *et al.,* 2009). In a similar study, the antinociceptive effect of methanolic extract of the fruit bark of *P. nigrescens* was demonstrated in experimental mice using the formalin-induced nociception test (an assay that demonstrates a distinct biphasic nociceptive response which are the neurogenic and inflammatory phases) and the acetic acid induced writhing response assay which investigated the peripherally mediated effect. Both assays thus, provide a likely mechanism of action as a pain-relieving agent. It was concluded that the methanolic extract of the fruit bark of *P. nigrescens* shows a dose-dependent analgesic effect in animal models both centrally and peripherally (Okunrobo *et al.,* 2014).

Gastroprotective Effect

Some authors have reported the use of P. nigrescens as a medicinal plant that inhibits gastrointestinal inflammation and gastric ulcers. The ulcer is described as a circumscribed erosion of mucosal tissue that occurs at various gastrointestinal tract sites exposed to gastric juice (Aderibigbe *et al.,* 2011). Thus, the ingestion of excess ethanol, administration of non-steroidal anti-inflammatory drugs (NSAIDs) as well as the colonization of the stomach with *Heliocobacter pylori* are considered the etiological factors that result in gastritis characterized by mucosal edema and sub-epithelial haemorrhage (Aderibigbe *et al.,* 2011). *H. pylori* is habitually dependent on the urease enzyme, whose deficiency effectively threatens its existence (Andrade-Cetto *et al.,* 2008). *In vitro* studies by Oloyede *et al.* (2018) suggested that cardenolides such as 17α-strophadogenin, nigrescigenin and strophanthidol, as well as the lipid-based fixed oil fraction isolated from the leaves of *P. nigrescens* demonstrated significant urease inhibitory activity thus, potentially mitigating cases of peptic ulcers and gastritis.

Ulcerogenic effect of a pharmacological substance assesses the ability of test extract to induce gastric mucosa irritation similar to that caused by non-steroidal anti-inflammatory drugs (NSAID), increased gastric acid secretions and gastric ulceration. Odetola *et al.* (2006) first reported the gastrointestinal protective properties of the aqueous leaves extract of *P. nigrescens*

where the experimental rats were pre-treated at a concentration of 100 mg/kg (b.wt) and 500 mg/kg (b.wt) before ethanol-induced ulceration. The results demonstrated the ability of the extract to significantly reduce gastric acid secretions, cause an elevated gastric mucus secretion and consequently modulate ethanol-induced gastric ulceration considerably at the higher dosage of 500 mg/kg (b.wt), thus justifying the claim of its having anti-ulcer properties. Owoyele *et al.* (2009), in their studies on the anti-inflammatory effect of the aqueous leaf extract of *P. nigrescens*, also tested the ulcerogenic effect of the extracts on mice. In their study, the animals were treated with aqueous extracts of *P. nigrescens* at a concentration ranging from 50-800 mg/kg (b.wt), and a standard NSAID indomethacin. The latter was found to increase ulcer index significantly. The result revealed that the extract did not induce gastric irritation compared to the standard NSAID, suggesting that the aqueous extract of *P. nigrescens* may have a soothing effect on the gastric mucosa.

Kayode et al. (2009) also investigated the therapeutic properties of hexane and chloroform leaf extracts of *P. nigrescens* in protecting mice stomach and liver from ulcer. The study tested two concentrations (500 mg/kg and 1000 mg/kg body weight) of hexane and chloroform extracts as a pre-treatment before ethanol at a concentration of 1 ml/200 g body weight was used to induce ulcer, with the resultant effect of gastric lesion and reduced activity of stomach and liver antioxidant enzymes: superoxide dismutase (S.O.D.) and catalase, as well as highly significant reduction in reduced glutathione (G.S.H.). The groups pre-treated with hexane and chloroform extracts of *P. nigrescens* were found to show nearly normal activities comparable to those treated with standard anti-ulcer drug, cimetidine. However, it is to be noted that both extracts showed anti-ulcer activity at different concentrations; for instance, hexane extract at a concentration of 500 mg/kg (b.wt) was able to reduce the ulcer index at a higher rate than at a concentration of 1000 mg/kg (b.wt) whereas, chloroform extract reduced the ulcer index more vigorously at the concentration of 1000 mg/kg (b.wt). Aderibigbe *et al.* (2011) also reported the gastroprotective effect of methanol leaf extract on mice through the antioxidant defence system, where the animals were pre-treated with 500 mg/kg and 1000 mg/kg b. The extract and gastric ulceration were assessed using the scoring index, lipid peroxidation, and antioxidant enzymes activities of gastric juice and gastric mucosa homogenate after ethanol-induced ulceration.

Modulation of Sexual Dysfunction

Using herbal plants as an aphrodisiac agent to boost libido is an age-long practice. *P. nigrescens* has been used in folkloric medicine in the management of sexual dysfunction; few studies have demonstrated this in animal models. For instance, Oyelowo *et al.*, (2012) reported that the aqueous root extract of *P. nigrescens* at doses between 50-150 mg/kg body weight caused a significant increase in the frequencies of mount and intromission, a decrease in the latencies of mount and intromission, prolonged latency of ejaculation and also a substantial increase in serum testosterone level of male Wistar rats. This suggests that the root extract exhibited aphrodisiac activities in male rats. However, they deduced that prolonged use of *P. nigrescens* aqueous root

extract may be harmful to the reproductive function of male rats, a position derived from the significant reduction in sperm quantity and quality during the study period coupled with the degeneration of the basement membrane, sperm maturity delay and reduction in epidydimal volume as observed in the histology of the testis after three weeks of extract treatment and the consequent improvement after withdrawal of extract administration. In a similar study by Kayode and Yakubu (2017), oral administration of aqueous leave extract of *P. nigrescens* at doses of 40 and 80 mg/kg significantly attenuated paroxetine (a serotonin-specific uptake inhibitor)-induced male sexual dysfunction by increasing the libido, copulatory efficiency, sexual arousal and sexual execution. Also, the biochemical indices arising from changes in reproductive hormones like testosterone, luteinizing hormones and follicle stimulation hormone were positively ameliorated at a higher dosage of 80 mg/kg; further study also indicated that the aqueous extract of *P. nigrescens* positively modulated spermatogenic, testicular and prostatic functions in paroxetine induced reproductive tissue dysfunctions (Kayode, 2018). In female Wistar albino rats, the methanolic extract of *P. nigrescens* was reported to increase the proliferation of follicles on the ovaries, while also inducing effects similar to oestrogen/oestrogen like substances on the female reproductive system (Akinjiola *et al.,* 2018). Thus, from these studies, *P. nigrescens* plant parts could serve as plant source of therapy for the treatment of sexual dysfunction.

Other Pharmacological Actions

The aqueous leaf extract of *P. nigrescens* was investigated for antipyretic activity in animal model; brewer's yeast was used to induce pyrexia as measured by the increase in rectal temperature of about 0.7 °C. The extract was found to significantly reduce the elevated temperature from the pre-drug/extract state, which is comparable with the standard antipyretic drug indomethacin applied, thus lending credence to its use in the treatment of fever (Owoyele *et al.,* 2009).

The ability of parquetina to protect the kidney and repair damaged renal tubular cells during different types of medical conditions such as hyperglycemia through the deployment of an antioxidant enzyme defence system in the renal tissue and reduction of some kidney function parameters like creatinine, blood urea nitrogen is also documented (Adeyomoye and Adewoye, 2018). Hydromethanolic extract of *P. nigrescens* was demonstrated to stimulate uterine contraction in isolated myometrium of pregnant rats. This was essentially done by inducing the mobilization of extracellular calcium responsible for the development of uterine contractile activity in a manner like oxytocin. This observed effect could, therefore, justify its use during labour (Datte *et al.,* 1996). Extract of *P. nigrescens* was shown to act like sympathomimetic drugs where it activated the contractile activity of portal veins isolated from Wistar Kyoto rats.

Another study reported that *P. nigrescens* extract acted like noradrenalin and tyramine by increasing the amplitude of spontaneous contractions (an effect reportedly due to α_1 receptor activation) of the rat's portal vein in a dose-dependent manner. The effect entirely suppressed by the prazosin ($\alpha_1$receptor antagonist), thus, suggesting that the extract contains direct and indirect

sympathomimetic principles which may justify its use in the treatment of conjunctivitis (Datte *et al.,* 1999).

The cardiotonic and catecholamine-like effects of the extract-induced contractile force of guineapig left and right atria were determined in-vitro and reported to increase the force of contraction in a dependent manner in electrically driven left atria (Datte and Ziegler, 2001). The cytotoxic effect of extracts of *P. nigrescens* has been tested against certain human cancer cell lines. The ethanolic extract was tested for anti-tumour activity on four human cancer cell lines addressing different cancer types (breast carcinoma cells, prostate carcinoma cells, colorectal carcinoma cells). The results showed a significant cytotoxic effect of the dose- and time-dependent extract (Onyegeme-Okerenta *et al.,* 2018).

Conclusion

The importance of medicinal plants cannot be overemphasized; *P. nigrescens* is one of nature's gifts loaded with a lot of medicinal benefits and well utilized by folks in African countries. However, care must be taken in its application as evidence from different studies suggest that it shows dose and time-dependent pharmacological activities and may require controlled usage to avoid unpleasant side effects from prolonged usage. Further studies on the scientific validation of other folkloric uses and identifying specific bioactive compounds are highly recommended. In addition, the fruits are lesser known and researched in terms of medicinal properties, thus, it is essential to explore the medicinal potential of the fruits also.

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Effectiveness of DNA barcoding in identifying species of the African *Isolona* using selected chloroplast markers

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Abstract

Isolona is a genus mostly found in lowlands and mountainous forests across Africa with distinct characteristics. Identifying species within this genus based on morphological characteristics has led to some taxonomy inconsistencies. Using Chloroplast markers will ensure a proper identification of morphologically related species within this genus. In this study, 31 sequences of single barcodes matK (5), rbcL (6), and trnL (20) were used to assess the phylogenetic relationships among the species of *Isolona* of providing efficient information on their proper Identification. The sequences were aligned using the ClustalW component of MEGA 11. Genetic characteristics, best match and close match identification, barcoding gaps, haplotype diversity, and nucleotide diversity of the barcodes used were determined. Also, a phylogenetic tree was constructed using the Neighbor-joining method implemented in MEGA 11. The aligned sequence showed that number of variable sites ranged from 8 (rbcL) to 984 (matK+rcL+trnL), while parsimony-informative sites varied from 2 (rbcL) to 775 (matK+rbcL+trnL). The average intraspecific distance for all single and concatenated barcodes was found to be zero (0), while the average interspecific distance ranged from 0.006 (matK0 to 1.05 (matK+rbcL+trnL). Results also showed that matK had the highest for best match (80%) and best close game (60%) identification. The phylogenetic tree analysis revealed that all species are monophyletic except *Isolona hexaloba, I. cauliflora, I. campanulata,* and *I. cooperii* which are paraphyletic. The results of this study can be applied to the classification of the genus *Isolona,* most especially where Identification using morphological characterization has proved inefficient.

Keywords: ***Chloroplast markers, Isolona, matK, rbcL, trnL, diversity***

Introduction

Isolona is a tropical African genus in the family Annonaceae with about 20 species and comprises trees and shrubs with a range of height between 30-40m (Couvreur, 2008). It can be found in lowland and mountainous forests throughout Africa, from West to East. These genera have unique characteristics within the Annonaceae, with their female reproductive parts enclosing the ovules, called carpels, fused and in a state referred to as syncarpy (Couvreur, 2015). The rest of the Annonaceae and most of the taxa in the Magnoliales are distinguished by their apocarpy or freely organized carpels. These unique characteristics have made many scientists and researchers conclude a close relationship between this genus and another genus (Monodora) in the family. The diverse species of plants and other living organisms can be traced to the global warming affecting regional climate and ecosystem, leading to physical and biological changes throughout the planet. Therefore, the need to develop a technique to identify plants and other living organisms and differentiate between very closely related species is required to conserve species diversity (Purty and Chatterjee, 2016).

Identifying species based on morphological characteristics could be difficult, especially when species possess similar characteristics (Lestari and Azrianingsih, 2019). Some features in species might not be visible, and the absence of some morphological features can make Identification impossible (Fitri, 2015). Different genera display variations, but species within the same genus are similar phenotypically and have constituted many problems for taxonomists using morphological Identification alone. Thus, the advent of DNA barcoding gives more detailed information on variations of closely related species. DNA barcoding is a strategy that uses standardized and conserved yet different sequences of Chloroplast markers that are

variable enough to distinguish closely related species for conservation (Kang et al., 2017; Fatima et al., 2019). Taxonomists are urged to differentiate species according to their molecular information rather than just identifying based on morphological characteristics, as this will help to streamline the gap of information on species identification (Al-Samarai and Al-Kazaz, 2015). This study was therefore designed to provide genetic information that could be invaluable in identifying the species of *Isolona* using chloroplast markers such as rbcL, matK, and trnL.

Materials and Methods

Three Chloroplast markers/barcodes were selected based on their availability, their identified ascensions, and barcode length of 300bp and above. The barcodes include MatK, rbcL, and trnL. A total of 31 sequences were retrieved from the National Center for Biotechnology Information (NCBI) website (https://www.ncbi.nlm.nih.gov) (Table 1) and used for this study. This comprised five (5) sequences of matK, six (6) sequences of rbcL, and twenty (20) sequences of trnL. The downloaded sequences were manually cleaned using the Molecular Evolutionary Genetics Analysis Software Version 11 (MEGA11) by replacing letters that are different from the standard nucleotide bases (ATCG) with the correct letters using the nucleotide table (Table 2). The cleaned sequences for each barcode were aligned using the Clustal W of the MEGA11 package (Kumar et al., 2018), which provided information on parsimony and variable sites. Each sequence file was duplicated and converted to a 'txt' format to allow importation into the Taxon DNA software (Meier et al., 2008), which was used to determine the matching identification rate of each barcode.

All single and concatenated barcodes ' range of intra and inter specific distances were computed using the aligned sequence saved in a file format and exported to ExCaliBAR software (Onefeli, 2021) for calculation. The ExCaliBAR software calculates the distance data and exports the result in an Excel spreadsheet. The sequences in 'txt' format were imported into the Taxon DNA to derive the pairwise summary, range of intra and inter-specific distances, and the Best-match and Best-close match Identification. This information was copied and pasted into an Excel spreadsheet for proper arrangement. The Taxon DNA analysis provided the intra- and inter-specific distances at every 0.5% interval. The analysis result was used to plot a graph between both distances to reveal the presence of barcoding gaps among the markers used.

A tree-based analysis was performed to assess the discriminatory ability of the barcodes of the species. A phylogenetic tree was produced using the Neighbour joining tree method with the Kimura 2-parameter substitution model (Kumaru et al., 2018; Onefeli, 2021). Phylogeny was tested using a bootstrap method to estimate the branch support at 1000 sequence pseudo-replicates. Branch support of 50% and above was retained on the phylogeny tree. Kimura 2-parameter model is the most widely used among all the nucleotide substitution models for determining phylogenetic affinities and estimating genetic differences (Nishimaki and Sato, 2019). DNA markers can also reveal genetic and molecular diversities (Rungis et al., 2019). Molecular diversity indices (the number of haplotypes, haplotype diversity, and nucleotide diversity) were estimated using DNASp 6.0 (Rozas et al., 2017)

Table 1. Tree species and corresponding barcodes used for the study

S/N	Species	barcodes	length (bp)	Ascension no.
1	Isolona campanulate	matK	831	AY238963.1
2	Isolona campanulate	matK	775	KC627771.1
3	Isolona campanulate	matK	775	KC627596.1
4	Isolona campanulate	rbcL	1415	AY238954.1
5	Isolona campanulate	rbcL	705	KC628439.1
6	Isolona campanulate	rbcL	706	KC628204.1
7	Isolona campanulate	trnL	529	AY231287.1
8	Isolona campanulate	trnL	404	AY238947.1
9	Isolona campanulate	trnL	933	EF179318.1
10	Isolona campanulate	trnL	1076	JQ742033.1
11	Isolona capuronii	trnL	909	EU216708.1
12	Isolona California	match	824	EU169695.1
13	Isolona caulifora	rbcL	1425	EU169762.1
14	Isolona caulifora	trnL	907	EU169784.1
15	Isolona congolana	trnL	879	EU216704.1
16	Isolona cooperi	rbcL	1421	AY841626.1
17	Isolona cooperi	trnL	928	AY841704.1
18	Isolona dewevreii	trnL	767	EU216715.1
19	Isolona ghesquieri	trnL	833	EU216709.1
20	Isolona heinsenii	trnL	898	EU216710.1
21	Isolona hexaloba	matK	831	EU169696.1
22	Isolona hexaloba	rbcL	816	EU169763.1
23	Isolona hexaloba	trnL	751	EU169785.1
24	Isolona linearis	trnL	900	EU216711.1
25	Isolona maintlandii	trnL	888	EU216714.1
26	Isolona perriri	trnL	850	EU216707.1
27	Isolona pleurocarpa	trnL	909	EU216712.1
28	Isolona thonerii	trnL	317	EU216713.1
29	Isolona thonneri	rbcL	528	MN366651.1
30	Isolona zenkeri	trnL	879	EU216705.1
31	Isoolona zenkeri	trnL	875	EU216706.1

Table 2. Nucleotide symbol and their full meaning

Nucleotide Symbol	Full Name
A	Adenine
T	Thymine
C	Cytosine
G	Guamine
R	Guamine/Adenine
Y	Cytosine/Thymine
K	Guanine/Thymine
M	Adenine/Cytosine
S	Thymine/Cytosine
W	Adenine/Thymine
B	Guanine/Thymine/Cytosine
D	Guamine/Adenine/Thymine
H	Adenine/Cytosine/Thymine
V	Guamine/Cytosine/Adenine
N	Adenine/Guamine/Thymine/Cytosine

Results

Table 3 revealed the genetic characteristics of single barcode loci of the genus *Isolona*, showing the barcode length of aligned sequence for all the single barcode regions: matK (831bp), rbcL (1425bp), and trnL (1076). Of all the three single barcodes, the single barcode loci trnL recorded the highest number of variable sites (717), while rbcL had the lowest (8). Parsimony-informative sites ranged from 2 (rbcL) to 101 (trnL), with matK having 10 Parismony-informative sites. The intraspecific distance for all the single barcode loci for the genus *Isolona* was 0, while the interspecific distance varied from 0.006 (rbcL) to 1.5 (trnL), with the highest and lowest average being 0.006 (matK) and 0.18 (trnL) respectively.

In evaluating the characteristics of concatenated barcode loci of the genus *Isolona*, Table 3 shows that concatenated barcode loci matK+rbcL, rbcL+trnL, and matK+rbcL+trnL have the same barcode length (1425bp). In contrast, concatenated barcode loci matK+trnL had 1076bp (trnL). The three concatenated barcode loci matK+rbcL+trnL had the highest number of variable sites (984), while matK+rbcL had the lowest (493). The Parismony-Informative sites ranged from 486 (matK+rbcL) to 775 (matK+rbcL+trnL). The interspecific or congeneric distance varied from 1.3 (matK+rbcL) to 2.10 (matK+rbcL+trnL) with an average of 0.64 (matK+rbcL+trnL) and 1.05 (rbcL+trnL).

The efficiency of best match and Best close match identification for a single barcode is displayed in Table 4. matK had the highest correct Identification for best match (80%) and best close match (60%), followed by rbcL with 28.57% for both best match and best close match. The efficiency of Best match and Best close match identification for concatenated barcode can be found in Table 4. matK+rbcL had the highest correct Identification for best match and best close match (58.82% and 47.05%, respectively) followed by concatenated barcode matK+rbcL+trnL (best match; 41.66%, best close match; 27.77%).

The divergence of barcoding gaps of intra and interspecific distribution for the genus *Isolona* was determined by checking the distances at every 0.5% interval, and Figure 1 revealed that intraspecific distances exist for all single and concatenated barcodes with an overlapping of the distances between 19.5% and 20%. All single and concatenated barcode loci had a distribution of interspecific distances between 0% and 10%. Only single barcode matK and concatenated barcode matK+rbcL showed the distribution of interspecific distances between 1.0% and 2.0%

The phylogenetic tree generated using the three concatenated barcode matK+rbcL+trnL (Figure 2) indicates two significant groups. The tree revealed that all descendants are monophyletic except the descendants of *Isolona hexaloba, I. cauliflora, I. campanulata,* and *I. cooperii,* which are paraphyletic, i.e., belonging to the two different groups. In the genus *Isolona*, trnL displayed the highest diversity, followed by rbcL and matK, with haplotypic diversity of 1.000, 0.714, and 0.644, respectively (Table 5). Matk had the highest nucleotide diversity (0.00529) despite being the barcode with the lowest haplotype diversity.

Table 3: Characteristics of single and concatenated barcode loci of the Genus *Isolona*

Variable/Barcode loci	**MatK**	**rbcL**	**trnL**	**matK+rbcL**	**matK+trnL**	**rbcL+trnL**	**matK+rbcL+trnL**
Barcode length(bp)	831	1425	1076	1425	1076	1425	1425
Number of variable sites	12	8	717	493	831	910	984
Parismony-Informative sites	10	2	101	486	555	614	775
Ranges of Intraspecific distances	0	0	0	0	0	0	0
Ranges of interspecific distances	0-0.012	0-0.006	0-1.5	0-1.3	0-1.53	0-1.77	0-2.10
Average intraspecific distances	0	0	0	0	0	0	0
Average interspecific distances	0.006	0.03	0.18	0.64	0.71	0.75	1.05

Table 4. Best match and best close match identification for single and concatenated barcodes of the Genus *Isolona*

Barcode loci	Best match			Best close match			
	Correct (%)	Ambiguous (%)	Incorrect (%)	Correct (%)	Ambiguous (%)	Incorrect (%)	No match closer than 3%
MatK	80	0	20	60	0	20	20
rbcL	28.57	0	71.42	28.57	0	0	71.42
trnL	21.05	0	78.94	10.52	0	15.78	73.68
MatK+rbcL	58.82	0	41.17	47.05	0	11.76	41.17
matK+trnL	41.37	0	58.62	27.58	0	17.24	55.17
rbcL+trnL	30.76	0	69.23	15.38	0	11.53	73.07
matK+rbcL+trnL	41.66	0	58.33	27.77	0	13.88	58.33

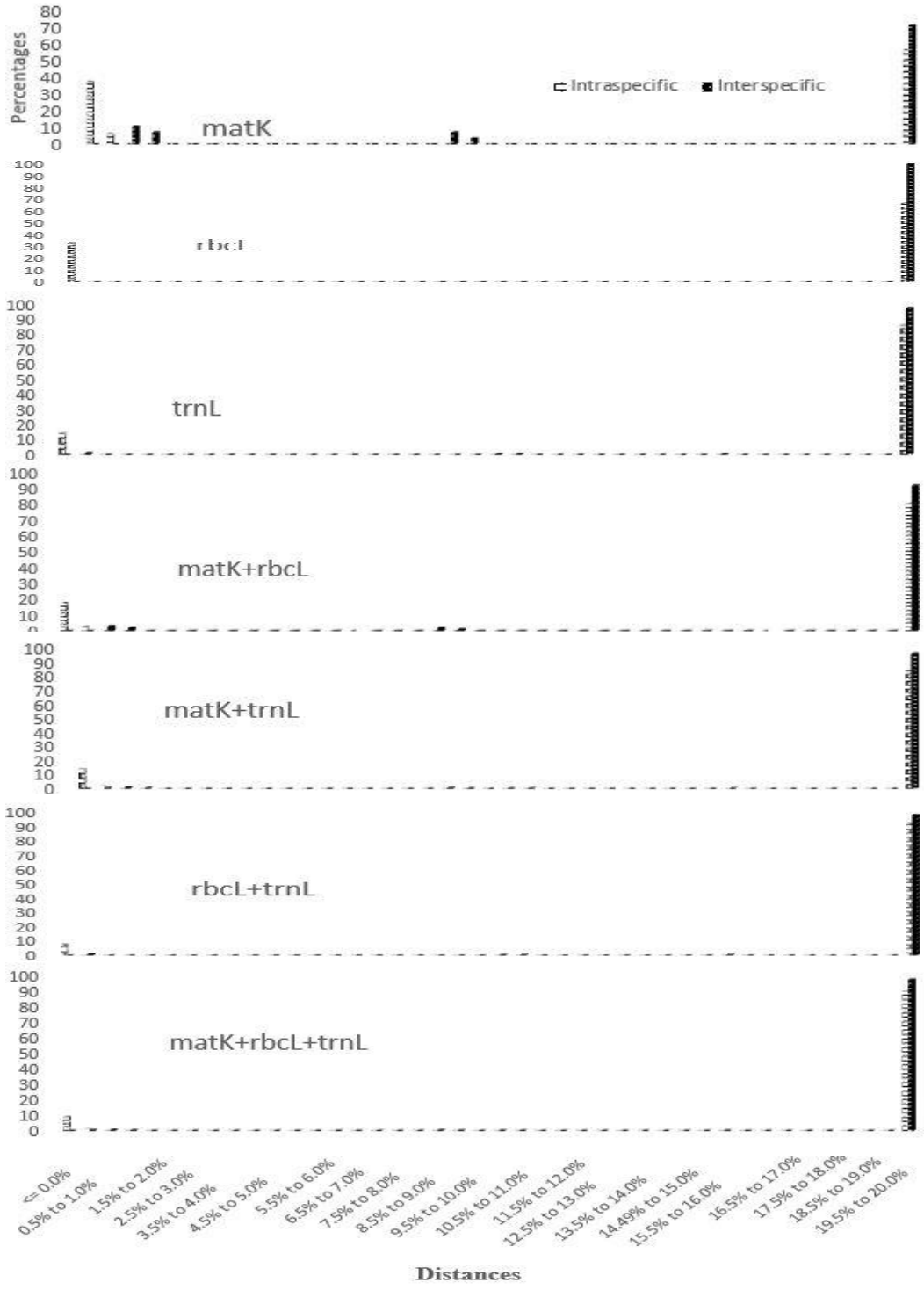

Figure 1: Barcoding gap with the distribution of inter- and intra-specific distances among all the samples of the genus *Isolona* for single and concatenated loci.

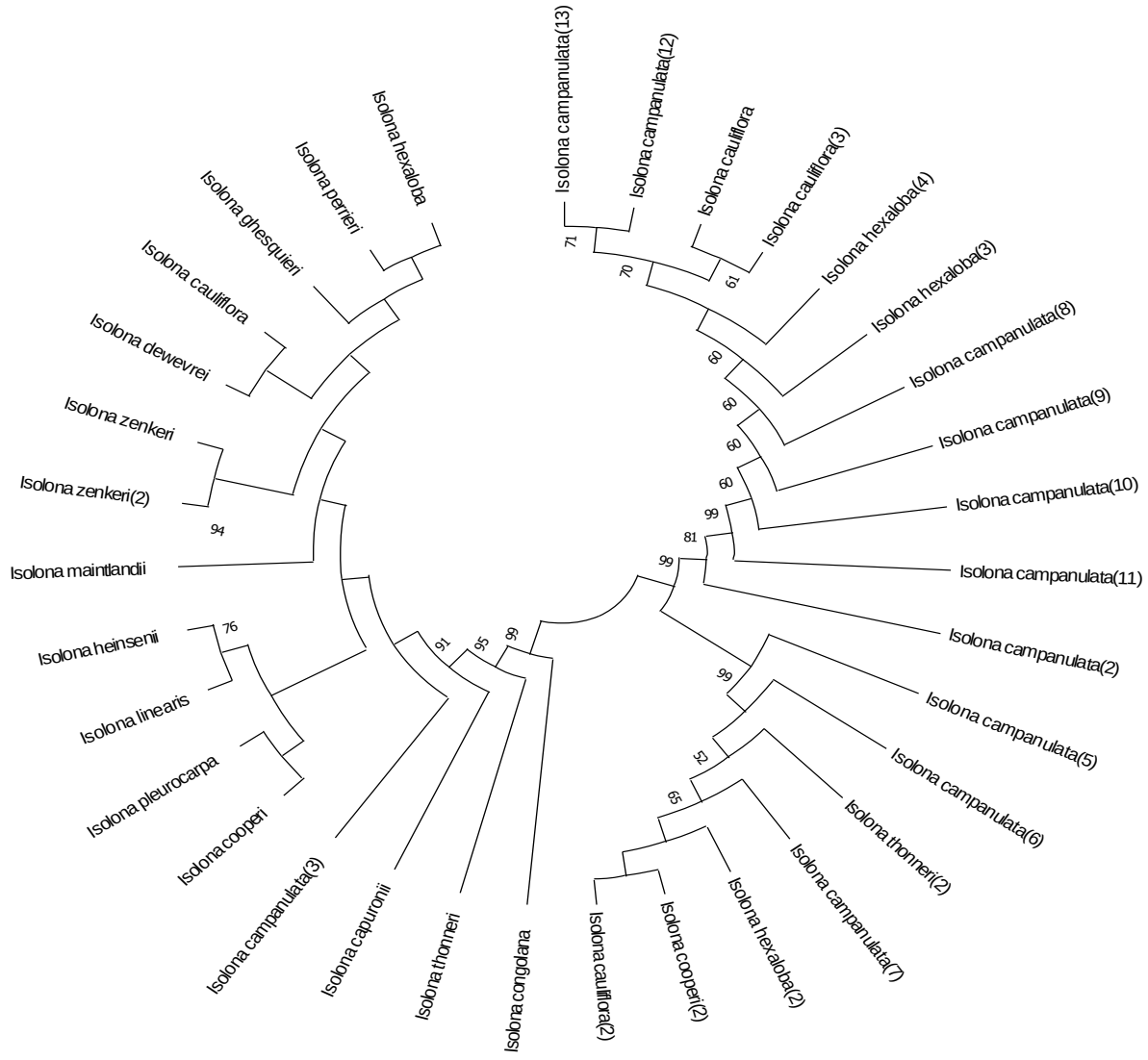

Figure 2: Phylogenetic tree generated using concatenated barcodes based on matK+rbcL+trnL sequence of the genus *Isolona*

Table 5: Diversity statistics of single barcode loci

Parameters	**matK**	**rbcL**	**trnL**
Number of segregating sites (S)	10	2	1079
Number of haplotypes (h)	4	3	19
Haplotype diversity (±SD)	0.64444±0.152	0.71429± 0.127	1.00000±0.000
Nucleotide diversity (±SD)	0.00529±0.00146	0.00216± 0.00036	0
Average number of nucleotide differences (Kt)	3.93333	1.14286	295.72515

Discussion and Conclusion

The identification properties of all single barcodes utilized in the study were assessed, and single barcode matK had the highest for best match and best close match in identifying all species of *Isolona.* Although single barcode loci matK had a perfect identification, few studies (Mishra et al., 2017) have mentioned that single barcodes are not variable enough to differentiate closely related species such as *Terminalia spp.* The effectiveness of a single barcode for Identification of plants could be species-specific when studying closely related species. Therefore, It is advisable to carry a combined analysis of single barcode matK with other DNA regions for taxonomic discrimination (Onefeli, 2021).

For concatenated barcodes used in identifying the species, matK+ rbcL had the best match and best close match Identification. The concatenation of rbcL with matK chloroplast gene sequences is an efficient tool for authentication of plant species and identifying alterations in genotypes (Awomukwu et al., 2015). Another study recorded that combined analyses of matK and rbcL were the most efficient multilocus barcode in placing more than half of the species of a particular genus (Li et al., 2019). The barcodes with a high number of variable sites (trnL, matK+trnL, rbcL+trnL, and matK+rbcL+trnL) all have a very low identification rate for both best match and best close match. This agrees with the study by Kavaliauskas et al. (2022), which states that highly variable loci do not guarantee the greatest and most meaningful evolutionary species discrimination.

Barcodes have been known to support morphological Identification, especially in complex and controversial taxa (Ha et al., 2018). In this study, considering single barcode identification, matK had the best discrimination ability and identification percentage rate. MatK has been classified by some experts as one of the core plant barcodes due to its efficiency in discrimination of plants in taxonomy (CBOL Plant of the World 2014, Onefeli 2021). RbcL has the longest barcode length followed by matK of all single barcodes. Concatenated barcode matK+trnL produced the shortest barcode length among all the concatenated barcodes used for Identifying the genus *Isolona*, and matK+rbcL had the highest barcode length used for identifying species of the genus *Isolona*. It is note-worthy that concatenation of matK and rbcL had a high performance of Identification in this study. Research has shown that a barcodes combination of rbcL and matK has higher resolution and exhibits higher discriminatory performance than any single marker (Li et al.,2019; Calleja-Cabrera et al., 2020;)

The term "barcoding gap" describes how mean intra- and interspecific sequence variables for congeneric COI sequences are distinguished (Meier et al., 2008). DNA-barcoding success for the taxon under study is frequently predicted using significant barcoding gaps (Seifert et al., 2007; Meier et al., 2008). Li (2020) states a barcoding gap between intra vs. inter specific divergences should exist. Some authors (Xu et al., 2015; Han et al., 2016; Adeoba et al., 2018) believe there should be a barcoding gap in barcodes to assess their appropriateness. The distribution of their divergence was checked at 0.5% interval units to evaluate these gaps. The result shows the existence of intraspecific distances for all single and concatenated barcodes with an overlapping of the distances between 19.5% and 20%. All single and concatenated barcode loci had a distribution of interspecific distances between 0% and 10%. Only single barcode matK and concatenated barcode matK+rbcL showed the distribution of interspecific distances between 1.0% and 2.0%

Although significant barcoding gaps did not exist in the seven tested barcode loci on discrimination of species of the genus *Isolona*, a significant level at the single barcode loci matK and rbcL. The least overlap exists in the concatenated barcode loci, which disagrees with the stamen that concatenated barcodes produce overlapping intra and interspecific divergence (Kijak et al., 2017). In this research, the intraspecific distances were more significant than the interspecific distances along 19.5% to 20% where the overlapping exists. Still, between the 0.0% to 4.0% region of all single and concatenated barcodes, the average interspecific divergence was found to be higher than their respective intraspecific variations(Pang et al., 2010) with the most significant difference found in single barcode rbcL.

The Neighbour-joining phylogenetic tree's frequently high branch support values show that the concatenated loci provided enough precision for within-species identification. The distribution of species into phyletic

groups is an indication of the diversion of genetic characteristics a species possesses that are different from its ancestors (Hörandl and Stuessy, 2010). *Isolona hexaloba, I. cauliflora, I. campanulata,* and *I. cooperii* being present in the two major groups of the phylogenetic tree generated indicates that the ancestors of these species do not include all its descendants. The paraphyletic group of species was once monophyletic before younger derivatives arose from that group. These younger derivatives could be influenced by environmental changes, which has altered their genetic make-up. This distribution into phyletic groups could also be related to the high genetic diversity recorded, most especially using the single barcode trnL, which could be a result of open pollinated nature of the species (Rungis et al., 2019)

The use of single barcode matK, rbcL, and trnL, however proved efficient in discriminating the species of the genera Isolona, also the concatenation of the three barcodes provided a tree that shows that the result of this study can be applied to the classification of the genus *Isolona* most especially where Identification using morphological characterization is abortive. Nevertheless, further research should be done if there would be a new identification of the species that existed in different phylogenies.

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CONSTRAINTS TO THE AGROFORESTRY PRACTICES AROUND ONIGAMBARI FOREST RESERVE, OYO STATE, NIGERIA

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Abstract

The study investigated the constraints faced by agroforestry farmers in the villages around Onigambari Forest Reserve Area of Oyo State, Nigeria. A multistage sampling technique was used to select eighty-three (83) respondents in the villages around the reserve. Data were collected using questionnaires. Descriptive and inferential analyses were used for the objectives and the hypothesis, respectively. The level of various types of agroforestry practices was high (62.7%), which resulted in a larger percentage of the respondents participating in agroforestry practices in the study area. The categorization level of the dwellers' constraints on the practices was slightly high, with the majority (66.3%) responses on the issues unfavorable in the study area. A positive relationship was identified between constraints and agroforestry practices (P = -0.000, r = -0.611). The study recommends aggressive support through the provision of tree seedlings and seeds, along with information dissemination to underscore the importance of these practices in the region.

Keywords: Agroforestry, Constraints, forestry, forest reserves, Agroforestry practices

Introduction

Agroforestry, the integration of trees or shrubs into farming landscapes for environmental conservation, has a rich historical background and is globally recognized for its benefits. According to IPCC, 2001, the benefits of agroforestry have been identified in global policy and many international assessments and scientific studies. This sustainable agricultural practice not only supplements food production but also enhances biodiversity in existing agricultural systems, given the urgent need to address deforestation and promote environmental sustainability. Agroforestry is a multifaceted agricultural approach beyond simply growing crops or raising livestock. By integrating trees and bushes into farming landscapes, agroforestry enhances the productivity and resilience of agricultural systems. One of its key advantages is its ability to complement traditional food production methods, particularly in areas where land resources are limited or degraded. According to Smith and Johnson (2023), the use of agroforestry is shared in an area where land and resources are scarce most especially in a forest zone of the world.

The ongoing destruction of forest areas due to human activities poses a significant threat to biodiversity and environmental sustainability, particularly in developing countries. Urgent action is needed to address this issue and prevent further ecological devastation. Finding a balance between

conservation efforts and the needs of local communities reliant on natural resources is a complex challenge (smith and Johnson, 2020). Agroforestry has emerged as a promising solution on the international stage due to its potential to enhance agricultural productivity and environmental conservation simultaneously (Nair, 2009).

In Nigeria, where stringent laws protect forest resources, some state governments have collaborated with forest users to promote agroforestry as a sustainable land use strategy. This initiative encourages residents to adopt diverse agroforestry methods, thereby supporting environmental sustainability while safeguarding livelihoods. However, stakeholders involved in agroforestry face numerous constraints that hinder its widespread adoption and implementation (Smith et al., 2017). To address these challenges and foster synergy between environmental conservation and livelihoods, research is being conducted to identify and understand the constraints associated with agroforestry practices in and around the Onigbamari forest reserve in Oyo state, Nigeria. This research seeks to provide insights into the barriers hindering the practical application of agroforestry and ultimately contribute to developing more sustainable land management practices.

i. What are the socio-economic characteristics of the respondent?
ii. What are the types of agro-forestry practices in the study area?
iii. What are the constraints to agro-forestry practices in the study area?
iv. Do any relationships exist between different types of agroforestry practices and constraints face in the process by the respondents in the study area?

Methodology

The study was conducted in villages around Onigambari Forest Reserve in Oluyole Local Government Area of Oyo State—the reserve is located between latitude 70º 25^{1}N and longitude 30º 50^{1}E. The target populations of the study were agro foresters' households in the communities around Onigambari enclaves of Oluyole Local Government, in Oyo State. (Aluko *et al*, 2019) Data were obtained with the use of a structure questionnaire. The villages were selected based on the 8km proximity to the reserve. Selected villages were Aba-Igbagbo, Akintola, Ajibodu, Okeseyi, and Lagunju. Systematic sampling techniques were used to select 18 respondents from Aba-Igbagbo, 12 respondents in Akintola, 15 in Ajibodu, 23 in Okeseyi, 15 respondents in Lagunju. The differences in the number of dwellers selected per community were due to the differences in the number of agroforesters in these communities. In all, 83 respondents were selected.

Result and Discussion

Table 1 revealed that 70% of the participants identified as male, while 30% identified as female. This suggests a gender disparity favoring males in agricultural engagement, likely due to the occupational demands. Additionally, the data indicates that the majority (56.6%) of respondents aged 40-59 years exhibited the highest level of participation. This finding implies that individuals within this age bracket demonstrate heightened energy levels conducive to environmental activities. Moreover, the Table illustrates that a significant portion (94%) of respondents possessed one or two educational certificates, suggesting a positive correlation between education and engagement in agroforestry practices. Furthermore, the majority (94%) of respondents reported having 1-20 years of experience in agroforestry, aligning with Oyewole's (2020) assertion that the average experience in agroforestry farming is 14 years.

Table 1: Socio-Demographic Profile of Respondents

Socio-Demographic Profile of Respondents		n(%)
Gender	Male	58(70)
	Female	25(30)
Marital Status		
	Single	19(22.8)
	Married	60(72.3)
	Divorced	4(4.8)
Age		
	20 -39 years	17(20.5)
	40-59 years	47(56.6)
	Above 60 years	19(22.9)
Level of Education		
	No formal education	5(6.0)
	Formal education	78(94)
Agroforestry Experience		
	1-20years	53(63.8)
	Above 20 years	30(36.2)

Source: (Field Survey, 2021)

Table 2 presents the outcomes concerning agroforestry practices among inhabitants within the study area, indicating that 60.2% of respondents maintain trees on their land, whereas 39.8% do not. This underscores the role of agroforestry in fostering farmer engagement in tree cultivation (Otegbeye and Ogigirigi, 1991). Additionally, 86.7% of respondents engage in shifting cultivation, suggesting that most lack a permanent farming site and instead move between various farmlands. This finding resonates with Ureigho et al.'s (2021) study, which identified shifting cultivation as a prevalent livelihood among farmers. Furthermore, 61.4% of respondents practice improved fallow, while 8.4% do not.

Moreover, 61.4% have scattered trees on their land, with 38.6% lacking such trees—additionally, 45.8% plant trees along their land boundaries. The data also indicates that 77.1% of respondents practice Tanguay farming, indicating widespread engagement in agroforestry within the study area. Furthermore, 55.4% of respondents engage in home gardening, suggesting using small farming spaces within their homes for agricultural activities.

Table 2: Types of Agroforestry practices in the study area

Variable	**Yes**	**No**
Retaining trees on landscape	50(60.2)	33(39.8)
Shifting cultivation	72(86.7)	11(13.3)
Improved fallow	76(91.6)	7(8.4)
Scattered trees on the landscape	51(61.4)	32(38.6)
Planting trees on the landscape	38(45.8)	45(54.2)
Taungya farming	64(77.1)	19(22.9)
Home Gardening	46(55.4)	37(44.6)

Source: (Field Survey, 2021)

Table 2.1 revealed that the level of agroforestry practices was high based on the responses from the more significant proportion (62.7%) of the respondents. This implies that the majority of the respondents are agro-foresters in the study area

Table 2.1: Categorization of respondents based on agroforestry practices

Level	Frequency	Percentage	Mean= 4.78
High	52	62.7	
Low	31	37.3	
Total	**83**	**100.0**	

Source: Derived from Mean Value

Table 3 displays the findings regarding the constraints to agroforestry within the study area. The results indicate that a significant majority (84.3%) of respondents identified the scarcity of incentives such as tree seeds and seedlings as a significant hindrance to practicing agroforestry. Amanor (1996) noted that farmers often refrain from tree planting due to the unavailability of seeds, supporting this observation. This suggests that agroforestry practitioners encounter challenges related to accessing necessary inputs. Additionally, a majority (91.8%) of respondents highlighted the lack of funding sources as a significant barrier to the advancement of agroforestry in the area. Furthermore, the majority (92.8%) of respondents identified insufficient extension services as serious impediments to agroforestry practice.

Table 3: Constraints to Agroforestry Practices in the study area

Variable	VSC	SC	MC	NC
Lack of incentives	70(84.3)	13(15.7)	-	-
Lack of technical know-how	4(4.8)	11(13.3)	10(12.0)	58(69.9)
Small farm holdings	1(1.2)	14(16.9)	10(12.0)	58(69.9)
Fire outbreak	1(1.2)	9(10.8)	34(41.0)	39(47.0)
Lack of funding sources	71(91.8)	1(4.8)	2(2.4)	1(1.2)
Inadequate extension services	77(92.8)	5(6.0)	1(1.2)	-
Poor market information	9(10.8)	31(37.3)	43(51.8)	-
Non-availability of manpower	5(6.0)	12(14.5)	12(14.5)	54(65.1)
Long gestation period	3(3.6)	40(48.2)	39(47.0)	1(1.2)
Trees casting down crops.	-	12(4.5)	16(19.3)	55(66.3)

Source: (Field Survey, 2021)

Note: VSC- Very serious constraints, SC- Serious constraints, MC- Mild constraints, NC- Not a constraint

Table 3.1 revealed that the level of constraints to agroforestry was high based on the responses from the more significant proportion (66.3%) of the respondents. This implies that agro foresters have a severe constraint in practicing agroforestry in the study area. (Otitoju, 2019)

Table 3.1: Categorization of respondents based on constraints to agroforestry.

Level	Frequency	Percentage	Mean=14.54
Low	23	27.71	
High	60	72.29	
Total	83	100	

The result in Table 4 reveals a a significant relationship between constraints to agroforestry practices and types of agroforestry practices. This implies that there is an issue in the application of various types of agroforestry to improve the agroforestry practices in the study area.

Table 4: PPMC analysis showing the relationships between constraints to agro-forestry practices and types of agroforestry practices.

Variables	r-value	P-value	Decision
Constraints and practice	-0.611	0.000	S

The result in Table 4 reveals a a significant relationship between constraints to agroforestry practices and types of agroforestry practices. This implies that there is an issue in the application of various types of agroforestry to improve the agroforestry practices in the study area.

Conclusion

Based on the empirical evidence gathered in this study, it emerged that a predominant proportion of respondents were male, possessing formal educational backgrounds. Furthermore, the research delineated the diverse array of agroforestry practices embraced by respondents within the study area, offering them a spectrum of operational options. This was substantiated by the comprehensive categorization table, affirming the widespread prevalence of agroforestry practices in the locale. Moreover, the study underscored the formidable constraints impeding agroforestry practices, signaling an urgent need for intervention.

Drawing from the study's insights, several recommendations were formulated. Primarily, there is a pressing necessity for the provision of extension services tailored to agroforesters within the study domain. Such services aim to enhance operational efficacy, augment farming skills, foster innovative approaches, and facilitate access to pertinent market information. Additionally, governmental initiatives are imperative, including the facilitation of financial support mechanisms such as loans to uplift the socio-economic status of farmers. Given the reliance on farming proceeds for sustenance, such financial interventions are paramount. Lastly, governmental agencies should institute incentives targeting farmers, encompassing provisions for agricultural inputs like chemicals, fertilizers, and mechanized equipment, alongside infrastructural enhancements such as improved access roads, crucial for efficient transportation of farm produce to markets.

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HEAVY METALS POLLUTION AND SOME WATER QUALITY PROPERTIES IN IKOGOSI WARM SPRING, SOUTH-WESTERN NIGERIA

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Abstract

This study thoroughly examines heavy metal contamination and water quality parameters in Ikogosi warm spring, exploring its suitability for fish biodiversity. The spring was divided into three locations and sampling points: IKW 1 – 4 tagged Ikogosi Warm Water points 1 - 4, IKC tagged Ikogosi Cold Water points 1 - 4, and IKM tagged Ikogosi Mixed Water points 1 – 3. Samples were collected fortnightly for five months from each sampling point. Most heavy metals in the samples, such as lead, copper, arsenic, chromium, cadmium, zinc, manganese, and magnesium, pose minimal health risks to fish populations based on their low Health Hazard Quotient (HHQ) values of 0, 0.005385, 0, 0, 0, 0.0012, 0.04, 0 respectively. However, nickel and iron have moderate HHQ values of 0.08 and 0.05333, respectively, indicating a potential impact on aquatic fauna although < 1. The mean values of temperature were highest and significant($P<0.05$) in IKW (38.25±1.52 ºC), dissolved oxygen in IKC (4.83±0.22mg/L), pH in IKW (6.31±0.10), and conductivity in IKM (103.10±0.36µS/cm). IKW had higher temperatures and conductivity levels, while IKC showed increased dissolved oxygen and pH contents. These variations affect habitat suitability, biological productivity, and water quality management. Continuous monitoring is essential to safeguard the environment and sustain biodiversity, especially in managing the moderate risks of nickel and iron contamination.

Keywords: Ikogosi, Metal contamination, Health Hazard Quotient water quality parameters, Health risks.

Introduction

Water, a fundamental resource for all life forms, is unequally distributed globally, emphasizing its scarcity (Akinsorotan et al. 2023). Its availability in the correct quantity and quality is required to sustain aquatic biodiversity (Iyiola and Asiedu 2020). Spring water originates from the movement of groundwater through fissures until it emerges on the earth's surface, and it constitutes a significant portion of the planet's water sources, with groundwater being the primary reservoir of freshwater. The concerns over the health issues from prolonged exposure to heavy metal contamination are increasingly alarming, which can result from both natural occurrences and anthropogenic activities (Morais et al., 2012). This issue is more pronounced in urban environments, where inhabitants face risks from constant exposure to heavy metals (Emumejakpor and Adewumi, 2023). Studies suggest

that contaminated soil or dust, ingested directly or indirectly, poses a significant health risk, especially to children who are more vulnerable due to their behaviors (Durowoju et al., 2018).

Moreover, heavy metals, although essential in trace amounts, can induce adverse health effects when present in excess, affecting growth and mortality rates and potentially causing mutagenic outcomes (Akinsorotan et al. 2023; Kolawole et al. 2023). Heavy metals, integral to the functioning of biological systems, also present ecological challenges as pollutants. Industrial processes, urbanization, and acid rain contribute to introducing heavy metals into water bodies, thereby impacting ecosystems and human health (Kumar et al., 2016; Kumari and Mishra, 2021; Iyiola et al. 2022).

Given that water serves as an avenue for heavy metal transmission, the concern intensifies in areas like Ikogosi. The area draws visitors globally as it is a prominent tourist destination known for its warm spring.

Furthermore, if water from Ikogosi is utilized for aquaculture, the potential bioaccumulation of heavy metals in fish poses risks to consumers (Ali & Khan, 2018). Adekeye et al. (2016) reported that the examination of heavy metal pollution in surface water resources within Ikogosi-Ekiti, South-Western Nigeria, serves as a baseline for the study. Therefore, this study was undertaken to determine the present condition of spring and its suitability for fish culture.

Materials and Method

Study area.

Ikogosi is a small town in the Ekiti West Local Government area of Ekiti State, about 55 kilometers from Akure, the state capital of Ondo State (Figure 1). Ikogosi warm spring lies about 2km west of Ikogosi town on longitude 4° 56.46'E and latitude 7° 36.88'N. The topographical elevation determined from the topographic map varies from less than 473 m in the valleys to 549 m on the hills (Ojo et al., 2011). The spring is a low enthalpy system, its temperature being around 36°C (Oladipo et al., 2005). The study area was within the tropical rain forest of Nigeria with two distinct seasons: rainy and dry seasons, signifying the climatic system. The wet season is because of the prevailing moisture-laden winds emanating from the Atlantic Ocean, while the dry season is from the North-East dry, hot, and dusty winds from the Sahara Desert. The area is characterized by annual rainfall of 1500mm, high relative humidity of between 70 – 85% with an average yearly temperature of 28°C.

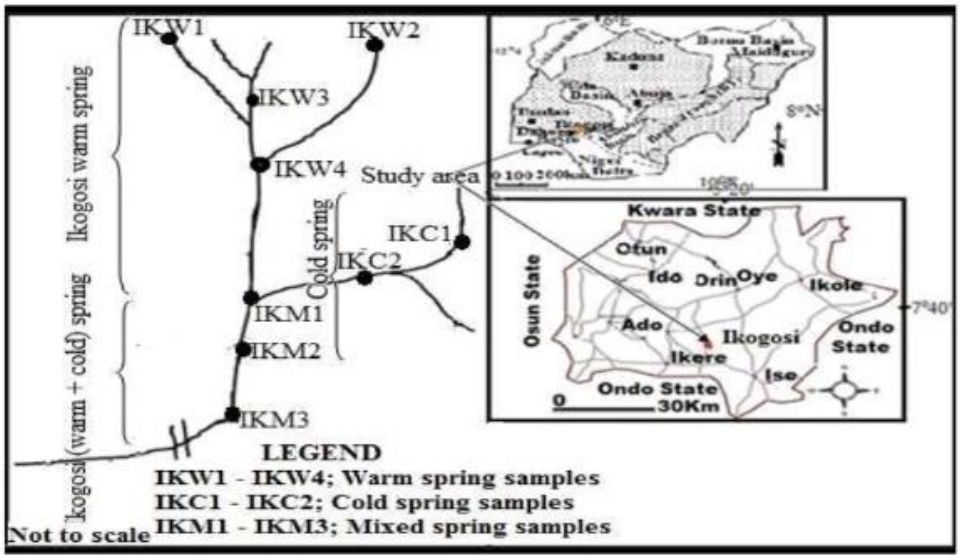

Figure 1: Map of Ikogosi water spring

Collection of water samples

The spring was divided into three locations: IKW – Ikogosi Warm Water, IKC – Ikogosi Cold Water, and IKM – Ikogosi Mixed Water. Samples were collected fortnightly using 100ml bottles from each of the sampling points for 5 months. The points were tagged as shown:

IKW 1 – IKW4 = Ikogosi warm water samples 1 - 4

IKC1 – IKC4 = Ikogosi cold water samples 1 - 4

IKM1 – IKM3 = Ikogosi mixed water samples 1 - 3

Heavy metal Analysis

The water samples collected were measured for lead, copper, arsenic, chromium, cadmium, nickel, zinc, iron, manganese, and magnesium. Water samples were preserved using nitric acid and were filtered to remove impurities**.** Metal concentrations in the water samples were determined utilizing an Atomic Absorption Spectrophotometer (Model AA32ON). Specific cathode lamps corresponding to each metal were employed in the spectrophotometer to emit light at respective wavelengths. The instrument quantified the amount of light absorbed by metal atoms, which correlates with their concentration in the sample. Calibration curves were established by measuring the absorbance of known metal standard solutions to estimate metal concentrations in the sample based on absorbance values. Each analysis batch included blanks to correct for background absorption or contamination, and certified reference standards were employed to verify the accuracy of the analytical method.

Water quality parameters

The water samples were measured for pH, dissolved oxygen, conductivity, and temperature. The pH was measured using a pH meter and calibrated using buffer solutions with known pH values of 4 and 7 to ensure accuracy. Subsequently, the water sample was poured into a clean, dry beaker, and the pH meter probe was immersed into the sample. The pH value was recorded on the meter, indicating readiness. Dissolved oxygen concentration was determined using the Winkler titrimetric method and recorded in milligrams per liter (mg/L). The water conductivity was measured using a conductivity

meter, and a meter reading was taken when a stable value appeared on the meter screen and recorded in milliSiemens per centimeter (µS/cm). Water temperature was measured using a mercury-in-glass thermometer, which was immersed into the water sample, and readings were recorded once the graduations stabilized and recorded at degrees Celsius (°C).

Health Hazard Quotient (HHQ)

The HHQ was determined according to USEPA (2021) using the equation below:

$$\text{HHQ} = \frac{\text{Average concentration}}{\text{Maximum Contaminant Level}}$$

A THQ below 1 implies that the fish can be considered safe for consumption with no potential associated risks (Salam et al. 2019).

Statistical analysis

Data were presented sing simple descriptive analysis involving means and percentages and Microsoft Excel 2021 was used for all graphical illustrations. Analysis of Variance (ANOVA) was used to determine the level of significance in water quality across IKW, IKC, and IKM using SPSS 25.0 package.

RESULTS AND DISCUSSION

Health Hazard Quotient Analysis

The Health Hazard Quotient (HHQ) values for each metal analyzed in Ikogosi Spring are presented in Table 1. Figures 1 and 2 present the mean values and health quotient of metals. Examining water quality parameters and their implications for heavy metal contamination risks and fish health in Ikogosi Spring provides crucial insights for fisheries and aquaculture management. Most metals detected in the water sample, including lead, arsenic, chromium, cadmium, zinc, manganese, and magnesium, exhibited Health Hazard Quotient (HHQ) values of 0, indicating minimal health risks to fishing activities. These metals are unlikely to cause significant harm to fish populations in the Ikogosi Spring ecosystem. Lead, arsenic, chromium, and cadmium were below the Maximum Contaminant Level (MCL) of 0.015 mg/L, 0.01 mg/L, 0.1 mg/L, and 0.005 mg/L, respectively. Copper was highest in IKW (0.008mg/L) with an average concentration of 0.007 mg/kg across the sampling locations, which falls below its MCL of 1.3 mg/L and HHQ value of 0.005385, suggesting minimal health risk. While copper toxicity in fish can lead to adverse effects such as gill damage and altered blood chemistry (Liao et al. 2023), the observed contamination levels are within acceptable limits. They are unlikely to cause significant harm to fish populations in Ikogosi Spring.

However, nickel and iron showed slightly elevated HHQ values, indicating a moderate health risk. Nickel exhibited the highest concentrations in IKW (0.005 mg/kg) and IKM (0.005mg/kg) with an average concentration of 0.004 mg/kg, below MCL of 0.05 mg/L and HHQ of 0.08. Iron was highest in IKW (0.018 mg/kg) with an average concentration of 0.016 mg/kg and below the MCL of 0.3 mg/L with an HHQ of 0.053. Although exposure to nickel and iron may lead to adverse effects such as gill damage and tissue damage, the risks are below the threshold of concern (HHQ < 1) (Salam et al. 2019). Thus, while there is some potential risk associated with nickel and iron, it is not severe enough to cause significant harm to fish populations in Ikogosi Spring. Zinc concentration was highest in IKW (0.007mg/kg) with an average concentration of 0.006mg/kg, below the MCL of 5 mg/L, and an HHQ of 0.0012. Manganese concentration was similar across the locations (0.002mg/kg), with an average concentration of 0.002mg/kg below its MCL of 0.05 mg/L and an

HHQ of 0.04. Magnesium's concentration was highest in IKW (9.12mg/kg) and was not a contaminant in drinking water at natural levels.

Adekeye et al. (2016) gave a comprehensive insight into the distribution patterns of heavy metals, offering valuable parallels to our findings within Ikogosi Warm Spring. Moreover, Adekitan et al. (2020) elucidated that health risk assessments associated with heavy metal contamination in the spring align with the determination of the Health Hazard Quotient (HHQ) as carried out in this study to gauge potential risks to fish populations. A comparison of HHQ values between our research and Adekitan et al. (2020) revealed a consistent narrative, underlining minimal to moderate health risks associated with certain heavy metals. The calculated HHQ values suggest minimal health risks from heavy metal contamination in Ikogosi Spring, but continued monitoring is advised.

Table 1: Metals and their respective HHQ values

METALS	IKC (Mg/kg)	IKW (Mg/kg).	IKM (Mg/kg).	AVERAGE (Mg/kg).	MCL(Mg/L) (USEPA 2021)	HHQ (< 1*)
Lead	0	0	0	ND	0.015	0
Copper	0.002	0.008	0.01	0.007	1.3	0.005385
Arsenic	0	0	0	ND	0.01	0
Chromium	0	0	0.002	0	0.1	0
Cadmium	0	0	0	ND	0.005	0
Nickel	0.003	0.005	0.005	0.004	0.05	0.08
Zinc	0.004	0.007	0.006	0.006	5	0.0012
Iron	0.014	0.018	0.016	0.016	0.3	0.053333
Manganese	0.002	0.002	0.002	0.002	0.05	0.04
Magnesium	6.24	9.12	8.26	7.87	-	-

IKC – Ikogosi cold spring; IKW – Ikogosi Warm Spring; IKM – Ikogosi Mixed Water, MCL – Maximum Concentration Level; HHQ – Health Hazard Quotient, (<1)* - recommended level of HHQ must be less than 1 (Salam 2019)

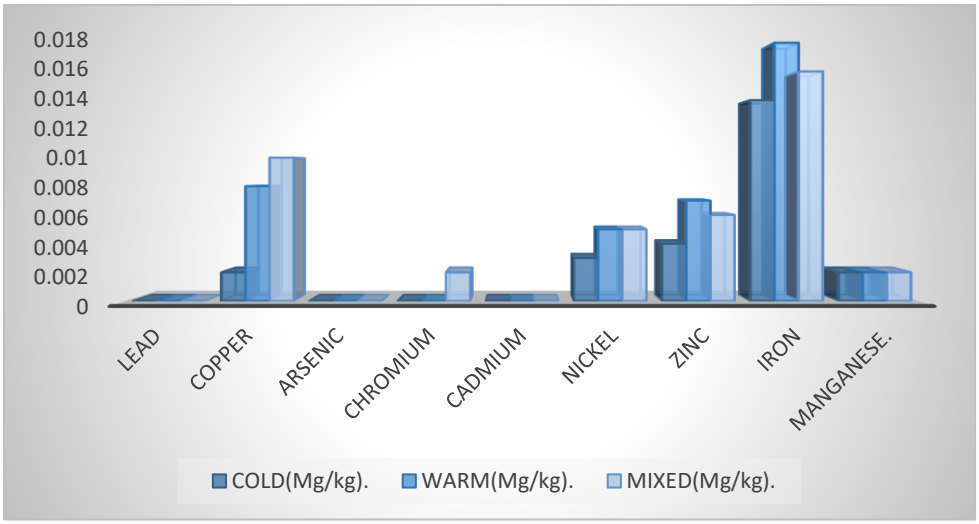

Fig 1: Metals and their respective values

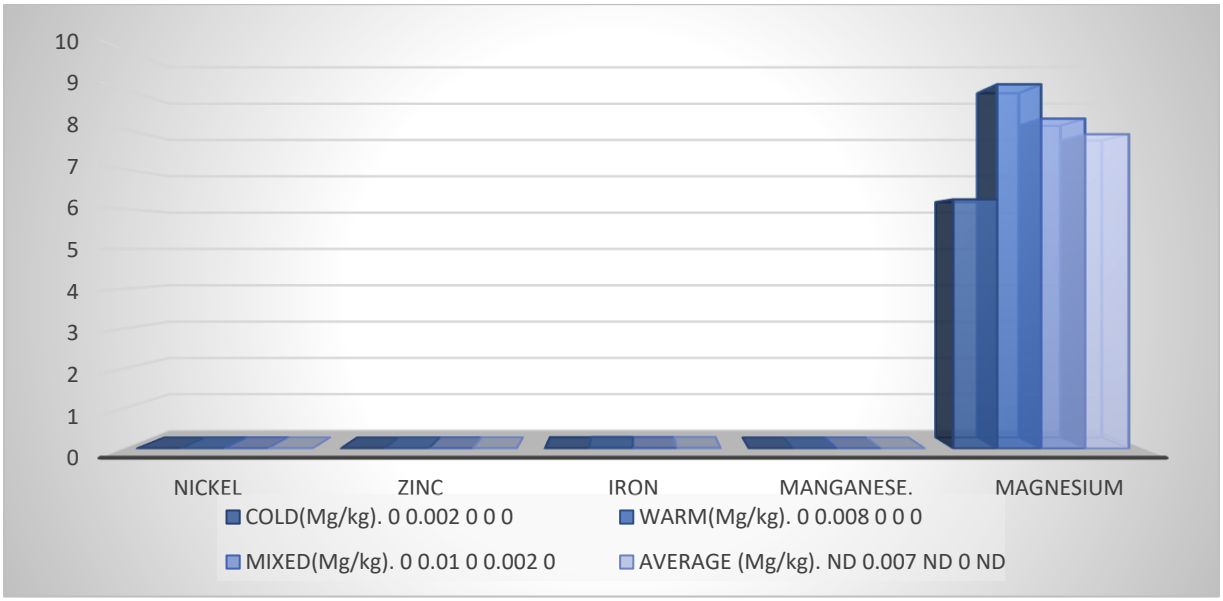

Fig 2: Metals and their respective health hazards quotients

Effects of Metal Presence in Ikogosi Spring on Fish

A summary of the potential effects that heavy metals may have on fish if the spring is harnessed for fish culture is presented in Table 2. It was observed that the water samples contained several metals, and their corresponding Health Hazard Quotient (HHQ) values indicated no significant health risk associated with their presence. Lead, arsenic, chromium, cadmium, and magnesium all show HHQ values of 0 and are expected to cause significant harm to fish health and behavior. Copper also exhibits a low HHQ value of 0.005385, indicating minimal health risk. While copper toxicity in fish can result in gill damage, reduced oxygen uptake, altered blood chemistry, and behavioral changes, the low HHQ suggests that the contamination levels are within acceptable limits and unlikely to cause significant harm to fish populations (Salam et al. 2021, Iyiola et al. 2017). While high levels of zinc in water can be toxic to fish, potentially causing gill damage, impaired growth, changes in behavior, and reproductive issues, the low HHQ suggests that contamination levels are within acceptable limits and unlikely to cause significant harm to fish populations.

Similarly, manganese, with an HHQ of 0.04, also suggests no significant effect on fish health. Although manganese toxicity in fish can lead to neurological damage, impaired growth, reproductive issues, and decreased resistance to environmental stressors, the low HHQ value indicates that contamination levels are within acceptable limits and are not expected to cause significant harm to fish populations (Adekeye et al. 2016). However, nickel and iron show slightly different results, indicating a moderate health risk. Nickel exposure in fish can lead to gill damage, respiratory distress, and alterations in enzyme activity. At the same time, iron accumulation can result in oxidative stress, tissue damage, and changes in enzyme activity. Although these values suggest some potential impact on fishing activities, they remain below the threshold of concern (HHQ < 1) (Salam et al 2021). Thus, while there is some potential risk associated with nickel and iron, it is not considered severe enough to cause significant harm to fish populations.

In summary, most metals in the water sample are within acceptable limits, posing minimal health risks to fishing activities. Nevertheless, ongoing monitoring and evaluation of water quality are essential to ensure the continued safety of fishing activities and environmental well-being.

Specifically, periodic assessments should focus on nickel and iron to manage any potential moderate risks they may pose.

Table 2: Effects of Metal Presence in Ikogosi Spring on Fish

Metals	Health Hazard Quotient	Effect on Fishes	The effect they can have on Fishes
Lead	0	No significant effect	Lead can accumulate in fish tissues and organs, leading to neurological damage, reproductive issues, and decreased growth rates. It can also affect fish behavior and impair their ability to evade predators.
Copper	0.005385	No significant effect	Copper toxicity in fish can result in gill damage, reduced oxygen uptake, altered blood chemistry, and behavioral changes. It may also impair fish reproduction and development.
Arsenic	0	No significant effect	Arsenic exposure in fish can lead to cellular damage, oxidative stress, and disruptions in metabolic processes. It may also increase fish mortality rates and impair their overall health.
Chromium	0	No significant effect	Chromium accumulation in fish tissues can cause DNA damage, altered enzyme activity, and disruptions in hormonal regulation. It may also lead to reproductive abnormalities and impaired growth.
Cadmium	0	No significant effect	Cadmium toxicity in fish can result in kidney damage, impaired calcium regulation, and skeletal deformities. It may also affect fish behavior, reproduction, and immune function.
Nickel	0.08	Significant effect	Nickel exposure in fish can lead to gill damage, respiratory distress, and alterations in enzyme activity. It may also impair fish reproduction, growth, and immune function.
Zinc	0.0012	No significant effect	High levels of zinc in water can be toxic to fish, causing gill damage, impaired growth, and changes in behavior. It may also affect fish reproduction and interfere with metabolic processes.
Iron	0.053333	Significant effect	Iron accumulation in fish tissues can lead to oxidative stress, tissue damage, and alterations in enzyme activity. It may also affect fish behavior, reproduction, and overall health.
Manganese	0.04	No significant effect	Manganese toxicity in fish can result in neurological damage, impaired growth, and reproductive issues. It may also affect fish behavior and decrease their resistance to environmental stressors.
Magnesium	0	No significant effect	Magnesium is an essential nutrient for fish, playing a role in various physiological processes such as osmoregulation and enzyme function. Its presence in water is generally beneficial for fish health.

Water Quality Parameters Analysis

The water quality measured across the locations is presented in Table 3. Encompassing water quality assessment, the HHQ is a critical avenue through which the analysis of temperature, dissolved oxygen, pH, and conductivity parameters can be contextualized (Akinsanmi et al. 2017). This holistic approach grants us a nuanced understanding of the intricate ecological dynamics shaping Ikogosi Warm Spring's environmental health. The results provided valuable insights into the characteristics of these different water types. IKW samples exhibited the highest mean temperature at 38.25°C. They were significant ($P<0.05$), indicating a relatively warmer environment, while cold water samples displayed a significantly lower mean temperature of 18.38°C, reflecting more excellent conditions. Mixed water samples fall between these extremes, with a mean temperature of

31.63°C. These variations in temperature among the samples suggest differing thermal regimes, which can influence aquatic habitats and biological processes.

Additionally, cold water samples exhibit the highest mean dissolved oxygen level at 4.83 mg/L, indicating more excellent oxygen saturation in colder water, while warm water samples display the lowest mean dissolved oxygen level at 4.23 mg/L, suggesting decreased oxygen availability in warmer conditions. Mixed water samples demonstrate intermediate dissolved oxygen levels at 4.28 mg/L. These differences in dissolved oxygen concentrations among the samples can impact aquatic organisms' respiratory processes and overall ecosystem health.

Regarding pH levels, warm water samples have the highest mean pH value at 6.31, indicating a slightly alkaline environment. Cold water samples possess a slightly lower mean pH value at 6.26, while mixed water samples show the lowest mean pH value at 6.21, suggesting a somewhat acidic environment. Variations in pH levels among the samples may influence chemical reactions, nutrient availability, and the overall health of aquatic ecosystems. Furthermore, warm water samples demonstrate the highest mean conductivity at 100.20 µS/cm, indicating elevated ion concentrations and electrical conductivity. Cold water samples display a lower mean conductivity at 63.65 µS/cm, indicating decreased ion concentrations and conductivity. Mixed water samples exhibit intermediate conductivity levels at 103.10 µS/cm. Variations in conductivity levels reflect differences in dissolved ions and can signify alterations in water composition and salinity levels among the different water samples.

In summary, the data highlights distinct differences in water quality parameters, including temperature, dissolved oxygen, pH, and conductivity, across warm, cold, and mixed water samples. As Bhatnager and Devi (2013) reported, the water parameters measured fluctuated around the recommended levels. These variations affect aquatic ecosystems, influencing habitat suitability, biological productivity, and water quality management. Understanding these discrepancies is paramount for assessing environmental conditions and implementing effective conservation and management strategies.

Table 3: Mean water quality parameters measured during the study.

Water Quality Parameters	**Mean ± SD**			**Recommended levels****
	IKW	**IKC**	**IKM**	
Temperature (^{o}C)	38.25±1.52*	18.38±3.58	31.63±0.92	25 – 32
Dissolved oxygen (mg/L)	4.23±0.22	4.83±0.22	4.28±0.28	3 - 5
pH	6.31±0.10	6.26±0.21	6.21±0.12	6.5 – 8.5
Conductivity (µS/cm)	100.20±0.70*	63.65±0.33	103.10±0.36	100 - 2000

* is significant at P<0.05, IKW – Ikogosi Warm Water, IKC – Ikogosi Cold Water, IKM – Ikogosi Mixed Water, **Bhatnagar and Devi (2013)

CONCLUSION

The analysis suggests that most metals in the Ikogosi Spring water sample are within acceptable limits, posing minimal health risks to fishing activities. Continuous monitoring of water quality parameters and heavy metal concentrations is essential to ensure the safety of fishing activities and environmental well-being in Ikogosi Spring. Periodic assessments should prioritize nickel and iron due to their moderate health risks. Concerning water quality parameters, temperature fluctuations are critical in influencing fish metabolism, growth rates, and behavior. Dissolved oxygen levels are crucial for fish respiration, with low oxygen levels posing risks of suffocation and disease

susceptibility. pH levels affect fish physiology and susceptibility to toxins, while conductivity reflects the presence of dissolved ions, indicating potential pollution sources or natural mineral deficiencies. Thus, the findings from this study have provided critical insights into the prevailing heavy metal contamination risks and their far-reaching implications for fisheries and aquaculture management in Ikogosi Spring and beyond.

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SUB-THEME:
BLUE ECONOMY

MANAGEMENT OF VARIABLES ASSOCIATED WITH FISH FARMING IN IBADAN, OYO STATE, NIGERIA

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Abstract

Fish feed is an important input in catfish farming and one of the profit-margin determinants the business. Therefore, this study assesses the variables and coping strategies in catfish farming in Ibadan, Oyo State, Nigeria. A multistage sampling method was employed in which three local government areas (Oluyole, Ido, and Lagelu) were purposefully selected among the eleven in Ibadan, Oyo State. A snowball sampling method was employed to administer 120 copies of the prepared structured questionnaire. Descriptive and inferential statistics were used to analyze the data obtained. The results show that all (100%) of the farmers agreed that the price of catfish feed is increasing, and the majority (84%) of them agreed that the increasing cost of fish feed hurts the business's profitability. Farmers employed measures such as increase the selling price of their fish (37.6%) and use homemade feeds (26.4%) to cushion the effects of high cost of feed, although poor-quality feed usually pollutes pond water. In addition, many (54.4%) farmers agreed that there is an advantage to buying fish feed in bulk. However, it is observed that the age and family size of the farmers influence the bulk purchase of catfish feed. Likewise, age, gender, education level, and family size had an influence on the impact of the high cost of feed on the profitability of the business in the study areas ($P < 0.05$).

Keywords: **Fish seeds, fish feed, stunted growth, catfish farmers, resources**

Introduction

In aquaculture, especially in catfish farming, challenges are evenly distributed across every stage of production, from the acquisition of ponds and fish seeds (fry, fingerlings, and juveniles) to the marketing of table-size catfish. The most prominent among these challenges, besides water, relates to the two major input resources, viz., the procurement of quality fish seeds and quality fish feed (Ajagbe *et al*. 2020). Water is an essential resource in fish farming which is required in both good quality and abundant quantity. Notwithstanding, in Nigeria, many catfish farmers usually ignore the cost of securing quality water in the required amount and, in addition, usually do not recognize it as a challenge that can limit catfish production. However, water, in an actual sense, is a limiting factor to the optimum productivity of fish (Mohammad and Haque, 2021). Water is to fish what air is to human beings. It is the immediate environment of fish that supports the existence of fish.

The quality and quantity of fish feeds contribute to the growth and harvest yield of catfish at the end of the production cycle. Many authors have adjudged its contribution to catfish production as the highest, which can be up to 70% of the total input resources (Ajagbe *et al.,* 2022; Onyekuru *et al.,* 2019; Ashley-Dejo *et al.,* 2017; Engle, 2010). Therefore, fish feed could be seen as a major determinant of profitability in catfish production (Eriegha and Ekokotu, 2017). For this purpose,

Zlaugotne *et al.* (2022) reported the need for efficient and sustainable fish feed, and most importantly, the feed costs must be economically justified.

Therefore, this study aims to assess how the catfish farmers in the study areas manage the challenges associated with fish feed as well as some coping strategies adopted by the farmers to keep themselves in the business.

Materials and Methods

Study Area

This study was carried out in Ibadan, the capital of Oyo State located in the southwestern part of Nigeria. The rainy season in Ibadan is between March and October, while the dry season is between November and February. Agricultural activities in Ibadan are characterized mostly by secondary and quaternary services, although there are still features of primary functions such as farming. Ibadan is known as one of the hubs for catfish production from which many catfish marketers source their fish and to sell to other parts of Nigeria.

Sampling procedure

A multistage sampling method was employed as three local government areas were purposefully selected among the eleven local government areas in Ibadan, Oyo State. The selected local governments were Oluyole, Ido, and Lagelu. Then, the snowball sampling method was employed to administer the prepared structured questionnaire since the number of respondents could not be ascertained during the sampling period. The sampling relies on the introduction of different catfish farmers by their colleagues who have met and responded to the questionnaire. Some visited areas in these three local government areas are Fodacic Adeoyo, Omi Panada, and Olodo.

A structured questionnaire was used to collect data from the respondents. The questionnaire focused on issues such as the socioeconomic characteristics of catfish farmers in the study area, means of sourcing Fish seeds and culture period, challenges associated with sourcing of fish seeds and challenges associated with catfish feeding. A total of 125 copies of the questionnaire were duly attended to by the respondents in the study areas. Descriptive and inferential statistics were used to analyze the collected data.

Results and Discussion

Socio-economic characteristics of catfish farmers

Catfish producers in the research locations are categorized according to their socioeconomic status in Table 1. The range in age of farmers were between 23 to 77 years old, the average age of catfish farmers within the study locations weres 48.16±1.79 years, with the modal age class interval falling between 51 and 60 years old. According to Omeje *et al*. (2020), the mean age of farmers in the Kainji Lake Basin of Nigeria was 36.7 years. This result is more noteworthy. But according to Olaleye *et al*. (2019), the study's results indicate that middle-aged farmers predominate because they are at their peak of productivity. A record of male dominance in the catfish farming industry exists, even though both genders engage in the company (Brummett *et al.*, 2010; Ashley-Dejo *et al.*, 2017; Onyekuru *et al.*, 2019). Concerns about the dominance of males and low female participation in paid initiatives in many emerging economies have been raised by the International Labour Organization (ILO) (2016). The industry’s intense labor- and management-intensive character (Engle, 2010) and male dominance in catfish production (Omeje *et al*., 2020) are further factors contributing to this phenomenon. Catfish farmers in the study area are entirely literate, with men making up the majority

(68%) of farmers. 13.6% of them had completed at least elementary school, 34.4% had completed secondary school, and 52% had completed postsecondary education. According to this, graduates who are unable to get employment in the government or corporate sector may find self-employment options through catfish farming.

Six to ten children make up the bulk of farmers' families (54.4%), with most of them being married (92%). Furthermore, it was suggested by this that catfish farming in Nigeria provides a stable means of income for households to survive. Marital status is seen as a sign of social duty, trust, and success, according to research by Iruo *et al*. (2018). With an average experience of 11.26±0.98, the catfish farmers in the research region ranged in years from 2 to 27. It is noteworthy that many catfish farmers (32%) had experience ranging from 1 to 5 years, while only 4% had experience exceeding 21 years. Elfitasari and Albert (2017) noted that a crucial prerequisite for the success of catfish farming operations is years of experience along with sufficient technical and administrative abilities (Olaleye *et al*. 2019). Since just 48% of the fish farmers in the research region are members of a catfish farmers association and 52% are not, most fish farmers in the area are unconcerned about belonging to one. This could be that catfish farmers association is a voluntary association, although it is beneficial.

Table 1: Socio-economic of catfish farmers

Variables	Frequency	Percentage (%)	Mean
Age:			
20 – 30	17	13.6	48.16±1.79
31 – 40	23	18.4	
41 – 50	25	20	
51 – 60	40	32	
61 – 70	15	12	
71 – 80	5	4	
Maximum: 77	Minimum: 23		
Gender			
Male	85	68	
Female	40	32	
Education			
Tertiary	65	52	
Secondary	43	34.4	
Primary	17	13.6	
Marital status			
Married	115	92	
Single	10	8	
Family size			
1 – 5	57	45.6	
6 – 10	68	54.4	
Year of experience			
1 – 5	40	32	11.26±0.98
6 – 10	25	20	
11 – 15	20	16	
16 – 20	35	28	

>21	5	4
Maximum: 27	Minimum: 2	
Member of catfish association		0
No	65	52
Yes	60	48

Challenges associated with catfish feeding.

The challenges associated with catfish feeding are presented in Table 2. All the farmers agreed that the price of catfish feed is increasing. The high cost of commercial fish feeds is a major limiting factor for profitability in aquaculture (Adeogun *et al.,* 2007; Ugwumba and Nnabuife, 2008). Shitote *et al*. (2013) emphasized that commercially produced feeds are hard to come by and, when available, are expensive for most farmers to afford. The implication is that the cost of producing catfish will invariably increase. This is because the feed cost in catfish production is observed to be the single largest input resource that determines the enterprise's profitability (Ajagbe *et al.,* 2022; Engle, 2010). The majority (84%) of catfish farmers agreed that the increasing cost of fish feed negatively affects the business's profitability. This observation agrees with the reports of Sadiq and Kolo (2015) and Okpeke and Akarue (2015). Therefore, catfish farmers adopted various strategies to cope with the increasing cost of fish feed. Such systems include increasing the selling price of catfish at harvest (37.6%) and using homemade or locally produced meals with adjusted feed composition or formulation (26.4%), while 36% of them increase their capital base by securing more loans. Anita *et al*. confirmed the high cost of imported feeds, which could force many fish farmers to use locally produced meals that are not up to international standards. The use of homemade or locally made feed has negative impacts on pond water.

Effects of unconventional feed on pond water

Most (94.4%) of the farmers agreed that unconventional feeds pollute the pond water. This agrees with the findings of Ifeonu *et al*. (2019) that locally made feed, which is substandard feed, usually causes pollution and regular water contamination. Elfitasari and Albert (2017) reported that internal and external factors cause pollution of pond water. Such feeds that pollute pond water, according to the farmers, are maggot blood meal (62.4%), locally made feeds (28%), and sinking pelleted feed (9.6%). Mohammad and Haque (2021) identified daily feed input as one of the substances contributing to pond water deterioration. Likewise, Mramba and Kahindi (2023) opined that pond management practices such as daily feed input, stocking density, and fertilization have a significant impact on water quality. All respondents agreed that pond water should be changed when observed to be polluted. This is necessary because reduced water quality will weaken and reduce fish's immune systems and make them vulnerable and easily susceptible to disease, which will invariably reduce their survival rate (Suwarsito *et al.,* 2022).

Mode of feeding

Catfish farmers in the study area are indifferent about the mode of feeding fish, as 50.4% agreed that they do not feed their fish to satiation, while 49.6% confirmed that they do provide their fish to satiation. As reported by the respondents, the management of fish feed is essential because fish feed is wasted if it is fed in excess (37.6%). The possible reason could be the difficulty in retrieval of fish feed after being given to fish in water like other livestock. In addition, 34.4% of the farmers agreed that feeding fish should be discouraged due to scarcity of resources or funds (34.4%), and some (28%) farmers believed that if the feed is supplied in excess, the pond water may be polluted, and fish may die. These observations agree with the report of Eriegha and Ekokotu (2017) that feeding fish in excess will result in wastage of valuable feed nutrients, poor fish growth, and a high

possibility of water quality deterioration, which could culminate in fish mortality and reduced profitability.

Bulk purchase of fish feed

Many (54.4%) farmers agreed that there is an advantage to buying fish feed in bulk. However, catfish farmers identified some challenges that can discourage the practice. Most (68%) farmers identified rat and cockroach attacks as a challenge; some (12%) identified loss of flavor and mold infestation, while few (8%) identified expiration of the feed as challenges that discourage buying catfish in bulk. These observations agree with the report of Ifeonu *et al*. (2019), who identified similar challenges with fish feed storage.

Table 2: **Challenges associated with catfish feeding**

Variables	Frequency	Percentage (%)
Increasing cost of fish feed		
Yes	Yes	100
Coping with high cost of feed		
Increase catfish selling price	47	37.6
Go for loan	45	36
homemade/ adjust feed formulation	33	26.4
Negative impact on profitability		
No	20	16
Yes	105	84
Impact on pond water		
it does pollute water	118	94.4
no impact	7	5.6
Feeds that pollute pond water		
Locally made feeds	35	28.0
Maggot and blood meal	78	62.4
Sinking pelleted feed	12	9.6
What to do		
Change pond water often	125	100
Feeding fish to satiation		
No	63	50.4
Yes	62	49.6
Reason for feed management		
Wastage	47	37.6
Lack of funds	43	34.4
They die if the food is too much	35	28
Is there any advantage in buying fish feed in bulk		
Yes	68	54.4
No	57	45.6
Challenges of storing fish feeds		
Rat and cockroach	85	68
Loss of flavor	15	12
Expiring	10	8
Mold infestation	15	12

Impact of dependent variables on the catfish demographic

Additionally, Table 3 demonstrates how bulk catfish feed purchases impacted age and family size. The profitability of high feed costs also impacted age, gender, education level, and family size (P<0.05). The present discovery aligns with the findings of Ngeywo *et al*. (2015), who reported that age is an important determinant of a farmer's productivity and profitability. The degree of education significantly impacts the production and profitability of catfish farming, according to Onyekuru et al. (2019). More significant family sizes give catfish farming a free labor force to boost output and profitability (Nkamleu and Manyong, 2005; Amsalu and de Graaff, 2007).

Table 3: Impact of dependent variables on the catfish demographic

	Bulk purchase of feed			Impact of feed on profitability		
	Coefficient	T-value	P-value	Coefficient	T-value	P-value
Age	1.14*	4.563	0.033	1.391*	3.864	0.049
Gender	1.074	1.099	0.294	-2.777*	3.761	0.052
Education	-0.122	0.025	0.874	2.22*	3.356	0.067
Marital status	-0.456	0.135	0.714	-1.178	0.672	0.412
Family size	-1.823*	4.493	0.034	-2.19*	3.225	0.073
Year of experience	-0.778	2.26	0.133	-0.239	0.154	0.695

NB: The value with * are significant at P < 0.05

Relationships between significant input variables in catfish production

Table 4 shows various relationships between significant input variables in catfish production. It is observed that being a member of the catfish farmers association is significantly and inversely related (-0.298) to the impact of the high cost of feed on the profitability of catfish. The indication is that the increasingly high cost of fish feed is beyond the control of the Catfish Farmers Association and requires the attention of the government. Likewise, years of experience (0.384) are significantly related to the impact of high feed costs on the profitability of catfish. This may be because experienced catfish farmers could have become experts in feed management and efficiency. Catfish farmers usually learn from experience like other farmers engaged in agribusiness on how to be more productive by improvising technology to overcome challenges, reducing the cost of production, and increasing revenue (Oluwasola and Ige, 2015; Ashley-Dejo *et al.,* 2017; Onyekuru *et al.,* 2019). Experienced catfish farmers know some feed alternatives that could be used to lessen the impact of high-cost feeds.

Table 4: Relationships between major input variables in catfish production

	A	B	C	D	E
A	1				
B	-0.183	1			
C	0.454**	-0.253	1		
D	-0.06	-0.263	0.277	1	
E	-0.298*	-0.011	-0.044	0.384**	1

Key:

A: Member of Catfish Farmers Association

B: Bulk purchase of fish feed

C: Feeding fish with one type of feed

D: Years of experience

E: Impact of high cost of feed on the profitability of catfish

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Conclusion

Like any other industry, catfish farming has a limited potential profit margin. Due to some inherent problems, producers may not even break even or perhaps experience a loss. The effective handling of these difficulties increases the business's potential for profitability. Catfish growers are finding it increasingly difficult to manage and sustain the exorbitant expense of fish feed. Many catfish producers have employed homemade or local feed to grow their fish. Many people feed their fish unusual feed supplies, such as poultry excrement, which frequently contaminates pond water and occasionally has been shown to have infections that are dangerous to fish. To save their industry, catfish farmers are thus putting out intense demands for assistance from the government and other essential parties.

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Influence of Health Shocks on Productivity of Cassava Farmers in Iwo Local Government of Osun State Nigeria

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Abstract

The productivity of the agricultural sector has been linked to health status of major actors as healthy farmers are expected to possess higher level of human capital that will enable them to produce than their unhealthy counterparts. In this study, the effect of health shocks on productivity of cassava farmers was examined. Primary data was collected with the aid of a well-structured questionnaire. Data were analyzed using descriptive statistics, Body Mass Index (BMI), measure of productivity and Ordinary Least Square (OLS) regression. The result of the study revealed that majority of the farmers were male (87.27%), married (79.09%) and less than or equal to 40years of age (59.09%). Majority of farmers cultivated less than 5acres of land (83.64%) with no access to credit (100%) and extension services (89.18%). Higher percentage of the farmers harvested 1-5tonnes of cassava (62.73%) with output value of 100,000-300,000 naira (70%) per production period. Most of the farmers had normal weight (90.91%) and mostly suffered malaria (95.45%), body pain (90.91%), cold and catarrh (89.09%) as health shocks. Over 60% of farmers' loss days and are incapacitated to work during illness with about 67.14% of the farmers' losing 1-5days of work. Illnesses are majorly treated using prescribed drugs from medical practitioners and herbs from native doctors. The BMI had positive significant effect on productivity of cassava farmers thus implying that healthy farmers would produce more cassava. It is thus recommended that farmers should be sensitized on the need to keep themselves healthy to enhance their productivity.

Keywords: Cassava Farmers, Health Shocks, Productivity, OLS Regression

1.0 Introduction

Agriculture is important bedrock of development with its crucial roles in food price stability, reduction of poverty and enhancement of food security. The issue of healthcare for those involved in agricultural activities is of paramount importance if agriculture is to enhance its roles in enhancing food security and contributing to the country's Gross Domestic Product. The production and productivity of the agricultural sector has been linked to health status of those involved in the sector as healthy farmers are expected to possess higher level of human capital and would be more productive than those without good health (Echebiri and Nwaogu, 2017). Asenso-Okyere *et al.* (2011) reported that the effects of ill health on farm households include three broad impacts: absenteeism from work due to morbidity (and eventual death); diversion of family time to caring for the sick and the loss of savings and assets while dealing with diseases and its consequences. They reported further that the long-term impacts of ill health include loss of farming knowledge, reduction of land under cultivation, planting of less labor-intensive crops, reduction of variety of livestock and crop planted.

Cassava is one of major crop produced in Nigeria and it is grown across the six geopolitical zones of the country. It is the one of the fastest expanding staple food crops that has continued to gain prominence among farmers with consistently rising industrial demand. Nigeria is the largest producer of cassava in the world with more than 90% of production consumed locally (Dentol *et al.*, 2004). In 2020, world cassava production was at 302.66 million metric tonnes with Africa being the

largest cassava growing region with total production of 193.62 million metric tonnes and Nigeria being the highest producer of cassava in the world (FAO, 2022; Onyediako and Adiele, 2022). Despite high production in Africa, the continent is yet to contribute significantly to world trade in cassava as majority of cassava produced are consumed locally both for consumption and industrial purpose. There is huge potential for foreign exchange and economic growth for Nigeria if there is increase in the productivity of cassava. The health of the cassava farmers is paramount to enhance productivity of crop as increased productivity of cassava will not only increase income and enhance livelihood but will also enhance food security, eliminate hunger, and contribute to economic growth and development.

Although, several studies have examined the relationship between health status and different indicators such as ill-health burden (Adelowo, 2016); returns/profitability (Gbigbi, 2020) and productivity (Inosha, 2016; Chebiri *et al.,* 2017). All these studies concentrated generally on the farmers and their farming households. However, this study focused on cassava farmers as increased productivity of cassava would enhance food security, achievement of zero hunger and contribute to economic growth in Nigerian that falls within the developing country category. The study will provide answers on the productivity of cassava, nature of health shock experienced by farmers and days of incapacitation and how the health shock influence cassava productivity of farmers in Osun state.

Methodology

Study area: The study was carried out in Iwo Local Government which is one of the thirty-three (33) Local Governments in Osun State. The headquarters is Iwo central. It lies on Latitude 7°38'N 4°11'E and Long 7.633^{o}N 4.183^{o}E. The Council Area has an extensive landmass, mostly grassland with an area of 245km^{2}, and a population of 248,400 (City Population, 2022). Iwo Local Government shares boundaries with Aiyedire, Ola-oluwa and Bode-osi Local Governments and Oyo state in the west and north respectively. There are about 18-24 semi-urban areas and about 50 villages which includes Adana, Afiku, Afingba, Agbodan, Elemi, Fagbayibi, Idi-iroko, Jagun, Lemomu, Molare, Obajoko, Olobusan, Osunjobi, Papa, Sade, Tantan, Yakoyo and Omoba and many hamlets in the local government area. The people are predominantly farmers, who have their homesteads and farmlands in the area and their major occupation is farming. Major crops cultivated in the area include yams, cassava, corn, beans, millet, plantains, cacao, palm oil and kernels and fruits.

Source and Type of Data: Primary data was used for the study. Data were collected with aid of a well-structured questionnaire. Data were collected on socio-economic characteristics of the farmers, productivity of cassava, weight and height of farmers and other health shocks indicators.

Sampling Technique and Sample size: Multistage sampling technique was used to select the cassava farmers for the study.

- The first stage is purposive selection of Iwo Local government due to high predominant of cassava farmers in the area.
- The second stage involved purposive selection of Olupona and Iwo central zone.
- The third stage involved random selection of 6 villages in each zone.
- The fourth stage was random sampling of 10 cassava farmers from each of the 6 villages to give a total of 120 farmers. However, after data collection only data of 110 farmers were found analyzable.

Method of Data Analysis

Data were analyzed using descriptive statistics such as frequency, mean and percentage which was used to profile the socio-economic characteristics of farming households and value of cassava that was used as proxy for productivity.

Measure of Productivity: Productivity of cassava farmers was captured using value of cassava output as proxy. The value of cassava output was calculated using the formulae below:
Value of Cassava Output= Quantity of cassava output produced X Output price at farm gate

Body Mass Index (BMI): This was used together with number of day's incapacited due to illness to measure the health status of cassava farmers. BMI of farmers was calculated using the formulae in equation while cassava farmers were later categorized into using the thresholds in Table 1.

$$BMI = \frac{Weight\ in\ Kg}{(Height\ in\ meters)^2} \quad \ldots\ldots(1)$$

Table 1: BMI Classification for Adults

Body Mass Index (BMI) kg/m^2	Classification
Below 18.50	Underweight
18.50-24.90	Normal weight
25.00-29.90	Overweight
≥30	Obese

Source: World Health Organization

Ordinary Least Squares (OLS) Regression: Ordinary least squares (OLS) or linear least squares is a method for estimating the unknown parameters in a linear regression model. This method minimizes the sum of squared vertical distances between the observed responses in the dataset and the responses predicted by the linear approximation. The resulting estimator can be expressed by a simple formula, especially in the case of a single regressor on the right-hand side. The OLS model for this study was specified as;

$$Y_i = \alpha_0 + \alpha_1 X_{i=1} + \cdots + \alpha_9 X_{i=9} + e, \quad \ldots\ldots(1)$$

Where; Y_i=Productivity of cassava farmers; X_1= age of the farmer; X_2 = household size; X_3= farm size; X_4= farming experience; X_5 = BMI (1, if farmer has normal weight; 0, if farmer is under weight or overweight); X_6= Membership of social group; X_7= Days loss to illness; X_8= Access to financial services; X_9= Number of hired labour; $\alpha_1 - \alpha_9$ =coefficients, e=error term.

Result and Discussions

Socio-Economic Characteristics of Respondents

The socio-economic characteristics were presented in Table 2. The result showed that most of the farmers were less than or equal to 40 years (59.09%), while less than 10% of the farmers were greater than 60 years. This implies that most of the cassava famers are in their productive age. Majority (87.27%) of the farmers were male. About 79.09% of the farmers were married while others were single, divorced, or widowed. Majority (52.73%) of the farmers had between 1-5 household members while about 47% of the farmers had more than five members.

Faming experience of respondents in the study area revealed that majority (43.64%) of the farmers had 11-20 years' experience, 34.55% of the farmers had between 1-10 years of experience, and 15.45% of the farmers had 21-30 years of experience while 6.36% of the farmers had above 30 years of experience. It was further revealed that majority (83.64%) of the respondents had below 5acres of land while 16.36% of the farmers had above 5acres. This difference in farm size is relative to the farmers' year of experience. Also, 41.82% of the lands were inherited, 40% of the land was rented, 14.55% of the lands were family land while 3.64% of the lands were purchased. About 100% and 98.18% of the farmers did not have access to extension and credit services. This may be because majority of the farmers (60%) of the farmers did not belong to any social group.

Table 2: Frequency and percentage distribution of respondents by socio-economic characteristics

Variable	Frequency	Percentage
Age		
<30	28	25.45
31-40	37	33.64
41-50	18	16.36
51-60	18	16.36
>60	9	8.18
Sex		
Male	96	87.27
Female	14	12.73
Marital status		
Single	11	10
Married	87	79.09
Divorced	3	2.73
Widow	9	8.18
Household size		
5-10	58	52.73
6-10	46	41.82
>10	6	5.45
Farm size		
<5 acres	92	83.64
>5 acres	18	16.36
Farming experience		
1-10	48	43.64
11-20	17	15.45
21-30	7	6.36
>30	38	34.55
Source of farm land		
Inheritance	46	41.82
Rent	44	40.00
Purchase	4	3.64
Family	16	14.54
Access to Extension		
Yes	1	0.91
No	109	99.09
Access to credit		
No	110	100
Member of social group		
Yes	44	40
No	66	60

Source: Data Analysis, 2022

Quantity and Value of Cassava produced by Farmers.

The quantity and value of cassava produced is presented in Table 3. It was observed that about 63% of the farmers produce 1-5 tonnes of cassava, 36.38% of the farmers produce between 6-10 tonnes of cassava while 3.64% of the farmers produce greater than 10 tonnes of cassava. This implies that most of the cassava farmers operate on small scale. It was further revealed that 70% of the farmers in the study area earned ₦100,000- ₦300,000 from the sales of their produce, 19.09% of the farmers earned ₦301,000- ₦500,000 while 9.09% of the farmers earned less than ₦100,000 and 1.82% of the farmers earned above ₦500,000 from the sales of cassava.

Table 3: Output and Value of cassava produced by Farmers in the study area

Output category (in tonnes)	**Frequency**	**Percentage**
1-5	69	62.73
6-10	37	33.63
≥11	4	3.64
Output in monetary value	**Frequency**	**Percentage**
≤ 100,000	10	9.09
100,001 - 300,000	77	70.00
300,001-500,000	21	19.09
≥500,000	2	1.82

Source: Data Analysis, 2022

Health shocks and how they are treated by Cassava Farmers

The major health shock experienced by cassava farmers and how they are treated in the study area is presented in Table 4. The results showed that 95.45% of cassava farmers had Malaria, 90.91% of the farmers had body pain, 89.09% of the farmers had cold and catarrh, about 33% of the farmers had typhoid, almost 26% of the farmers had diarrhea while about 15% of the cassava farmers area had ulcer during the last production season. This implies that malaria is most common type of health shock experienced by cassava farmers while ulcer is the least type of health shock experienced by the surveyed cassava farmers. This finding agrees with the result of Adelowo (2016) and Gbigbi (2020) who found that more households are infested by malaria in Kwara State and arable farmers in Osun state respectively. Furthermore, the result showed that 39.09% of cassava farmers in the study area treated the health shocks using herbs, 12.73% of the farmers used medical prescription by nurses and doctors while 48.18% of the farmers treated the health shocks using both herbs and medical prescription. However, it was revealed that only 67.27% had access to health care services while 16.22% of the cassava farmers frequently visit health care providers. Gbigbi (2020) also found that majority of arable farmers in Osun State patronized traditional medication whenever they are sick. The use of herbs among farmers may be due lack of money to seek health services from trained medical personnel. Sometimes farmers resolve to taking medical prescription after the use of herbs are not effective in curing their ailment.

Table 4: Types of Health Shocks experience by Cassava Farmers

Types of ailments	**Frequency**	**Percentage**
Malaria	105	95.45
Typhoid	36	32.73
Cold and Catarrh	98	89.09
Body pain	100	90.91
Diarrhea	28	25.45
Ulcer	16	14.55
Treatment of health shocks		
Use of herbs only	43	39.09
Use of medical prescription only	14	12.73
Use of medical prescription and herbs	53	48.18

Source: Data Analysis, 2022

Days Lost to Illness

The number of days lost to illness is presented in Table 5. It revealed that majority 63.64% cassava farmers had days lost due to illness, while 36.36% do not experience day loss to illness. However, majority (67.14%) of the cassava farmers lost 1-5 days to illness while about 33% of farmers lost 6 days and above. This corroborated with findings of Wiggins (2017) who reported that malaria attack generally lasts for 14days including 4-6 days when its symptoms effectively leave the sufferer completely incapacitated hence the sufferer loss possible work time to malaria.

Table 5: Days Lost due to Illness.

Variable	Frequency	Percentage
Farmers experience day loss due to illness		
Yes	70	63.64
No	40	36.36
Number of day loss to illness		
1-5	47	67.14
6-10	17	24.29
>10	6	8.57

Source: Data Analysis, 2022

Farmer's Body Mass Index Category

The farmers body index is presented in Table 6. It was revealed that majority (90.91%) of cassava farmers had normal weight. This implied that they were in good health condition and has access to fresh food due to proximity to the farm. Also, about 5.5 % of the farmers were underweight; this could be because of strenuous works that come with farming and health shocks while almost 4% of the farmers were overweight. Health and productivity are directly linked through a synergic relationship. Illness on its part impairs nutritional status by reducing both appetite and the body's ability to harness body mass which in turn lowers the individual's ability to work on the farm. This finding is contrary to findings of Omotayo (2020) who reported that majority of farmers in South-western Nigeria were overweight.

Table 6: Farmer's Body Mass Index Categorization

Variable	Frequency	Percentage
Underweight	6	5.45
Normal weight	100	90.91
Overweight	4	3.61
Mean BMI	21.43±1	86

Source: Data Analysis, 2022

Effect of Health Shocks of Productivity of Cassava Farmers

The coefficient of BMI was positive and significant at 10%, this implies that farmers with normal health are likely to produce more (Table 7). This agrees with the findings of Inosha (2016) which stated that healthier and better nourished people are likely to be more productive than unhealthy people. The coefficient of day loss to illness was not significant, however, the magnitude follows appropriate expectation, the negative coefficient of day loss to illness implies that an increase in day loss to illness will lead to a decrease in productivity.

The regression results further revealed that household size, farm size and hired labour were significant which imply that these variables also had direct effect on the productivity of cassava farmers. The coefficient of household size was positive and significant at 1%. This implies that a unit increase in the household size will lead to 31.9% increase on the productivity of cassava farmers. This is in line with the findings of Ayaz and Mughal (2022) which stated that larger family size are good sources of labour. The coefficient of farm size was positive and significant at 1% this implies that a unit increase in farm size will lead to increase in the productivity of cassava farmers. The coefficient of hired labour was positive and significant; this implies that a unit increase in the number of hired labour would result to increased productivity.

Table 7: Regression Result showing the Effect of Health Shocks on Productivity of Farmers

	Coefficient	**Standard Error**
Constant	2.0350	3.1534
Age	0.0297	0.0313
Household size	0.3140***	0.1219
Farm size	2.0969***	0.1408
Farming experience	-0.0243	0.0393
BMI	1.1424*	0.6888
Number of hired labour	0.2890**	0.1202
Membership of social group	0.3899	0.5117
Day loss to illness	-0.2533	0.2337
Access to financial service	0.3547	1.4809

*****, **, * Significant at 1%, 5% and 10%**
Source: Data Analysis, 2022

Conclusion/Recommendation

The study examined the effect of health shocks on the productivity of cassava farmers and revealed that majority of the farmers were male, married and less than or equal to 40 years of age. Majorit cultivated less than or equal to 5acres of cassava with output and value of output of 1-5acres and 100,000-300,000 naira respectively. Higher percentage of the cassava farmers had normal weight and malaria is the most prominent health shock suffered by the farmers. Farmers missed 1-5 days of work due to the health shocks and most of the illnesses were treated using prescription from medical practitioners and herbs from traditional doctors. The regression result revealed that health status influenced the productivity of cassava farmers. It is thus recommended that:

(i) Preventive health care campaign should be organized to reduce exposure to health shocks and the government should provide quality health care services for farmers.
(ii) The government should implement "transient health policies" such as distribution of mosquito nets to prevent the incidence of malaria.
(iii) Cassava farmers should be encouraged to cultivate more land and efficiently utilized hired labour to increase their productivity.

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SUB-THEME:
GENDER MAINSTREAMING

Empowerment of Feminist- Led Local Actions for Food Security through Agroforestry in Nigeria.

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Abstract

The general opinion that gender inequalities (in areas such as ownership and access to resources, land tenure system, education, extension and financial facilities, and decision-making processes) have mainly contributed to lower agricultural practices, particularly in agroforestry and higher poverty level, cannot be overemphasized. Agroforestry, a sustainable land use system integrating trees and shrubs with crops and livestock, present unique opportunities for advancing feminist agendas, especially in rural communities. Applying feminist principles to Agroforestry can catalyze transformative changes in how food is produced, accessed, and distributed, particularly in marginalized communities where women play significant roles in Agroforestry practices. Women play significant roles in Agroforestry systems management, household food production and nutrition, processing and value addition of tree products and crops, income generation, integration of valuable indigenous knowledge and participation in leadership groups. Despite all these roles, several specific gender constraints limit their productivity. This paper highlights the challenges and successes of a few existing agroforestry initiatives and strategies that can be integrated into agroforestry to empower feminist-led local actions for food security through agroforestry in Nigeria. However, the success of the adoption of such methods will require collaborative efforts among governments, civil societies, researchers, and communities to ensure that Agroforestry system initiatives are inclusive and equitable and ultimately lead to more resilient and food-secured societies.

Keywords: Agroforestry, Food security, Gender, Feminism, Strategy

Introduction

Empowerment of feminist-led local actions for food security through agroforestry represents a progressive and inclusive approach to addressing global challenges at the intersection of gender equality, sustainable agriculture, and food production. This intersection has emerged as a critical area of study and practice in recent years. As a sustainable land use system integrating trees and shrubs with crops and livestock, agroforestry enhances ecological resilience and presents unique opportunities for advancing feminist agendas in rural communities (Ahmed *et al*.,2021; Gbadebo *et al.,* 2023). Feminist principles emphasize equity, inclusivity, and amplifying women's voices and agency in decision-making processes. Applying these principles to agroforestry can catalyze transformative changes in how food is produced, accessed, and distributed, particularly in marginalized communities where women play significant roles in agriculture and natural resource management. There is a consensus that gender inequalities in areas such as ownership, access to resources, land tenure systems, education extension and social-cultural factors have contributed to lower agricultural productivity and higher poverty level (Waithanji *et al.,* 2013).

In the developing world, women play pivotal roles (Debharma *et al.,* 2015) in agricultural production, particularly in agroforestry practices. Women contribute significantly to food production, distribution, and utilization, which are the three components of food security (World

Bank 2009). They broadly support agricultural development through soil and water conservation, afforestation, and crop domestication. Women are managers of agricultural, natural resources, and it is estimated that 60-80% of smallholder farmers are women (Vikki Davies, 2023) and if global food demand is expected to rise by 60% by the year 2050 must be met, then agricultural production must increase by 70-100% and this has to come from the smallholders of which are primarily women (Vikki Davies, 2023). Women comprise 20-50% of the agricultural labor force in developing countries (FAO, 2011; FAO, 2012) and 79% in underdeveloped countries and are economically active in agriculture as their primary economic activity (Doss, 2011). In Nigeria, women constitute 80% of the labour force in agriculture, including Agroforestry and 60% of food production (Ejiogu *et al.*, 2021), and over 60% of women contribute to tree planting and management (Epaphra, 2001). Research has shown that if women farmers were given the same access to resources (land, finance, technology, and others) as men, their agricultural yields could increase by 20-30% (reNature, 2023), national agrarian output could rise by 2.5-4% and the number of malnourished people could be reduced by 12-17% (Bertini 2011). Empowering women and promoting their leadership in agroforestry will not only enhance gender equality but also significantly contribute to improving food security at the local level and the status of the future generation. An African proverb says if you educate a man, you educate an individual, but if a woman is educated, a family or nation will be educated.

Roles of Women in Agroforestry

Agroforestry, a sustainable land use management system that integrates trees and shrubs into agricultural landscapes as an approach to farming, embodies principles of ecological sustainability, resilience and biodiversity. Ishola *et al*. (2020) and Ahmed *et al.* (2021) reported that by intercropping food crops with trees and shrubs, agroforestry will not only boost agricultural productivity but also support ecosystem health and biodiversity conservation. Furthermore, the practice has shown potential in mitigating climate change effects, mainly through carbon sequestration and improved soil health. However, beyond its ecological benefits, agroforestry presents unique opportunities for advancing feminist agendas in rural communities by empowering women as agents of change in the food system.

Farm Management: Women are often involved in managing agroforestry systems, including seed and seedling management in nurseries, planting, weeding, tending to trees and harvesting trees and crops. Although men and women are both involved in the management of trees planted on farms, the initial stages of establishment are being taken care of by women (Mwangi *et al.*, 2011).

Processing and Value Addition: Women are involved in processing agricultural and forest products derived from agroforestry, adding value to these products through techniques like drying, salting and other preservation methods as well as packaging to support the livelihood of the households, hence playing the significant role of value addition to forestry products.

Income Generation: They also generate income from agroforestry activities through direct produce sales or by participating in value-added processing activities. Rural women tend to spend more of their income from food crops on food, health, clothing, and education of their children, hence improving the entire household's food security (FAO,2009; FAO 2011b). In marketing, a study revealed that women transport 26 metric ton-kilometres per year compared to less than seven metric ton-kilometres by men (World Bank, 2009)

Household Food Production and Nutrition: Women are typically responsible for food preparation and are, therefore, crucial to the dietary diversity of their households. The edible fruits, nuts, seeds, leaves, tubers roots, mushrooms, gum, and saps collected by women add diversity, flavouring and

essential nutrition to diets. Okereke-Ejiogu *et al.* (2021) reported that women practising agroforestry have positive food security status. A positive and significant relationship existed between perceived Agroforestry practice and household food security. However, it has been reported that women are more malnourished than men in times of food shortage, and this is because they eat less than men (Dankelman, 2010; WHO, 2011)

Environmental Stewardship: Women often possess valuable traditional knowledge about local ecosystems and unique skills and play a crucial role in conserving biodiversity and maintaining soil fertility within agroforestry systems.

Community Leadership: They also serve as leaders and facilitators in agroforestry projects, promoting sustainable management practices and fostering community cohesion.

What is Agroforestry?

Agroforestry can be defined as a dynamic, ecological-based natural resource land use management system that, through the integration of trees and shrubs on farms and agricultural landscapes, diversifies and sustains production for increased social, economic, and environmental benefits for land users at all levels (FAO, 2015; Leakey, 2017). Agroforestry bridges the gap between forestry and agriculture by building integrated systems addressing environmental and socio-economic objectives. Studies have shown that the adoption of Agroforestry practices notably has proven capacities to increase food and livelihood security, expand Nigeria's forest cover, enhance forest conservation service function, sequester carbon, improve soil fertility, ameliorate environmental challenges and, more importantly, alleviate rural poverty through employment opportunities (Idumah *et al.,* 2020). The integration of trees with crops and/or livestock can prevent environmental degradation, improve agricultural productivity and food security through crop diversification, increase carbon sequestration and support healthy soil and ecosystems, re-awakening scientific interest in farming systems while providing stable income, nutritional and medicinal benefits to human welfare (Elevitch and Wilkinson, 2003). It is practised by 1.3 billion people worldwide (Leakey, 2010; Dawson *et al*., 2013). Agroforestry is rapidly becoming a resource management with the potential of meeting farmers' basic needs through sustainable food supply and income generation due to its component diversity and the alleviation of poverty. According to Lulandala (2004), Agroforestry remains the only resource management option with real and tangible opportunities to break the bondages of energy, food insecurity, poverty, and poor and imbalanced nutrition in developing world rural communities. Agroforestry systems include a broad range of practices and configurations, ranging from sparsely retaining trees on a pasture to complex multistrata food forest systems containing many species.

The various Agroforestry practices can be classified under three significant systems according to their structure (composition and arrangements of components), functions, socio-economic scale of management and ecological spread.

Common Sustainable Agroforestry Practices in Nigeria

Agrisilviculture System: This system combines trees with the cultivation of food crops. Such food crops include cereal, shrubs like soybeans, vines, mushrooms, medicinal herbs, spices or fodder mixtures.

- Taungya: In this practice, forestry overlaps agriculture. During the early establishment stages of the trees, the local farmers are allowed to interplant food crops with trees in a unit land area for 2-3 years. Once the trees canopy closes, the farmer moves to another Taungya plot. The system is beneficial to both the forest department and the individual farmers. Farmers

farm on the land to produce crops for their livelihood while taking care of the emerging tree plantation to ensure the development of the young trees. The plots are kept weed-free and soil well aerated, and such practices encourage the growth of the trees. Crops like maize, groundnuts, vegetables, soybeans and others are grown with the trees.

- Integrated Taungya: This is similar to Taungya farming, but here, when the tree canopy closed, livestock grazing substituted for raising crops.
- Improved Fallow: This practice involves growing trees and crops sequentially at different times. The trees, shrubs or cover crops are grown during the fallow period when the land is left to rest. The purpose is to minimize soil degradation associated with excessive agricultural practices, protect soil from erosion, speed up their regeneration and replenish the soil nutrients. Leguminous tree species like *Leuceana leucocephala*, *Gliricidia sepium* and *Acacia* spp that fix nitrogen in the soil are best for this practice. Their leaves and fruits serve as livestock feed, and the rest can be used for fuel, plywood or pulpwood.
- Alley cropping/ Hedge row Intercropping: Arable crops are grown on the alleys or between the hedgerows of planted shrubs and trees, preferably leguminous species, which are pruned periodically to prevent shading of the companion crops and the pruning applied as mulch for the crops. This practice fixes atmospheric nitrogen, recycles nutrients from the depth of the soil, suppresses weeds and increases organic matter in the soil, thereby improving soil health.
- Shelterbelts: Food crops are planted between rows of tree belts planted as shelter. The trees and shrubs are planted in one or more rows at a right angle to prevailing winds. The purpose is to increase crop yield because of their beneficial effects on soil and microclimate. This practice reduces stress from heat and wind on animals. Shelterbelts planted along animal barns have been effective in mitigating unwanted odour.
- Windbreaks: Double rows of trees can be planted around the boundary of food crop farms on the windward side. This practice mimics forest alongside food crops, reduces wind and erosion, prevents infrastructure damage, and serves as a habitat or corridor for small wildlife.
- Scattered trees on farmland: Farmers intentionally leave trees on farms when clearing the land. Such trees include locust beans, shea butter, and fruit trees, which are economically important.

Silvopasture Systems: (Raising livestock with the trees). The system integrates trees with grazing animals on the same farming land.

- Fodder and Protein banks: this is a range of perennial trees or shrubs judiciously planted on marginal lands to supplement feed during the dry season, drought or low rainfall when green pasture is absent. The livestock can roam and graze among the fodder trees, or farmers prune the trees and feed the pruning in the stable or other livestock enclosures. In any case, tree pruning from these banks makes up to 25% of the diet. Fodder banks are called protein banks if the trees are leguminous species rich in protein and minerals and are thus preferred. *Leuceana leucocephala*, *Gliricidia sepium*, Ficus species, *Acacia* spp, *Calliandra calothrysus*. Mulberry is a non-leguminous tree species but is excellent for pig nutrition because of its foliage consistency and nutrient content. It is easily digestible and has good results in pig fattening.
- Live fences: trees or shrubs are planted along the pasture boundaries. It gives the animals a feeling of comfort and shelter. Fodder trees that enrich the animal's feed or economically essential timber species can be used.

Agrosilvopasture System: A highly diverse land use system that integrates crops with livestock and trees. This is mainly practised in the tropical drylands and on marginal lands susceptible to

degradation when cultivated intensively. It gives the best result to sustain rural populations by providing a great variety of products like crops, meat, milk, nuts, fruits and wood.

- Home gardens: An assemblage of multipurpose trees and shrubs, vines and herbaceous plants growing adjacent to a homestead in a multistorey association with crops and livestock raising. Trees in this system provide fruits, diversity of fodder, and non timber and provide more supportive functions for crops and animals. Provides shades from the sun, and slow down winds, and their foliage enhances soil properties and water distribution.
- Apiculture: it consists of carefully chosen wooden species grown for their nectar-producing flowers and pollen valued by bees. Boost wax and honey products. Bee hives can be placed along the tree lines, leaving plenty of space for other agricultural production and livestock.
- Aquaforestry: the practice of cultivating aquatic animals (fish, molluscs, crustaceans) and plants (seaweed) for human consumption. Trees are planted along ponds to provide fodder for herbivorous fish. Shelter and shade created by the trees provide a desirable microclimate for the pond.
- Multipurpose woodlots: consists of multipurpose tree species planted for their fast-growing biomass, good quality timber, and fodder for livestock or soil enrichment. Examples are eucalyptus, acacia, nut and fruit trees, shrubs and climbing crops like beans and medicinal herbs.

The introduction of agroforestry and the role of women in its practices set the stage for exploring how feminist-led local action can transform food security outcomes through Agroforestry. This is centred on women's empowerment in a sustainable regenerative agricultural systems including Agroforestry. The approach will promote economic independence and social inclusions and foster resilience against climate and market fluctuations. However, despite the significant proportion of women in the agricultural labour force globally, they often face systemic barriers to accessing productive resources (land, labour, education, extension, financial services and technology), decision-making, spaces and markets (Jamal, 2023; Nguyen *et al*., 2021). Such challenges include:

- Gender Norms and Power Dynamics: Gender norms and power imbalances within households and communities can hinder women's participation and decision-making in agroforestry activities. Women are seen as "farmwives" rather than actual farmers and, are incapable of producing and sharing valuable knowledge about farming.
- Cultural beliefs: Society ignores the value of Indigenous knowledge by continuing to view the knowledge and practices of women as "primitive", unscientific and a hindrance to development. This may limit women's access to land, resources and technology needed for agroforestry, hindering their ability to contribute effectively to food security.
- Limited Access to Resources: Women often face challenges in accessing credit, inputs and extension services compared to men. This limits their capacity to invest in agroforestry practices and diversify their agricultural activities, affecting overall food security outcomes.
- Unequal Land Tenure and Property Rights: In many regions, women have limited land tenure and property rights, restricting their ability to engage in agroforestry and make life-long investments in sustainable land use. In developing world, land is owned predominantly by men and transferred intergenerationally to males even when women can access land. Lack of ownership creates disincentives to invest time and resources into sustainable farming practices. Securing land rights for women is crucial for their empowerment and participation in food security initiatives.

Technological and Knowledge Gaps: Women may have limited access to training and information on agroforestry techniques and sustainable practices. Bridging knowledge gaps and providing tailored training opportunities for women are essential to enhance their skills and decision-making in agroforestry.

- Unpaid Care and Domestic Work: Women often bear the burden of unpaid care and domestic responsibilities, which can limit their time and mobility for engaging in agroforestry activities. Reducing women's unpaid workload and recognizing their contributions to agriculture are essential for promoting gender equality in food security efforts.
- Limited Market Access and Value Chains: Female farmers may face challenges accessing markets, fair prices, and value chains for agroforestry products. Strengthening market linkages and supporting women's entrepreneurship can enhance their economic opportunities and food security outcomes.
- Lack of Gender-Responsive Policies and Institutions: Many agricultural policies and Institutions lack gender responsiveness, overlooking women's needs and priorities in agroforestry development. Advocating for gender-responsive policies and building institutional capacity to address gender inequalities critical for sustainable and inclusive food security is essential for women's development and productivity.
- Social and Cultural Barriers: Deep-rooted social and cultural norms may restrict women's mobility, participation in decision-making forums and leadership roles in agroforestry initiatives. Creating awareness, fostering community dialogue, and challenging gender stereotypes are essential to overcome these barriers.
- Climate Change and Environmental Risks: Women farmers are disproportionately affected by climate change and environmental risks, which negatively impacts AFS productive food security. Building women's resilience through adaptive strategies and climate-smart practices is crucial for sustainable food production.

Strategic Approaches to Integrating feminism into agroforestry for enhanced food security include the following:

- Gender Analysis and Needs Assessment: A comprehensive gender analysis must be conducted to understand existing roles, relationships, responsibilities, and challenges faced by women and men in relation to food security and agroforestry. Women farmers' specific needs and priorities, including access to land, resources, technology, markets and decision-making processes, must be identified.
- Promote Women's Participation and Leadership: Women should be actively engaged in all stages of Agroforestry projects, from planning and implementation to monitoring and evaluation. Women's leadership in farmer's groups, cooperatives and community organizations must be involved in agroforestry initiatives.
- Capacity Building and Training: Tailored capacity-building programs and training opportunities for women in regenerative agricultural systems (agroforestry practices, cover cropping, multiple cropping, pest control, and post- harvest processing) must be provided to enhance their income-generating opportunities. Women should constantly be introduced to modern AFS concepts and techniques through the Extension services and NGOs. This will help facilitate the dissemination and adoption of such ideas. They are to be equipped with entrepreneurial skills, financial literacy and access to microfinance to enhance their income-generating opportunities.

- Access to Resources and Land Rights: Advocate for women's land tenure rights and secure access to productive land for agroforestry activities. Access to essential resources such as seeds, tools, irrigation, and credit must be facilitated by women farmers.
- Promotion of Agroecological Practices and Diversity: Agroecological approaches (polyculture, permaculture, AFS practices) that prioritize biodiversity, soil health and ecosystem resilience, which are often more compatible with women's knowledge and practices, should be encouraged. The growth of diverse crops and tree species that meet the nutritional needs and contribute to climate resilience should be promoted and supported.
- Women's Knowledge and Traditional Practices should be Valued: Women's indigenous knowledge and traditional practices relating to agroforestry, seed storage and natural resource management should be valued. Indigenous knowledge on seed collection and preservation and mushroom production should be valued to enhance food security.
- Address Gender-Based Barriers and Discrimination: Challenge and patriarchal norms, discriminatory practices and cultural barriers that limit women's participation and decision-making authority in agroforestry must be adequately addressed. Awareness about gender equality and women's rights among community members, policymakers and stakeholders must be created and raised.
- The Need to Monitor, Evaluate and Learn: In assessing the impact of integrating feminism into agroforestry, gender-sensitive monitoring and evaluation mechanisms must be established for food security, nutrition, income, and gender dynamics. Utilize feedback from women and communities to adapt and improve strategies over time, ensuring continuous learning and responsiveness to women's needs.
- Advocate for Policy Change and Institutional Support: Collaborating with government agencies, NGOs, and other civil society organizations will help advocate for policies and programs that promote gender-responsive agroforestry and women farmers. Agricultural research agendas and investments prioritising women's empowerment and equality should be advocated.

Examples and Successes of feminist-led local actions that have contributed to food security, gender equality and environmental sustainability.

- The Women Environmental Program (WEP) is a non-profit organization founded by Priscilla Achakpa. Its mission is to empower women to participate in sustainable development and environmental conservation actively.
- Tree Initiative: The Rural Environmental Empowerment Initiative created the National Shea Tree Restoration Advocacy Program (NASTREP), an initiative to mobilize youths and women across the shea butter belt in Nigeria to adopt the planting of improved shea butter tree seedlings as an innovation in landscape restoration to stop the cutting down of shea butter tree from being used for charcoal production. This helps to survive the livelihood of over one million rural women across the shea butter belt in Nigeria (Tree Initiative, 2017).
- The Green Belt Movement (GBM) in Kenya: This was founded by Nobel Peace Prize Laureate Wangari Maathai. It is an environmental organization that empowers women to participate in tree planting and sustainable land management activities. GBM exemplifies how grassroots efforts led by women can generate significant positive impacts on multiple fronts.
- In Nicaragua, the World Agroforestry Center (ICRAF) is working with groups of women farmers.
- Community-Based Agroforestry Initiatives in Nepal

- Indigenous Women's Agroforestry Group in Latin America: By incorporating feminist perspectives that prioritize indigenous women's rights and knowledge, we have strengthened food sovereignty, preserved cultural heritage, and empowered marginalized communities.

The combined successes of these initiatives are listed below:

Improved Food Security: These initiatives promote agroforestry practices, encouraging women to plant trees, manage seedling nurseries and value addition of tree products like fruits, nuts, and herbs. Emphases were made on organic farming techniques and agroecology. Through capacity-building and training women are equipped with knowledge and skills to enhance crop productivity and preserve soil fertility. By diversifying agricultural activities with trees, communities experience enhanced food security through increased availability of nutritious foods and improved soil health. Women are involved in tree planting, managing nurseries, and adding value to agroforestry products.

- Gender Equality and Women's Empowerment: They put a strong emphasis on empowering women as critical agents of change in environmental conservation and community development. By advocating for women's rights and access to resources, women participate in tree planting and community projects, gain economic independence, improve family well-being and leadership skills, and increase decision-making power within their households and communities. Women are empowered to take leadership roles in community development and environmental governance.
- Environmental Sustainability: Tree planting initiatives contribute to reforestation efforts, combating deforestation and degradation of the natural ecosystems. The presence of trees helps restore biodiversity, conserve water resources and mitigate climate change impacts by sequestering carbon dioxide from the atmosphere.
- Community Resilience and Social Unity: These initiatives foster community resilience by building social networks and promoting collective action for environmental stewardship. Women become advocates for sustainable land management practices, influencing broader attitudes towards conservation and natural resource management and also empowering the communities to thrive in harmony with nature.

Conclusion

In conclusion, integrating feminism into agroforestry for enhanced food security is about producing more food sustainably and transforming power dynamics, promoting social justice and valuing women's contribution to agriculture and natural resources management. Various studies have shown that sustainable development is impossible without women's empowerment and that gender equality is both a human right issue and a a precondition for an indicator of sustainable development. Furthermore, it is essential to note that gender disparity is prevalent across the cultures of the world and that without serious steps taken to tackle it, sustainable development cannot be achieved.

Recommendations

Statutory laws need to be changed to strengthen women's entitlements. An increase in the enforceability of women's claims to natural and physical assets. Empowering women through natural capital (land, water, trees, livestock and physical capital (buildings, houses, infrastructures such as roads, electricity transportation and other technical structures), social and financial capital (cooperative societies, microfinance banks, group savings, credit and insurance programs) will boost the morale and confidence of women to be more productive.

The implementation of creative programs that enable women to use and benefit from their resources and capabilities, such as groups that provide women opportunities to build social capital for their

lack of physical and financial assets. Increase women's ability to actively participate in the development process by changing the perceptions and increasing awareness of both men and women themselves. Investing in women's human capital through education and training and removing barriers to the productive use of women's time and energy are keys to sustainable and gender-sensitive food policy empowerment. However, all those as mentioned above require collaborative efforts among governments, civil society, researchers and communities to ensure that AFS initiatives are inclusive and equitable and ultimately lead to more resilient and food-secure societies.

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SUB-THEME: Application of Machine Learning, Artificial Intelligence and Big Data in Forestry Research

Linking Intact Forest Landscapes with Conservation and Security Planning along Lagos-Ibadan Expressway, Nigeria

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Abstract

Forest ecosystems offer one of the most potent biological options for addressing the challenges of global warming and biodiversity conservation. Ungoverned forestlands are progressively associated with bandits terrorizing motorists along Nigeria's Lagos-Ibadan Expressway (LIBE). This paper, therefore, evaluates the spatial distribution of forested landscapes along the route stretching about 132 kilometres from Ibadan to Lagos. Geospatial techniques and band rationing algorithms were deployed to offer perspectives on how ungoverned forest spaces and policies can be integrated into improving modern landscape restoration and security in Nigeria. Within the forest setbacks of 5km and 30km to both sides of LIBE, dense forests account for 0.16% (1.73sq.km) and 4.43% (47.97sq.km), respectively, of the 1083.9249sq.km or 12.58% of forestland within the Region of Interest (RoI). The identified forest areas belong under territories with high concealment factors providing cover for bandits. More than 87% of the RoI is under non-forest land use/land cover with low susceptibility to occupation by bandits. Intact forests with a high risk of occupation by bandits and high potential for biodiversity conservation only account for 6.3% (68.29sq.km) of the forested landscape in the study area. The core forests identified overlap with areas to be administered under an inclusive landscape governance and security plan. Suppose 1.73sq.km of high-risk forest patches within the 5km setbacks to LIBE are mainstreamed into governance under the revised 2019 Nigeria's national security strategy. In that case, LIBE will be safer for all and sundry. With recent national developments, future discourses on forest conservation should revolve around improving biodiversity and national security.

Keywords: Intact Forest landscapes; Policy; Lagos-Ibadan expressway; Forest conservation; National security.

Introduction

Nigerian forest is the collective currency millions of citizens spend to deliver on life's essential requirements for survival. Although widely reported as decreasing at the rate of 3096.14 sq. km per annum (Aina and Kosemani, 2016), the forests still provide critical habitats for the threatened species of flora and fauna, including the forest elephants of southwestern Nigeria. In recent times, the heightened call for forest conservation and landscape governance is connected to the high rates of deforestation and the premium placed on forest ecosystems for beneficial services. Forest ecosystems operate as vehicles for capturing additional carbon and as carbon reservoirs (Zheng et al., 2017), delaying the onset of global warming and the thresholds of its attendant effects. Governance of forest landscapes has remained a significant challenge with the unending spate of kidnappings along the Lagos-Ibadan Expressway (LIBE). The forests are no longer safe (Abodunrin and Alabi, 2022). The advantage of concealment derived from the forests by criminal groups to launch surprise attacks on motorists indicates the state of forest governance in Nigeria. According to Larinde and Chima (2014), the ineffective management of Nigerian forests has made them safe

homes for hoodlums who engage in various nefarious activities. Therefore, a critical review of the concepts that define forest conservation and governance is pertinent in Nigeria.

Forest conservation involves the upkeep of natural resources within a forest that benefit humans and the environment (Pawar and Rothkar, 2015). Aside from investments in planting activities and the maintenance of forest stands to meet landowner's objectives, modern forest conservation should be expanded to ensure unharmful land uses within forest land covers. Effective forest governance should include measures and policies to reduce illegal and subversive uses of forested areas (Okoli, 2019). According to Vizzrri et al. (2015) and Pandey et al. (2015), the forest ecosystem's capacity to maintain the numerous ecological benefits in the future is potentially threatened by anthropogenic impacts such as climate change, land use and unsustainable management practices. The criminal usage of forested corridors for the movement of small arms and safekeeping for kidnapped victims along LIBE will take a considerable toll on biodiversity conservation, climate change mitigation efforts and the livelihood of thousands of local artisans, forest user groups and road users in Nigeria. James Odebiyi, in a recent media publication, called on the Federal Government to rid Nigeria's forests of bandits, kidnappers, and terrorists (Olaniyi, 2022). This is because commuters plying LIBE are currently in fear of being kidnapped following reports of several abductions on the road (Daniel et al., 2022).

Suspected herders laid an ambush at the Ajebo end of the Lagos-Ibadan expressway and kidnapped three persons (Babalola and Bosun, 2022). Makinde Olufemi (2020) also reported the kidnap of two foreigners close to the Tollgate along LIBE. According to Oseni Rufai (2022), the Lagos-Ibadan expressway that stretches 132 kilometres to Ibadan has become a den for kidnappers as it has large swathes of ungoverned spaces. An ungoverned space

is a territorial sphere lacking firm governmental control (Okoli, 2019). It is a physical or non-physical area without state capacity or political will to exercise control' (Whelan, 2006). Between January 2019 and January 2023, at least 52 reported attacks on LIBE were reported. In this period, an estimated 179 individuals were kidnapped, and total ransoms paid in the range of ₦690 million – ₦1.50 billion. Ungoverned forest spaces could knock out the logic supporting forest conservation if specific policies are not formulated and implemented across local communities to secure beneficial land uses within the forests. Administrative failures at the third tier of governance and the lack of proper integration of geospatial techniques with other conventional security strategies to gather intelligence and track potential criminal hideouts are at the root of state-wide insecurity in Nigeria. This view is supported by Adejumobi et al. (2009) and Oyenike et al. (2016), who concluded that the use of Geographic Information Systems (and drones) as a tool for the police in crime control and management is infrequent in Africa, especially in Nigeria.

Therefore, this paper aims to support rural intelligence gathering towards improving forest conservation and the safety of commuters plying LIBE by identifying intact forest landscapes, conservation priority zones and potential criminal hideouts along the LIBE. A positive correlation exists between the quality of information and the quality of decision-making (Oyenike et al., 2016). It is envisaged that the level of information revealed will guide policy revisions and formulation, as well as catalyst actions designed to make LIBE safer for motorists in Nigeria.

Study area

Lagos-Ibadan Expressway is the oldest highway in Nigeria. It was commissioned in August 1978 and has a linear distance of about 127.6 km[1]. It is the primary route connecting the Lagos metropolis to the ancient town of Ibadan and has an average smooth travel time of 60 minutes at 100km/h velocity. The route extends from the Ibadan interchange in Iwo Road to the Ojodu-Berger axis of Lagos state. It is sandwiched between the geographic coordinates: Longitudes: 3.9434 N – 3.3716 N and Latitudes: 7.4038 E – 6.6402 E. The expressway is one of the busiest in Nigeria, and it overlays the landscapes of Oyo, Ogun, and Lagos states by approximately 32%, 66% and 2%, respectively.

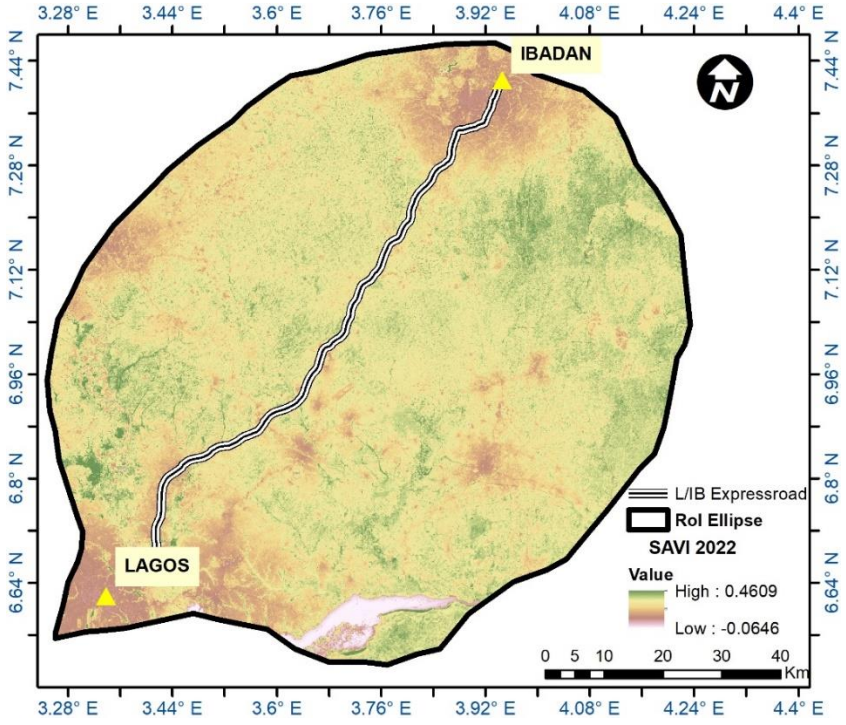

Figure 1: Map showing the express route connecting Ibadan with Lagos metropolis.

Materials and Method

Datasets

The length of LIBE was delineated from Google Earth Pro Version (GEP, 2022) and formatted into the ESRI shapefile in ArcGIS 10.5 under the UTM 31N projected coordinate system. Landsat 8 (OLI) imagery with 30m spatial resolution was accessed from the Earth Explorer database maintained by the U.S. National Aeronautical Space Agency. The Red (RED) and Near-Infrared (NIR) data, corresponding to Bands IV and V of the satellite imagery, were corrected to the top-of-atmosphere reflectance and fitted into the image algebraic formula by Huete (1988), as shown in **Eq. 1** to generate the Soil Adjusted Vegetation Index (SAVI) for the land use/land cover (LULC) analysis.

[1] Wikipedia contributors, 2022. Lagos–Ibadan Expressway. In Wikipedia, The Free Encyclopedia. https://en.wikipedia.org/w/index.php?title=Lagos%E2%80%93Ibadan_Expressway&oldid=107328914. Retrieved on February 1, 2022.

$$SAVI = \frac{NIR - RED}{NIR + RED + 0.5} * (1 + 0.5) \quad \text{Equation 1}$$

SAVI expected values range from -1 to +1, with pixel values closer to the upper bound, implying strong correlations with forest presence. In contrast, pixel values clustering around zero (0) indicate correlations with non-forest features. The reclassified SAVI aided the separation of the LULC classes and identification of continuous forest pixels and their variations within the 5km and 30km setbacks (buffers) on both sides of the Lagos – Ibadan Expressway (LIBE).

Forest Landscape Assessment

Intact Forest Landscapes' distribution and fragmentation were assessed within the Region of Interest (RoI). The analyses were implemented with the Landscape Fragmentation Tool (LFT) v2.0 toolbox, and outputs were finalized within the ArcGIS 10.5 workspace. The assessment was premised on the assumption that if effective environmental policies and strategies secure and govern dense forests within 5km and 30km lateral distances to the expressway, ambushes by hit-and-run bandits on LIBE will be reduced to their barest minimum. Hideouts used by criminal groups within the RoI targeting motorists may not extend beyond a 6-hour trekking distance to LIBE at a walking speed of about 5km/h or 30km offsets from the highway.

Results

The RoI in **Fig. 1** enclosed about 8625.1023sq.km of landscapes belonging to Lagos (8%), Ogun (60%), Oyo (24%) and Osun (8%) States. The LIBE only connects Lagos metropolis with Ibadan through Ogun State, creating a false midrib through the leaf-like ellipse (RoI). The RoI provides at least a 30 km buffer to both sides of the passage to Ibadan from the Lagos metropolis. The values of the SAVI generated from **Eq. 1** range from -0.0650 to 0.4609 (**Fig. 1**), with 0.2950 delimiting the forest pixels from other non-forest pixels.

The reclassified vegetation index (**Fig. 2L**) has four (4) thematic classes, namely (SAVI values enclosed in parenthesis); Aquatic body (-0.0650 to 0.0100), Built-up areas/Bare soils (0.0100 – 0.1735), Shrublands/Agricultural fields (0.1735 to 0.2590) and dense forestlands (0.2590 to 0.4609). The dense forestland constitutes 12.5671% of the ellipse, while 25.2644%, 60.9544% and 1.2141% are distributed among the Built-up areas/Bare soils, Shrublands/Agricultural fields and the Aquatic body LULC categories, respectively. The ratio of the non-forest regions to forested areas is 6.96.

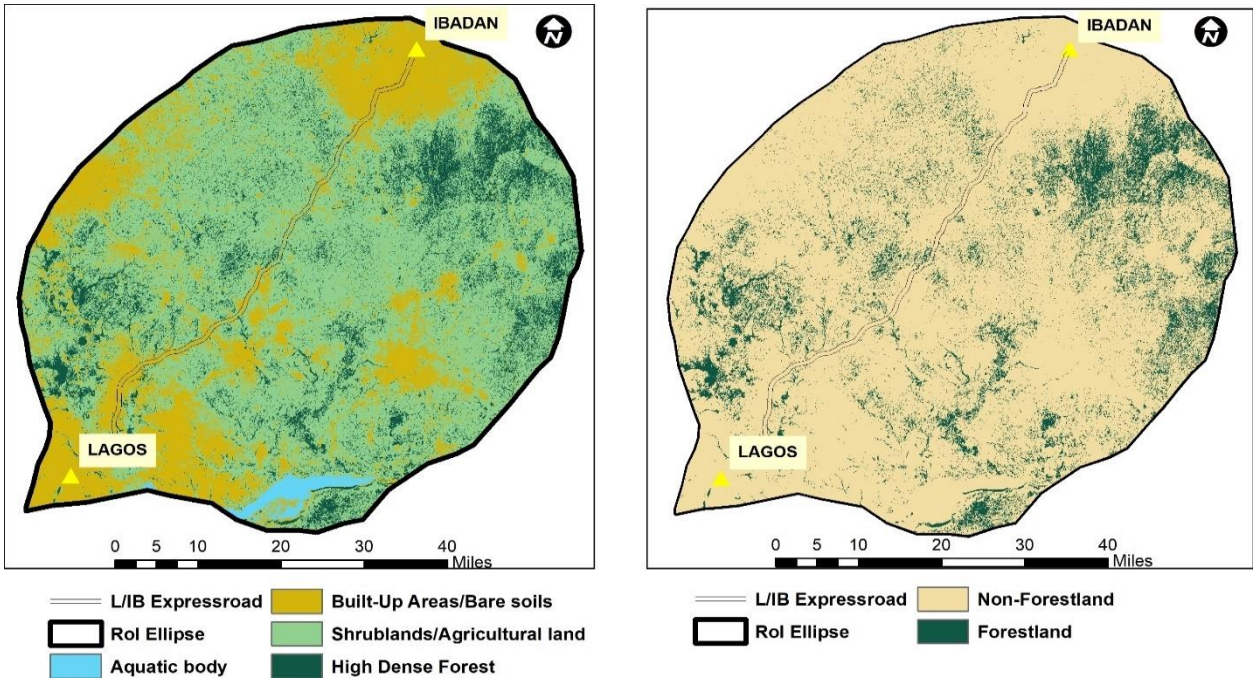

Figure 2 (L-R): Region of Interest along LIBE showing the distribution of other land cover classes around the forest cover theme (Left). Map showing the proportion of forest to non-forest land use/ land cover classes (Right).

An evaluation of forested landscape for shreds of evidence of fragmentation and forest cover types indicates that 560.36sq.km (51.70%), 319.01sq.km (29.43%), 136.95sq.km (12.63%), 43.01sq.km (3.97%), 9.32sq.km (0.86%) and 15.27sq.km (1.41%) of the forest landscapes are distributed as the patch, edge (set at 30m), perforated, core (<101 ha), core (101 – 202 ha) and core (>202 ha), respectively. The categories of the forest accounted for approximately 1083.9249sq.km or 12.58% of the ellipse, with the core forests accounting for 67.6053sq.km or 6.2370% of the forest landscapes.

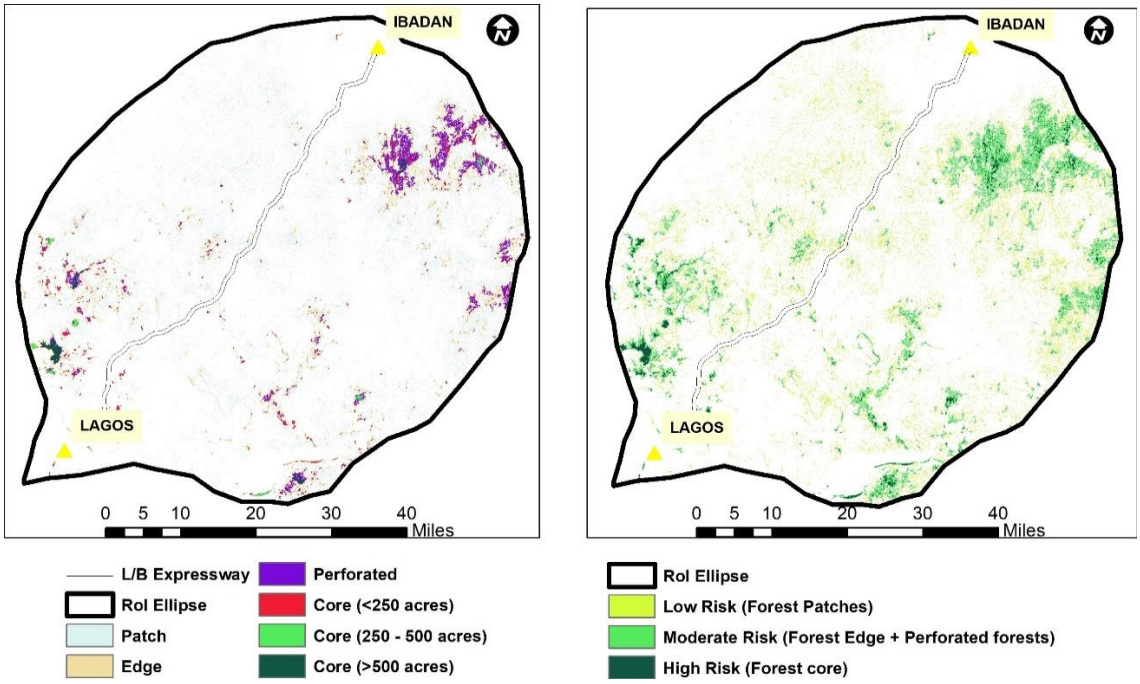

Figure 3 (L-R): Spatial distribution of forest fragmentation (Left) and classification of forest landscapes according to their expected likelihood to be used as hideouts for bandits (Right).

Proximity and Risk Analyses

Forest class proximity to LIBE shows that 72.18sq.km (6.66%) and 730.43sq.km (67.39%) of the forest landscape in **Fig. 3R** is contained within the 5km and 30km setbacks created along LIBE, respectively. In Fig 3R, the forest classes were regrouped according to the degree of their concealment factor, from Low, Medium, to High, within the RoI. Three groups of forests- Low-Risk, Moderate-Risk and High-Risk forests - were identified in (Fig. 3R) regarding their likelihood to conceal criminal activities. For the 5km and 30km setbacks, forests with the highest risk and concealment factor accounted for 1.73sq.km and 47.97sq.km, respectively.

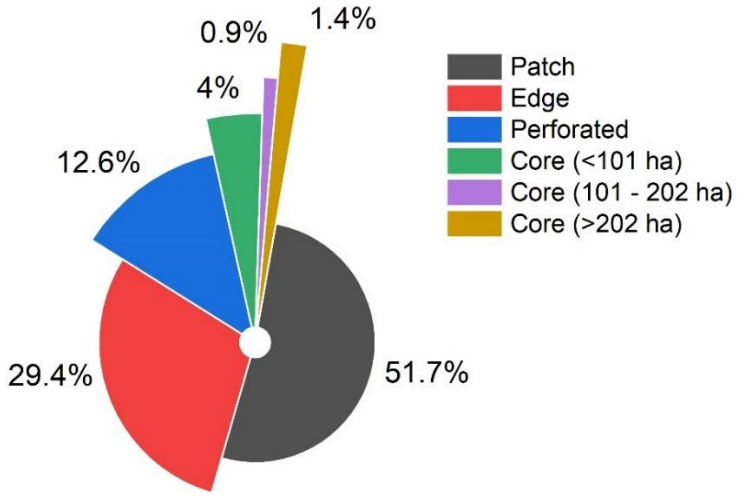

Figure 4: Percentage distribution of forest landscapes along Lagos-Ibadan Expressway.

Conservation Priority Zones

Within the ellipse created (Fig. 5.), forests with intact landscape ≥ 101 ha are distributed over 11 distinct sites covering 24.59sq.km. Ogun alone accounted for 7 (64%) of the 11 sites, while Lagos, Osun and Oyo States had 2, 1 and 1 parcels of the forest core ≥ 101 ha, respectively. Ogun State has the most contiguous and compact sequence of trees and canopy cover along LIBE.

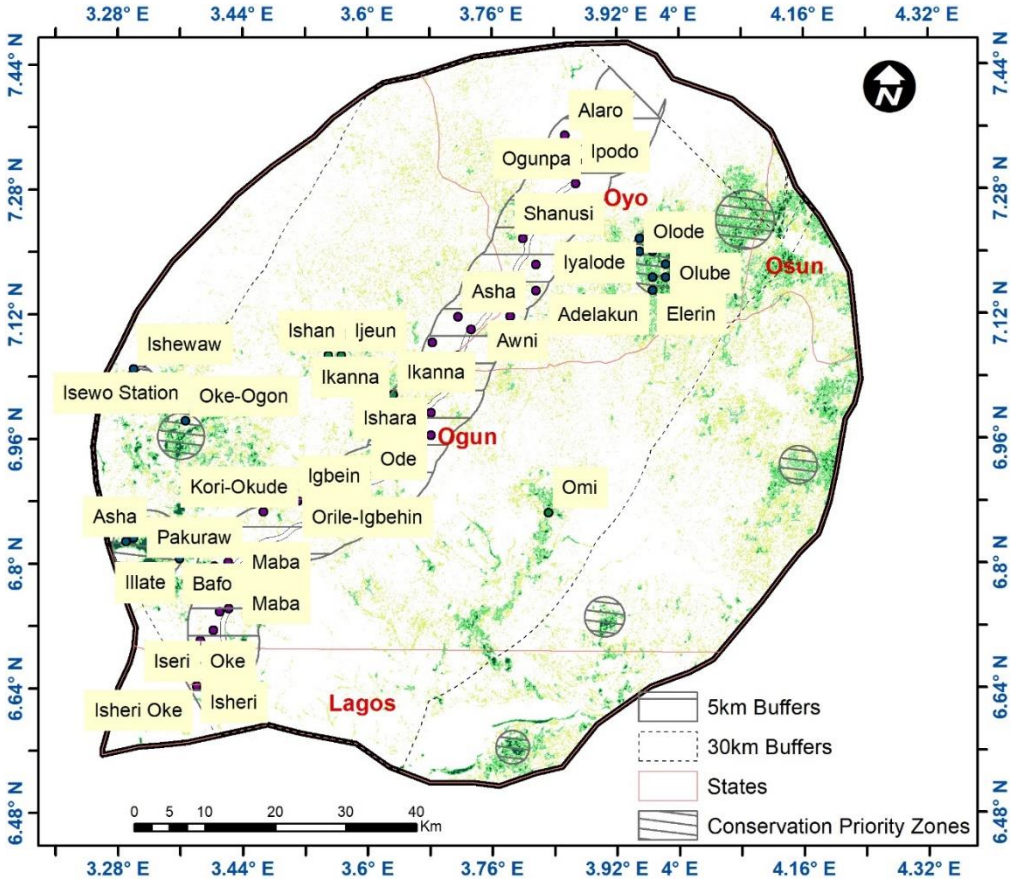

Figure 5: Map showing the 5km/30km buffers and the support zone communities relevant to landscape governance and biodiversity conservation along the Lagos-Ibadan Expressway.

Discussion

A Geographic Information System is a management tool capable of resolving spatial queries related to forest cover variations, conservation planning and physical security of lives and properties in Nigeria. The forests, which many non-technical professionals and national dallies are reporting as "bushes", are fast becoming synonymous with the activities of non-state armed groups in Nigeria. This development is gradually effacing the premise for justifying reforestation, afforestation and ecosystem restoration campaigns across Nigeria. Ogun State, which provides the lengthiest passage for the LIBE, requires more precision surveillance and other logistics commitments, as about 60% of the route overlays its landscape and contains about 64% of the core (dense) forests. An assessment of forest distribution and fragmentation along the 127.6km stretch of the LIBE uncovers forest spatial locations as a basis for planning forest governance and the security of lives and wealth of commuters plying the route.

In their research, Gupta et al. (2018) and Pertile and Nicoletti (2021) demonstrated the potential of SAVI for forest discrimination and mapping. The SAVI deployed unveiled forest presence and potential natural hideouts for bandits along the route of interest. The route is bounded on both sides by swathes of highly fragmented forestland. Forestland is not the predominant LULC category, as revealed by the non-forest to forest LULC ratio 6.96. Despite the high level of forest fragmentation, the study area has tremendous potential to put the 1083.9249sq.km (12.58%) of the forestland under rural landscape governance and biodiversity conservation regimes. This is true for the forest core

(≥101 ha) with an approximate coverage of 24.59sq.km (2.27%) of the forest LULC (**Fig. 4**). For example, the only forest patch ≥201ha within Oyo State is found within Olokemeji Forest Reserve (OFR), currently managed by Oyo State government and other interest groups. With less than 12% of Nigeria's terrestrial ecosystem under Protected Areas (P.A.s), forests outside P.A.s should be administered under a pronounced governance structure towards an unharmful use of forestlands. A Policy is a plan or course of action designed to influence and determine decisions, actions and other matters (Bolaji et al., 2015). The revised 2019 policy on National Security Strategy (NSS) for Nigeria recognized ungoverned forest spaces as one of the threats to national security. However, the generic line of actions proposed betrayed the policy document and, at best, was seen as handling critical issues with a kid's glove. The facts in this research are intended to bridge similar and essential information gaps in the NSS.

According to Ladan (2015), bandits have camps in the forest reserves, which creates fear in the minds of local people, and hence, farmlands located near the forest are no longer cultivated due to the risk of being attacked. The guerilla tactics adopted by bandits along LIBE using the forests as smokescreens can be curbed if the positioning of security checkpoints is guided with information on forest cover distribution along the route. The study assumes that if unbiassed landscape governance is entrenched across all forest fragments, biodiversity and the lives of commuters using the LIBE will be secured. The bandits' increasing occupation informs this position of the forests in southwestern Nigeria. LIBE is the life-wire of economic activities within and outside the southwestern geopolitical zone. Its economic mileage should not become inverted and siphoned through accessible forests to fund terrorism and undermine national security in Nigeria. The third tier of governance saddled with the responsibility to localized national policies, such as the revised 2019 NSS, have become usurped by state agents. Therefore, even poorly designed policies may remain unimplemented where positive changes are best desired. This view is supported by Ahmed and Dantata (2016), who concluded that implementation is the graveyard of many policies due to the underlying constellation of powerful forces of politics and administration and high corruption.

Forests with high concealment factors are identified as the core forests in **Fig. 3R.** Bandits prefer them to safeguard victims and arms. If the highly vulnerable forest of 1.73sq.km or 0.16% of the forestland within the 5km buffers to the LIBE is under surveillance by local volunteers, LIBE would be safer. The 30km setbacks, or 6 hours trekking distance off LIBE, are the expected bands delimiting the forest hideouts where victims of kidnappings are kept before ransoms are negotiated. Aderayo and Olusola (2022), in similar research, revealed that the thick forests are used as hideouts where heinous activities are perpetrated against the host communities. Both authors also showed that herders keep weapons in ungoverned spaces where no security agents will see them for apprehension. The forest cover dispersed within this band is 47.97sq.km or 4.43% of the forestland. If the distribution of the core forests within the 30km buffers is translated into natural earth coordinate positions, tracking of criminal hideouts will be exemplary.

In contrast, forest surveillance plans can be integrated with social forestry programmes for effective forest management and surveillance. This should improve travellers' safety and other dependent communities' livelihoods. The map showing residential areas in **Fig. 5** implies that LIBE can be made safer with human resources drafted from the 44 villages and communities close to the core forests in the study area. Forest surveillance plans can, thus, be activated based on the proximity of crime scenes to map potential search radius for preemptive and rescue operations by the security agencies with the support of the rural people. This will ensure the current forest land-use dilemma does not lock conservation experts out of the territories they often campaign to conserve.

Despite the degree of landscape fragmentation, the study area has sizeable and highly dispersed core forests that can act as smokescreens for the kidnappers. Changing current approaches to forest

landscape restoration will lead to more jobs at the grassroots level, the governance of ungoverned forest spaces, and the discovery of illegal camps within Nigerian forests.

Conclusion

The safety of motorists along LIBE is contingent on the effective administration of the 1.73sq.km (0.16%) of the forest cover within the delimited 5km buffer under an appropriate social scheme. Other core patches should be operated under an improved Forest Management Unit (FMU) with local institutions set up for proper forest administration. To achieve this, Ladan (2014) advocated that adequate funds should be allocated to the forestry sector to allow it to perform its duties and ensure that criminals and insurgents do not attempt to take over the forests and forest reserves. The new paradigm of forest infiltration by lawless groups requires a merger of expertise across all disciplines to revise and update Nigeria's forest landscape management plans and policies.

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THE ROLE OF BIG DATA IN PROMOTING FORESTRY RESEARCH IN NIGERIA

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ABSTRACT

Big data generally describes data that is too large and diverse to be analyzed using traditional means, and it has a wide array of applications, including research. The Nigerian forestry subsector is pivotal in the country's economic goals and environmental sustainability. However, the subsector has failed to harness its potential and is plagued with challenges that limit its productivity and prevent forestry research from driving innovation. Big data exists as a transformative tool to create opportunities for promoting forestry research in Nigeria. Therefore, this paper examines the potential of big data in catalyzing forestry research in Nigeria. The challenges facing forestry research in Nigeria have been identified, emphasizing the need for data-driven solutions and increased funding. The paper comprehensively addresses the nature of big data, its characteristics, sources such as remote sensing, geographical information systems (GIS), and socioeconomic data, and its applications in forestry research. In addition, this study addresses the obstacles and limitations that could impede the utilization of big data analytics for forestry research, such as funding concerns, issues surrounding data quality, and human resources capabilities. Big data helps improve forest mapping, monitoring, and predicting forest hazards, pests, and diseases, and it encourages interdisciplinary collaborations and data sharing. To fully harness the potential for big data, this study recommends government investment in significant data sources and analytics, personnel training, encouraging public-private partnerships, leveraging all relevant stakeholders, and addressing insecurity concerns.

Key Words: forestry, big data, machine learning, artificial intelligence, research

INTRODUCTION

The Nigerian forestry subsector is vital because of its contributions to the socioeconomic well-being of the populace. The contributions of the forestry subsector to the Nigerian economy via commercial activities revolving around timber and non–timber forest products (NTFPs) are usually reflected in terms of its contributions to the Gross Domestic Product (GDP), exports, balance of payment, employment and income generation (Rotowa et al., 2019). Olujimi and Adekunle (2015) mention that regarding poverty alleviation and income generation, the average annual value of forest products collected in Nigeria, such as fuelwood, construction materials, wild fruits, and leaf litter, was estimated to be 39% of average gross cash income per year. Forests are considered a national economic resource due to their primary nature in the production line. The trees provide a source of income, food, wood, and fuel for rural and semi-urban areas and raw materials for industries (Abubakar and Ibrahim, 2019). According to Idumah et al. (2016), the subsector's contribution goes beyond monetary terms, with the sector being responsible for timber production and the reduction of greenhouse gases, contributing to the growth and development of the Nigerian economy.

Despite the potential of the forestry subsector in Nigeria, it has not lived up to its potential. Among the subsectors in the agricultural sector, the forestry subsector had the lowest contribution to the GDP, with 3.0% between 1960 and 2011 (Idumah et al., 2016). According to Ayeni (2013), the forestry subsector in Nigeria has suffered from several challenges, such as a lack of political commitment, lack of government transparency, inadequate personnel, poor funding of the forestry

subsector, and high levels of poverty especially in the rural areas. Insecurity resulting from the activities of marauding criminals, forest fires, rural/urban migration, and climate change have also added to problems facing the forestry subsector in Nigeria (Adeogun, 2022). Ogunjobi et al. (2010) further identify the failure to incorporate the support of stakeholders, especially the local or rural people who live around the forests, as part of the subsector's problems. Deforestation and forest degradation have also had immense negative impacts on the overall forestry subsector in Nigeria. These problems have constantly plagued the forestry subsector, making improving its productivity and reaching its potential almost impossible.

Forestry research is essential to developing the forestry subsector, especially in Nigeria. In Nigeria, forestry research encompasses several key areas that contribute to the scientific knowledge and the sustainable management and conservation of the country's forests and resources (Idoko, 2023). According to Erakhrumen (2007), forestry research in Nigeria helps enable the government to deploy forest resources to contribute to attaining development goals, reducing poverty and attracting investments into the subsector. Idoko (2023) mentions that forestry research in Nigeria is essential because it allows scientists to gain significant insights into the country's biodiversity and ecosystems and efforts into sustainable forest management and conservation.

According to Ujor (2018), forestry research and development as part of the National Forest Policy 2006 is ultimately aimed at promoting intensive activities in the areas of forest conservation, biotechnology, silviculture, agroforestry, resource assessment, wildlife management, socioeconomic issues and the optimum utilization, including the development, exploitation, and marketing of both timber products and NTFPs. Given the irrefutable role research plays in developing the forestry subsector in Nigeria by driving innovation and developing insights into the total values of forest products, all efforts must be devoted to promoting it. Therefore, this paper examines significant data's important role in improving forest research in Nigeria.

BIG DATA AND ITS APPLICATIONS IN FORESTRY RESEARCH

According to De Mauro et al. (2016), big data has gained several applications and usefulness across data–reliant disciplines such as sociology, biology, medicine, economics, management information, etc., and can be defined "as the information asset characterized by such as high volume, velocity and variety to require specific technology and analytical methods for its transformation into value". Owais and Hussein (2016) summarize this by stating that big data is too diverse, rapidly changing, or massive for traditional or conventional technologies, databases, or infrastructure to handle or address efficiently.

The main characteristics of big data are expressed via the 3Vs: volume, velocity, and variety (Saeed and Husamaldin, 2021).

- **Volume** – This characteristic describes the sheer size of the data. According to Panimalar et al. (2017), big data is usually stored in terabytes (and beyond), and it measures the quantity of data collected and stored. Here, big data refers to datasets whose size is beyond the ability of a typical database software to store, manage, capture and analyze (Sonka, 2016).
- **Velocity** – This describes the speed at which the data are processed and is limited to the speed of the receiving data and the speed of the data flow (Qader et al., 2020). Yaseen and Obaid (2020) further mention that this attribute refers to how fast the data is generated. This relates to understanding and responding to events (Sonka, 2016).
- **Variety** – Data variety as a characteristic of big data refers to the various formats and types of data, which could be structured, semi-structured and unstructured (Owais and Hussein, 2016). Big data exists in different formats, such as audio, video, picture, text, etc. Yaseen and

Obaid (2020) further mention that this characteristic aids data analysts as it helps them use the data efficiently and effectively.

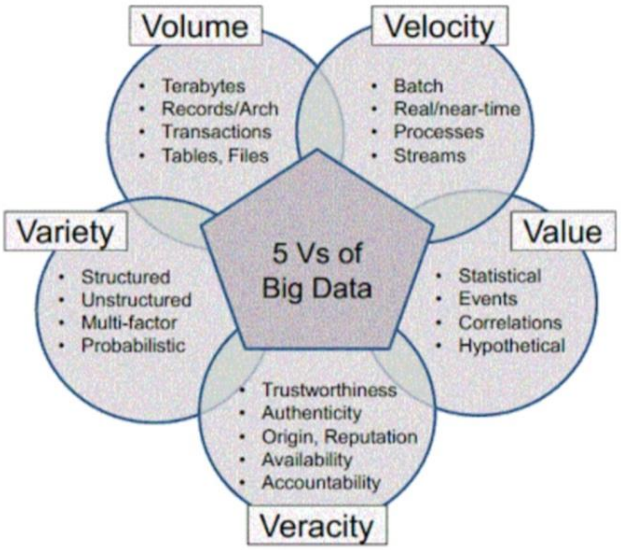

Figure 1: Characteristics of Big Data

Source: Siddardha and Suresh (2016)

According to Panimalar et al. (2017), big data is characterized by other attributes and characteristics such as value, integrity, validity, visualization, complexity, vagueness, vocabulary, venue and virality. These characteristics further help to describe the integrity and worth of data as well as the visualization of it (Owais and Hussein, 2016). There are several sources of big data with relevant applications to forestry research. Big data can be obtained from a variety of categories such as humans, machines, sensors as well as business processes and includes records from business processes, industry data, social media networks, satellite imagery, mobile sensors, Global Positioning System (GPS) as well as information from public records (Owais and Hussein, 2016).

Remote Sensors – Remote sensing is an essential tool in collecting data. It heavily implies obtaining information from an object or phenomenon without making physical contact or from a distance, and the converted data is helpful for farmers, foresters, ecologists, geologists, etc. (Esbri, 2021). According to Gao et al. (2022), remote sensing has the potential to offer forestry researchers detailed contiguous spatial, multidimensional, and vast spectral data, and this allows forestry scientists and researchers to accurately predict forest structural parameters based on the structural and spectral characteristics of the remote sensing data. Remote sensing platforms such as ground-based systems, aircraft–based systems (e.g. Unmanned Aerial Vehicles or UAVs), GPS and satellite-based platforms are effective in monitoring forests, performing forest management tasks, e.g. mapping via large-scale and low-cost data (Zou et al., 2017). Accessing particular forests or parts of some forests may be difficult in Nigeria, but this platform has become very useful. Remote sensing could also allow researchers to adequately observe deforestation patterns and other vital information central to forest management and research.

Figure 2: Experimental Forests with Sensors

Source: Gabrys (2020)

Geographic Information System (GIS) – According to Singh et al. (2022), GIS technology has become very popular in a lot of fields, including engineering, natural and social sciences, and assists foresters in recordkeeping, analyzing and decision making, providing data based on location, trends, patterns, and modelling. They further mention that GIS technology is also helpful regarding forest resource assessment and monitoring, forest protection, forest harvesting, forest rehabilitation, wildlife conservation, etc. The GIS provides spatial data and is an essential tool for forestry analysis and research with many applications, such as landscape mapping, yield forecasting, predicting diseases and forest fires, and configuring forest data based on spatial properties (Zou et al., 2017). Combining GIS and GPS data helps generate richer data supporting local forest management. It provides a means to ground truth and refine automated systems for interpreting, visualizing, and analyzing satellite data at international and national scales (Taylor et al., 2020).

Figure 3: GIS Forest Sampling

Source: Forestry and Land Scotland (2019)

Human/Demographic Responses/Socioeconomic Information - Human responses and information can be a tremendously significant data source. According to Zhang et al. (2023), social media and search engine information can be a source of information. Human and demographic data can be collected using tools from secondary and primary data sources. Secondary data includes information collected from databases, which could be national or international agencies and bodies. Owais and Hussein (2016) state that big data can also be obtained from processes such as data from commercial transactions, banking, etc., which can be collected from businesses, organizations, and international agencies. These significant data sources have enormous opportunities to enable big data analytics through emerging technologies that support forestry research.

BIG DATA ANALYTICS, INTERNET of THINGS (IoT), MACHINE LEARNING (ML) AND ARTIFICIAL INTELLIGENCE (AI)

The primary purpose of big data analytics is to provide accurate, reliable, and understandable information to support decision-making and research (Saeed and Husamaldin, 2021). As technology improves, more complex tools are needed for big data analytics. Aly et al. (2015) mention that given that vast amounts of heterogeneous raw data are collected, new technological concepts such as the Internet of Things (IoT) help bypass big data's challenges. The Internet of Things (IoT) generally refers to interconnected devices over the Internet that collect, store, and manage big data (Kundhavai and Sridevi, 2016). According to Breur (2015), given the explosion of big data, especially in recent years, IoT has also become more common as it allows for the exchange of data among connected devices over the Internet, which has practical applications for businesses and research. IoT has also become more popular, especially with the growth of devices connected to the Internet. IoT not only allows for the generation of big data, it also enables the use of remote sensing, ensures forecasting and trend analysis, and promotes governance and transparency as it monitors the monitoring real-time inflow of data (Brou and Janssen, 2015). Therefore, IoT becomes essential in deploying big data analytics in forestry research by enabling data collection and transmission from various sources.

Artificial intelligence (AI) and Machine Learning (ML) go hand in hand with big data. "AI systems refers to machine-based systems with varying levels of autonomy that can, for a given set of human-defined objectives can, make predictions, recommendations and decisions" (OECD, 2021).

According to Shivaprakash et al. (2022), the breakthroughs of AI have increased their applications in fields such as e-commerce, environmental conservation, healthcare, etc. and the increase in the use of AI is driven by the pace at which information is available (considerable data velocity), lower costs in data storage because of cloud computing technologies as well as the availability of wholistic data sources. The goal of big data analytics using AI is to automate data analysis and make the process faster, more accurate and more scalable, allowing organizations to harness the full potential of their data and gain competitive advantage (Gandomi et al., 2023). AI uses big data to detect anomalies, determine the likelihood of future events, and recognize patterns and data visualizations, making it easier to determine trends and gain insights (Demigha, 2020). Significant data results in a variety of data, which could be structured or unstructured, and AI makes it possible to analyze such data.

Machine learning is a subset of artificial intelligence which provides efficient and automated tools for data gathering, analysis and assimilation with practical applications on extensive data operations such as data segmentation, data analytics and simulations (Das et al., 2021). Machine learning is where computers gain the ability to learn from data using appropriate algorithms, making it possible to identify the hidden patterns in data without having a user actively program it (Matthew, 2022). An objective of machine learning is to discover knowledge and make intelligent decisions via the use of its algorithms (decision tree learning, Bayesian networks, clustering, support vector mechanisms, artificial neural networks, association rule learning, classification, regression etc.) (Wang and Alexander, 2016).

AI and ML have also been deployed in forestry and have numerous applications. AI technologies can be deployed to quickly detect anthropogenic threats to the forests, such as illegal tree felling, predict and assess forest hazards such as fires, pests and diseases and as well as forest mapping and monitor forest health and phenology (Shivaprakash et al., 2022). According to Raihan (2023), AI, as an emerging technology alongside ML in the fields of forestry and biodiversity, helps facilitate effective surveillance, administration and preservation of biodiversity and forest resources. Estrada et al. (2023) mention that machine learning techniques combined with robotic platforms and artificial vision systems have been used to remotely monitor the health of the forests, including moisture content, chlorophyll, nitrogen estimation, forest canopy, forest degradation, etc.

BIG DATA CHALLENGES AND LIMITATIONS

Despite the enormous advantages of adopting big data in forestry research, several limitations may be encountered.

- **Low Funding** – Adopting big data analytics usually depends on high financial commitments, which may be unavailable to researchers depending on the government or other national planners. According to Shivaprakash et al. (2022), the leading prerequisites for the adoption of AI are having access to high–volume and high–quality datasets, network infrastructure for IoT, advanced technologies, e.g. sensors, UAVs etc., as well as computational space and storage.
- **Privacy and Security** – This is the most critical challenge regarding big data due to its sensitivity and conceptual, technical, and legal significance (Satyanarayana, 2015). Bhadani and Jothimani (2016) further state that as newer technologies, such as cloud computing, provide a gateway to access and store sensitive information, integrating IT architectures will pose more significant risks to data security and intellectual property. Since big data also contain human responses and information, there is a chance that data privacy may be compromised, which poses problems.

- **Data Heterogeneity** – Big data is characterized by a wide variety of data sources such as images, videos, and audio and, as a result, may be affected by noise and inconsistencies (Siddardha and Suresh, 2016). According to Satyanarayana (2015), working with structured and unstructured data is often cumbersome and costly; converting all these unstructured data into structured data useful for research is not feasible.
- **Data Storage and Analysis** – According to Siddardha and Suresh (2016), storing big data often requires high costs in finance and computational power due to the sheer enormity of big data. Big data is growing continuously exponentially, thus requiring an ever-growing need for storage and computation (Acharjya and Kauser, 2016). The ever-growing need for storage would imply that big data would also need to be transferred to a new storage location, and the time required to transfer this data would increase each time (Satyanarayana, 2015).
- **Technical Knowhow** – Deploying big data analytics requires a high level of capabilities that may not be available to researchers. Bhadani and Jothimani (2016) corroborated this, stating that an increase in significant data results in an increased need for experts in this area where there is a gap.

Circumventing these obstacles will allow researchers and other data users to maximize the opportunities big data presents in the forestry subsector.

OPPORTUNITIES FOR BIG DATA IMPROVING FORESTRY RESEARCH IN NIGERIA

Big data has been identified to significantly impact forestry research in forest mapping, monitoring the anthropogenic activities in forests, and predicting pests, diseases and hazards, which are helpful for research and developing the forestry subsector. By utilizing big data, more intelligent knowledge and information can be integrated to accurately assess a forest's ecological performance (Hasan et al., 2019). According to Taylor et al. (2020), big data technologies can also augment efforts to strengthen forest policies and governance.

Big data ensures that a considerable amount of data is generated for research. According to Zou et al. (2017), forestry big data allows for large datasets to be created using technologies that ensure high–level precision. Hasan et al. (2019) further add that the data collected from satellites, UAVs, GPS, GIS, sensors, and other digital technologies help provide information across the linkages in the forestry supply chain and develop an efficient database. These significant data sources generate data that gives room for socio-political research (Gabrys, 2020). Big data also enables increased collaboration between Nigeria's government and environmental research institutes. Increased data sharing allows for increased research into the Nigerian forestry subsector. Deploying big data technologies in forestry will also improve collaborative efforts between the Nigerian federal government and state governments, reducing duplication, redundancy, and corruption.

CONCLUSION

Forestry has been demonstrated to play a critical role in Nigeria's economic growth and development, as well as poverty alleviation, employment, and environmental sustainability. Several challenges, such as data scarcity, dilapidated infrastructure, poor funding, and inadequate personnel, have prevented research in the forestry subsector from delivering the total values of the country's forest products. Big data has been identified as crucial for developing Nigeria's forestry research via essential data sources such as RS, GPS and GIS. The seamless integration of emerging technologies such as IoT, AI and machine learning presents researchers with unprecedented capabilities, all of which contribute to more profound insights into the forestry ecosystem and its intricate dynamics. Big data provides an environment for interdisciplinary collaboration, data sharing, and increased datasets, all aimed at improving forestry research in Nigeria. Public-private partnerships, stakeholder

inclusion, data sharing, and intensified cooperation have been recommended to the Nigerian government and other national planners.

RECOMMENDATIONS

Big data has been identified to be an essential tool in improving forestry research in Nigeria. Therefore, it is heavily recommended that the government and national planners invest heavily in sources of big data such as remote sensors, drones, UAVs, etc., as well as the supporting infrastructure and tools for big data analytics such as IoT, machine learning and AI. The government should also invest in training its available personnel, enabling Nigerian researchers to be up to date with current global trends and technologies, especially in Information Technology (IT). National planners and the government should also improve supporting frameworks for research, such as libraries, laboratories, and basic infrastructures. A private partnership between the government and the private sector is recommended to strengthen research, personnel, and data sharing. Involving relevant stakeholders from the private sector to support the government's efforts can improve research and the adoption of big data analytics in forestry.

Furthermore, it is also recommended that stakeholders from rural communities where the forests are located be involved in government decisions and ongoing research efforts. The government and other national planners must also provide frameworks to ensure data security and user privacy. To improve forestry in Nigeria, the government needs to intensify its efforts to address insecurity, especially in forests.

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Comparative Analysis of the Accuracy of Thirteen Photo-based Applications in the Identification of Trees Species in Northern Ghana

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Abstract

Photo-based tree identification applications have gained prominence for their convenience and speed in identifying tree species. However, the accuracy of these applications remains a critical concern to prospective users. This Study assessed the accuracy of thirteen photo-based tree identification applications in identifying twenty-two tree species in the savannah ecological zone of Ghana using their leaf samples. In their natural environment, three photographs were taken from well-developed and diseased-free leaves from each tree using a Samsung Galaxy Tab S4 phone with an inbuilt camera. The pictures were uploaded to the respective applications' platforms for processing and identification. This study used 858 photographs from 22 plant species using 13 photo-based applications. The number of times the application identified the species was recorded and analyzed using Microsoft Excel.

The results showed that the mean identification accuracy was 65.03%. Seven applications could identify the tree species up to 72.73 - 95.45% accuracy. The remaining eight had an accuracy range of 9.90 -50.09%. LeafSnap, PlantNet, and PlantID had the same and the highest accuracy rate, 95.45%, corresponding to 21 of the plant species identified. These were closely followed by Plant ID, PictureThis, Google Lens and Nature ID with accuracy rates of 86.36%, 81.81%, 77.27% and 72.73%, respectively. Plant-X had the lowest accuracy of 9.09%. The Study recommended applications with identification accuracy above 70% for identifying species in the Savanna Zone of Ghana. The results of this study have significant implications for identifying and managing tree species as non-taxonomists, non-botanists, and non-naturalists will be able to work effectively.

Further studies, considering up to the family level, are needed to improve the accuracy of these applications further. The study also recommends the inclusion of other plant organs, such as fruits, flowers, and bark, in future research. It is also recommended that other photo-based tree identification applications be studied and the results be compared with the findings of this study to assist in selecting the best applications for identifying trees in the Savanna Zone of Northern Ghana.

Keywords: Leaf identification, Photo-based applications, Savannah tree species

Introduction

Humans depend on plants for survival as they supply food, oxygen, medicine, and other essential livelihood needs, ameliorating our environment. The continued supply of these benefits by plants is declining due to the rise in activities such as human population growth, rapid urbanization, excessive logging, pollution, and global warming. Therefore, the protection of plant species has become an essential activity throughout the globe. The first step is recognizing and understanding plant species, their origins and how to manage them (Zhang *et al.,* 2020). According to Wäldchen and Mäder (2018), the exact identification of plant species is the foundation of all taxonomic and biological research. Plant species identification is also essential for preserving and exploring the environment, and it has excellent benefits for many stakeholders, including foresters, hikers, eco-tourists, nature

enthusiasts and environmentalists (Chopra, 2015). Further, accurately identifying plants, especially trees, is essential for urban tree inventories to understand the urban forest's consequences, advantages, and hazards from a management perspective (Schmidt et al., 2022). According to Finger *et al*. (2022), species recognition is crucial to raising people's knowledge about biodiversity and species extinction.

Plant identification, traditionally, is done by well-trained botanists and naturalists. However, The process can be challenging even for these skilled persons due to the vast number of species that share similar physical traits, such as stems, roots, flowers, and leaves (Hsiao *et al.,* 2014). Further, the similarity between species and the variety within species renders the identification process particularly difficult and time-consuming (Mouine *et al.,* 2013). According to Mäder *et al*. (2021), identifying species in the field requires adequate individual skills, making biodiversity monitoring a labour-intensive task. Plant identification applications are, therefore, becoming more widely available and more accurate, and their crowd-based structuring offers a considerable sample size that is not restricted to any geographic boundaries (Otter *et al*., 2020). Again, the introduction of mobile applications has made it easier to identify trees without needing a specialist or a professional botanist (Mäder *et al.,* 2021). Hence, numerous applications and strategies for plant identification have been created recently in response to this need (Finger *et al.,* 2022). These applications range from those that rely on automatic image recognition (Artificial Intelligence) to those that require the user to use classic dichotomous or multi-access keys and those that only supply a collection of pictures with no obvious method for identifying the species (Jones, 2020). Mobile applications offer many advantages compared to the traditional way of identifying plant species. For instance, the applications are user-friendly as one merely needs to take a close-up snapshot or picture of the tree or its favourite organ (typically the leaves, bark, bloom, or fruit) and upload it to the application for identification (Schmidt *et al.,* 2022). According to these authors, most of these applications also offer further recommendations on maintaining the species of plant they identified. Also, non-professionals will be able to conduct their research and have a much wider audience and more possibilities due to the availability of the Internet and mobile devices (Crocker *et al*., 2020). The advancement of current approaches utilizing automated visual identification will also encourage and promote people's participation in citizen science efforts (Bonnet *et al*., 2020). Zhang *et al.* (2020) posit that automatic identification of plant species is crucial for phytotaxonomy and everyone.

Photographs of various organs of plants, such as leaves, fruits, flowers and bark, could be used to identify them (Hassoon *et al.,* 2019). However, plant leaves are preferred for various reasons: leaves mostly contain the most crucial information about a plant's taxonomic identification (Hsiao *et al.,* 2014), are in abundance when in season, and are easy to collect (Zhang *et al*., 2020). According to these authors, leaves shape and structure are often constant and are present in a flat state, making them ideal for two-dimensional image processing. Leaves are the key focus in developing most identification applications using shape, edge pattern, venation, and similar characteristics consistent with foliar morphology (Schmidt *et al.,* 2022). According to Kaur and Kaur (2019), four processes commonly involve automatic plant identification: image acquisition, image pre-processing, feature extraction, and classification. Besides the usefulness of these applications in identifying species, little research has been carried out to examine their general precision and accuracy (Schmidt *et al.,* 2022). The authors argued that the precision and accuracy of these applications have not been thoroughly compared in research, without which users may unknowingly rely on flawed information, undermining the integrity of their work.

The current study, therefore, investigated the accuracy of thirteen mobile applications in identifying plant species in the savanna ecological zone of Ghana. It employed applications which identify plants automatically from uploaded images, with at most the need for only minor decisions by the

user. These included NatureID (Plantum), LeafSnap Google Lens, Blossom, PlantSnap, PlantNet, Seek, PlantApp- Plant Identifier, iplant (Planter), Plant ID, PlantID and Plant-X (Table 1). These applications were selected because they are highly recommended, from our online research on their respective user-review comments, to be adept at identifying tree species. The applications are also easily accessible from Google and Apple Play stores with little or no fees. Free trial versions of at least one week are also available for most of these applications. Hence, they are easy to reach by all researchers, especially non-botanists and naturalists. The twenty-two plant species used in the Study were also selected due to their accessibility and abundance in the University of Development Studies Campuses, where students and researchers are based with a high likelihood of the need to identify plant species. The study's main objective was to identify computer-based applications with high plant species identification accuracies. The Study results will contribute to selecting more reliable applications for use in plant identification, enabling informed decision-making in managing Ghana's forest resources.

Table 1. Details of Photo-based Applications used in the identification of Savanna plant species in Ghana

Name of Application & Version	Developer	Potential uses	Estimated cost
PictureThis-Plant Identification	Glority Global Group Ltd	Identifies over 17,000 plant species with 98% accuracy Diagnosing plant disease, identifying weeds, insects and birds, identification, and plant care tips.	GHS 170.0/year, GHS 35.00 per month, and GHS 20.00 per week for the premium version. A free trial is available.
NatureID (Plantum)	AIBY Inc.	Identifies over 15,000 natural things such as plants, rocks, insects, and mushrooms, diagnose plant disease, and gives care tips and reminders.	GHS 85.00/year Free trial available
LeafSnap Plant Identification	Appixi	Identifies up to 95% of flora and fauna species in the world Diagnosing plant disease and care reminders	GHS 130.00/year and GHS 20.00/ month for premium A free trial is available
Google Lens	Google LLC	Identifies flora and fauna species, scans QR codes and barcodes, identifies and learns about restaurants, landmarks, etc.	No estimated price was found.
Blossom	Conceptive Apps	Identifies about 10,000 plant species. It gives plant care reminders, disease diagnostics, botanist consultations, and a water calculator.	GHS 25.00/month for premium A free trial is available
PlantSnap plant identification	PlantSnap, Inc.	Identifies over 600,000 species and gives plant care tips	GHS 8.99/year and GHS 0.75/ month for Pro Free trial available
PlantNet Plant Identification	Cirad-France	Identifies over 20,000 plant species. It gives information on plant geographical locations. Shares observations of plants	No estimated price was found.
Seek	iNaturalist	Identifies flora and fauna species	No estimated price was found.
PlantApp-Plant Identifier	ScaleUp	Can identify any plant species. Gives plant care tips and disease diagnosis	GHS 85.00/ week for premium A free trial is available

implant (Planter)- Plant Identification	GymMusic Studio	Identifies over 15,000 plant species	No estimated price was found
Plant ID: Plant Identification/ Plant identifier	Control INC.	Accuracy is up to 98%. Identifies rocks, minerals, and crystals, Diagnoses diseases and treatment for plants, plant care tips	GHS 220.00/ year, GHS 60.00/month for premium A free trial is available
PlantID- Plant identification	IKONG JSC	Identifies plants and gives plant care tips	GHS 160.00/ year and GHS 40.00/ month Free trial available
Plant-X, Plant Identification	Duff HL	Identify plants and insects and offer watering reminders	GHS 25.00/ week for premium A free trial is available

Source: Google play store retrieved in July 2023. *Note: 1USD = GHS12 (UDS = United States Dollar. GHS = Ghana Cedis).*

Table 2. List of Plant Species used in the Study

Scientific Names	**Local Name (S)**
Azadirachta indica	Neem
Senna siamea	Cassia siamea
Vitellaria paradoxa	Shea
Dalbergia sissoo	North Indian Rosewood, Shisham
Calotropis procera	Apple Of Sodom, Rubber Bush, Rubber
Khaya senegalensis	Senegal Mahogany, African Mahogany
Delonix regia	Phoenix Tree, Flamboyant, Royal Poinciana
Anacardium occidentale	Cashew
Terminalia catappa	Tropical Almond, Indian Almond
Tectona grandis	Teak
Leucaena leucocephala	White Lead Tree
Gliricidia sepium	Grow Stick
Mangifera indica	Mango
Ficus benjamina	Weeping Fig
Terminalia mantel	Umbrella Tree
Annona squamosal	Custard Apple
Moringa oleifera	Moringa
Psidium guajava	Guava
Codiaeum variegatum	Joseph's Coat
Ceiba pentandra	Kapok Tree
Prunus serotina	Black Cherry, Rum Cherry
Morinda citrifolia	Great Morinda

Materials and Methods

Study area

The study was conducted on the Nyankpala Campus of the University for Development Studies, Tamale, in the Tolon District. The district is located between latitudes 9° 15′` and 10° 02` North and longitudes 0° 53′and 1° 25′ West (Ghana Statistical Service, 2014).

Data collection and analysis

Thirteen mobile applications were downloaded from the Google Play Store. These included PictureThis- Plant Identification, NatureID (Plantum), LeafSnap Plant Identification, Google Lens, Blossom, PlantSnap plant identification, PlantNet Plant Identification, Seek, PlantApp- Plant Identifier, iplant (Planter)- Plant Identification, Plant ID: Plant Identification/ Plant identifier, PlantID- Plant identification, Plant-X, Plant Identification (Table 1). The applications were first downloaded to a smartphone, the Samsung Galaxy Tab 4S, with a built-in camera. Three leaf photographs were taken from each of the 22 plant species (Table 2) and uploaded into the 13 applications, making a total of 858 images. Thus, using three images, each application was allowed to identify the 22 selected plant species. It gave a subtotal of 66 images per application. All photographs were taken from the frontal view of matured, well-spread and diseased-free leaves, which were entirely illuminated by sunlight. The Photographs were taken from 10 am to 12:00 pm in July 2023 on the same day. This duration ensured that phenotypic variations between the photos of each species were reduced to the barest minimum. The Study avoided the "zoom" feature on the camera as much as possible to ensure the photographs would not be distorted. To ensure that the applications identified the leaf, the study ensured that only one leaf was photographed at a time against the natural environment to minimize the background effects. Leaf photographs were chosen because a plant's leaves often contain a lot of data necessary to determine its taxonomic identity. The 22 plant species chosen were also well-known by the researchers of this Study. This enabled us to confirm or otherwise confirm the results produced by the applications. When an application correctly identified a species, it was recorded as P and U when it failed. For instance, an application which identified a plant species using all three images was scored PPP. Likewise, an application that failed to identify a species using the tree images were scored UUU. The same procedure was repeated for all three images for each of the 22 plant species (858 images) with all 13 applications to obtain a data matrix (Table 3). The data matrix obtained in section 2.1 was analyzed in Microsoft Excel and represented using bar charts.

Results

The cumulative performances of the 13 mobile applications in identifying the 22 plant species showed a mean accuracy rate of 65.03%. The mean number of plant species identified was 14. Three applications had an accuracy rate of greater than 90%. These included LeafSnap, PlantNet and PlantID, with the same and the highest accuracy rate of 95.45%, corresponding to 21 of the plant species identified. These were closely followed by four applications, with an accuracy rate between 72.73 and 86.36%. These included Plant ID, PictureThis, Google Lens and Nature ID with 86.36%, 81.81%, 77.27% and 72.73% accuracy, respectively. Three of the applications had an accuracy rate between 50 - 59.09%. Blossom and PlantApp had an accuracy rate of 59.09%, whereas Seek had 50%. Three other applications had an accuracy below 40%. These were PlantSnap, iplant (Planter) and Plant-X, with 36.36%, 27.27% and 9.09% accuracy rates, respectively (Figure 1). The three best applications, LeafSnap, PlantNet, and PlantID, could not identify one out of the 22 plant species. For

instance, LeafSnap could not identify *Gliricidia sepium* whereas PlantNet and PlantID could not identify *Senna siamea* and *Ceiba pentandra*, respectively (Table 3).

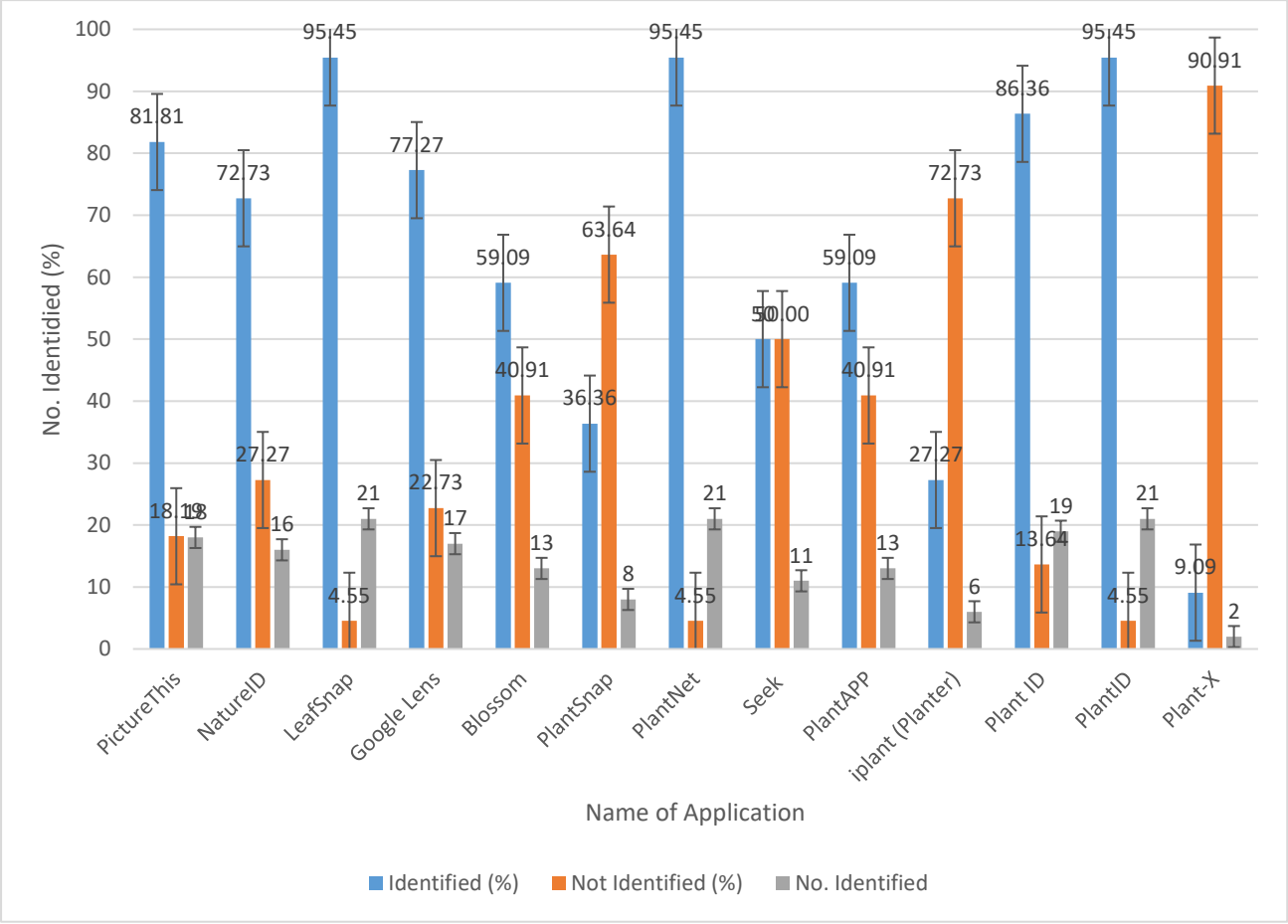

Figure 1: Percentage accuracy of 13 mobile applications in the identification of 22 plant species in the Savanna Zone of Ghana

Table 3: Details of plant species tested using 13 plant identification applications in the Savana Ecological Zone of Ghana

	Name of Application												
Plant Species	PictureThis	NatureID	LeafSnap	PlantNet	Plantsnap	Plant ID	Blossom	Plant-X	Google lens	Seek	PlantApp	PlantID	iplant
Azadirachta indica	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗
Senna siamea	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗
Vitellaria paradoxa	⊗⊗⊗	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗
Dalbergia sisso	⊗⊗⊗	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗
Calotropis procera	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗
Khaya senegalensis	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗
Delonix regia	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	✓✓✓
Anacardium occidentale	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗
Terminalia catappa	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗
Tectona grandis	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗
Prunus serotina	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗
Leucaena leucocephala	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗
Mangifera indica	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	✓✓✓
Gliricidia sepium	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	✓✓✓	✓✓✓
Ficus benjamina	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗
Annona squamosa	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗
Moringa oleifera	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
Psidium guajava	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓
Codiaeum variegatum	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
Ceiba pentandra	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	⊗⊗⊗
Terminalia mantel	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	⊗⊗⊗
Morinda citrifolia	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗
Identified	**18**	**16**	**21**	**21**	**8**	**19**	**13**	**2**	**17**	**11**	**13**	**21**	**6**
Not identified	4	6	1	1	14	3	9	20	5	11	9	1	16
Total	22	22	22	22	22	22	22	22	22	22	22	22	22

Note: ✓✓✓ All three images correctly identified, ⊗⊗⊗ All tree images incorrectly identified

Discussion

Generally, all the applications could correctly identify at least two of the plant species studied. This observation is supported by the fact that developing these applications focuses on image pattern recognition using shape, edge pattern, venation, and similar characteristics consistent with foliar morphology (Keivani et al., 2020). The Study observed that if an application failed to identify a species in the first image, it automatically was unable to do the same in the subsequent two images. Likewise, if an application could identify a species, it did so for all three images. It could be a reasonable guide for researchers using these applications.

Nine of the applications had an accuracy of between 50 and 95.45%. The current study's findings are supported by Jones (2020), who reported that over one-third of all identifications use ten applications to correctly identify plants at the genera and species level with more than 65% accuracy and 75% at the family level. A similar study by Schmidt & Casario (2022) reported that plant identification applications consistently offered correct leaf identifications to the genus level with an accuracy of 95% or above.

The best three applications were LeafSnap, PlantNet and PlantID, with an identification accuracy of 95.45%, each corresponding to 21 of the plant species identified. The best three applications, however, could not identify some of the commonly used species in the Savannas of Ghana.

LeafSnap, for example, could not identify Gliricidia sepium whereas PlantNet and PlantID could not identify *Senna siamea* and *Ceiba pentandra*, respectively (Table 3). *Ceiba pentandra* was, however, identified by Plant-X even though the application had the lowest accuracy of 9.09%. It was also striking to note that nine of the applications could not identify *Vitellaria paradoxa* (the shea tree) even though the species is one of the most commercial trees of the Northern Savannas. Seven of the applications with over 70% accuracy were also unable to identify Khaya senegalenses, a dominant and widely used species in the Northern Savannas. This species was, however, identified by Seek, even though it had an accuracy of 50% (Table 3). Hence, it can be inferred from the results of this study that the species to identify and the useability of the application are worth considering when deciding which application to use. According to Akindele (2022), PlantSnap works anywhere on Earth and has 37 language translations with useability across over 475 million images of plants and trees. As such, it could be preferred even though it had an accuracy of 63.64% in the current Study. Although it does not have an exceptionally high identification rate at the species level, seek is reported to be among the best applications for identifying genus and family levels (Jones, 2020). Furthermore, factors such as the accuracy of the applications and the users' confidence in the identification process are critical in determining their usefulness (Jones, 2020). This means that the criteria for selecting the best application for any research are closely dependent on the species to be identified, the level of identification required (family, genus, and species levels) and the confidence level of the application user and not solely on the rankings done in this Study.

Conclusions and Recommendations

The study recommends a selective preference of these applications in order of their accuracy score. However, it is advisable to select applications using the species intended to be identified. Further research involving more plant organs such as fruits, bark, and flowers is needed to improve the current study's findings. The Study further recommends studies beyond the species and genus levels to the family level. It is also recommended that the Study be repeated using species from the high forest zone to assist in establishing the accuracy levels of these applications in identifying plant species in Ghana.

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DEVELOPMENT OF A LOCATION-ENABLED APPLICATION FOR THREATENED TREE SPECIES AT THE UNIVERSITY OF IBADAN, NIGERIA.

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ABSTRACT

Combining geospatial tools and data provision elements can greatly benefit threatened species management, particularly where location services are added. Therefore, this study was designed to develop a location-enabled mobile application for managing threatened trees within the University of Ibadan. The selection of threatened trees was based on the IUCN Red List. Threatened trees with a diameter at breast height of not less than 10cm within the University of Ibadan were identified to species level and wholly enumerated. The growth variables of each threatened tree were estimated, and each identified tree was georeferenced. Identified threatened trees were categorized based on their IUCN status, and the mean growth variables and the total number of trees, families and species per family were displayed. Icons on a map also represented identified trees to show their spatial. A data addition form was created, and the Google Firebase Real-time Database was used as a temporary repository of user-suggested data. A navigation system was also designed to navigate to threatened tree locations. A user-friendly mobile application called "UITTNav" was developed within the scope of this study. The application can be downloaded with the name "UITTNav" for free on the Google Play store without any restriction from June 2024. The application combines the ability to show where trees are, help users find their way to these trees, give detailed information about them, and allow users to suggest tree data. It will provide adequate location and tree data to manage threatened trees within the University of Ibadan.

Keywords: Threatened trees species, Mapbox SDK, Navigation System, and IUCN Red list

INTRODUCTION

Across the world's continents, 30% of trees are threatened with extinction, and well over 142 species have already been recorded as extinct in the wild. Unfortunately, these tree species' major threats are anthropogenic activities due to exploitation and climate change (Botanic Gardens Conservation International, 2021). Africa, including Nigeria, stands at the epicentre of this crisis, with the most threatened tree species reported by the Botanical Gardens Conservation International (Botanic Gardens Conservation International, 2021).

This high extinction rate can be attributed to an expansion of the human population (Gao *et al*., 2020). The human population, which is increasing at an alarming rate, is over-exploiting the environment at an alarming rate (Marselina and Prasetyo, 2023). Unfortunately, the degradation of the natural environment due to the human population explosion is affecting not only natural forests but also urban forests (Vogt, 2020). Nigeria is significantly burdened by overpopulation and is also experiencing this forest degradation (Adegbite *et al.*, 2020).

Consequently, the management of urban forests in Nigeria is necessary. According to Usman *et al.* (2020), forest resources management using geospatial tools is highly indispensable for sustainable development. The availability of structural information also ensures the comprehensive management of forests. This is because this structural information can be used to estimate the actual and potential physical, biological, and social risks to species in the forest. (Ghorbanzadeh *et al.*, 2019).

Beyond general urban forest management, accurate data on threatened trees can be used to demonstrate the importance of protecting these species, garnering support for conservation efforts (Barker, 2019). Additionally, combining elements of geospatial tools and data provision can greatly benefit threatened species management, particularly where location services are added (Dracott *et al*., 2019).

A location-enabled management application will combine elements of geospatial tools, data collection and location. It will provide benefits, including identification of target species, identification of seed sources, monitoring species population, and conservation planners (Fan *et al*., 2019). It can then be concluded that a real-time location-enabled forest application for threatened tree species can play a crucial role in managing and conserving threatened tree species in urban areas in Nigeria.

MATERIALS AND METHODS

Study Area

The study was carried out within the University of Ibadan campus. The University of Ibadan is the oldest in Nigeria. It is in the Northern part of Ibadan City, the capital of Oyo State in southwestern Nigeria (Oyekola *et al*., 2021). The coordinates of the University are longitudes 3°53′21″E to 3°54′26″E and latitude 7°25′58″N to 7°26′42″N. It is divided into different areas, including residential areas, administrative areas, parks and gardens, and academic areas (Agbaogun and Jimoh, 2021). The University of Ibadan is in the rainforest vegetation zone, characterized by dense and diverse plant life. (Oluwakayode *et al.*, 2020).

Collection of Tree Data for The Application

Data was collected by completely enumerating all the threatened trees within the University of Ibadan. A stratified sample technique (Hauglin *et al.*, 2021) was used to divide the University of Ibadan into administrative and academic, residential and conservation areas. The conservation area includes the botanical and zoological gardens. The following data was obtained for all the threatened trees encountered;

1. Coordinates of threatened trees,
2. Total Height (TH, m),
3. Merchantable Height (MH, m),
4. Diameter at Breast Height (DBH, cm),
5. Diameter at base (db, cm)
6. Diameter at middle (dm, cm)
7. Diameter at top (dt, cm).

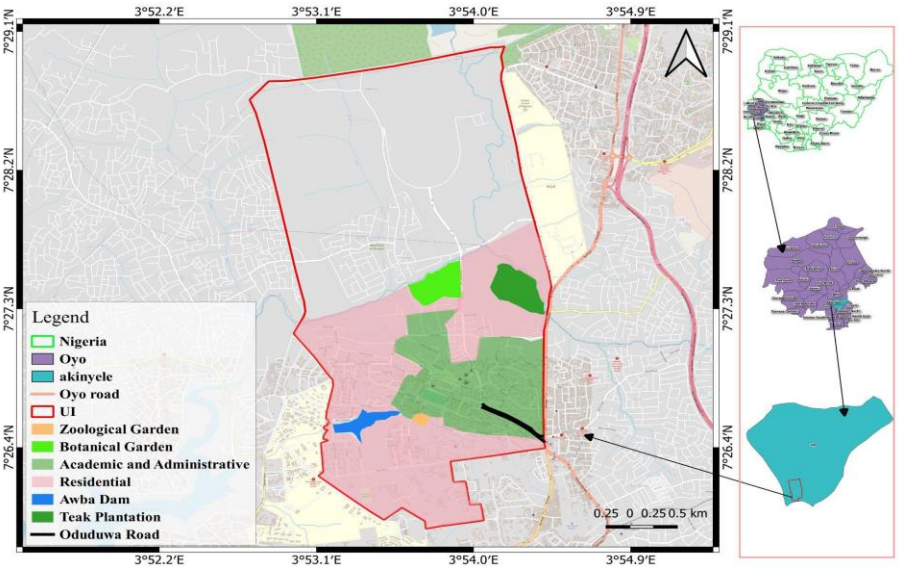

Figure 1.: Map of The University of Ibadan.

The coordinates of each tree were taken using Mapinr, a mobile GIS application (Naharudin *et al.*, 2016). The height was taken using a Haga Altimeter. At the same time, the diameter at the top and middle was measured using a Spiegel Relaskop, and the diameter at breast height and base was measured using diameter tapes. The diameter at breast height measurement of forked trees and other atypical trees followed the standard convention for these measurements. Tree family names were also obtained from the literature.

The measured diameter at breast height in centimetres was used to calculate the basal area (BA) of individual trees as per Elledge and Barlow (2020).

$BA(m^2) = \pi \times DBH$… Equation I

Where BA = basal area; DBH = diameter at breast height (1.3 m) and π *= 3.142.*

The stem volume was estimated using Newton's formula, as per Elledge and Barlow (2020). The stem volume of individual trees was calculated as

$V(m^3) = \pi H \left[\frac{Db^2+4Dm^2+Dt^2}{24}\right]$… Equation II

V = Volume(m^2), H = stem height (m), Db = Diameter at the base, Dm = Diameter at the middle, Dt = Diameter at the top and π *= 3.142.*

The slenderness coefficient was estimated using the formula below, as per Hanum *et al.* (2021).

$SC = \frac{H}{DBH}$… Equation III

Where: SC = tree slenderness coefficient, H = tree height (m) and DBH = diameter at breast height (m)

Development of The Mobile Application

The mobile application was developed using Kotlin in Android Studio (Dimitrijevic *et al.*, 2023).

Back End

Mapbox SDK was initialized in the Android application by setting up the required dependencies. After all necessary dependencies were added, a Mapbox Secret Access Token and a Public Access Token were generated from the Mapbox official website. Following the installation guide on the Mapbox website, the

secret access token was added to the "gradle. properties" file of the project as "MAPBOX_DOWNLOADS_TOKEN= secret access token", and the public access token was added to the "string.xml" resource file of the project as "<string name="mapbox_access_token">public access token</string>." The maven repository was also added to the "settings. gradle" file. After this, the application was built, and the necessary services were downloaded.

The routing and navigation logic was implemented on the backend. It involved handling route requests, managing route updates, and monitoring the user's progress along the route. Route request call-backs and route progress observers were also set up.

Real-time updates for location and route progress were established. It included managing user location data, matching it to the road, and updating the route progress based on the user's location. It also involved ensuring that voice instructions were generated at the right moments.

Google Firebase Real-time Database was used to accommodate the storage of tree data. Authentication and security rules were configured to ensure controlled data access. A data submission mechanism was developed in the frontend, facilitating the real-time transfer of tree data to the backend. The backend was configured to accept incoming tree data in a structured format and store it within the Google Firebase Real-time Database. An appropriate database schema was set up to manage tree data effectively.

Front End

An Android Studio project and Kotlin activities were created. MapView was integrated and configured to display the map.

Mapbox SDK was used for the navigation aspect. Location permission requests were implemented and handled to ensure the application could access the device's GPS. Mapbox's routing API was used to calculate routes based on user input. Logic was implemented to accept source and destination coordinates and make route requests. The computed route was displayed on the map using appropriate styling. The turn-by-turn navigation feature was then implemented. Mapbox's voice guidance was also used to provide spoken directions to the user at each turn. Controls were added for muting/unmuting voice instructions and displaying upcoming manoeuvres. Map interactions like pinch-to-zoom and map re-centring were also implemented.

An activity that included collapsible buttons representing vulnerable, threatened, endangered, and critically endangered trees was created to display tree data. Each one of these buttons was designed to expand to reveal 3 buttons each — Spatial Distribution, Mean Growth Variables and Number. Each one of these buttons leads to separate activities. In the Spatial Distribution activity, Mapbox Mapview was configured and integrated into the activity's layout. It includes UI elements such as buttons for user location zoom and a space to display tree characteristics via alert dialogues.

In the Spatial Distribution activity, a "tree data class" defines the structure of tree characteristics, which includes attributes like tree total height, merchantable height, Volume, slenderness coefficient, diameter at the top, diameter at the middle, diameter at the base, diameter at breast height, Volume, etc. was developed. A Tree Data list that houses the objects of the tree data class was also created. In the Number activities, the total number of trees per IUCN classification was displayed, and in the Mean Growth Variable Activities, the mean of each growth variable estimated was displayed.

To handle annotations in the Spatial Distribution activity, "add annotations to map" was implemented. A point annotation manager was created by iterating through the Tree Data List, and a "click listener" was added for annotations. Tree data lookup was done through the "getTreeDataForAnnotation" method to find tree data for a clicked annotation based on coordinates. Tree information was then added to the alert dialogue when clicked. A copy button was added to copy tree coordinates to the clipboard, and a close button was added to close the alert dialogue box.

In the Spatial Distribution activity, Mapbox was configured to enable the display of the user's location on the map using the default location puck icon. A button that allows users to zoom to their present location on the map was implemented. A different activity was created for users to suggest threatened tree data. The form layout was constructed with fields for tree image, total height, diameter at the top, diameter at the base, diameter at the middle, diameter at breast height, location, and coordinates. A functionality for automatically capturing tree coordinates when users double-click on the form coordinate field was also implemented. A button was added to submit the form data to the backend database for real-time storage.

The front and backend components were thoroughly tested to identify and rectify any issues. The Android application was deployed with the integrated map functionality and the linked backend database.

RESULTS

A mobile application called "UITTNav" was developed within the scope of this study (Figure 2.). It aims to provide a user-friendly management system for trees within the University of Ibadan. The application can be downloaded with the name "UITTNav" for free on the Google Play Store without any restriction from June 2024. The application opens into a main menu that has 5 buttons.

i. "Getting Started" button,
ii. "Start Navigation" button,
iii. "View Tree Data" button,
iv. "Add Tree Data" button
v. "Tree Database" button.

On selecting the Getting Started button, the user is directed to a page where the user's guide for the application is obtained. The Start Navigation button directs the user to the navigation system designed within this study's scope. This navigation system can navigate to an address or a tree coordinate. It uses the GPS coordinates provided by the user's device and provides a turn-by-turn navigation service with voice navigation.

The View Tree Data button directs the user to a page with collapsible buttons for the categories of threatened trees, according to IUCN: Vulnerable, Endangered, and Critically Endangered. It enables users to view data on trees of their preferred conservation status. Each of these collapsible buttons expands on click to show 3 additional buttons: Spatial Distribution, Number and Mean Growth Variable.

The Spatial distribution button has a map view, and a tree annotation represents each tree under the selected IUCN status. A popup containing the tree information comes up when clicking on each annotation. It includes the Species, diameter at breast height, diameter at base, diameter at middle, diameter at top, total height, merchantable height, tree volume, slenderness coefficient, basal area, IUCN status, longitude, latitude, location, area of identification and date of data collection. This popup includes a "close" and "copy" buttons. The copy button copies the tree's searchable code, which can be used within the navigation system in UITTNav or any other navigation application. At the base of the page is a "Zoom to My Location" button that allows users to see threatened trees close to them.

The Number button directs the user to a page displaying the number of trees, species, and family in the IUCN status within the University of Ibadan. The Mean Growth Variable button leads to a page where the mean diameter at breast height, mean diameter at the base, mean diameter at the middle, mean diameter at the top, mean total height, mean merchantable height, mean tree volume, mean slenderness coefficient and mean basal area of all the trees within the selected IUCN status in the University of Ibadan are displayed.

UITTNav allows users to suggest data for addition. It is done under the Add Tree Data segment. A form is displayed on selecting the "Add Tree Data" button. This form includes fields like tree image, the user's name, tree species, tree growth variable, area of identification, tree location and tree coordinates. Some of these fields can be left empty. However, tree species, coordination and exact tree location were compulsory; the form cannot be submitted unless filled. An asterisk in front of the field name differentiates these mandatory fields.

The form has a coordinate collection function that automatically updates the user's coordinate when the user double-clicks the empty field. It also has an in-app image-capturing function that works after granting the application permission to use the phone camera. Captured images can be accepted or rejected and can even be changed.

Two things are likely to occur when selecting the submit button. If one or more compulsory fields have not been filled out, the form remains on the screen, and a toast that says, "Tree Species, Tree Coordinates and Exact Tree Location are compulsory fields. Please fill them out" is displayed on the screen. A new page with 2 buttons (Submit Now and Edit First) pops up if all compulsories were filled. If Edit First is selected, the user is returned to the filled form, and a toast that says, "Make necessary edits before submitting" is displayed. If Submit Now is selected, the form is sent to a real-time database, and the user will see a toast on the screen that says, "Data saved." The user is then automatically returned to the application menu.

On clicking the Tree Database button, a page showing all the data in the application in tabular form is displayed. This data includes the Species, diameter at breast height, diameter at base, diameter at middle, diameter at top, total height, merchantable height, tree volume, slenderness coefficient, basal area, IUCN status, longitude, latitude, location, area of identification and date of data collection. This page also shows the total number of filtered trees and the total number of trees recorded in the application. The data in this table can be filtered by species, location, and IUCN status by typing it into the required field and selecting the search icon. All the data in the table can also be displayed after filtering by selecting the eye icon beside the search icon.

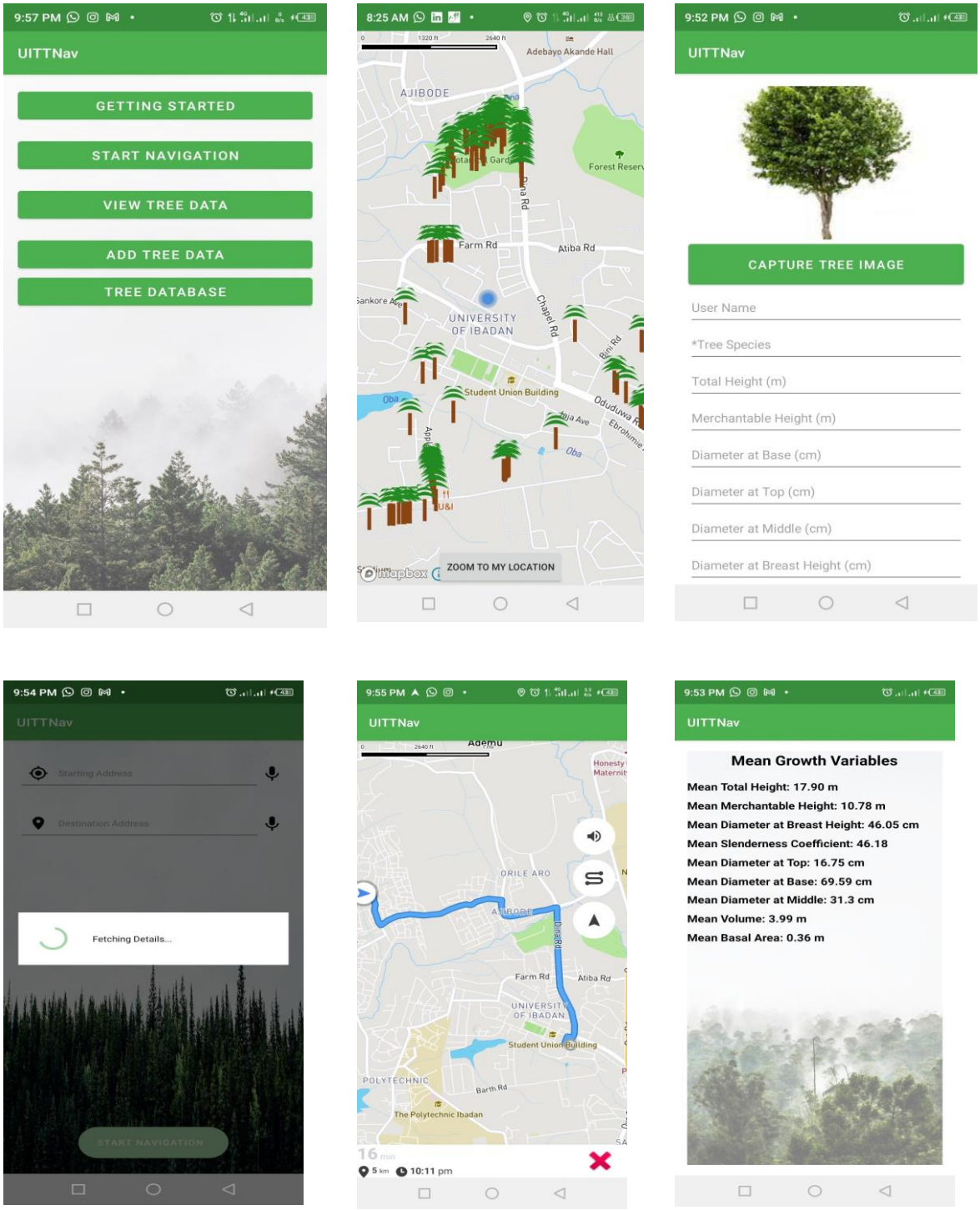

Figure 2: Screenshots from UITTNAV

DISCUSSION

Accurately identifying threatened trees is essential for quantifying current biodiversity crises and prioritizing conservation efforts (Silva *et al.*, 2022). UITTNav was created to combine location data of threatened trees, turn-by-turn navigation to the specific location of these trees, as well as the collection and display of growth characteristics of each threatened tree within the University of Ibadan in a single application for easy

management of these threatened trees. At its current state of development, UITTNav allows users to have ready access to inventory and location data of threatened trees. It also allows users to suggest the addition of tree data.

However, a significant concern is the duration of data accuracy within the application. Many studies have addressed the issue of the accuracy of tree inventory data over time. Maltamo *et al.* (2021) found that data updated 5-years before was just as accurate as new inventory data. This suggests that data within the application remains accurate for at least five years after data collection. Another concern in the application is the Google Firebase integration used for storing submitted data. Google Firebase is a database commonly used for applications due to its real-time capabilities and developer-friendly environment (Khafid and Putri, 2020). It has been used successfully in various applications such as hydroponic farming monitoring systems (Megantoro *et al*., 2022), user complaint support systems (Fitriastuti *et al.*, 2022), fault detection in power line transmission (Goswami and Agrawal, 2020), cloud computing optimization analysis (Semma *et al.*, 2023), among others.

As regards the navigation system, at the current state of its development, the navigation system in UITTNav provides a suitable way for its users to move to the location of threatened trees. It was done using services provided by MapBox. However, it was noticed during testing that while the navigation system automatically makes the user's current location the starting address, it sometimes adjusts the user's location once the navigation view opens up to give a more accurate estimate.

Also, the navigation system does not fetch the user's address once there is no internet connectivity. It makes it unsuitable for situations where connectivity is poor. However, since it was meant for the University of Ibadan, which is in an urban area, this does not pose much of a challenge.

CONCLUSION AND RECOMMENDATIONS

This study has led to development of an application that can help manage trees within the University of Ibadan. During this study, it was discovered that the University of Ibadan is home to many threatened species. Unfortunately, these trees are poorly managed, and no record exists. These species are also unevenly distributed among the academic, residential, and protected areas.

This study, therefore, recommends that the management of threatened trees within the University of Ibadan be made a priority. Trees within the University of Ibadan should be well protected from vandalism, and unauthorized harvesting of any forest resource within the University should be banned. Regular monitoring of threatened trees within the University of Ibadan and a regular inventory of threatened trees should also be promoted to assist in managing these threatened trees. Lastly, the management of trees within the University of Ibadan should follow a management plan.

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Investigating the Efficiency of AI Methods for Predicting Moisture Diffusivity in var. Golab Apples: Fuzzy Logic, ANFIS, and Multi-gene Genetic Programming

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Abstract

Effective modelling and prediction of drying processes assists process design, analysis and optimization. This study investigated the effectiveness of four artificial intelligence (AI) modelling methods, including Fuzzy Logic (FL), Adaptive Neuro-Fuzzy Inference System (ANFIS) and Multi-gene Genetic Programming (MGGP), to model the effective moisture diffusivity (EMD) of the apple drying process. The AI model algorithms were implemented in Matlab R2013b, and published open-access experimental data was utilized after post-processing to test the algorithms. A coefficient of determination (R^2) was adopted to determine the effectiveness of each modelling and prediction method. Results showed that FL and ANFIS methods successfully developed networked model architecture while MGGP developed an empirical mathematical model. FL, ANFIS and MGGP models had R^2 values of 0.9930, 0.9690 and 0.9812, respectively. It is concluded that the intelligent methods could adequately model the experimental drying data of apple; however, the process designer has a decision to make on the conflicting objective of whether to utilize a networked structured model with slightly higher accuracy or a mathematical structured model with slightly lesser accuracy for the process management.

Introduction

Drying is an essential unit operation in post-harvest management. It enables the preservation, storage, and increased availability of agricultural products throughout the year. In addition, drying reduces the packaging size and, thus, the transport cost. Effective drying increases products' shelf life without adding preservatives. However, drying is a complex process involving dual inward penetration of heat energy and outward diffusion of moisture in the materials concerned, making authors regard it as one of the most expensive post-harvest operations in energy consumption. Over the years, the critical requirement in drying processes has been to reduce the price of the energy resources used, increase the drying efficiency through optimum drying factors, and improve the dried product quality (Kaveh *et al.*, 2020a). These requirements are well assisted by rendering the process predictable with adequate representation, which would encourage prototyping before committing to pilot or industrial upgrading.

To properly understand, analyze, automate, and design a drying process, modelling and simulation under different conditions are crucial to enable process and product standardization, as well as the overall acceptability of the final products (Meisami-asl *et al.,* 2010). Realistically, predicting the kinetics of the drying process through the application of precise modelling techniques and extracting patterns for describing such drying behaviours seems unavoidable for processing factories to optimize the quality of dried food products and reduce operational costs (Jafari *et al.,* 2015). Therefore, modelling and predicting the drying process assist in selecting the most suitable drying method and drying operating conditions.

Mathematical models applied to the description of drying kinetics are categorized into theoretical, semi-theoretical, statistical, and semi-empirical models, amongst others (Adeyi *et al.,* 2018).

Theoretical models are based on the diffusion process or synchronized heat and mass transfer equations. Semi-theoretical equations are compared to Newton's law of cooling in addition to some theoretical background, and empirical models are predefined equations whose constants need derivation (Okonkwo *et al.,* 2022). In applications, semi-theoretical equations usually justify high fitting rates of drying processes but ignore the fundamentals of those processes (Jafari *et al.,* 2015). Recently, the application of artificial intelligence (AI) modelling methods to drying processes has shown better performance in process modelling. AI methods excel in difficult and complex multi-dimensional modelling situations and are non-mathematical with high accuracy and precision, as widely established statistically (Ojediran *et al.,* 2021). The primary reason for applying AI methods is to understand patterns, extract inherent relationships amongst factors responsible for a dataset and generalize the results to other situations (Kaveh *et al.,* 2020b).

AI modelling methods are tolerant to variations and noise and are a set of flexible structural interrelationships which are biologically inspired. A further attraction of these modelling methods compared to the conventional ones are the increased flexibility, reduced assumptions, online non-destructive measurement, and tolerance of incomplete or noisy data, efficiency in learning capabilities, accuracy on ill-posed problems and possession of easy model adaptability (Onwude *et al.,* 2016). Processing incomplete information through perception is the essence of AI methods, and this functionality may be complex for mathematical modelling methods (Buragohain, 2008). Various AI methods consisting of machine learning and meta-heuristic categories have been applied successfully to the drying process in the literature; these include Artificial Neural Network (ANN), Support Vector Machine (SMV), Genetic Algorithm (GA), Adaptive Neuro Fuzzy Inference System (ANFIS), Multi-gene Genetic Programming (MGGP), Fuzzy Logic (FL), Grey Wolf Optimizer (GWO) and Particle Swamp Optimization (PSO). This study investigated the efficiency of FL, ANFIS, and MGGP in modelling and predicting Apple's experimental drying data.

FL method is the most critical issue around fuzzy theory; it is a linguistic modelling scheme described with fuzzy quantities (Aghdam *et al.,* 2015). It is an alternative methodology for some complex processes that do not accept a practical application of traditional modelling techniques but require approximate and fast solutions (Váquiro *et al.,* 2008). In FL, a membership function numerically describes the partial membership of a set of universes, which assumes values between zero and one. Fuzzy membership functions take several forms (Aghdam *et al.,* 2015), including gbellmf, piemf, trimf, gaussmf, and gauss2mf. In addition, ANFIS is a hybrid machine learning system that incorporates both ANN and FL. It combines the training ability of an artificial neural network (ANN) and the approximation capability of FL to understand the dynamics within a data set (Onwude *et al.,* 2016). Lastly, Multi-gene Genetic Programming (MGGP) is a meta-heuristic method evolved by applying computer program populations, represented by a tree structure, to solve a task of interest (Searson, 2009). Apart from being a process minimization method, MGGP can forecast process behaviour and create the structure and parameters of an empirical mathematical relation using its intrinsic symbolic regression capabilities.

AI methods have been successfully applied to forecast the drying parameters of several agricultural materials. For instance, Jafari *et al. (2015) applied FL and ANN to model and predict the moisture content during drying of Onion, and promising results were* reported. Ojediran *et al.* (2020) applied ANFIS to the moisture content prediction of yam slices (*Dioscorea rotundata*) in a convective hot air drier with better performance when compared to empirical models. Kaveh *et al.* (2018b) found out that ANFIS and ANN models predicted the drying characteristics of potato, garlic, and cantaloupe convincingly when dried under a convective hot air dryer. It showed that AI methods had been utilized mainly for modelling and predicting the moisture content of agricultural produce.

There is a shortage of knowledge on using the same for agrarian produce's effective moisture diffusivity (EMD). The EMD is a material-specific property that depends on all the conditions associated with the process. EMD describes all possible mechanisms of moisture movement within the product, such as liquid diffusion, vapour diffusion, surface diffusion, capillary flow and hydrodynamic flow (Okereke and Onunkwo, 2014), and its knowledge is necessary for designing and modelling mass transfer processes such as dehydration, adsorption and desorption of moisture during storage. Therefore, this study compared the applicability and efficiency of FL, ANFIS and MGGP AI methods in modelling and predicting the EMD of dried apples.

Materials and Methods

Data information and pre-processing

The open-access published experimental data of Meisami-asl *et al. (2010) was used in this study to test* the selected AI algorithms implemented with Matlab R2013b software. The data consisted of the effect of apple slice thickness (three levels), drying air velocity (three levels) and drying temperature (four levels) on the EMD of apples during drying. The study resulted in 45 experimental data points. The experimental design is represented in Table 1.

Table 1: Experimental Design

Inputs Factors			Output Response
Slice thickness (mm)	Air Velocity (m/s)	Temperature (^{O}C)	EMD (m^2/s)
2	0.5	40	
4	1.0	50	
6	2.0	60	
		70	
		80	

The normalization of the EMD data to enhance simulation accuracy and speed was done following the method of Kaveh *et al.* (2018) using Microsoft Excel 2010 Software following Eqn. 1

$$X_n = \frac{X_i - X_{min}}{X_{max} - X_{min}} \quad (1)$$

Where: X_n depicts the normalized value of the specific experimental data, X_i depicts the value of each experimental data, X_{max} depicts the maximum value for the particular experimental data, and X_{min} depicts the minimum value of the specific experimental data.

Theory of FL modeling

FL represents the idea of using uncertainty to explain an occurrence. It involves four components: fuzzification, fuzzy rule, fuzzy output engine, and defuzzification. Fuzzification converts each piece of input data to degrees of membership by a lookup in one or more of several membership functions. FL depicts an object's ability to belong to one or more sets, while crisp variables are not fuzzy. Membership function is the engine room of FL, and membership function values may be assigned using intuition, inference, rank ordering, angular fuzzy sets, neural networks (NN), genetic algorithms (GA), and inductive reasoning. FL rules are guides that enable the FL system to learn about a process and to make predictions for the process when the input variables change. How rules are formulated in FL is essential and should be formulated to reflect the fundamental ideals that control the operation of a system. The rules in FL are formulated with antecedent and consequent parts, respectively. A fuzzy inference engine considers all the fuzzy rules in the fuzzy rule base and

learns how to transform a set of inputs into corresponding outputs. Defuzzification converts the resulting fuzzy outputs from the fuzzy inference engine to a number.

In this study, FL modelling and simulation were performed using Mamdani type FL with If–Then fuzzy rules matching for input and output variables. FL simulation was done in natural language by considering input-output parameters with fuzzy division, as represented in Table 2.

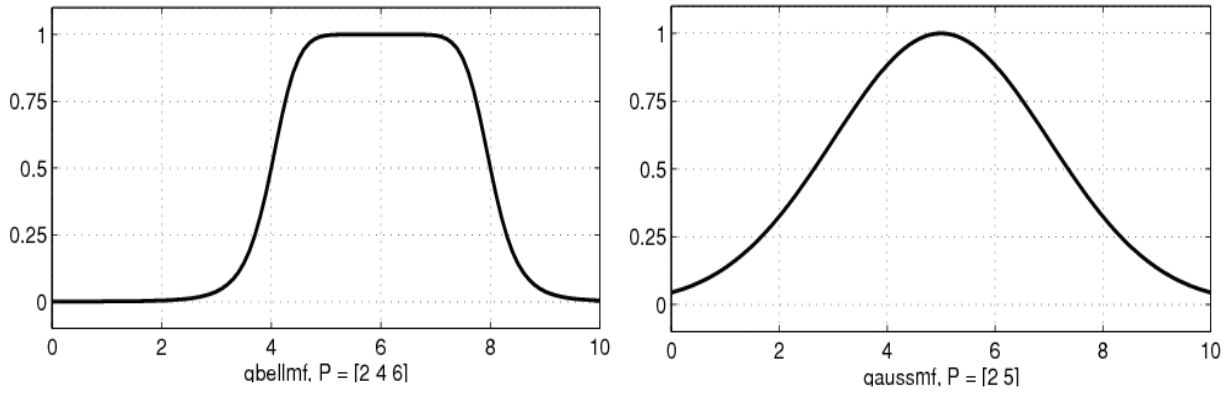
Table 2: Fuzzy natural language division of experimental data

Fuzzy division	Slice thickness (mm)	Drying velocity (m/s)	Effective Moisture Diffusivity (m^2/s)				
			40	50	60	70	80 (^{O}C)
L	ST1	DV1					
M	ST2	DV2					
H	ST3	DV3					
VVL			EMD1	EMD1	EMD1	EMD1	EMD1
VL			EMD2	EMD2	EMD2	EMD2	EMD3
ABL			EMD3	EMD3	EMD3	EMD3	EMD3
LL			EMD4	EMD4	EMD4	EMD4	EMD4
HH			EMD5	EMD5	EMD5	EMD5	EMD5
ABH			EMD6	EMD6	EMD6	EMD6	EMD6
VH			EMD7	EMD7	EMD7	EMD7	EMD7
VVH			EMD8	EMD8	EMD8	EMD8	EMD8
EH			EMD9	EMD9	EMD9	EMD9	EMD9

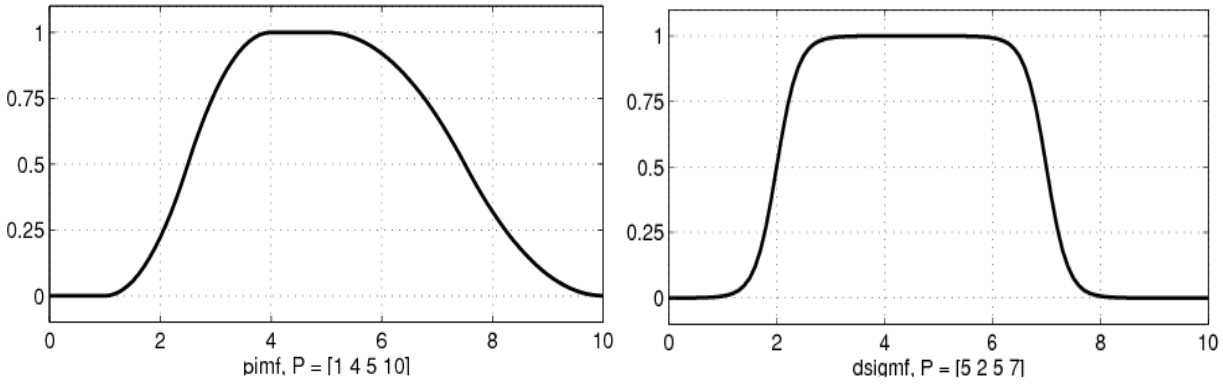
**

L = LOW, M = MEDIUM, H = HIGH, VVL = VERY VERY LOW, VERY LOW, ABL = A BIT LOW, ABH = A BIT HIGH, LL = LOW LOW, HH = HIGH HIGH, VH = VERY HIGH, VVR = VERY VERY HIGH, EXTREMELY HIGH, ST = EXPERIMENTAL SLICE THICKNESS, DV = DRYING VELOCITY, EMD = EXPERIMENTAL EFFECTIVE DIFFUSIVITY.

Four membership functions, including gbell, gaussmf, pimf, and dsigmf, were investigated to design the optimum FL that models the experimental data in this study. The shapes of the investigated membership functions are depicted in Fig. 1



(a) (b)



(c) (d)

Fig.1: FL membership function (a) gbellmf, (b) gaussmf, (c) pimf and (d) dsigmf (Bystrov and Westin, 2013)

Theory of ANFIS modeling

Adaptive Neuro-Fuzzy Inference System (ANFIS) represents Sugeno fuzzy inference structure, which accepts multiple inputs and single output data dimension. A generalized model of the ANFIS structure with two inputs and one output is represented in Fig. 2.

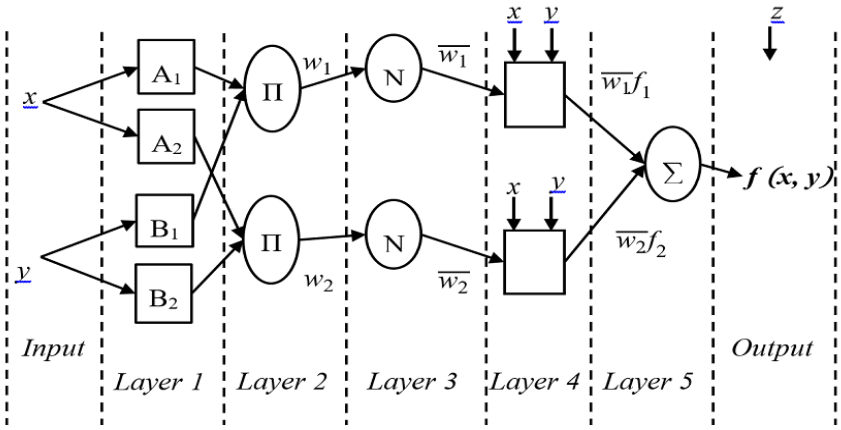


Fig. 2: The structure of ANFIS (Sonmez *et al.*, 2018)

The rules of a typical ANFIS structure are represented in Eqn. 2 – 5

Rule 1: If x is A_1 and y is B_1, then $f_1 = p_1x + q_1y + r_1$ (2)
Rule 2: If x is A_2 and y is B_2, then $f_2 = p_2x + q_2y + r_2$ (3)
Rule 3: If x is A_3 and y is B_3, then $f_3 = p_3x + q_3y + r_3$ (4)
Rule 4: If x is A_4 and y is B_4, then $f_4 = p_4x + q_4y + r_4$ (5)

Layer 1 corresponds to the crisp inputs for the system of interest; this layer is called the input layer and is represented in Eqn. 6. O_i^1 is a representation of the layer, and i is the ANFIS node

O_i^1= (inputs) (6)

In the structure in Fig. 2, the input layer consists of two inputs, x_1 and x_2. In layer 2, the supplied crisp input data are put into a fuzzy space using a choice membership function. This process is called fuzzification; therefore, this layer is called the fuzzification layer. The nodes in this layer are

adaptive, and the layer is represented by Eqn 7 and 8, where μA_i and μB_i represent the antecedent membership functions (gbell, gauss, gauss2, etc.).

$O_i^2 = \mu A_i$ (input 1) for i = 1, 2 (7)
$O_i^2 = \mu B_i$ (input 2) for i = 3, 4 (8)

Layer 3 is called the firing strength layer. This layer gives the product of the degrees to which the inputs fit the membership functions. Eqn represents it. 9

$O_i^3 = wi = \mu A_i$ (input 1) × μB_i (input 2), …… i=1,2,3,4 (9)

Layer 4 is the normalization layer. The ratio of each rule's firing strength is calculated based on the sum of the firing strengths of all the rules. Fixed nodes are available here and depicted in Eqn. 10.

O_i^4 = w'= $wi/w1 + w2$, i = 1, 2 (10)

Layer 5 is the defuzzification layer, which is represented in Eqn. 11. The layer consists of the consequent parameters of the fuzzy rules. The neurons here are connected to the normalization neuron.

$O_i^5 = w_i' f_i = w'(p_i x + q_i y + r_i)$, i = 1, 2 (11)

Layer 6 produces the total output for each input in the fuzzy space, which equals the sum of inputs in layer 5. It is represented in Eqn. 12

O^6= overall output = $\sum_i w'_i f = \sum_i w_i f_i / \sum$, = 1, 2 (12)

This study investigated the performance of four different types of membership functions, including gbell, gaussmf, pimf and dsigmf, at three (3) numbers each on the effectiveness of the ANFIS structure. Data were portioned into training (50 %) and testing (50 %) data.

Theory of MGGP modeling

Apart from being a process response minimization method, MGGP can reproduce a data set, notably creating the structure and parameters of an empirical mathematical relation of the data set using its intrinsic symbolic regression capabilities (Jabeen *et al.*, 2010). The MGGP uses functions close to the genetic algorithm (GA) to obtain solutions from a created population of computer programs. These computer programs have a tree structure. The population is iteratively improved from one generation to another through crossover and mutation until the production of a better solution that solves a definite task. A typical MGGP tree is represented in Fig 3.

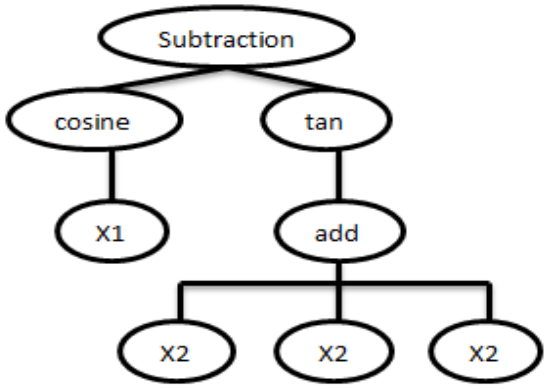


Fig 3: Typical MGGP tree structure

The symbolic regression is multi-gene; each gene is a traditional genetic programming gene (Season, 2009). A multi-gene equation involves the linear combinations of low-order non-linear transformations of the non-dependent or input variables. The genes are built incrementally to strengthen the stiffness by minimizing the model sum of square residual using the data set as done in curve fitting. The result of the gene building is a model fortified with weights and bias, which adequately captures the dynamics of the data set. A typical multi-gene regression is represented in Eqn. 13:

$$y = d_o + d_1 Xtree_1 + \cdots \ldots + d_M Xtree_M \quad (13)$$

where d_0 is the model constant or bias term d_1, …, d_M are the gene coefficient or weights, and M is the number of genes (i.e. trees) present in the current or ith set of input.

Population size and the number of generations are essential settings that affect the performance of MGGP. This study investigated an optimum choice of these two parameters following Table 3. Data were portioned into training (50 %) and testing (50 %) data.

Table 3: MGGP setting

Parameter	Value
Population size (varied)	100, 200, 500 and 1000
Number of generation (unvaried)	100
Tournament size (unvaried)	4
Elitism fraction (unvaried)	0.02
Termination value (unvaried)	0.001
Maximum gene (unvaried)	6
Node Functions (unvaried)	times, minus, plus, rdivide, psqroot, plog, square, tanh, pdivide, iflte, sin, cos, exp

Prediction efficiency

The model structure optimization of FL, ANFIS, and MGGP methods and comparison of their efficiency was established by applying statistical metrics represented in Eqn. 14.

Coefficient of determination (R^2= 1 – ($\sum_{i=1}^{N} \frac{(Pred,i-exp,i)^2}{(Pred,i-AverageExp)^2}$) (14)

Where Pred, i is the ith predicted value, Exp, i is the ith experimental value. AverageExp is the mean experimental value, and N is the number of observations.

Results and Discussion

FL simulation

The built structure of FL for modelling and predicting the contribution of drying parameters on the EMD of apples is shown in Fig. 4 and 5. The Fig. 4 represents the interconnectivity between the input and output variables.

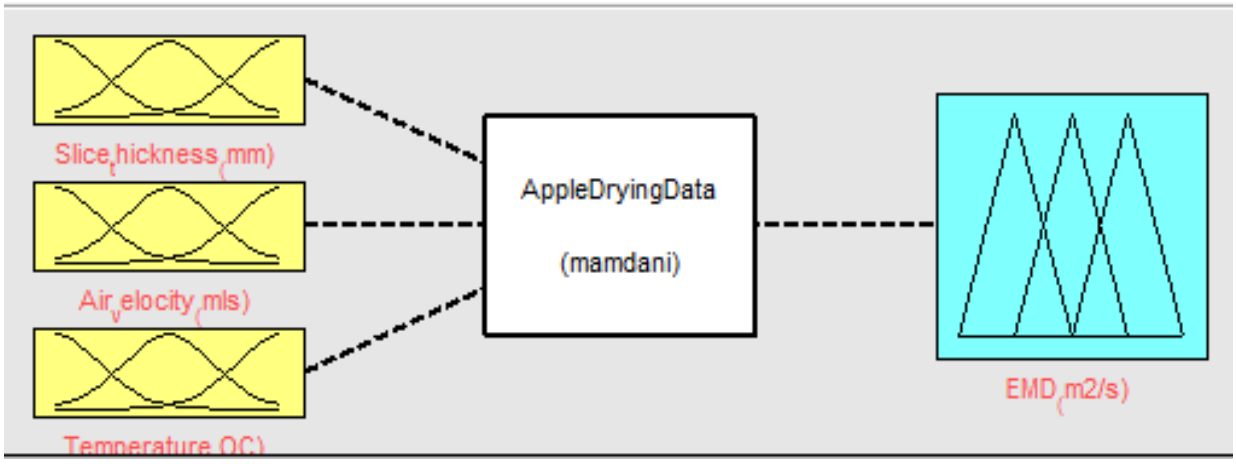


Fig. 4: Structures of FL

Fig. 5 shows the formulated rules used in the designed FL. The formulated rules are the brain of the FL. The figure showed that the FL's If-Then rules relate to the logic 'and' operator. The rules' importance is the same as seen with the weight set to one (1).

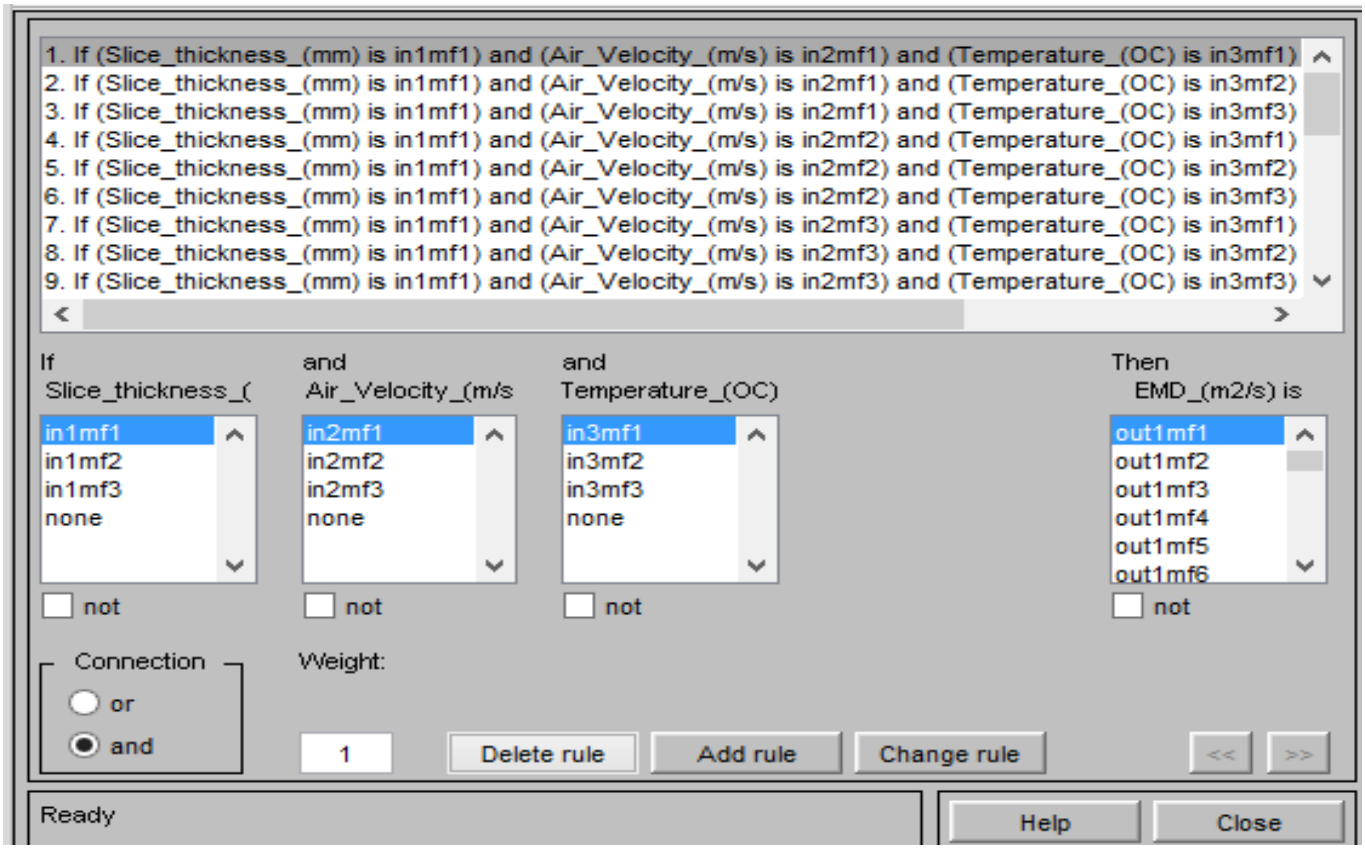


Fig. 5 FL Rules

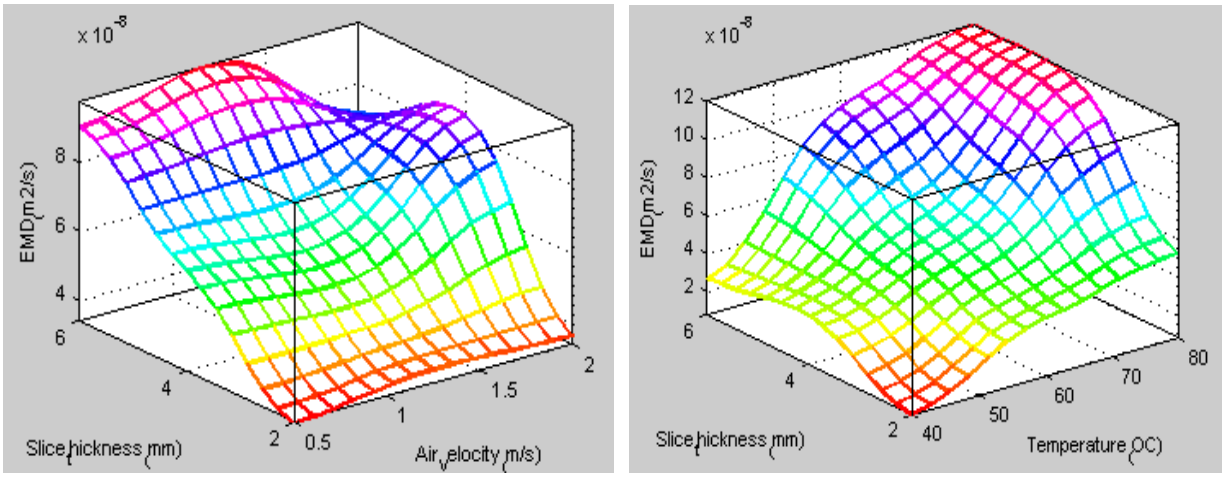
Table 4 shows the performance of the tested FL membership functions.

Table 4: Statistical performance of membership functions

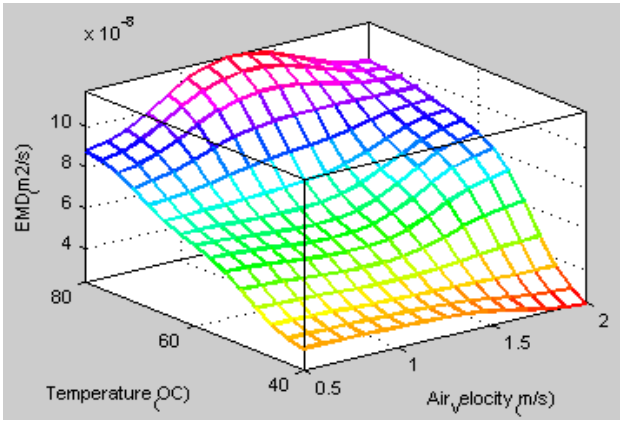
Membership function type	R^2

gbellmf	0.9560
gaussmf	0.9930
pimf	0.8812
dsigmf	0.9383

The table showed that gaussmf performs best in modelling and predicting the applied experimental drying data judging from its associated coefficient of determination (R^2) values. The relational graphs between the input and output process variables using gaussmf being the best performer is represented in Fig. 6 (a) – (c). Fig. 6 (a) informs that the EMD increased as the slice thickness increased. Drying air velocity does not seem to influence the EMD significantly, and an increase in drying temperature increased the EMD of the drying apple.



(a) . (b)



(c)

Fig. 6: EMD relationship between (a) slice thickness against air velocity, (b) slice thickness against temperature and (c) temperature against air velocity

ANFIS simulation

The parameter of ANFIS that best simulates Apple's experimental drying data was optimized by assessing the epoch number and most minor root mean square error of four selected membership functions, including gbell, gauss, pie, and dig. The representation in Fig. 7 (a) – (d) is the performance of each selected membership function. Each subfigure in Fig 7 has training (green) and

checking (red) error trends. The best epoch number in each membership function type tested is labelled in the sub-figures.

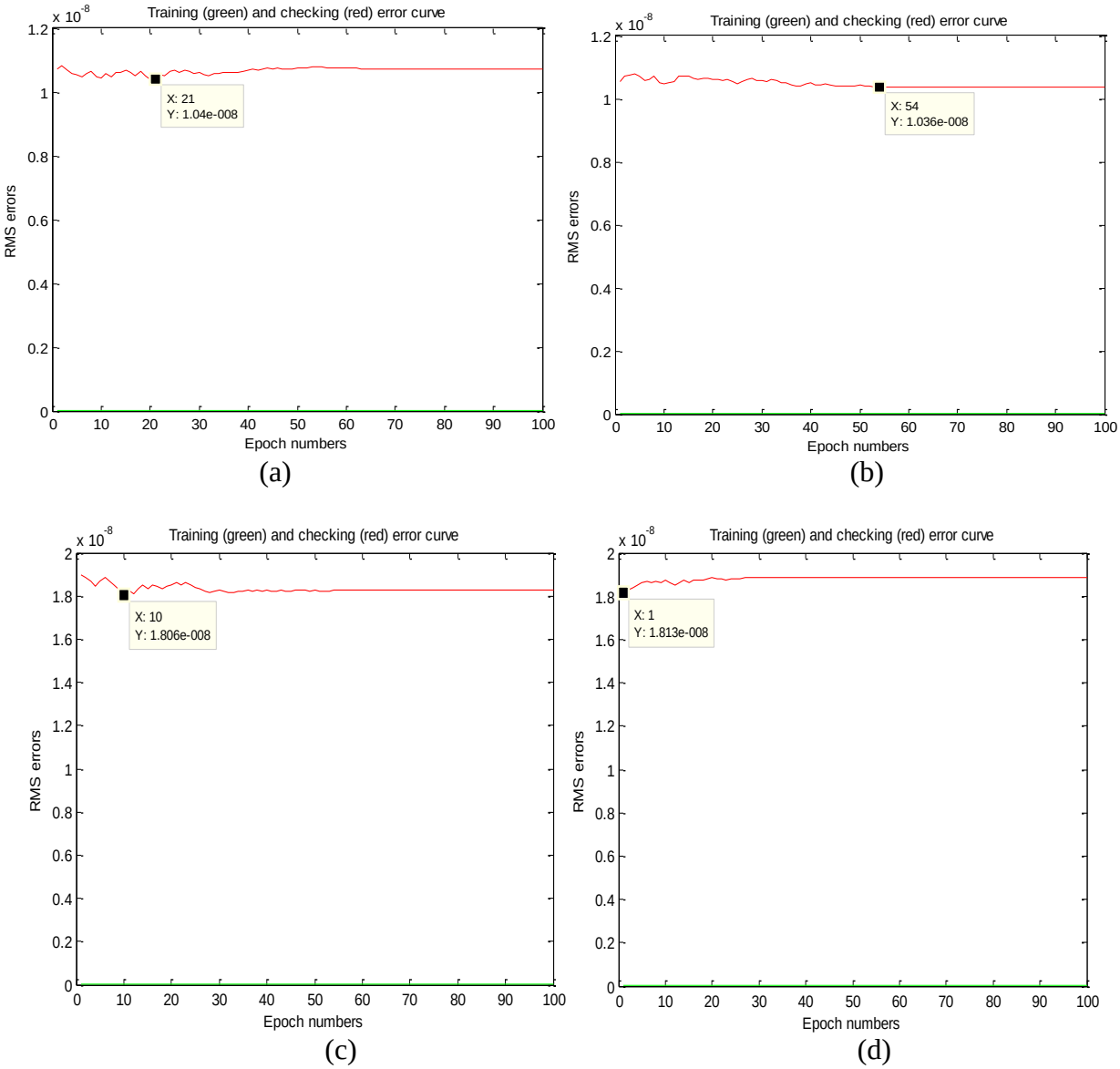


Fig. 7: Optimization of parameters of ANFIS structure (a) gbellmf, (b) gaussmf, (c) pimf and (d) dsigmf

Table 5 summarizes the performance of each of the chosen membership functions. The last epoch number was observed in gaussmf, while the highest epoch occurred with dsigmf. The low number of epoch in gaussmf shows effectiveness in using computer memory and the speed of responsiveness of the structure. The gaussmf also showed the highest R^2 value, showing its efficacy above others. Therefore, the gauss membership function performs best and is further utilized for ANFIS model structure development.

Table 5: Optimization of ANFIS Structure

Input Membership Function	Optimal Epoch Number	R	R^2

gbellmf	21	0.9841	0.9685
pimf	10	0.9486	0.8998
dsigmf	54	0.9460	0.8949
gaussmf	1	0.9844	0.9690

The initial and final refined ANFIS structure built with gaussmf are shown in Fig. 8 (a) and (b). Each input of the Gauss membership function is represented in different colours (blue, green, and red). Comparing Fig 8 (a) and (b), ANFIS did not significantly refine the shape of the membership function. This can be explained by the fact that ANFIS could build the optimum network structure in just one (1) epoch or iteration when the Gaussmf membership function was used. Typically, ANFIS refine the shape of the membership function until a suitable shape that approximates or models the data is established. This is one of the most essential characteristics of AI methods whereby structure parameters are adjusted to fit a specific problem.

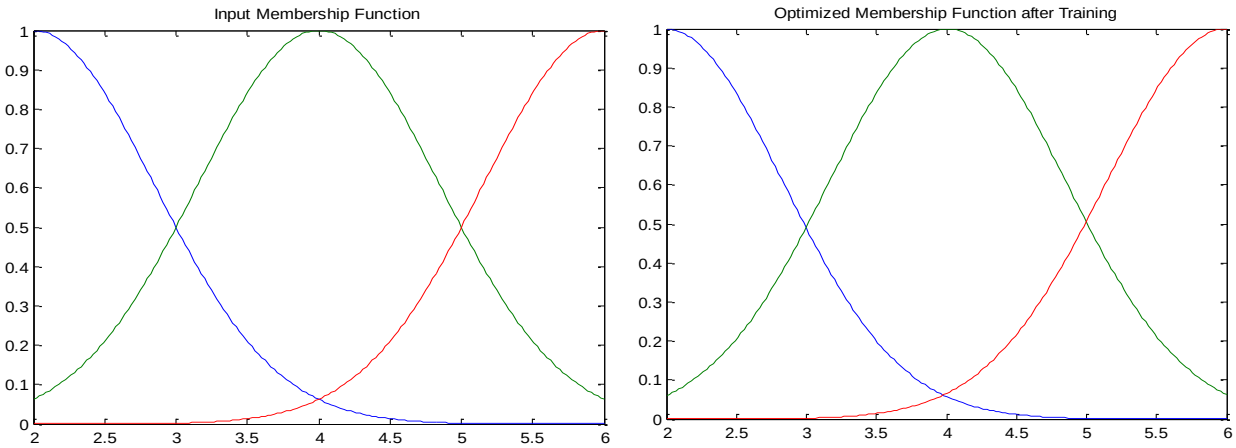


Fig. 8: Membership function of (a) initial unrefined and (b) final refined gauss membership function

The rule formation in ANFIS is the composition of the Fuzzy Inference System (FIS) subset. The number of expected rules is usually defined as Kd, where K is the number of input membership functions, and d is the number of independent data input factors. According to this definition, twenty-seven (27) rules are expected in this study and are represented in Fig. 9.

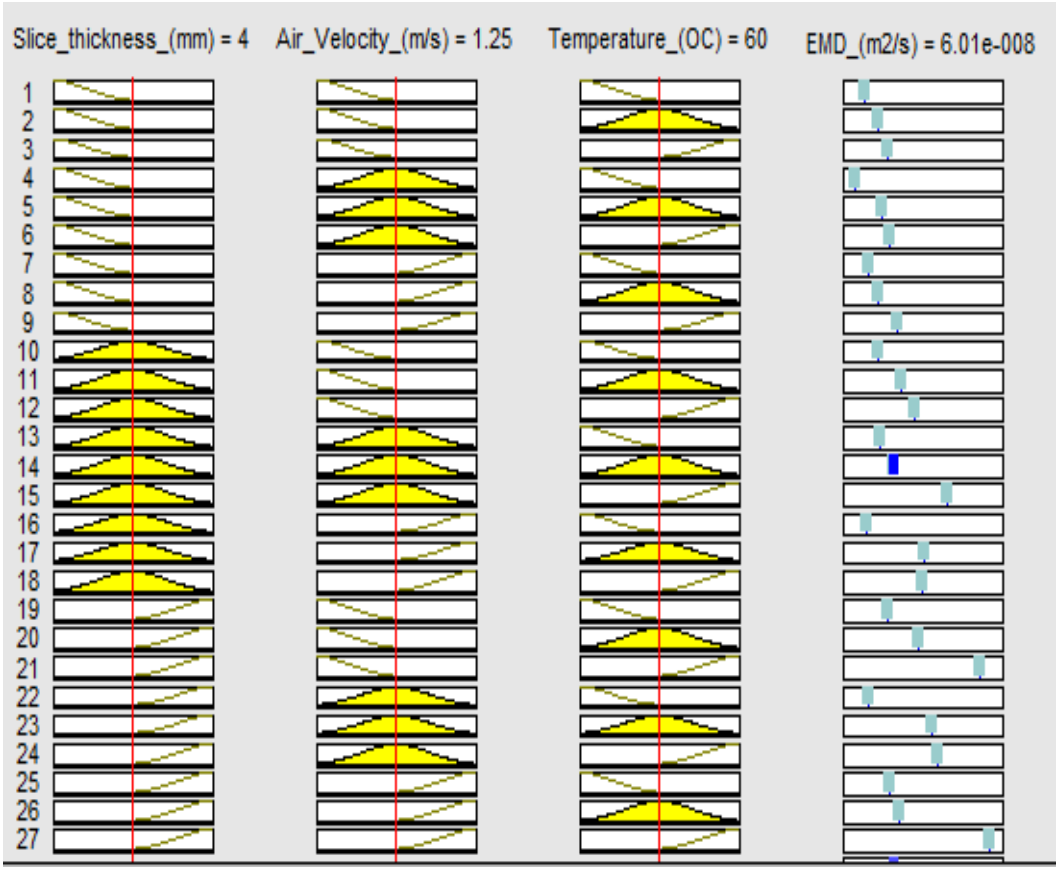
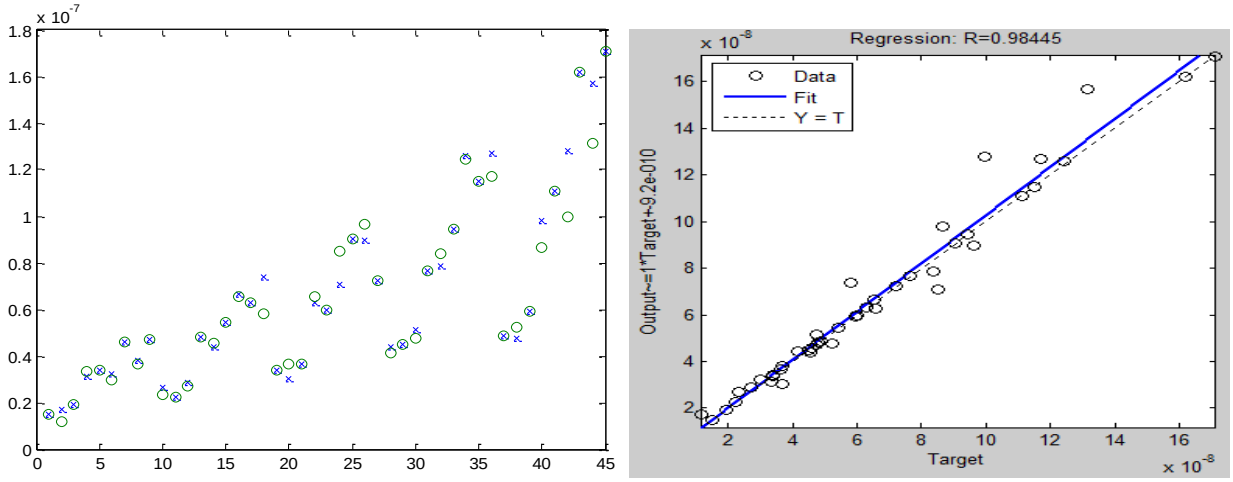


Fig. 10: ANFIS 3^3 Rule

Once the ANFIS structure is created, this set of rules can be tuned to make predictions even on points not experimentally examined but within the experimental data bound.

Furthermore, the ANFIS performance and efficiency are represented in Figure 11 (a) and (b)



(a) (b)

Fig. 11: ANFIS (a) performance and (b) prediction efficiency

In Fig. 11 (a), the experimental data points are represented by 'o', while the ANFIS approximation of the experimental data points is represented by 'x'. It could be deduced from Fig. 11 (a) that most of the ANFIS approximation falls precisely or very close to the experimental data points. It shows good

performance from the developed ANFIS model structure. In Fig. 11 (b), the correlation coefficient (R) of the built ANFIS structure is 0.98445, giving an R^2 value of 0.9690 since the coefficient of determination is the square of the correlation coefficient. The accumulation of data around the straight-line fit in 11 (b) indicates low residual occurrence in the prediction capacity of the optimized ANFIS structure developed for this study.

The optimum ANFSI structure developed is represented in Fig. 12. The structure comprises interconnected nodes and neurons that assist in data modelling and prediction.

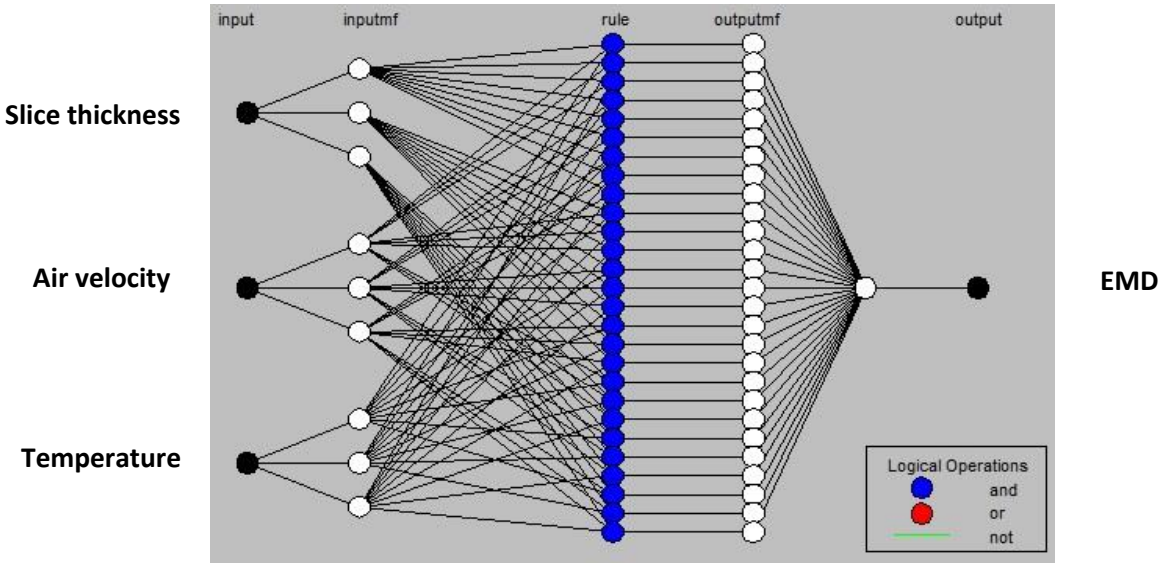


Fig. 12: Optimum ANFIS structure in this study

MGGP simulation

The MGGP modelling efficiency with varied numbers of the population while keeping other MGGP settings constant is represented in Table 6. It can be deduced from the table that the population of 100 had the highest efficiency, judging from the R^2 value.

Table 6 Efficiency of MGGP setting parameters

No of Population	**R^2**
100	0.9812
200	0.9592
500	0.9038
1000	0.9807

The performance of the MGGP model, a population of 100, is represented in Fig. 13.

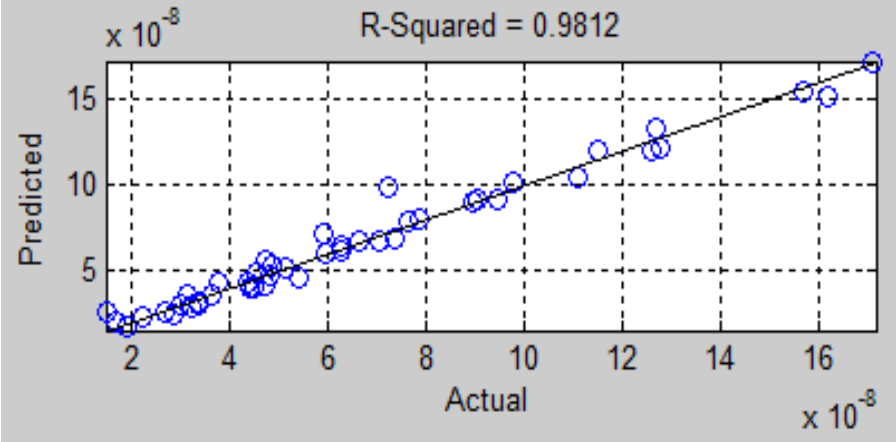


Fig. 13: MGGP efficiency

The mathematical equation determined using MGGP is presented in Eqn. 15

$$EMD=\left(\frac{1.028*x_3}{10^8}\right)+\left(\frac{4.712*tanhx_2}{10^{10}}\right)-\left(\frac{5.062*tanhx_3}{10^8}\right)-\left(\frac{5.576*tanh(x_2-2.923)}{10^8}\right)-\left(\frac{5.033*tanhx_1*tanhx_2}{10^8}\right)-\left(\frac{2.026*x_3(x_2-x_3)}{10^{11}}\right)-+\left(\frac{3.022}{10^7}\right) \quad (15)$$

The equation is composed of six genes and a bias. The importance of the individual gene and bias used in MGGP simulation and the distribution of the optimum 100-population of probable solutions is represented in Fig. 14 (a) and (b).

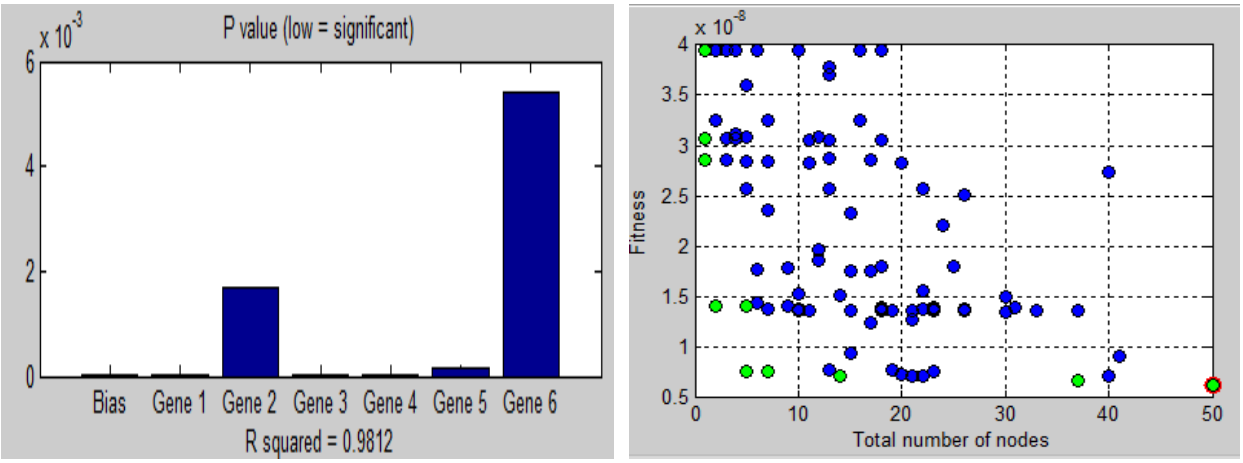


Fig 14: (a) the genes and bias of the equation and (b) the distribution of optimum 100-population of probable solution

Fig. 14 (a) informs that bias, gene 1, gene 3 and gene 4 have the strongest and equal influences on the effectiveness of Eqn. 15. This is followed by gene 5, gene 2 and gene 6, respectively. The green individual solutions in Fig. 14 (b) are the acceptable solutions, while the green individual with red scribe is the optimum solution whose equation is represented in Eqn. (15)

Comparison of modelling methods

Having tested the AI methods on their respective modelling and prediction on the Apple drying experimental data, the comparison of the efficiency of the utilized AI methods used is represented in Fig. 14.

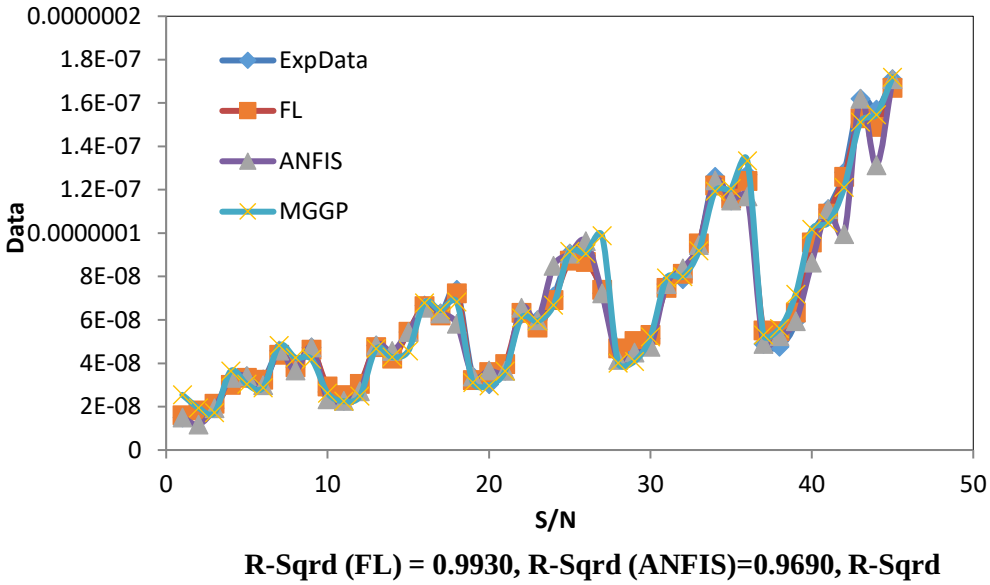


Fig.14: Comparison of modeling methods

The figure showed that all the modelling methods applied performed well. However, Fuzzy logic showed the highest prediction effectiveness with the highest R^2 value of 0.9930. The effectiveness of FL is followed by that of MGGP and ANFIS, respectively. Furthermore, it was observed that models developed by FL and ANFIS methods are architectural, consisting of a network of structures. These architectures are abstract and may not be accessible for analysis and prediction of the drying process beyond the limit of the experimental data utilized for model development. This deficiency was not the case in the MGGP method, where an empirical mathematical model that can predict within and beyond the limit of the experimental data used for the model development was derived. Therefore, the engineer must stay aware of this efficiency and deficiency when choosing modeling methods for Apple drying process management from the ones surveyed in this study.

Conclusion

This work investigated the applicability and efficiency of three (3) selected artificial intelligence (AI) methods applied to the modelling and prediction of the effective moisture diffusivity (EMD) of Apple fruit drying based on the published open access data of Meisami-asl *et al.*, (2010). The results showed that all the AI methods used in the experiment performed well. However, FL had the best performance, while ANFIS had the most minor performance. Furthermore, FL and ANFIS deduced networked models, while MGGP deduced empirical mathematical models. It is concluded that AI methods are sufficient in apple drying data simulation, as widely concluded in the literature.

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LEVERAGING ARTIFICIAL INTELLIGENCE FOR FOREST DATA AND GROWTH PREDICTION

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ABSTRACT:

Forests are vital ecosystems that provide numerous benefits, including carbon sequestration, biodiversity conservation, and timber production. However, managing forests effectively requires accurate data and predictive insights. In this manuscript, we explore the application of artificial intelligence (A.I.) techniques for the Analysis of forest data and the prediction of forest growth, citing real-life case studies. We discuss the challenges associated with traditional methods of forest data analysis and highlight the potential of A.I. to overcome these challenges. Our study demonstrates the effectiveness of A.I. algorithms in processing large volumes of forest data, extracting meaningful patterns, and predicting future growth trends. By leveraging A.I., forest managers and conservationists can make informed decisions to ensure the long-term health and productivity of forest ecosystems.

Keywords: Forests, Artificial intelligence, Forest data, Analysis.

INTRODUCTION:

Forests are complex systems, and understanding their dynamics is crucial for sustainable management. They are vital components of the Earth's ecosystem, providing numerous ecological, economic, and social benefits. Effective management and conservation of forests require accurate health and growth monitoring. Traditional methods of forest data analysis often involve manual data collection and Analysis, which can be time-consuming, labour-intensive, and frequently inaccurate. A.I. offers a paradigm shift in forest data analysis, enabling faster, more accurate, and data-driven decision-making. A.I., or artificial intelligence, refers to the simulation of human intelligence processes by machines, especially computer systems. These processes include learning (acquiring information and rules for using the information), reasoning (using rules to reach approximate or definite conclusions), and self-correction. A.I. encompasses various technologies and techniques, including machine learning, natural language processing, computer vision, robotics, and expert systems.

Machine learning is a subset of A.I. that focuses on developing algorithms that enable computers to learn from and make predictions or decisions based on data without being explicitly programmed. Natural language processing (NLP) involves the interaction between computers and human language, enabling machines to understand, interpret, and generate human-like text or speech. Computer vision involves teaching computers to analyse and understand visual information from images or videos, enabling task recognition, image classification, and scene understanding.

A.I. technologies have applications across various industries and domains, including healthcare, finance, transportation, manufacturing, and entertainment. Examples of A.I. applications include virtual personal assistants (e.g., Siri, Alexa), recommendation systems (e.g., Netflix, Amazon),

autonomous vehicles, medical diagnosis systems, and industrial robots. Therefore, AI refers to the development of computer systems that can perform tasks that typically require human intelligence, including learning, reasoning, problem-solving, perception, and decision-making. It can integrate large datasets, identify patterns, and make predictions, making it an ideal tool for forest management. In recent years, there has been a growing interest in leveraging A.I. techniques to streamline the process of forest data analysis and enhance the accuracy of growth prediction models. In this manuscript, we will explore the potential of A.I. in revolutionizing forest management practices by providing more efficient and accurate insights into forest dynamics.

FOREST ANALYSIS

Forest analysis is a crucial aspect of forest management, involving collecting, processing, and interpreting data to understand forest ecosystems. Traditional methods have been used for decades but have limitations and challenges. Artificial Intelligence (A.I.) technologies offer a revolutionary approach to forest analysis, enabling faster, more accurate and comprehensive insights.

Types of Traditional Methods:

- Manual Surveys: These are field measurements and observations by humans manually. Foresters and ecologists can conduct a study to assess forest characteristics such as species composition, tree density, and canopy cover. Foresters collect data using handheld instruments, visual observations, and measurements, recording information on paper maps or field notebooks, but they are labour-intensive, time-consuming, and subjective, relying on the expertise and experience of field personnel. They may also suffer from spatial bias and sampling errors.

- Remote Sensing: Remote sensing techniques use sensors mounted on satellites, aircraft, or drones to capture imagery and data about forest ecosystems, forest cover and land use classification from a distance. Remote sensing data, such as multispectral or hyperspectral imagery, LiDAR (Light Detection and Ranging) data, and thermal infrared imagery, are analyzed to extract information about forest structure, composition, and health. However, remote sensing provides broad-scale coverage and spatially continuous data, it may lack fine-scale detail and accuracy. Interpretation of remote sensing data requires specialized training and expertise.

- Geographic Information Systems (GIS): GIS technology integrates spatial data (e.g., maps, satellite imagery) with attribute data (e.g., forest inventory data, land use data) to analyze and visualize spatial patterns and relationships. GIS software allows users to overlay, query, and analyze spatial data layers, perform spatial analysis operations (e.g., buffer analysis, spatial interpolation), and generate maps and visualizations, but it is limited by the quality and resolution of input data, as well as the complexity of spatial relationships and processes. It may require significant computational resources and technical expertise.

INTRODUCTION TO AI TECHNOLOGIES:

Artificial Intelligence offers automated and data-driven approaches to forest analysis, enabling more efficient, accurate, and scalable assessments of forest health, biodiversity, and growth patterns. By combining traditional methods with A.I. technologies, researchers and practitioners can gain deeper insights into forest ecosystems and support informed decision-making for sustainable forest management and conservation.

A.I. Tools for forest Analysis Include:

(i) Machine Learning: Machine learning algorithms enable computers to learn from data and make predictions or decisions without explicit programming. In forest analysis, machine learning algorithms can analyze large satellite imagery datasets, climate data, and ecological variables to identify patterns and trends. Machine learning allows for automated Analysis of complex datasets, with the ability to detect subtle patterns and relationships that may not be apparent to human observers. It can also handle large volumes of data efficiently and analyze entire landscapes on a large scale.

Application of Machine Learning Algorithms to Analyze Historical Forest Growth Data:

1 **Data Collection:** Gather historical forest growth data, including measurements of tree height, diameter at breast height (DBH), canopy cover, and biomass accumulation over time.
2 **Data Preprocessing**: Clean and preprocess the data to remove outliers, handle missing values, and standardize or normalize numerical features.
3 **Feature Engineering**: Extract relevant features from the data, such as growth rates, growth patterns, and environmental variables (e.g., climate data, soil characteristics).
4 **Model Selection**: Choose appropriate machine learning algorithms for analyzing forest growth data, such as regression models (e.g., linear regression, random forest regression) or time series forecasting models (e.g., ARIMA, LSTM).
5 **Model Training**: Split the dataset into training and testing sets and train the machine learning model using the training data. Adjust model parameters and hyperparameters to optimize performance metrics such as RMSE (Root Mean Square Error) or R-squared.

6 **Evaluation**: Evaluate the performance of the trained model using the testing dataset, assessing its accuracy, precision, recall, and other relevant metrics.
7 **Deployment:** Deploy the trained machine learning model to analyze new or incoming forest growth data, providing insights into historical growth patterns and trends.

(ii) Computer Vision: Computer vision involves teaching computers to interpret and understand visual information from images or videos. In forest analysis, computer vision algorithms can analyze satellite imagery, aerial photographs, or drone footage to extract information about forest structure, composition, and health. Using image classification and anomaly detection techniques, computer vision enables automated detection of forest disturbances, such as tree

mortality, insect infestations, or disease outbreaks. It can process large volumes of imagery rapidly and consistently.

Application of Computer Vision to Analyze Historical Forest Growth Data:

a) Image Preprocessing: Preprocess historical forest imagery to enhance image quality, remove noise, correct for atmospheric effects, and standardize image formats for consistency.

- Apply techniques such as image registration and orthorectification to align images spatially and geometrically, ensuring accurate comparison across different periods.

b) Feature Extraction: Use computer vision algorithms to extract key features from historical forest imagery, such as tree crowns, canopy cover, tree height, and forest structure.

- Employ object detection algorithms, such as convolutional neural networks (CNNs) or region-based CNNs (R-CNNs), to identify and delineate individual trees or forest patches within images.

c) Change Detection: Perform change detection analysis to identify temporal changes in forest cover, structure, and composition over time.

- Utilize image differencing techniques, pixel-based offset methods, or semantic segmentation algorithms to detect and quantify changes in forest growth, deforestation, regeneration, and land use conversion.

d) **Canopy Height Modeling**: Estimate forest canopy height from historical imagery using computer vision-based approaches, such as structure-from-motion (SfM) photogrammetry or stereo-matching algorithms.

- Generate digital surface models (DSMs) or digital terrain models (DTMs) from historical imagery to derive accurate measurements of canopy height and vertical structure.

e) Species Classification and Biodiversity Assessment: Train machine learning models to classify tree species and assess biodiversity levels based on historical forest imagery.

a. Utilize deep learning architectures, such as CNNs or recurrent neural networks (RNNs), to classify tree species and vegetation types from image features and spectral signatures.

f) **Growth Modeling and Prediction**: Develop predictive models to analyze historical forest growth data and forecast future growth trajectories.

a. Incorporate temporal variables, environmental factors, and historical growth patterns into growth models using machine learning techniques such as regression analysis, time series forecasting, or recurrent neural networks (RNNs).

g) **Visualization and Interpretation**: Visualize and interpret results of computer vision analysis using GIS software, remote sensing platforms, and interactive visualization tools.

2.5 Generate maps, charts, and graphical representations to communicate findings and trends in historical forest growth data to stakeholders and decision-makers.

(iii)Remote Sensing Algorithms: Remote sensing algorithms process data from remote sensing platforms to extract information about land cover, land use, and environmental conditions. In forest analysis, remote sensing algorithms analyze satellite imagery, LiDAR data, and other remote sensing datasets to assess forest structure, biomass, and carbon stocks. Remote sensing algorithms provide quantitative information about forest characteristics at various spatial and temporal scales, allowing for the monitoring of forest dynamics and changes over time. They can map forest extent, assess habitat quality, and monitor ecosystem health.

Application of Machine Learning Algorithms to Analyze Historical Forest Growth Data:

1. **Data Acquisition:** Collect historical remote sensing data, including satellite imagery from sensors such as Landsat, Sentinel, or MODIS, LiDAR (Light Detection and Ranging) data, aerial photographs, and other relevant datasets spanning multiple years.

    a. Ensure consistency in data acquisition parameters (e.g., spatial resolution, spectral bands) to facilitate comparative Analysis over time.

2. **Preprocessing:** Preprocess remote sensing data to remove noise, correct for atmospheric effects, and enhance image quality using techniques such as radiometric calibration, atmospheric correction, and geometric registration.

    a. Integrate multiple datasets into a consistent spatial and temporal framework, ensuring compatibility and alignment for time-series analysis.

3. **Change Detection:** Apply change detection algorithms to compare historical remote sensing data and identify changes in forest cover, structure, and composition over time.

    - Utilize techniques such as image differencing, vegetation indices (e.g., NDVI, NDMI), and spectral mixture analysis to detect changes in vegetation health, biomass, and land cover.

4. **Forest Growth Modeling:** Develop models to quantify forest growth dynamics and trajectories based on historical remote sensing data and ancillary information (e.g., climate data, topographic variables).

    a. Employ machine learning algorithms such as random forest regression, support vector machines, or neural networks to predict forest growth parameters such as biomass accumulation, canopy height, and carbon sequestration rates.

b. Incorporate spatial and temporal variables into growth models to account for factors influencing forest development, such as climate variability, disturbance events, and land management practices.

5. **Biomass Estimation:** Estimate forest biomass and carbon stocks using remote sensing-based biomass mapping techniques, such as LiDAR-based canopy height models, radar backscatter measurements, and optical imagery-based biomass models.

    a. To ensure accuracy and reliability, calculate and validate biomass estimation models using ground-based measurements, field surveys, and forest inventory data.

6. **Spatial Analysis and Visualization:** Conduct spatial Analysis of historical forest growth data to identify spatial patterns, hotspots of biomass accumulation or loss, and areas of rapid forest change.

    - Visualize and interpret results using GIS (Geographic Information Systems) software, remote sensing platforms, and interactive visualization tools to communicate findings to stakeholders and decision-makers.

OTHER POTENTIAL APPLICATIONS IN FOREST ANALYSIS:

1. Tree species classification and biomass estimation.
2. Forest structure and composition analysis.
3. Forest health monitoring and anomaly detection.
4. Growth prediction and simulation modelling.
5. Large-area mapping and spatial Analysis.
6. Integration with GIS and other data sources.

CASE STUDIES AND APPLICATIONS

i. CASE STUDY 1: CONSERVATION DRONES FOR FOREST MONITORING IN INDONESIA

Background: In Indonesia, deforestation and habitat loss threaten the survival of endangered species like orangutans and Sumatran tigers. To combat illegal logging and encroachment, the Sumatran Orangutan Conservation Programme (SOCP) partnered with researchers from the University of Zurich to deploy conservation drones equipped with A.I. algorithms for forest monitoring.

Implementation: The drones, equipped with computer vision algorithms, autonomously patrol designated forest areas, capturing high-resolution imagery and detecting signs of deforestation, logging activities, and habitat disturbances. Machine learning models analyze the imagery to classify different land cover types, identify forest degradation areas, and prioritize conservation interventions.

Impact:

- Using conservation drones has significantly improved the efficiency and effectiveness of forest monitoring efforts, enabling rapid detection and response to illegal activities.
- AI-driven Analysis of drone imagery has provided valuable insights into forest health, biodiversity distribution, and habitat connectivity, informing conservation strategies and land management decisions.
- By promoting sustainable forest management practices and combating illegal logging, the project has contributed to the conservation of endangered species and the preservation of vital ecosystems in Indonesia.

ii. CASE STUDY 2: AI-POWERED FOREST FIRE PREDICTION IN AUSTRALIA

Background: Australia faces recurrent wildfires, which significantly threaten human lives, property, and biodiversity. Researchers from the Commonwealth Scientific and Industrial Research Organization (CSIRO) developed AI-powered models for predicting forest fires to enhance early warning systems and improve fire management strategies.

Implementation: The A.I. models, trained on historical weather data, satellite imagery, and vegetation indices, use machine learning algorithms to analyze environmental factors and identify patterns indicative of fire risk. By integrating real-time weather forecasts and remote sensing data, the models provide accurate fire occurrence and spread predictions, enabling proactive firefighting efforts and evacuation planning.

Impact:

- The AI-powered fire prediction models have demonstrated high accuracy in forecasting forest fires, allowing authorities to allocate resources more effectively and prioritize high-risk areas for prevention and mitigation measures.
- By providing timely warnings and actionable insights, the project has helped reduce the impact of wildfires on communities, ecosystems, and infrastructure, saving lives and minimizing economic losses.
- Using A.I. technologies has enhanced the resilience of forest ecosystems to climate change and extreme weather events, promoting sustainable land management practices and ecosystem restoration initiatives.

iii. CASE STUDY 3: SMART FOREST MANAGEMENT IN FINLAND

Background: In Finland, sustainable forest management is critical for maintaining biodiversity, ecosystem services, and carbon sequestration capacity. The Finnish Forest Centre collaborated with tech companies and research institutions to develop an intelligent forest management platform powered by A.I. and remote sensing technologies.

Implementation: The platform integrates satellite imagery, LiDAR data, and ground-based sensors with A.I. algorithms to monitor forest health, growth dynamics, and carbon stocks. Machine learning models analyze the data to predict timber yield, assess biodiversity indicators, and optimize forest management practices, such as thinning, harvesting, and reforestation.

Impact:

- The innovative forest management platform has enabled data-driven decision-making and adaptive management strategies, improving the productivity and sustainability of forest ecosystems in Finland.
- By optimizing harvesting schedules and minimizing environmental impacts, the project has enhanced the economic viability of forestry operations while preserving ecosystem integrity and biodiversity.
- AI-driven Analysis of forest data has facilitated compliance with certification standards and regulatory requirements, ensuring responsible forest stewardship and promoting transparency in the forest sector.

These case studies demonstrate the transformative potential of A.I. technologies in forest management, highlighting their role in promoting sustainability, biodiversity conservation, and climate resilience on a global scale.

CHALLENGES AND OPPORTUNITIES

- **Challenges:**

  Forest management undergoes several challenges due to traditional limitations, which include:

  - Data Quality Challenges: Addressing issues related to the quality, completeness, and reliability of forest data, including inconsistencies in data collection methods, biases in sampling techniques, and gaps in spatial and temporal coverage.
  - Algorithm Accuracy: Ensuring the accuracy, robustness, and interpretability of A.I. algorithms for forest analysis, including challenges associated with model overfitting, data heterogeneity, and uncertainty quantification.
  - Integration of Multisource Data: Overcoming challenges in integrating multisource data from diverse sources, including satellite imagery, field surveys, and ecological databases, to improve the accuracy and reliability of AI-driven forest analysis.

2. **Opportunities:**

   Opportunities are endless when exploring A.I. technologies in forest management. A few include;

1. Interdisciplinary Collaboration: Fostering collaboration between forest scientists, ecologists, computer scientists, remote sensing experts, and policymakers to leverage diverse expertise and perspectives in AI-driven forest analysis.

- Knowledge Sharing: Promoting knowledge sharing and capacity-building initiatives to empower stakeholders with the necessary skills and tools to harness A.I. technologies for forest management and conservation.

- Open Data Initiatives: Supporting open data initiatives and data-sharing platforms to facilitate access to high-quality forest datasets and promote transparency, reproducibility, and collaboration in A.I. research.

CONCLUSION AND RECOMMENDATION:

A.I. has the potential to transform forest data analysis and growth prediction, enabling data-driven decision-making and sustainable forest management. By harnessing A.I. capabilities, we can unlock new insights, improve forest productivity, and ensure the long-term health and resilience of our forests. As A.I. continues to evolve, its applications in forest management will only continue to grow and provide new opportunities for innovation and sustainability.

Below are some recommendations and calls to action to expedite innovative practices in forestry;

- **Capacity Building**: Investing in capacity building programs, training workshops, and educational resources to empower forest managers, conservation practitioners, and local communities with A.I. tools and techniques for forest analysis and decision-making.

- **Research Funding**: Advocating for increased investment in A.I. research and innovation for sustainable forest management, including public-private partnerships, government grants, and philanthropic support.

- **Technology Transfer**: Promoting the transfer of A.I. technologies and best practices from academia and research institutions to forest management agencies, conservation organizations, and industry stakeholders.

- **Policy Support**: Encouraging policymakers to prioritize A.I. research and development in forest management policies and initiatives and to create regulatory frameworks that support innovation, data sharing, and ethical A.I. use.

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SUB-THEME: MARKET TRENDS AND INDUSTRIAL DEVELOPMENT OF NTFPs

PROMOTING INNOVATION AND MARKETING OF NATURAL HONEY IN NIGERIA.

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ABSTRACTS

Forest Products is a significant supplier of raw materials for food processing, beverages, and textile industries. It accounts for 70% of the labor force and 38.7% of the export earnings. The forests and woodlands of the country contain diverse plant species that are home to nectar and pollen. The beekeeping subsector has been an integral part of the forestry sector in Nigeria. It has contributed significantly to household income and sustaining livelihood by reducing the poverty rate and helping to improve the national economy through exports. Also, it has medicinal value, is a food source, and is a livelihood option for retirees and the unemployed. This study reviewed market opportunities, structures, and marketing channels for intending entrepreneurs through deep literature. It identified challenges faced by honey marketers in Nigeria in making appropriate recommendations to the marketers. It was observed that to close the demand and supply gap, sustainable honey production depends mainly on its marketing structure and performance. Therefore, the need to produce and market honey should guide the development of business opportunities. The stakeholders should subsidize modern equipment for apiculture and promulgate a policy on bush burning.

KEYWORDS: Apiculture, Beekeeping, Economic values, Honey, Medicine, Food, Marketing

INTRODUCTION

Forest products other than timber are known as non-timber forests, NTFPs (Pandey *et al.,* 2016). These goods have long been a vital part of rural livelihoods, and more significantly, NTFPs have been recognized as essential forest products (Chandrasekharan, 1998). The forest products available for various consumable and non-consumable applications in the livelihood include exudates (gum, resins, and latex) to canes, fruits, flowers, seeds, seed derivatives, entire leaves, root or stem bark, fungi, microorganisms, and insects. Shackleton & Pullanikkatil (2019) and Angelsen et al. (2014) acknowledged that adopting NTFPs improves rural communities' quality of life. NTFPs are essential for functioning, security, and decreasing sustenance (Endamana *et al.,* 2016). NTFPs significantly contribute to impoverished people's health by their medicinal and dietary properties. It has a significant cultural value and importance for various ethnic communities worldwide. In and within the forest areas and communities, the income shares from NTFPs range up to 50 percent of household total income (Angelsen *et al.,* 2014; Vedeld *et al.,* 2007). In recent years, there has been an increase in the demand for NTFPs for nutrients, medications, fodder, timber, thatch, building equipment, and mulch in rural households and urban dwellers (Wahyudi, 2017). Such products include honey, which is produced by honeybees.

The honeybee is one of the non-timber forest products from the wild. Bees (*Induce apis*), generally called Honeybees, belong to the genus (*Apis)*, Tribe (*Apini*), Sub-family (*Apinae*), Order

(*Hymenoptera*), Class (*Insecta*), Phylum (*Arthropoda*), and Kingdom (*Animalia*) (Okeme *et al.*, 2014). Nectar is transformed into honey by honeybees through a process called regurgitation, and this honey is stored in wax honeycombs in the beehive as the primary food source; while the bees are in their hives, they use their honey stomachs to ingest and regurgitate the nectar repeatedly until it is partially digested (Standifer, 2007). According to (Okeme *et al.,* 2014 and Famuyide *et al.*, 2014), the bees work in a group in the digestion and regurgitation until the product reaches the desired quality and is stored in a honeycomb cell. After the final regurgitation, the honeycomb is left unsealed. However, the nectar is still high in both water content and natural yeasts, which, if unchecked, would cause the sugar in the nectar to ferment (Natural Honey Board, 2010). Beekeeping constitutes the line of production that makes up agribusiness. It is also known as apiculture (Onwumere *et al.,* 2012). Beekeeping is rearing or keeping bees to explore their products, such as honey, pollen grain, propolis, and comb (Onwumere *et al.,* 2012). Apiculture is the management of bees in a hive so that their developmental processes will be observed and manipulated (Oyeleye, 2003). Humans have been rearing bees for honey production since 4,000 B.C. (Halil and Nuray, 2007). Africa and other tropical countries in the Caribbean and Pacific have highly appropriate habitats for bees. According to (Oluwaseun., 2009), the typical African honeybee in Nigeria is *Apis Mellifera adansonni*.

Honey is a delicious viscous sweetener made naturally by bees for their nourishment from the nectar or secretion of flower plants. Honey has a long history of human consumption as a natural food source and is also used as ingredients in various food preparations, in both alcoholic and non-alcoholic beverages as sweeteners, and in confectionaries as flavoring agents (Durrani *et al.*, 2011; Eleazu *et al.,* 2013). Honey is a naturally sweet food product, complex in nature, that has extraordinary flavor and aroma, sugars, pollen grains, waxes, pigments, flavonoids, phenols, lipids, vitamins, minerals, enzymes, amino acids, organic acids, and other phytochemicals (Belay et al. 2017, Machado et al. 2018, Mulugeta & Belay 2022). Honeybees are made from honeydew or nectar and are widely consumed worldwide due to their health benefits (Gebeyehu and Jalata, 2023).

Okpokiri *et al.,* (2015) reported that Beekeeping as a commercial venture is still largely unexplored in Nigeria in large-scale production, and the country meets domestic demand for honey primarily by importation from producer countries and locally by bee hunters (Ayansola, 2012). There is a growing consumption of honey and other bee products because of their high value in maintaining good health and treating various diseases. With the current growth in domestic consumption of honey in Nigeria coupled with mechanized agriculture in most of Nigeria, resulting in large crop acreage, the future of apicultural enterprise is very bright as the demand for honey and pollinators is bound to increase. It could provide food, nutrition, and livelihood security to the rural workforce ecologically and sustainably.

MEDICINAL VALUE OF HONEY

Globally, honey is known to have several applications and uses in industry, medicine, and nutrition (Gela *et al.,* 2021). It plays a critical role in human health, food, and the treatment of diseases (Ranneh *et al.* 2021; Asari *et al.* 2022). Honey has been credited for many biological and therapeutic purposes, such as treating colds, skin wounds, and various gastrointestinal diseases. (Ndife et al. 2014). This beneficial role is attributed to honey's antimicrobial and anti-inflammatory properties that arise from the low-acid nature of high sugar, mainly of glucose and fructose components (Amril and Ladjama, 2013). Raw honey contains glucose oxidase and water to produce hydrogen peroxide, a mild antiseptic (Amiot *et al.,*1989). In addition, other enzymes found in honey also help the healing process (Khalil *et al.,* 2010). It is also used expansively in making Ayurvedic medicines. The United States Department of Agriculture (2007) reported that honey combines different

compounds, including sugars, mainly fructose and glucose, other carbohydrates, water, trace amounts of vitamins and minerals, and other compounds. Besides being delicious and nutritious, it has been helpful in many industries, especially pharmaceutical ones. Bee venom is beneficial for treating rheumatism and eye and skin diseases, while royal jelly is used to cure infertility and dressing wounds. Apart from the direct consumption of honey, it is used for dressing wounds, as an anti-diarrheal drug, in alcoholic drinks, in tobacco curling, and manufacturing cosmetics. It helps against infection, improves tissue regeneration, and reduces scar tissue in its raw, unprocessed form. Pollen is applied in the case of prostate problems, as well as for prostate cancer and allergies.

LIVELIHOOD OPTION OF HONEY

It is traded globally and commands a higher premium (García 2018; Gela et al. 2021). Honey also plays a vital role in the economic status of both rural and urban dwellers, and it contributes to the nation's economy (Arowolo et al. 2020; Gebeyehu & Jalata 2023; Mulugeta & Belay 2022; Verma et al. 2018). Honey, through production and marketing, is also an important economic activity that can be used to fight against poverty (Shrestha 2017).). Honey is bred in Nigeria for income earning and human consumption. Honey production is a good business enterprise where farmers in southwest Nigeria invest their resources to generate income. Beekeeping enjoys many advantages, such as the availability of local and international beekeeping markets, recent technologies, employment, income generation, and the insect's ability to source food all year round. (Folayan and Bifarin,2013). Honey is referred to as a money spinner because it is so much in use and consequently in demand. There is a reduction in poverty and malnutrition due to involvement in Beekeeping, and one can attain a large quantity of honey and other products for home consumption and business purposes. Beekeeping has improved poverty in Nigeria (Adedeji and Omoba., 2016). It also increases incomes in the rural communities and benefits the country's economy.

In 2003, China was the world's largest honey producer, producing over 310,756MT and consuming 146,112 MT (Musa *et al.*, 2014). The average customs value was $ 0.52/kg. The Chinese government encourages Beekeeping as a means of supplementing rural incomes. The United States of America was the second largest producer, with 77,110MT, followed by Argentina (F.A.O., 2003). Argentina exports over 90% of its honey, and it's the second largest exporter of honey behind China. The recently estimated annual honey production and marketing was over 2000 tonnes, yet Nigeria's productions appear insignificant as they were not recognized by the Food and Agriculture Organization (F.A.O., 1996). In Nigeria, poverty and unemployment remain the most widespread problems, and tackling them is a significant policy challenge for every successive government. However, despite this enormous potential, not enough has been done on its distribution and marketing. Investment in apiculture to battle poverty is joint in developing countries like Nigeria. World honey production is said to be over one million metric tonnes (M.T.) in 2003.

HONEY AS FOOD

Anineme (2007) and Igbokwe (1998) affirmed that honey is a consumable product used locally for food, as a sweetener, and for preparing herbal portions. Honey is an essential commodity. It has long been used as one of man's most highly desired foods (Peterson. 2006), is used in baking, as an additive in various beverages such as tea, and as a sweetener in some commercial beverages. as a spread on bread. Honey is also the main ingredient in alcoholic drinks, such as honey wine and honey beer. Bees produce honey, which contains about 80% of sugars readily absorbed by the body and is exceptionally suitable food for children, sick people, and those who perform heavy mammal Labor (A.D.P. 2007).

OTHER ECONOMIC VALUES

Bee wax is used in manufacturing cosmetic candles, foundation sheets (for houses), polishes, and propolis honeybees produce. It has some therapeutic properties, and pollen is used to make perfumes. The application of pollen as a supplement in animal feed led to an increase in the weight of pigs, chickens, and laboratory cultures of insects. (Bogdanov 2004)

TYPES OF HONEY

There are two different types of honey: floral honey and honeydew. It has been observed that floral honey is higher in simple sugars (fructose and glucose), lower in disaccharides and higher sugars (dextrins), and contains much less acid. The higher number of mineral salts (ash) in honeydew gave it a less active acidity (higher pH). The nitrogen content reflecting the amino acids and protein content was also higher in honeydew. Even though honey contains an active sucrose-splitting enzyme, the sucrose level in honey never reaches zero. Honey varies tremendously in color and flavor, depending on its floral source (White and Doner, 1980). Honey harvested from various parts of the world contains a small amount of honeydew. Such honey exhibits the characteristics of honeydew honey to a degree dependent on the proportion of the honeydew contribution. Honeydew honey differs principally from nectar honey because it is derived from the internal phloem sap of the plant instead of from actively secreted nectar and, most significantly. After all, enzymes from the honeydew-producing insects are involved in its production. However, the main constituents of both honeys are primarily similar (Crane, 1990). Honeydew can be produced by a wide variety of sucking insects on several different Coniferae, such as *Abiesalba*L. (Central and Northern Europe), *A. cephalonica*Loudon (Greece), *Piceaexcelsa* (Lam.) Link. (Central and Northern Europe), *Pinushalepensis* Miller and *P. brutia* Ten. (Greece) (Oddo and Piro, 2004). When compared to nectar honey, honeydew honey was generally distinguished based on its higher values of pH, acidity, ash, electrical conductivity, and darker color, as well as by a lower monosaccharide and a higher di- and trisaccharide content (Diez*et al.,* 2004; Soria*et al.,* 2004)

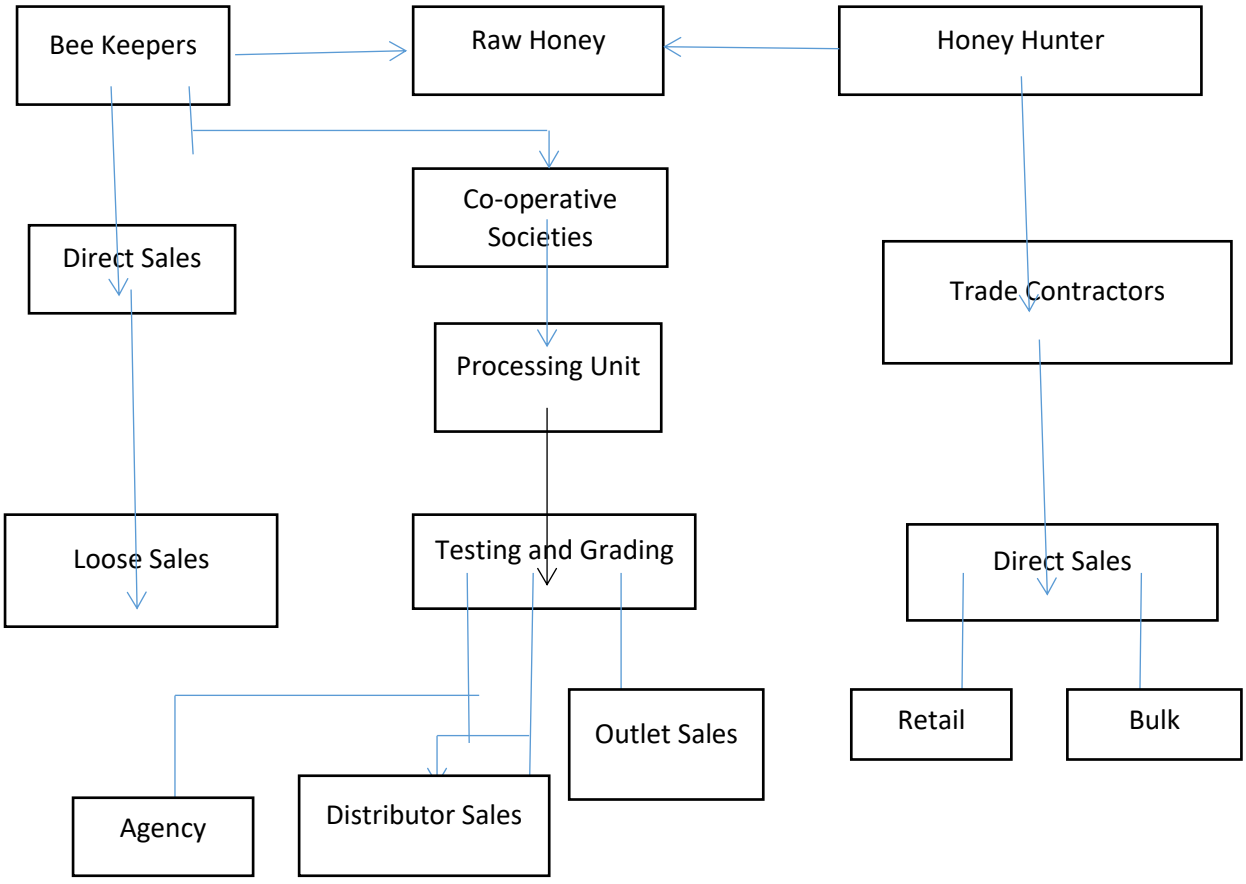
STRUCTURE OF THE HONEY MARKET IN NIGERIA

Marketing channels: A marketing channel is a business structure of interdependent organizations that reach from the point of product origin to the consumer to move products to their final consumption destination (Kotler and Armstrong, 2003). This knowledge is acquired by studying the participants in the process, i.e., those performing physical marketing functions to obtain economic benefits (Getachew, 2002). In addition, channels may be short or long depending on the kind and quality of the product marketed, available marketing services, and the prevailing social and physical environment (Islam *et al.,* 2001). The channel system creates time, place, possession, and form utilities. However, the benefits of the channel system cannot be enjoyed without an element of cost.

The marketing channel is the route of the produce, and the people involved in the marketing channel may be simple or complex, and commodity specifics and region usually determine them. Through a distribution channel, goods are moved from producers to consumers. In the process of movement, the produce could change in shape, form, taste, and quality. There are six classes of middlemen in Nigeria, and their functions overlap. The middleman includes farm gate intermediaries, the commission agent, and the non-commissioned agent. The non-commissioned agents do not take the title from the producers and the retailers but from the consumer. The commissioned agent does not take title from the commodities they handle. These agents engage in negotiation that transports the title from the seller to the buyer. The non-commissioned agent, however, takes title to the commodity it handles. (Adegeye and Dittoh 1985). Cooperative marketing agencies are mainly trade organizations that provide general industry or physical marketing facilities. Agricultural marketing has a multiplier effect on storage, processing, packaging, etc., and requires the establishment of

industries to handle these activities. This increases employment and stimulates local production (Adegeye and Dittoh 1985). Efficient marketing paves the way for an increase in volume that consequently motivates the government to provide necessary infrastructure, such as good roads, pipe-borne water, storage facilities, provision of agricultural credit, etc., to develop the economy and create convenience for the masses. Marketing ensures that seasonal goods, especially in agriculture, are available throughout the year with slight fluctuations in price. This creates assurance in the producer of selling, and all the producers and consumers are also assured of obtaining the product throughout the year through an effective storage system (Adegeye and Dittoh 1985). According to them, marketing stimulates research into food and meat preservation techniques and the preparation of various food items to meet the different tastes of consumers through market surveying. Agricultural marketing indicates consumer preference through the price they are ready to pay. It helps study the economic problems of how much to produce as farmers are prepared to create high-demand products.

Marketing Channel of Honey



Source: Central Bee Research and Training. (Wakhle and Kamble., 2001)

According to the study by (Biruk, 2015) in the wait Zone of SNNPR, the prominent actors that participated in the honey value chain were producers, collectors, wholesalers, retailers, cooperatives, processors, and consumers, with the higher producers marketing margin of 90.67% for the channel that passes through cooperatives. The principal value-adding activities undertaken at each chain stage were transporting, sorting, and packaging, filtering, and processing. He identified and defined the honey value chain actors as follows:

Producers are the significant actors who perform most value chain functions, from procuring the inputs to harvesting and marketing. The primary value chain functions that honey producers perform in the study area include sorting, filtering, packaging, and transporting. Most of the honey producers in the study area sell their products in the markets found in the Zone and neighboring markets of the Hadiya zone.

Collectors: These are farmer traders who collect honey at the farm, get level from the producers, and sell it to wholesalers and retailers in the district market.

Wholesalers: These actors buy large quantities of honey from collectors or producers and resell it to other traders.

Retailers: These are critical actors in the honey value chain in Zone. They connect the wholesalers and urban consumers by offering according to the requirements and purchasing power of the buyers.

Processors: These are retailers in both urban and rural areas who purchase crude honey from wholesalers and supply honey to consumers in the form of breweries locally known as tej. Cooperatives: These are the significant actors directly participating in honey marketing and supporting producers. These actors organize the farmer households to supply filtered honey to them regularly and then sell it to consumers. They also give training on how to use it and provide quality honey to them.

Consumers are the final actors of the chain who buy the product for their consumption. They may afford it either as processed (tej) or non-processed. Amanuel (2011) identifies the honey value chain actors that participated, and these include honey producers, retailers, traders, wholesalers, processors, supermarkets, and tej brewers, while the service providers were Organic inspection and certification agencies, Forest products control committee, Microfinance Institutions, Transporters, and Non-Government Organizations.

Market Structure

Seller concentration, firm size, buyer concentration, and entry conditions are the essential elements of market structure. These elements, in one way or the other, influence market integration. Seller or buyer concentration inhibits the free flow of goods and services among markets, distorting the spirit of a unified or integrated market. Similarly, if the entry condition is restricted, the most prominent firm may control the entire market, leading to weakly integrated markets. Thus, these elements of market structure affect the degree of competition in the market, which in turn influences the magnitude of market integration. Therefore, the market's structure determines the degree of market integration. Bain refers to the term market structure as "those characteristics of the organization of a market which seems to influence the nature of competition and pricing within the market strategically." The characteristics of market organization emphasized were the degree of seller concentration, size of the distributing firms, degree of buyer concentration, degree of product differentiation, and the condition of entry in the market. (Clodius and Mueller 1961, Arowolo et al, 2020).

However, the above views cannot highlight the significance of various marketing channels and intermediaries in analyzing the market structure. In the view of Schultz (1946), the market structure includes all the strategic variables that control or influence the behavior of different agencies involved in the market. Cundiff and Still (1972) gave an all-encompassing version. To them, the market structure was the whole network of marketing institutions.
Serviced society's needs. At one end of the network, producers initiated the flow of goods and services, and various intermediaries, such as wholesalers and retailers, maintained the flow. Finally,

discharging the goods and services for consumer's use. 'To Lele (1973), market structure included various market channels. Intermediaries and traders move the produce from producers to the consumers. According to George (1984), market structure could be defined as all the agencies involved vertically or horizontally in selling and buying the produce. It includes different marketing channels, their form, market shares, and the market environment. Thus, the market structure through various marketing channels influences the nature of competition and pricing within the market through the intermediaries. However, it is in the market structure that the market agent must function. And it is the structure that determines the behavior of the market.

Challenges and opportunities of Honey marketing trend in Nigeria

Significant constraints of honey marketing include a lack of financial resources (such as access to loans) for beekeepers to obtain modern beehives and other tools necessary to increase honey production. Beekeepers have little access to financial products that would allow them to switch from traditional beehives to improved versions. Moving to transitional and modern beehives requires an initial investment of capital that most beekeepers do not have, so they continue to produce honey using traditional methods (Wagner *et al.*, 2019).

Supply-related barriers to properly managing modern beehives: The supply of tools necessary to manage modern beehives is not readily available. For instance, some beekeepers possess modern beehives (just boxes). Still, they lack the tools to properly manage these beehives (such as a smoker, queen excluder, or honey extractor). There is a lack of proper training regarding efficient management of a modern-style apiary. Generally, beekeepers with modern beehives do not have the skills or knowledge to manage them properly, and training is not readily available. Therefore, beekeepers tend to rely on ineffective extractive harvesting methods and inappropriate tools for this type of hive. Additionally, they usually do not provide additional feed (water and sugar syrup or flour) during droughts and have little knowledge about prevailing honey quality requirements in export markets—other associated obstacles. Additional barriers include the disappearance of bee-foraging areas due to crop intensification and the growing use of agrochemicals; extreme weather conditions in some parts of Nigeria (droughts); poor transportation infrastructure; weak knowledge of proper storage techniques (at the farm and local honey collectors'/traders' levels); problems with packaging, especially at the processors' level (e.g., difficulty obtaining a reliable supply of glass jars); weak access to profitable export markets due to low productivity; limited knowledge of export-market requirements; and Lack of or weak connections with processors. The key barriers to successfully expanding the Nigeria honey market trend primarily lay at the supply side of this commodity. Nigeria's honey production is insufficient in terms of quantity and quality. These supply-side issues need to be addressed to meet the growing domestic demand and a likely profitable demand in the export markets. Abebe (2009), Omotayo and Anekwe (2023). The level of the honey market was indicated by its low level of honey extraction and processing, storage, and transportation materials, means of transportation of honey to the market, flow of market information, honey transaction measurements, etc. Arowolo et al (2020). The identified constraints were Lack of well-organized market channels, Lack of rural market infrastructure, Lack of current market information flow, very limited or absence of credit extension and training, actors' Lack of skill in honey processing handling and marketing, Lack of strong business-oriented producers Cooperative e.t.c. Additionally, Arowolo et al. (2020) identified that the significant constraints affecting honey marketing in Nigeria include a lack of organized market, Adulteration, Transportation, Low demand, Financial constraints, Lack of information, Lack of coordination, Unstable market price and low product quality due to poor harvesting and handling techniques poor infrastructure, Lack of financial resource, Lack of processing equipment and skill and packaging, etc.

CONCLUSION AND RECOMMENDATION

The fact that Beekeeping can add value to man and alleviate poverty in Nigeria cannot be over-emphasized. Beekeeping boosts incomes, benefits the country's economic situation, has medicinal values, and is a food source and a livelihood option for retirees and the unemployed. This study reviewed market opportunities, structures, and marketing channels for intending entrepreneurs. This study addressed the challenges faced by honey marketers in Nigeria and made appropriate recommendations for the marketers. Sustainable honey production depends largely on its marketing structure and performance to close the demand and supply gap. Therefore, the need to produce and market honey should be a guide for developing business opportunities. The stakeholders should subsidize modern equipment for apiculture and promulgate a policy on bush burning.

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SOCIOECONOMIC CHARACTERISTICS OF FISH MARKETERS IN IBADAN, OYO STATE

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Abstract

The socioeconomic characteristics of catfish farmers were examined in this study. The study was carried out in Ibadan. Multistage random sampling is employed in this study. Three local government areas were purposefully selected among Ibadan's eleven local government areas. A structured questionnaire was used to collect data from the respondents. Descriptive and inferential statistics were used to analyze the collected data. The results showed that the mean age of the catfish marketers was 45.5 ± 1.15 years old. There were more men (65%) in the catfish marketing business than women (35%) in the study area. Most (80%) respondents were married, or 15%. Most (52.5%) catfish marketers had a family size between 1 and 5, while 42.5% had a family size between 6 and 10. Most (37.5%) of the marketers had years of experience between 6 and 10 years, while the mean years of experience were 2.45±0.21 years. Most (67.5%) of the catfish marketers confirmed that fish marketing is more profitable than catfish farming. Most (90%) respondents believed that fish farming has more risk than fish marketing. Most (67.5%) respondents confirmed that fish marketing has a quicker turnover than catfish farming. Most (70%) catfish marketers reported that fish farming is more labor-intensive than marketing. The majority (87.5%) of the respondents confirmed that fish farming is more capital-intensive marketing. Therefore, catfish marketing is less labor- and capital-intensive and has a quick return on investment.

Keywords: Marketers, labor-intensive, capital-intensive, quick returns, marketing.

Introduction

At its inception, catfish farming was practiced at the subsistence level, where catfish were produced for family consumption. Those who were involved had little or no knowledge of its economic importance. As the population increases, so does the demand for fish and the need to increase fish production. The increasing catfish production and demand for catfish necessitate the need for catfish marketing. Fish is a highly perishable product that starts to deteriorate when it leaves the water or dies. Also, many catfish farmers have limited knowledge of successfully marketing fish. Therefore, there is a need to add or create a new level in the value chain: marketing. Marketing is exchanging goods and services concerning price from one person to another (Agbebi and Adetuwo, 2018).

Catfish farming is now generally known as an economic enterprise, and many economic enterprises are attached to it. Catfish marketing is among the most essential enterprises associated with catfish farming. Catfish marketers ensure that fish is safely conveyed from the point of production, i.e., the farm, to the markets, where it will be available for consumers. It is concerned with all that happens

to catfish after they leave the farm gate (Olaleye *et al*. 2019). Catfish marketers are very close to catfish farmers in the catfish value chain. Their activities start immediately after catfish production ends at harvest. Catfish marketing's business life cycle is short, lasting only a few days, unlike catfish production, which varies between three and 12 months. So, they can link as many catfish farmers as their capital will allow them. Haruna *et al*. (2012) believe that an efficient market not only links sellers and buyers in reacting to current situations in supply and demand but also has a dynamic role in stimulating the consumption of outputs, which are essential elements of economic development.

The farm gate is the central place for catfish marketing, where catfish farmers sell their fish to marketers, especially wholesale marketers. In addition, catfish markets can be found wherever catfish is available for sale at various general markets, bus stops, hotels, and restaurants, *among other things*. Catfish is generally consumed in almost all parts of Nigeria, but its production is limited in some areas due to ecological and climatic conditions. However, demand for catfish from nearly every state in Nigeria necessitates the transportation of catfish from one state (the majority of catfish-producing states) to another. Likewise, each state prefers different sizes of catfish, which is another major factor to be considered in catfish marketing. Therefore, according to Adekanye (1988), marketing can also be seen as a method to bring the interpersonal forces of demand and supply together, irrespective of the market's location. Catfish marketers are noticed to be increasing due to the population and the demand for catfish (Agbebi and Adetuwo, 2018). However, despite the nutritional and commercial values of fish and fish products, their production and marketing remain low in Nigeria compared to other nations (F.A.O., 2012).

Nigeria is the second-largest aquaculture-producing country in Africa (F.A.O., 2020) and the top catfish-producing country in the world (F.A.O., 2016b). Likewise, Agbebi and Adetuwo (2018) believe Nigeria offers the largest market for fisheries products in Africa. Nigeria is also Africa's largest importer of fish (The Fish Site, 2021) due to increasing demand for fish. Hempel (2010), as cited by Animashaun *et al*. (2015), reported that the Nigerian catfish industry provides approximately US$75 million in revenues at the farm gate and accounts for nearly US$180 million in consumer spending. The sector equally contributes to the employment of almost 25,000 people, with the majority (over two-thirds) employed as restaurant workers. This indicates that catfish marketing is a reliable source of job opportunities and a good source of income.

Ibadan is one of the hub cities for catfish production in Nigeria. Catfish marketing is also known to be one of the most lucrative businesses in the city. Catfish is marketed in the town and distributed from Ibadan to other parts of Nigeria. Therefore, this study examines the socioeconomic characteristics of catfish markets in Ibadan.

Materials and Methods

This study was carried out in Ibadan, the capital of Oyo State. It is located in the southwestern part of Nigeria between latitudes 7° 23' and 7° 54' north of the equator and longitudes 3° 53' and 3° 54' east of the Greenwich Meridian (Figure 1). Ibadan is known as a hub for catfish production. Catfish marketers source fish from Ibadan to sell to other parts of Nigeria. The study population consists of fish marketers and fish farmers in Ibadan.

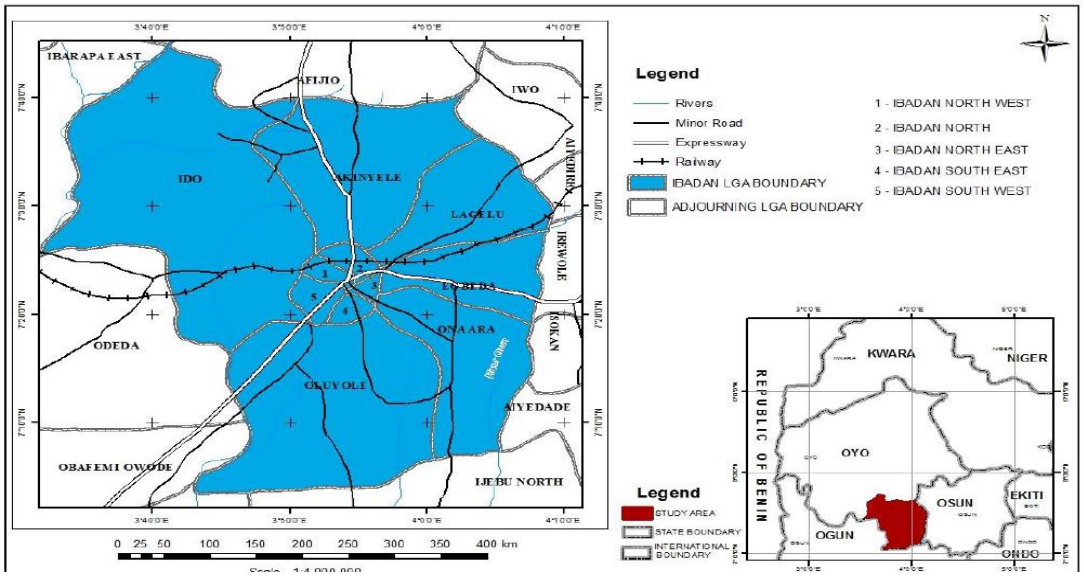

Figure 1: Map of Ibadan Metropolis Showing Local Government Areas

Source: Office of Surveyor General of the Federation (OSGOF, 2014).

Multistage random sampling is employed in this study. Three local government areas were purposefully selected among the eleven in Ibadan, Oyo State. The selected local governments were Southwest, Ido, and Ibadan Northeast. Likewise, from each of these selected local government areas, 25 catfish marketers were chosen randomly. Some visited regions in these three local government areas are Ikolaba, Dugbe Market, Aleshinloye Market, Omi Panada, Eleyele Market, and Mokola Market. A structured questionnaire was used to collect data from the respondents. The questionnaire focused on issues such as the respondent's data, information on the activities of catfish marketers, their challenges, and the preferences of their target customers. Descriptive statistics such as frequency, percentage, mean, standard deviation, and inferential statistics were used to analyze the socioeconomic characteristics of catfish marketers in the Ibadan metropolis.

Results and Discussion

The socioeconomic characteristics of the catfish marketers considered in the study are age, gender, academic status, marital status, family size, years of experience, and membership in a catfish marketer association (Table 1). The catfish marketers' minimum age (35 years) and maximum age (59 years) showed that the marketers are within the range of active economic and productive age. Most (27.5%) catfish marketers in the study area were between 36 and 40, while the mean age of the catfish marketers was 45.5±1.15 years old. This result shows that marketing requires a certain level of maturity, especially in age, for proper reasoning, decision-making, and taking on specific responsibilities (Agbebi and Adetuwo, 2018; Olaleye *et al.*, 2019). More men (65%) were in the business of marketing fresh catfish than women (35%). This agrees with the report of Otitolaye and Adejo (2010), who state that fish marketing is male dominated because of the stress and laborious nature of fisheries activities. However, Agbebi and Fagbote (2012) reported that fish marketers are more dominated by females than males because women are thought to have better bargaining power than men. Most (92.5%) of the catfish marketers were literate and had different levels of education, while only 7.5% had no formal education. This shows that their literacy level will help them make good decisions in their marketing activities (Folayan and Folayan, 2017). The majority (80%) of the

respondents were married, 15% were single, and 5% were divorced. This result is consistent with the result of Olagunju (2019), who confirmed that most catfish farmers are married, responsible, and can make crucial marketing decisions jointly with their spouses. Most (52.5%) catfish marketers had a family size between 1 and 5, while 42.5% had a family size between 6 and 10. This showed that the catfish farmers in the study area have access to free labor, which can be utilized to increase productivity and profitability (Onyekuru *et al.* 2019). Most (37.5%) of the marketers had years of experience between 6 and 10 years, while the mean years of experience were 2.45±0.21 years. This implies that most catfish marketers have enough experience with marketing, which may influence their efficiency and increase their profit (Hussayn and Gulak, 2020). Most (85%) of the marketers were the Catfish Marketers Association members.

Table 1: Socioeconomic characteristics of the catfish marketers

Variables	Frequency	Percentage (%)	Mean ± SE
Age			
31 – 35	12	10	45.5±1.15
36 – 40	33	27.5	
41 – 45	24	20	
46 – 50	24	20	
51 – 55	15	12.5	
56 – 60	12	10	
Gender			
Male	78	65	
Female	42	35	
Academic status			
No formal education	9	7.5	
Primary education	18	15	
Secondary education	57	47.5	
Tertiary education	36	30	
Marital status			
Single	18	15	
Divorced	6	5	
Married	96	80	
Family size			
1 – 5	63	52.5	
6 – 10	51	42.5	
11 – 15	3	2.5	
16 – 20	3	2.5	
Years of experience			
1 – 5	30	25	2.45±0.21
6 – 10	45	37.5	
11 – 15	21	17.5	
16 – 20	9	7.5	
.>20	15	12.5	
Member Catfish			

Association		
No	18	15
Yes	102	85

Table 2 shows the perceptions of catfish farmers about catfish farming. Most (67.5%) of the catfish marketers confirmed that fish marketing is more profitable than catfish farming. This could result from the low variable costs incurred by the catfish marketers. This is in agreement with Hussayn and Gulak (2020), who found out that the cost of purchases of catfish accounted for 89.41% of the total cost of marketing, transportation costs accounted for 6.06%, the tax levied was 1.34%, and labor costs accounted for 2.36% of the total cost of marketing. Bassey *et al*. (2015) also found that catfish purchases constituted 95.2% and 96.2% of the total cost of marketing fresh fish for the wholesalers and retailers, followed by transportation costs and security charges of 3.7% and 0.23% for the wholesalers and 2.6% and 0.24% for the retailers. Unlike catfish farmers cost analysis, in which feed usually claims about 70% of the cost of production (Ajagbe *et al.*, 2022; Onyekuru *et al.*, 2019; Ashley-Dejo *et al.*, 2017), Olagunju (2019) reported that catfish marketers have zero average costs, such as feed, water, fuel, and the daily running of farming activities.

Table 3 shows that the years of experience of the catfish marketers influenced their decision to compare profitability between catfish marketing and farming. This agrees with the findings of Offor and Nse-Nelson (2015) that marketing experience significantly influences net income and marketing efficiency. Experienced catfish marketers usually determine the price of catfish in the market rather than the forces of demand and supply. This practice is always to the detriment of catfish farmers, which may affect their expected profit. Jabo *et al*. (2020) described the catfish market as an oligopoly market structure where few sellers or firms control the commodity. Most (90%) respondents believed that fish farming has more risk than fish marketing. Most (67.5%) respondents confirmed that fish marketing has a quicker turnover than catfish farming. This could result from a short transition between when the marketers bought the fish from the farmers and when it finally got to the consumers. Oladoja and Adeokun (2013) confirmed that shorter distribution channels characterized the marketing of catfish in the country, in contrast to those for agricultural products. According to Njoku and Offor (2016), catfish marketers' profit from the margin difference between farmers' and consumers' prices. Unlike catfish farmers, who had to cultivate fish for at least four months before they could think of getting the investment back, most (70%) catfish marketers reported that fish farming is more labor-intensive than marketing. The majority (87.5%) of the respondents confirmed that fish farming is more capital-intensive marketing. These agree with the report by Engle (2010) that aquaculture businesses are both labor- and capital-intensive.

Table 2: Perception of catfish farmers on catfish farming

Variables	Frequency	Percentage (%)
Fish marketing is more profitable than farming.		
No	39	32.5
Yes	81	67.5
Fish farming has more risk than marketing.		
No	108	90
Yes	12	10
Fish marketing has a quicker turnover than farming.		
No	39	32.5
Yes	81	67.5

Fish farming is more labor-intensive than marketing.		
No	36	30
Yes	84	70
Fish farming is a more capital-intensive marketing		
No	15	12.5
Yes	105	87.5

Table 3: Fish marketing is more profitable than fish farming

Variables	Coefficient	T-value	P-value
Age	-0.014	0.031	0.861
Gender	0.644	0.601	0.438
Education status	-0.177	0.133	0.715
Marital Status	-0.686	1.115	0.291
Family size	0.194	0.897	0.343
Years of experience	-0.642*	3.455	0.063

Conclusion

Catfish marketing bridges the gaps between catfish farmers and consumers. The channel makes the fish produced by farmers available for consumption by consumers. This study showed that young adults with an average age of 45.5±1.15 years old dominated the business, and the majority of them are married. It has been demonstrated that catfish marketing is more profitable than catfish farming, with quicker returns on investment. It is both less capital-intensive and labor-intensive compared to catfish farming. However, it required high-level experience to make the desired profits.

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Agricultural Products marketers and their Constraints to use different modes of payments in Ido Local Government Area of Oyo State.

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Abstract

This study was carried out to investigate the Constraints of Agricultural Products Marketers using different modes of payments in the Ido Local Government Area of Oyo State. A multi-stage sampling technique was used to select data from 80 respondents in the study area. Data were collected using a well-structured questionnaire and analyzed with the use of descriptive (frequency counts, percentages, and mean) and inferential statistics (Pearson Product Moment Correlation PPMC). The result shows that the majority (55.0%) of the respondents were male, married (80.0%), 40.0% had an age range from 31-40 years, household size of 5-8, and with educational status of both secondary and tertiary. Most of the respondents were into Agricultural products selling Yam and Cassava tubers, with Maize and Beans in the study area. Furthermore, the result showed that the majority (58.8%) of the respondents had 0-10 years of Agricultural products marketing experience in the study area. Furthermore, the results of the analysis reveal that (95.0%) Fluctuation of Electricity, (90.0%) Fluctuation of Networks, (90.0%)High rate of Bank Charge, (75.0%)Inadequate government support/NGOs, (75.0%)Lack of technical know-how and (70.0%)Inadequate credit facilities were high constraints hindering use of different mode of payments in the study area. There is a significant relationship between different modes of payments and Constraints hindering respondents in the study area with r-value = 0.929 and p-value =0.000. It is therefore recommended government and NGOs in collaboration with Agricultural products marketers and extension agents should ensure effective training of fellow marketers for effective marketing of their products.

Introduction

A payment method refers is an avenue customers utilize to remit payment for a product or service. In a brick-and-mortar store, some accepted methods of payment are cash, the use of gift cards, credit cards, prepaid cards, debit cards, or mobile payments. For an e-commerce business, the method of payment is usually via internet-based (online) payment means such as credit or debit card options, prepaid cards, gift cards, direct debit or transfer from a bank account, payment processors, and more.

There exist multiple payment options within the methods of payment. For example, payment processors can include Stripe, Authorize.net, Braintree by Paypal, Shopify Payments, and more,

while credit card options can include American Express, Mastercard, Visa, and Discover. Other payment methods include Google Pay and Apple Pay. The earliest payment methods involved barter, an exchange of goods between the two parties. Subsequent evolutions in payment methods involved the use of cash coins and credit cards. In recent times, electronic bank transfers and, to a limited extent, the use of cryptocurrencies, such as Bitcoin, have gained popularity as modes of payment Ejiro 2012. Each type of payment method has advantages and disadvantages based on the situation and economic conditions. Depending on the type of payment method, there may be additional charges associated with it. For example, payments made using credit cards incur fees in the form of processing charges while those that use cash do not have charges. As technology solutions proliferate across the world, there has been a trend away from cash payments. Agriculture places a heavy burden on the environment in the process of providing humanity with food and fiber, while climate is the primary determinant of agricultural productivity (Apata et al., 2009). Nevertheless, rural communities in Nigeria have always managed their resources and livelihood in the face of challenging environmental and socio-economic conditions (Mortimore and Adams 2001, Ole et al., 2009). By that, they largely have been able to develop their livelihood strategies in a way that enables them to constantly cope with and adapt to erratic cashless issues, fluctuation networks, pest attacks, and changing agricultural policies at local, national, global levels and other natural factors (BNRCC,2008, Molua 2008).

The cashless economy policy initiative of the Central Bank of Nigeria (CBN) is a move to improve the financial terrain but in the long run sustainability of the policy will be a function of endorsement and compliance by end-users (Ejiro, 2012). A Cash-based economy is one in which the daily payments and business activities are primarily transacted in physical notes and coins. A cashless economy, on the other hand, is an economy where the physical cash circulating in the economy is reduced while other forms of payment, especially electronic-based payments (Pont –of –sale, Mobile payment system, Internet banking, Multifunctional ATM, Electronic Funds Transfer) are used. The CBN cashless policy stipulated a daily cumulative limit of one hundred and fifty thousand and one million on free cash withdrawals and lodgments by individual and corporate customers respectively in the Lagos state with effect from March 30, 2012 (Omotunde et al. 2013). When determining which and how many options for different payment methods to offer your shoppers, it's important to strike the right balance. Offering options for multiple payment methods allows your customer base flexibility to use their preferred payment method or backup payment methods when interacting with your business. After all, not all payment methods work for every customer. However, if there are too many available payment methods on your checkout page, you may introduce unnecessary complexity to the checkout process.

Ido Local Government Area is densely populated with diverse agricultural activities. It houses several large farms and the Oyo State Farm settlements which are hot spots for plant and livestock production. With this increased agricultural production, the area is faced with several challenges such as theft, poor road network most especially in the rural areas, and cash payment receipt during the sales of agricultural products by farmers and marketers. With the limited information on the challenges faced by the cash payment system in the area, this study therefore investigates the mode of payments available, and constraints associated with these modes in the study area. This will provide the necessary information for smooth and easy cash transfer for payment of goods and services.

Materials and Methods

Ido Local Government Area is one of the 33 Local Government Areas in Ibadan, with its headquarters in Ido town, lies between latitudes $7^0$45 and $9^0$45 North of the equator and longitudes $2^0$30 and $9^0$45 East of Greenwich meridian. Also, have an area of 986 km^2 and a total population of

103,261 based on the 2006 National Population Census. Ido Local Government Area covers the area spanning Apata, Ijokodo, Omi-Adio, Akufo, and Apete. The areas enjoy abundant rainfall of over 1800mm annually and south-westerly wind blows most of the year. The area is blessed with fertile land which is suitable for animal rearing, vast forest reserves, and rivers. The major crops grown in the state include cassava, maize, yam, sorghum, cocoa, cocoa yam, melon, peppers soya bean, and okra, the major livestock reared in the state include cattle, sheep, goat, fish production, and poultry production.

Sampling Procedure and Sample Size

Multi-stage sampling procedures were used for the study.

- The first stage involved the purposive selection of wards that have market centers.
- The second stage involved the purposive selection of market centers for agricultural products in selected wards of the Ido Local Government Area which are the Omi-Adio market, Apata market, Apete market, and Ido market.
- The third stage involved the random selection of 20 Agricultural Products Marketers in each of the market centers selected which gives a total number of 80 respondents used as the sample size for the study.

Analysis of data

Data Collected was subjected to descriptive and inferential Statistical analysis with statistical tools including frequency counts, mean, percentage, and Pearson Product Moment Correlation (PPMC) analysis.

Results and Discussion

Socio-economic characteristics of respondents

The characteristics of the respondents are presented in Table 1. It revealed that 40.0% of the respondents were between the ages of 31-40years, 30% of the respondents were above 41-50years, 15% of the respondents were between 51-60years, and 10% of the respondents were between the ages of 20-30years. The observed mean age was 35 years which implied that the respondents in the study area were adults, and the age bracket is a productive age which portends a better future for agricultural products marketers also it is considered an economically active age this opinion is in line with Olowosegun *et al.,* 2014.

Most of the respondents were male (55%), while 45% of the respondents were female. The slight gap between both sexes implied that both males and females could engage in agricultural product marketing activities in the study area. This result is contrary to the assertion of Brummett *et al.,* (2010) who reported that agricultural activities are mostly dominated by men. It further reveals that the majority (80%) of the respondents were married, and 20% of the respondents were single. This implied that most of the respondents in the study area were married and thereby had responsibilities, and thus required a steady flow of income. It also shows that below average (45%) of the respondents had secondary education, 40% of the respondents had tertiary education, 10.0% of the respondents had no formal education and 5% of the respondents had primary education. The result showed that most of the respondents in the study area were educated. These findings were corroborated by reports of Adefalu *et al.,* (2013), Salau *et al.,*(2014), Olasunkanmi & Yusuf (2014), Okunlola *et al.,*(2011), and Ideba *et al.,*(2013) who reported that most of the agricultural products marketers are educated to tertiary education**.** Most of the respondents had a 5-8 household size (75%) while 20% of the respondents had a 1-4 household size. The mean household size is 6 which implies that most of the respondents in the study area had moderate households. Results revealed

that 40% of the respondent's sold maize and beans, while 5% of the respondents' sold yams and cassava flours, rice, and pepper in the study area. About 58.8% of the respondents have been involved in agricultural products marketing for 10 years, while the least of respondents (10%) have been involved for above 21-30 years, which implied that most of the respondents in the study area had lengthy years of involvement in agricultural products marketing. This result is in line with Williams *et al.,* (2012) that the success in the business of agricultural product marketing is not a function of the number of years in the business. Most of the respondents (55.0%) were members of agricultural associations in one way or the other, while only 43.8% of the respondents were not a member of any association. Most (45%) of the respondents had no contact with extension services, while only 55% of the respondents had contact with extension services. This implied that most of the respondents had access to information on innovation of different modes of payment. Onyenweaku et al. (2010) reported that extension services play a very crucial role in creating capacities to improve the overall performances of agricultural product marketers through new technologies.

Table 1. Socio-economic characteristics of respondents

Variables	Frequency	Percentage	Mean
Age			
20-30	8	10.0	
31-40	32	40.0	35.0
41-50	24	30.0	
51-60	12	15.0	
61 and above	4	5.0	
Sex			
Male	44	55.0	
Female	36	45.0	
Marital status			
Married	64	80.0	
Single	16	20.0	
Educational status			
No formal education	8	10.0	
Primary	4	5.0	
Secondary	36	45.0	
Tertiary	32	40.0	
Household size			
1-4	16	20.0	
5-8	60	75.0	
Above 8	4	5.0	
Agricultural Products selling			
Yam and Cassava tubers	24	30.0	
Maize and beans	32	40.0	
Garri	12	15.0	
Yam and Cassava flours	4	5.0	
Rice	4	5.0	
Pepper	4	5.0	
Years of Agricultural Products marketing experience			
0-10yrs	47	58.8	
11-20yrs	24	30.0	
21-30yrs	8	10.0	

Access to Extension services		
No	36	45.0
Yes	44	55.0
Annual Income (#)		
0-500000	28	35.0
501000-1000000	32	40.0
1010000-2000000	20	25.0

Mode of payment in the study area

The summary of payment mode is presented in Table 2. It revealed that most of the buyers pay using cash (100%), 90% use USSD Transfer, 85% use POS, 75% use credit/debit cards, and 70% use applications made available as different modes of payment in the study area. A larger part makes use of draft (90%) draft and not made available of draft and cheques (55%) as a mode of payment in the study area. This is in tandem with the report of Ezinwanne Onwuka (2023) who reported that the decision of CBN (Central Bank of Nigeria) also set the maximum cash withdrawal limit via the Automated Teller Machine (ATMs) and Point of Sale (POS).

Table 2: Various modes of payment available in the study area

Mode of Payments	Frequency (Available)	Percentag	Frequency (Not Available)	Percentage
Cash	80	100	0	0
Cheques	36	45.0	44	55.0
Credit Card/ Debit Card	60	75.0	20	25.0
POS	68	85.0	12	15.0
Through Application	56	70.0	24	30.0
USSD Transfer	72	90.0	8	10.0
Draft	8	10.0	72	90.0

Constraints on the Mode of Payment

The constraints faced by agricultural product marketers in the study area are presented in Table 3. It was observed that the majority (95%) reported Fluctuation in Electricity, 90% reported fluctuation of networks,75% reported high rate of bank charges, Inadequate government support/NGOs, Lack of technical know-how, (70%) Inadequate credit facilities, (60%) were high constraints and (60%) Information Hoarding among members were mild constraints while (60%) Poor governance resulting in corruption were not a constraints hindering agricultural products marketers to use different mode of payment in the study area. This is in line with Anyanwu (2015) who opined those new technologies encountered difficulty on their first introduction by the users.

Table 3: Constraints hindering Agricultural Products marketers from using the mode of payments in the study area.

Constraints	High Constraints	Mild Constraints	Not a Constraint
Fluctuation of Networks	72(90.0)	4(5.0)	4(5.0)
Fluctuation of Electricity	76(95.0)		4(5.0)
High rate of Bank Charge	72(90.0)	4(5.0)	4(5.0)
Inadequate government support/NGOs	60(75.0)	12(15.0)	8(10.0)
Lack of technical know-how	60(75.0)	12(15.0)	8(10.0)
Inadequate credit facilities	56(70.0)	12(15.0)	12(15.0)
Illiteracy	48(60.0)	28(35.0)	4(5.0)
Information Hoarding among members	24(30.0)	48(60.0)	8(10.0)
Poor governance resulting in corruption	24(30.0)	8(10.0)	48(60.0)

Conclusion and Recommendations

The study concluded that most of the respondents were mostly adults, male, married, partially educated, and had large household sizes. it was observed that fluctuations in electricity, fluctuations of network service providers, high rate of bank charges, inadequate government support/NGOs, lack of technical know-how, and inadequate credit facilities, were high constraints, and information hoarding among members was mild constraints. Poor governance resulting in corruption was not a constraint hindering agricultural product marketers from using different modes of payment in the study area. It is therefore recommended that the Agricultural Products Marketers Association in collaboration with the government should endeavor to subsidies some mode of payment which includes technologies to the marketers, and Agricultural products marketers should collaborate with extension agents to ensure effective training of fellow marketers for effective marketing of their products.

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EVALUATING THE ECONOMIC PRODUCTIVITY AND MARKETING OF MANGO FRUITS IN OGBOMOSHO NORTH LOCAL GOVERNMENT AREA, OYO STATE, NIGERIA

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Abstract

This study assessed mango fruit marketing and profitability in Ogbomosho North Local Government Area of Oyo State, Nigeria. A three-stage sampling method was used to collect data for this study. Descriptive statistics such as frequency distribution and percentages and the profitability index of mango fruit marketing were captured using the Gross Margin analysis. In contrast, ordinary least square regression was used to determine the factors influencing the profitability of mango fruit marketing in the study area. The study concluded that the marketing of mango fruit is profitable that the business is efficient, and that purchasing prices, transportation and off-loading costs significantly influenced mango fruit marketing in the study area. Owing to these findings, the study thus recommended that the government and the existing roads should provide adequate transportation should be refurbished to minimize transportation costs, there is a need for the policymakers to make policies that would tinker with price fluctuations, among others.

Keywords: Mango, Fruits, Marketing, Socio-economic, Profitability

Introduction

One of the major problems facing farmers/marketers in the developing world is the lack of storage and processing facilities for the perishable and seasonal agricultural commodities (Farayola *et al*., 2013). Mango fruits, when harvested early or stored without drying correctly, could cause low-quality fruits and lead to poor pricing when taken to the market. Lack of knowledge on the marketing of some crops and their products partly leads to the inherent poor agricultural commodity markets in Nigeria (Onyenobi *et al.*, 2009; Adejo *et al.*, 2011). The problems of mango production include old trees, deforestation, lack of storage facility, low yield varieties and wild varieties, land acquisition, high cost of inputs, climatic conditions, diseases and pests, fire outbreaks, post-harvest losses, infrastructural constraints, poor qualities, market price of the product and the competition amongst the local buying agents (Olife *et al,* 2013). The inability of farmers to afford the application of inorganic fertilizers, coupled with its adverse effects on the environment, is also a problem facing mango production (Akanbi *et al.*, 2013).

Furthermore, according to Olateju (2023), Mango (*Mangifera indica*) is a tasty, juicy bean-shaped stone (drupe) belonging to the genus Mangifera, consisting of numerous tropical fruiting trees. It usually has a yellow, green or some yellow-green edible flesh around the stone. Mangoes belong to the flowering plant family Anacardiacea. To the Indians and many other nationals, mango is the king of fruits. Mangoes can be cut up or eaten by hand. Specifically, Ogbomoso mangoes usually have bright yellow skin with orange and red blush or purely Yellow with an Oblong shape. One thing about mangoes is that they are not just sweet but have impressive fruitritional values, just like other varieties of mangoes. These nutritional values motivate you to leap at the availability of mangoes in

your immediate environment. Riding on this crest, this study thus assessed the socio-economic factors that affect mango fruit marketing in Ogbomosho North Local Government Area of Oyo state.

Materials and Method

Study Area

This study was carried out in Ogbomoso, Oyo State. It is one of the largest towns in Oyo State, with an urban population of about 861,300. Ogbomoso comprises five Local Government Areas (LGAs): Ogbomoso North, Ogbomoso South, Ogo-oluwa, Oriire, and Surulere. The town lies between latitude 800 29' North of the equator and 40030' North of the Greenwich Meridian. Ogbomoso has a landmass area covering about 37,984 square kilometers and is is located in the Northern part of Oyo State. The vegetation of Ogbomosho is dominated by derived savannah vegetation, and it is a commercial centre situated in an agricultural region producing mango fruits (Adewuyi *et al.*, 2018).

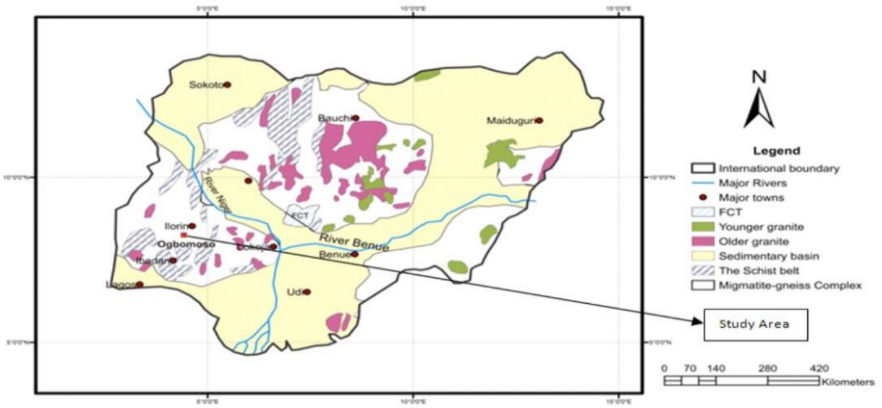

Fig. 1: Geological map of Nigeria showing the study area (Ajibade *et al.*, 1988)

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Figure 2: Ogbomoso Mango Fruits Sample

"Ogbomoso mango" is undoubtedly one of the prominent mangoes in the country as a result of the beautiful species they constitute. The significance of these natural resources to the people of Ogbomoso City cannot be overemphasized. Ogbomoso is a warm, moist and typically tropical climate with rainfall ranging between 600 mm-4500 mm per annual, an atmospheric condition most favourable to the germination of Mango fruits. The taste of Ogbomoso mango is one of a kind because it cannot be compared to others from other parts of the country.

Sampling Procedure and Sample Size

A three-stage sampling method was used. Firstly, Ogbomosho North Local Government Area (LGA) was purposively selected due to the high proportion of mango fruits marketers within the local government while four wards (Masifa/AguodoIsale-Afon, Okelerin, Asale-ora) out of the 10 wards that make up to Ogbomosho North Local Government were randomly selected. Lastly, 25 mango fruit marketers were randomly chosen in each of the earlier selected LGAs. In total, 100 mango fruit marketers were interviewed with structured questionnaires.

Data Analysis

Descriptive statistics such as frequency distribution and percentages were used to present the utilization pattern of mango fruit marketing. Also, cost and return associated with mango fruit marketing were captured using the gross margin and profitability (Π) analysis. The ordinary least square regression was further employed to determine the factors influencing the profitability of mango fruit marketing in the study area.

Results and Discussion

Table 1: Gross Margin Analysis of Mango Fruits

Total Revenue	TR	₦384,253.00
Total Variable	TVC	₦80,543.00
Total Cost	TC = TVC + TFC	₦331, 654.00
Fixed Cost	FC	₦323, 599.00
Gross Income (GI) or	Π = TR – TC	₦52, 599.00
Gross Margin GM %	GI ÷ TR × 100	13.6%
Gross Margin	PI= Π ÷ TR× 100	13.6%
Rate of Return Investment (RRI)	RRI= Π ÷TC× 100	13.85

Source: Field survey, 2021.

As shown above, the budgetary analysis indicates that the average total revenue of the entire sampled marketers in the study area would realize total revenue of ₦384, 253. 00 per month. The total variable and fixed costs were ₦8, 0543.00 and ₦323,599.00, respectively. The Gross income was ₦52,599.00, which means that the mango fruit marketers have the potential of returning ₦52,599.00 profit of the total investment worth to the households monthly. Then, the profitability index 13.6 implies that for every ₦1 spent by the mango fruit entrepreneurs in the study area on their respective businesses, 36 kobo was realized as profit on the aggregate. In sum, mango fruit businesses are profitable ventures with higher market efficiency in the study area.

Table 2: Pricing System of Mango Fruit Marketing.

Measurement	**Frequency (No 90)**	**Percentage (%)**
Jute bag	53	58.8
Bowl	20	22.3
Both jute bag and bowl	17	18.9

Source: Field survey, 2021.

According to the results, about 58.8% of the mango fruit marketers sold in jute bags measurement, while 22.3% sold their products in bowls and 18.9% used jute bag and bowl measurement to sell their mango fruit (i.e., wholesale). This means that the activities of the marketers are concentrated in the jute bag rather than a bowl. Note that a jute bag of mango fruit comprises 15 bowls worth of measurement while a bowl costs ₦2,700, which varies partially in price among marketers. In terms of weight size, a jute bag is about 80kg, which costs between ₦40,000 and ₦42,000 through wholesale marketers.

Table 3: Factors Influencing Mango Fruit Marketing

Variable	Beta	Std error	T-value	Significant
(Constant)	123271.033	416168.060	0.296	0.768
Age	16456.661	83804.385	0.196	0.845
Purchasing price	932***	0. 048	19.299	0. 000
Labour cost	-410	8.110	-051	0.960
Transportation	5.193***	1.557	3.335	0.001
Association levy	1.870	2.221	0.842	0.402
Off-loading cost	12.926**	6.585	-1.963	0.053
Handling cost	12.981**	5.220	-2.487	-0.015
Shop rent	2.064	1.539	-1.341	0.184
Amount sold/kg	432.460 ***	23.220	18.625	0.000
R^2	0.86			

Source: Field survey, 2021
*** ** significant at 1% and 5% respectively

R^2 was 0.86, indicating an 86% level of variation in the marketers specified, where the error term could explain the 14%. The transportation cost, purchasing price, and off-loading cost were the significant factors that significantly influenced mango fruit marketing in the study area. An increase in purchasing power of the marketers would increase their turnover and, subsequently their profit, provided that other costs of operation do not outweigh the turnover effect. Note that as transportation and off-loading costs rise, there is a tendency for the profitability index of the mango fruit sellers to decrease. Nigeria.

Conclusion and Recommendations

The study concluded that the marketing of mango fruit is profitable and that the business is efficient. The result further showed that price fluctuation is the significant challenge faced in the mango fruit business in the study area. Also, occasionally, scarcity of mango fruits is a challenge faced in the mango fruit business in the study area. Further, it was revealed that purchasing prices, transportation and off-loading costs significantly influenced mango fruit marketing in the study area. Owing to these findings, the study thus recommended that more attention should be given to mango production and marketing. At the same time, the government and the existing roads should also provide adequate transportation should be refurbished to minimize transportation costs. There is a need for the policy makers to make policies that would tinker on price fluctuations, among others.

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SUB-THEME:

POTENTIALS OF PROTECTED AREAS IN NIGERIA'S EMERGING BIOECONOMY

Food preferences and foraging ecology of the Bronze Mannikin (*Spermestes cumulate*s) Ilaro, Ogun State, Nigeria.

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Abstracts

The study was conducted in Ilaro, Ogun State, Nigeria, in 2023, aiming to understand the food preferences and feeding behaviors of the *Spermestes cucullatus*, commonly known as the Bronze Mannikin, to support sustainable tourism initiatives. This investigation spanned 12 months and focused on 20 pairs of Bronze Mannikins, ranging in size from one to ten, observed across three distinct areas: residential zones, farmland, and fallowland. Data collection utilized the Direct Observation method, with researchers employing Bushnell 750 binoculars from dawn to dusk to minimize bird disturbance during feeding activities. Throughout the study period, detailed records were maintained regarding foraging locations, feeding techniques, feeding duration, bird population density, types of food consumed, and interactions with other avian species. The result revealed that the Bronze Mannikin's diet predominantly comprised plant-based resources, accounting for 70% of their intake, while insects constituted 27%, and the remaining 3% consisted of leaves and flowers. Among plant-based foods, *Panicum maximum* seeds were the most consumed at 14.5%, followed by *Lawsonia inermis* fruits at 10.7% and *Ficus thonningii* seeds at 8.6%. Regarding the insects, Macrotermes bellicosus exhibited the highest observation frequency at 16.2%, trailed by *Parasyscia sudanensis* at 13%. Examination of habitat utilization patterns indicated that residential areas constituted 55% of the Black and White Mannikin's habitat, while farmland and fallow areas collectively represented 25%. These findings offer insights into the dietary preferences and habitat usage tendencies of the Black and White Mannikin within the study area, thereby providing valuable information for developing strategies aimed at sustainable tourism management.

Keywords: Diet, foraging ecology, habitat, utilization, sustainable tourism

Introduction

The *Spermestes cucullatus*, also known as the Bronze Munia or Bronze Finch, is a small songbird indigenous to sub-Saharan Africa, including Nigeria. This species thrives in diverse open environments throughout the region, including grasslands, savannas, and wooded areas such as forest edges, gallery forests, and acacia woodlands (Aerts *et al.*, 2019). They are frequently observed near rivers, streams, or marshes. Bronze Mannikins demonstrate adaptability to human-modified landscapes, commonly found in gardens, parks, farmlands, and even urban areas with appropriate vegetation (Chen, 2019). While the overall conservation status of the Bronze Mannikin is categorized as least concern by the International Union for Conservation of Nature (IUCN), specific populations and regions face distinct threats and conservation challenges. Among the primary threats are deforestation, conversion of land for agriculture, and urban expansion, which result in habitat fragmentation and degradation as human populations grow (Birdlife International, 2016).

Moreover, Bronze Mannikins are vulnerable to capture for the pet trade, particularly in areas where they are prized as cage birds (Birdlife International, 2016). Unregulated trapping can lead to declines

in local populations. Competition and predation from non-native birds and mammals, especially in areas where they have been introduced, pose significant risks to bird populations (Clement *et al.*, 1993). Changes in climate patterns, such as alterations in rainfall and temperature, can affect the availability of suitable habitat and food resources for the Bronze Mannikin. Furthermore, agricultural pesticides and pollutants from urban runoff can contaminate water sources and food supplies, potentially jeopardizing the health and reproductive success of Bronze Mannikins (Gill *et al.*, 2024). Understanding birds' dietary preferences and feeding ecology is crucial for conservation endeavors and ecosystem management, as it offers insights into their ecological roles, habitat needs, and susceptibilities to environmental changes, thereby facilitating the promotion of sustainable tourism.

Materials and method

Study area

Ilaro is located within the Yewa South Local Government Area of Ogun State, Nigeria, at coordinates 6.8894° N, 3.0471° E. The rainy season typically spans from March to November in the region, with December through February marking its conclusion, receiving an average annual rainfall ranging between 1700 to 2000 mm (Mengistu and Salami, 2007). The mean yearly temperature in the area averages 26°C. The soil composition in the heavily worn basement complex formation zones within the rainforest zone of southwest Nigeria predominantly consists of ferruginous tropical soils, a prevalent type in the region. The soils are old, well-drained, red, stony, and flinty at higher elevations. Sandy loam is the prevailing texture of the topsoil in the area. The native vegetation of the region comprises a tropical rainforest with emergent growth, numerous canopies, and lianas (Isichei, 1995). Commonly observed tree species include *Milicia excelsa*, *Afzelia bipindensis*, *Brachystegia Nigeria*, *Lovoa trichilioides*, *Terminalia ivorensis*, *Terminalalia superba*, and *Triplochiton cleroxylon* (Keay, 2005). However, except for designated farming areas, the natural vegetation has vastly been reduced to grassland and secondary regrowth forest thickets (Manu, 2007).

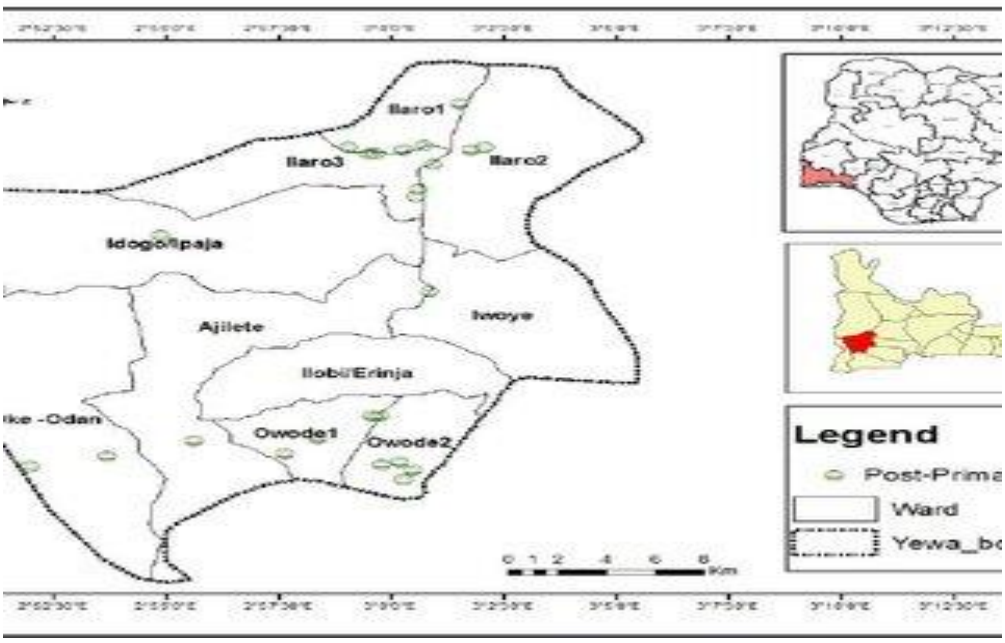

Figure 1: Map of the study area

Data Collection

For this investigation, the study area was segmented into three sections: the residential block, the forest/farmland block, and the nonresidential block. The investigation was done because of the Bronze Mannikin's ability to thrive in degraded and human-dominated landscapes. Over a continuous 12-month period from January to December 2023, data concerning the diet and feeding behavior of 20 pairs of Northern Grey Headed Sparrows, each consisting of one to three individuals, were compiled. The Direct Observation technique described by Okosodo *et al.,* (2016) was employed for this study. Field observations were conducted from dawn until dusk utilizing binoculars (specifically Bushnell 750) to observe the birds' feeding activities with minimal disruption. Each pair of sparrows was observed for a duration ranging from a few hours to up to five hours during each visit. While keeping several birds within sight simultaneously was typically feasible, observing the entire flock concurrently was seldom achievable. During each observation, data regarding the foraging location, feeding method, duration of feeding activity, number of birds present, types of diets consumed, and any interactions with other bird species were recorded. Additionally, seasonal variations in the birds' dietary patterns were examined. Due to the size of the trees and the height of the nests above the ground, further investigation into the birds' pellets was not feasible.

Data Analysis

The data gathered from the observations were analyzed using descriptive statistics. The diversity index of tree species in the study area was analyzed using the PAST Model version 3 computer software.

Results

Although the Bronze Mannikin primarily consumes grains, it also incorporates fruits, leaves, flowers, and insects. The findings reveal that 70% of the Bronze Mannikin's diet is sourced from plant resources, while 27% comes from insects and 3% from leaves and flowers (Figure 2). Among the plant-based foods, *Panicum Maximum* seeds are the most heavily consumed at 14.5%, followed by *Lawsonia inermis* fruits at 10.7% and Ficus Thonningii seeds at 8.6% (Table 1). Regarding insects, *Macrotermes bellicosus* exhibits the highest frequency of observations at 16.2%, followed by *Parasyscia sudanensis* at 13% (Table 2).

The assessment of habitat utilization indicates that the residential block constitutes 55%, while farmland and fallow areas comprise 25% (Figure 3). The family composition of the plant species utilized by the Bronze Mannikin shows that Poaceae is the most predominant, with 14 species, followed by Apocynaceae, with three species (Figure 4). Similarly, regarding insects, the family composition reveals that Formicidae is represented by three species (Figure 5).

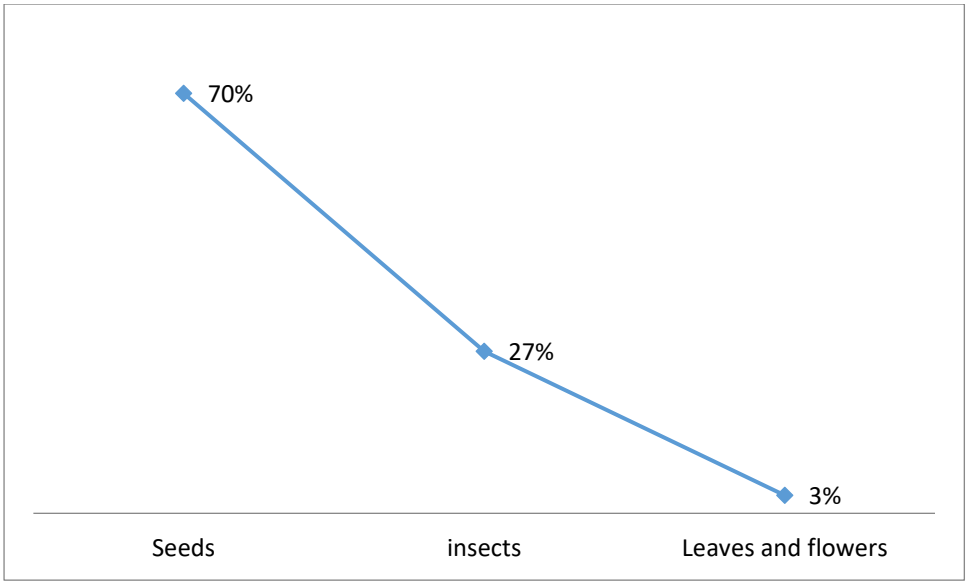

Figure 2 The rate of diet consumption by the bird species within the study area.

Table 1 Checklist of plant species consumed by Bronze Manikin in the study area

Name of plant species	Family	Parts used	Observations%
Amaranthus retroflexus	Amaranthaceae	Seeds	1.1
Andropogon gayanus	Poaceae	Seeds	0.06
Andropogon tectorum	Poaceae	Seeds	0.07
Aspilia africana	Asteraceae	Seeds	3.1
Bambusa vulgaris	Poaceae	Seeds	2.2
Boerhavia diffusa	Nyctaginaceae	Seeds	4.3
Carica papaya	Caricaceae	Fruit and seeds	6.8
Chromolaena odorata	Asteraceae	flowers and seeds	2.2
Cymbopogon citratus	Poaceae	Seeds	5.1
Cynodon plectostachyus	Poaceae	Seeds	2.8
Cyperus rotundus	Poaceae	Seeds	1.4
Diallum guineense	Fabaceae	Fruits	1.1
Duranta repens	Verbenaceae	Fruits	6.7
Ficus Thonningii	Moraceae	Seeds	8.6
Hyparrhenia rufa	Poaceae	Seeds	2.9
Hyptis spicigera	Lamiaceae	Seeds	1.1
Lawsonia inermis	Lythraceae	Fruits	10.7
Loudetia orundinacea	Poaceae	Seeds	0.07
Moringa oleifera	Moringaceae	Flowers and leaves	1.02
Nauclea latifolia	Rubiaceae	Seeds	4.4
Olea europaea	Oleaceae	Fruits	3.3

Ocimum gratissimum	Lamiaceae	Seeds	1.4
Oryza sativa	Poaceae	Seeds	9.3
Panicum maximum	Poaceae	Seeds	14.5
Pennisetum polystachion	Poaceae	Seeds	0.04
Psidium guajava	Myrtaceae	Seeds	0.05
Rauvolfia vomitoria	Apocynaceae	Fruits	0.03
Senna alata	Fabaceae	Seeds	0.06
Setaria barbata	Poaceae	Seeds	0.02
Solanlum nigrum	Solanaceae	Seeds	0.06
Sporobolus pyramidalis	Poaceae	Seeds	0.08
Trama orientalis	Cannabaceae	seeds	0.03
Tridax procumbens	Asteraceae	Flowers	2.1
Zea mays	Poaceae	Seeds	3.4

Table 2 Checklist of insect species consumed by Bronze Mannikin in the study area

Name of insect species	Family	Observation%
Parasyscia sudanensis	Formicidae	13.7
Zasphinctus rufiventris	Formicidae	2.1
Simopone conradti	Formicidae	7.2
Parasyscia cribrinodis	Formicidae	3.7
Dorylus savage	Formicidae	9.4
Dorylus nigricans	Formicidae	3.2
Dorylus braunsi	Formicidae	8.4
Dorylus depili	Formicidae	1.1
Aenictus vagans	Formicidae	2.1
Dorylus affinis	Formicidae	4.2
Technomyrmex Andrei	Formicidae	2.2
Lebistina subcruciata	Chrysomelidae	7.8
Diphasiastrum alpinum	Chrysomelidae	2.9
Macrotermes bellicosus	Termitidae	16.2
M. subhyalinus	Termitidae	4.7
Odontotermes sudanensis	Termitidae	11.1

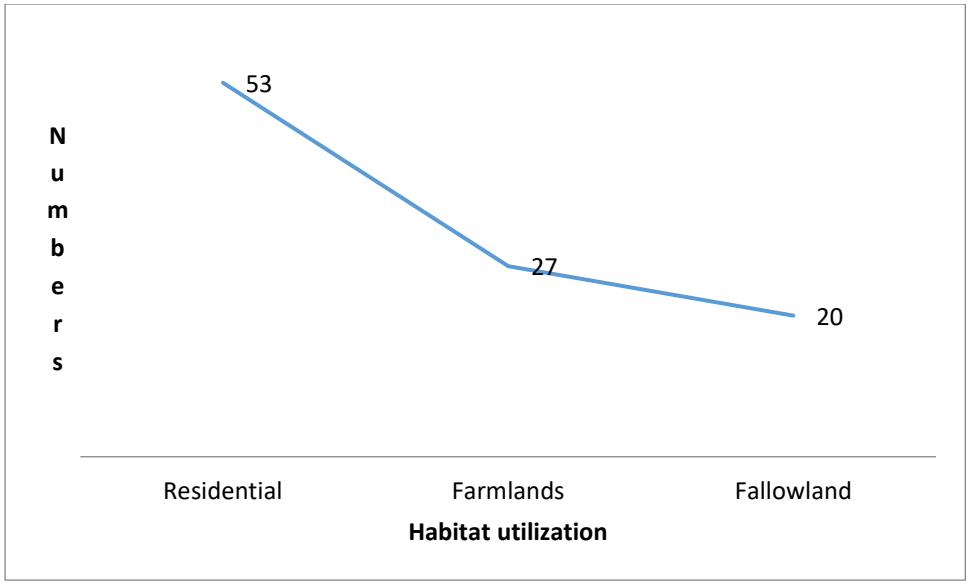

Figure 3. The utilization of habitats by *Spermestes bicolor* within the study area.

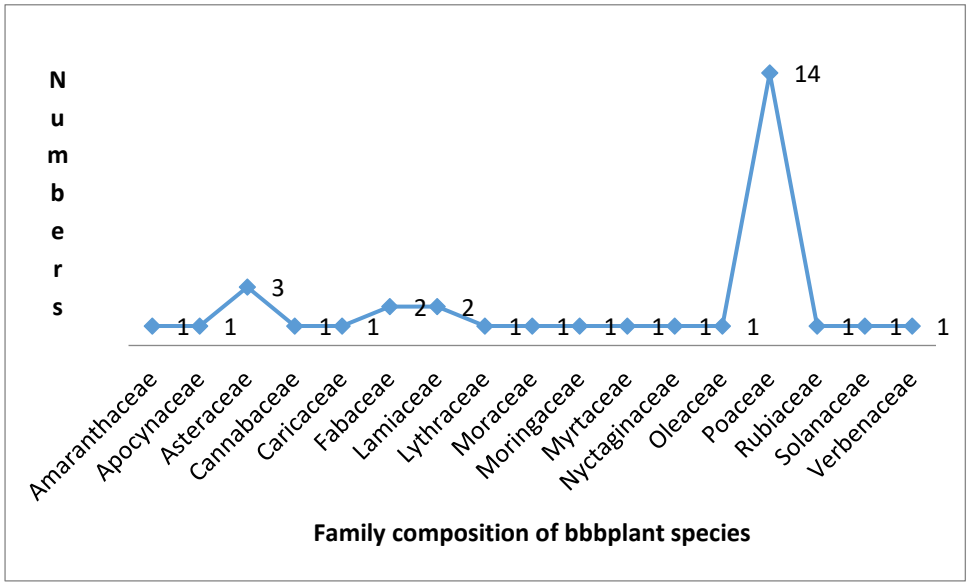

Figure 4. The family composition of tree species fed upon in the study area

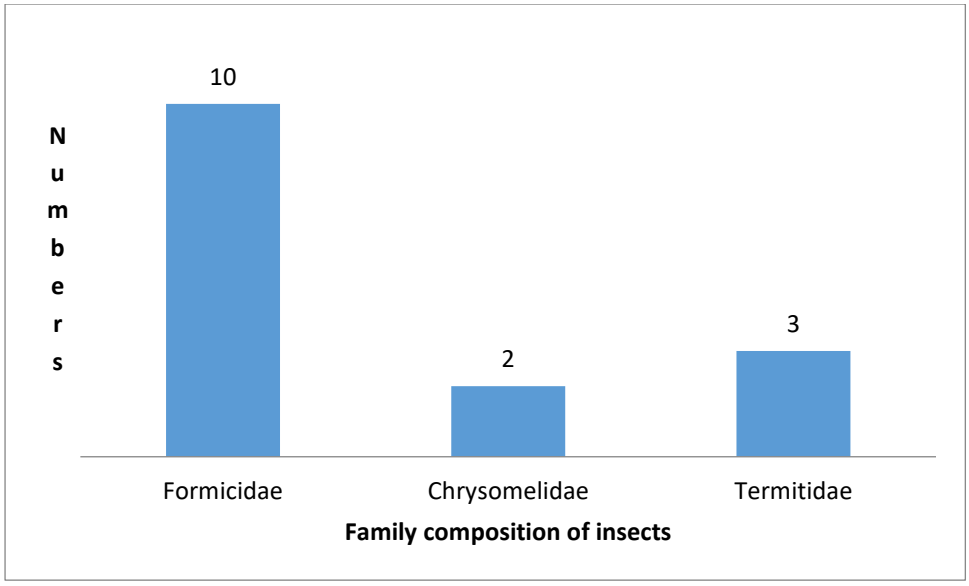

Figure 5. Family composition of insects utilized by the bird species in the study area

Discussion

The Bronze Mannikin (*Spermestes cucullatus*) primarily subsists on seeds, indicating a granivorous diet. However, they also partake in insects, fruits, leaves, and flowers. Their foraging behavior spans ground, shrub, and tree habitats, and they are even observed frequenting bird feeders for seeds and suet. During the breeding season, they supplement their offspring's diet with insects, including leaf beetles and termites. Various researchers support this dietary pattern. For instance, Marques *et al.*, (2003) documented Turdus pelios, a related species, consuming insects, blank ants, and fruits of Azadirachta indica in South Africa.

Similarly, Sagrario *et al.*. (2007) found that insects constituted the primary portion of Turdus pelios' diet. Orthoptera, Coleoptera, and Isoptera were the most numerically significant, comprising almost two-thirds of the insects consumed. They are known for consuming diverse seeds sourced from grasses, weeds, and various plants. Additionally, they may occasionally consume insects during the breeding season when their dietary needs shift to accommodate more protein for egg production and nurturing their offspring. The researcher observed that these bird species primarily feed on the ground within residential areas and the middle layer of trees in forest and farmland blocks. This observation aligns with the findings of Yusufu et al. (2004), who noted that during the breeding season, the northern green-headed sparrow can often be observed foraging on the ground or in low vegetation. They employ a "hop and scratch" technique to uncover seeds and insects from the leaf litter or grass. In the non-breeding season, they may form mixed-species flocks and search trees and shrubs for seeds. Like many bird species, the feeding behavior of the northern grey-headed sparrow can vary depending on several factors, including the season, weather conditions, and food availability.

Nonetheless, typically, sparrows exhibit peak activity and feed most actively during the morning and late afternoon or early evening hours. During the breeding season, *Spermestes cucullatus* often commence foraging shortly after sunrise to gather sufficient food for themselves and their offspring throughout the day. They may take breaks from feeding during the hottest part of the day and resume activity in the late afternoon. Northern grey-headed sparrows are predominantly granivorous, indicating that seeds constitute most of their diet. However, like numerous bird species, they may occasionally consume other plant materials such as flowers and leaves. There are several reasons why a *Spermestes cucullatus* might opt to consume flowers and leaves. One potential explanation is

their search for additional nutrients or minerals that may be lacking in their predominant seed-based diet. Specific flowers and leaves contain many vitamins, minerals, and other micronutrients essential for avian health. Another rationale is that Bronze Mannikin could be turning to flowers and leaves to supplement their diet during periods of seed scarcity, such as the winter months when food sources may be more limited. This dietary supplementation could aid in their survival during lean times.

Moreover, some manikins might derive pleasure from the taste of flowers and leaves and consume them solely for that reason. Nonetheless, it's crucial to recognize that while flowers and leaves offer some nutritional advantages, they shouldn't constitute a substantial portion of a northern grey-headed sparrow's diet, as highlighted by Marshall *et al.,* (2016) and McWilliams and Karasov (2014). In a study of house sparrows in Italy, Borgoni and Gambeloni (2011) observed mannikins consuming various plant materials, including flowers and leaves, across different seasons. This behavior appears to be influenced by the availability of seeds and other primary food sources in the surrounding environment.

Conclusion and Recommendations

The research demonstrates that *Spermestes cucullatus* feeds on various food sources, including grain seeds, fruits, leaves, flowers, and insects within the study area. Regarding habitat usage, the bird species predominantly utilize residential blocks over other regions. It was also noted that they forage on the ground and the upper shrub and middle-layer trees. Despite being categorized as a minor concern in conservation status, the fact that they utilize degraded forest ecosystems and urbanized residential areas underscores their importance for sustainable development. Preserving habitats and ecosystems that sustain diverse bird populations is crucial for biodiversity conservation. Sustainable tourism plays a significant role in this conservation effort by encouraging the preservation of habitats. Tourists participating in birdwatching or bird-focused activities often contribute to habitat conservation by supporting eco-tourism initiatives prioritizing conservation efforts. Avitourism and bird-related tourism can incentivize local communities to conserve natural habitats. This can include revenue generated from birdwatching tours, sales of birding equipment, and services such as accommodation and dining for birdwatchers. Sustainable tourism simultaneously supports local economies and conserves bird habitats by promoting activities that attract birdwatchers.

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Possible Funding Sources for the Development of Private Forest Plantations in Nigeria

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ABSTRACT

The international community has been actively mobilizing financial resources for several years to support sustainable forest management (SFM) techniques. Many nations are investigating more sustainable forest management techniques due to growing market globalization, environmental consciousness, and attention from international treaties and accords. Since 1995/1996, Nigeria's primary sources of funding—government grants, focused private sector investments, support from foreign donors, and in-kind donations from rural communities have all decreased. According to studies, government-managed forests in Nigeria are constantly depleting, and public funding for forest projects and activities has been inadequate and untimely at both the federal and state levels. However, numerous innovative financing mechanisms are being created and tested in various countries. They include a wide range of programs, including conservation concessions, debt-for-nature swaps, payments for environmental services, "green funds" (payments for carbon offsets), compensatory payments, and clean development mechanisms, to name a few. Some of these creative finance mechanisms are uncommon or limited in Nigeria and show that Nigeria's government-managed forests are continuously disappearing, and both at the federal and state levels, public financing for forest projects and activities has been insufficient and delayed. Still, many creative funding methods are being developed and experimented with throughout multiple nations. Concessions on conservation, debt-for-nature swaps, payments for environmental services, "green funds" (accounts for carbon offsets), compensating payments, and clean development methods are only a few of the many programs they encompass. In Nigeria, several of these innovative financing techniques are rare or restricted.

The financing strategy tackles the quantitative shortage by more precisely targeting conventional forest financing flows and channeling additional private sector resources through innovative financing mechanisms. These initiatives, however, are acknowledged as being dependent on institutional reforms required both to establish a 'conducive or enabling environment' for private sector investment and, more importantly, to allow the transition from unsustainable short-term forestry to SFM. Thus, financing private forest plantations can increase wood supply, reduce strain on natural forests, and ensure sustainable forest development. This paper explores innovative financing instruments for private plantation development to offer a strategy to create a favorable environment for these financing mechanisms in Nigeria.

Key Words: Sustainability, financing, private owners, plantations

INTRODUCTION

The rapid decrease of tropical forests has been on the global agenda for several decades, as seen by the growing number of international conventions and initiatives addressing forests, the environment, and sustainable development (IISD 2001). According to Fasoro and Ajewole (2019), the fast-increasing demand for forest and non-forest goods for industries, companies, and other activities is

one of the significant factors contributing to the loss of forest cover in Africa's natural forests. Nigeria's natural forests have been overexploited without proper conservation, and the depletion is due to urbanization, industrialization, and, most importantly, human population expansion. This decline, combined with a better awareness of the negative impact of forest destruction on climate change, has piqued the interest and concern of people, policymakers, and politicians worldwide for forests and forest-related issues. Most notably, improved forest management.

While a step forward, this interest is not accompanied by significant action. Considering what is in Nigeria's National Forest Policy, some of the country's forest policies exist primarily on paper, with few technical techniques or measures being applied (Fasoro, 2018). Another critical barrier appears to be a lack of financing for implementing sustainable practices. Governments have traditionally provided the majority of financial resources for forestry investments. My experience with public finance has been negative regarding service quality, coverage, and cost. Sustainable forest management should be self-sufficient by selling forest goods and services. However, this is not the situation in Nigeria's forests. This is not to argue that timber logging revenues are insufficient; nonetheless, mismanagement, wanton squandering, embezzlement, or misappropriation of forest funds by government officials contribute to decreased forest resources. Also, the Nigerian Government does not feel compelled to invest more in forest management. Furthermore, as profits from timber harvesting diminish, forests are more likely to be converted to other land uses, particularly agriculture. Fundamentally, government-managed forests cannot guarantee sustainable productivity.

As government funding dried up, governments faced tighter fiscal limitations, and official development assistance (ODA) struggled to keep up with rising requirements. The Collaborative Partnership on Forests (2018) revealed a significant gap between the US$70-160 billion that SFM requires each year and official development aid to forestry, which only accounts for roughly 1% of the estimated overall finance demand. As a result, the Government and forest community acknowledge that the private sector has a role in financing sustainable forest management. Governments are driven to seek domestic and international private capital through debt and equity participation from the private sector. At the same time, the financial markets evolved in favorable directions by inventing new and innovative financing structures that enabled the exploitation of new funding sources, such as insurance and pension funds, and a range of other institutional investors (Panayotou, 2002). The emergence of new types of credit guarantees, the availability of instruments to finance private and municipal projects without sovereign guarantees, and the proliferation of new modalities for private-public sector partnerships and joint ownership have created resource mobilization and risk-sharing opportunities unavailable to most developing countries a decade ago. At the same time, institutional reforms in developing countries, such as decentralization of Government and devolution of taxation authority to local governments and municipalities, created the opportunity for sub-national entities to access the global capital market without the need for sovereign guarantees from the central Government (for example, through the issuing of municipal bonds or the floating of shares of municipal utilities on domestic and international stock markets).

Despite the private sector's importance to forests, data on private forest finance is limited and insufficient. Data on private forest financing is not systematically documented in global or regional databases, and its quality is inconsistent. However, current data indicates that forest investment is unevenly distributed between regions and countries.

OVERVIEW OF FOREST FINANCING SOURCES

Collaborative Partnership on Forests (2018) reported that the total private sector plantation investments in developing countries were estimated at US$1,763 million in 2011 (excluding REDD).

Latin America accounts for most of the annual investments, with US$1,464 million or 83% of the global total. Investments in Asia and Oceania are estimated at US$279 million or 16% of the worldwide total. In comparison, private investments in plantation forests in Africa are estimated at US$20 million, or just 1% of total value. Although Latin America draws the most private forest investment, it is unevenly allocated—Brazil accounts for more than 80% of the regional total. From these figures, it is evident that Africa has yet to fully benefit from this investment, considering the land availability and potential it has in increasing the area of forest plantations.

Public funding is critical in addressing every sector's development and finance needs. Like other development sectors, forestry in Nigeria is funded through the regular annual budgetary allocations by the various tiers of Government. FAO (2001) stated that the domestic public financing mechanism is mainly used for financing operations for public forest administrations/institutions, conservation and management of protected areas, forest research, education and administration, and policy reform and institutional development. This shows that the National Government has little or no consideration for financing private investors involved in forest plantation development.

One other primary source of public finance is international or foreign public funding in the form of official development assistance (ODA), and this can be bilateral (grants and concessional loans) or multilateral (GEF, ITTO, FAO, World Bank, etc.). These international funding agencies funded many projects and programs in Nigeria in the 1980s when the precarious financial situation hampered forestry development. However, FAO (2001) observed that after the end of the foreign economic assistance, including the World Bank and AfDB, the forestry sector in Nigeria became largely dependent on government budgetary allocations, which has been inadequate and untimely.

To guarantee sustainable forests, the Federal Department of Forestry (FDF), through the National Forestry Development Committee (NFDC), convinced the Federal Government to issue a directive to State Forestry Departments (SFDs) to create the Forestry Trust Fund (FTF), where a percentage of royalties collected is deposited. This was done to create a situation whereby part of the revenue generated from the forests is plowed back for forestry development. FTF was expected to act to ensure re-investment in the forest resource base, especially in forest regeneration. The directive was issued in 1993. However, FAO (2003) reported that only six states complied. FDF (2000) and FAO (Ibid) stated that some states with FTF have not judiciously utilized the funds. The revenues accruing into such funds are never retained and plowed back into the forestry sector for forestry development as initially intended. The study further reported that in most cases, state governments utilized these funds for other purposes, such as payment of salaries in the public sector generally and other non-forestry-related development projects.

FAO (Ibid) also stated that the Ecological Fund (E.F.) was also established in 1981 by the Federal Government to address the growing inability of conventional funding sources to solve pressing ecological problems. The fund attracted 1% of the country's total revenue at inception, but this figure was raised to 2% in 1992. The National Committee manages the funds for ecological problems. It can be applied to solve issues like a) soil, coastal erosion, and flood control, b) desertification and drought control, c) oil spillage and pollution, and d) general environmental pollution {solid waste management, industrial pollution, water hyacinth infestation} e) relief to victims of natural disasters. The forestry sector benefited indirectly from the allocations. The study further revealed that the forestry sector benefited indirectly from the allocations to (a) and (b).

Great expectations have also been put on developing payments for environmental services (PESs) as a potential source of revenue and funding for sustainable forest management. The PES schemes of global public goods from forests (climate change mitigation and biodiversity) have been seen as the most promising way to raise additional financial flows to sustainable forest management in

developing countries. Carbon trading was supposed to offer opportunities for indigenous companies, particularly private investors. There are two main kinds of carbon markets: clean development mechanism (CDM) and reducing emissions from deforestation and degradation (REDD+).

However, the extent to which they have been successfully adopted and applied is minimal. In Nigeria, the U.N.- REDD Programme Steering Committee was established in 2013 and is leading the REDD+ strategy in the country. Its implementation time frame is supposed to span until 2017. However, only 42% of the USD 4 million received from UNDP, UNEP, and FAO for developing the strategy and a pilot project in Cross River State has been disbursed. UNEP is currently carrying out a REDD research project in about three hundred (300) sites contaminated by oil spills in Ogoni land in Nigeria (Minang *et al.*, 2014). Also, due to mistrust of citizens of their leaders, some local NGOs and communities are against Nigeria's participation in REDD, fearing that REDD+ could become a vehicle for corporate land grabs, that Nigeria's forest-dependent poor may be forcefully evicted from their land and denied access to the forests.

Gondo (Ibid) stated that a debt-for-nature swap is another mechanism that provides bilateral resources following negotiations and approval by the respective governments (debtor and creditor). The resources created by a debt swap provide compensation for environmental services (correction of the negative externalities generated by the payment of debt servicing on the environment) and have beneficial effects on biodiversity protection, especially regarding protected areas. The study further affirmed that these expectations have not materialized in most African countries for several reasons, chief among them being the lack of capacity and markets.

Furthermore, Credit Schemes provided by the National Government are another vital source of financing for the forestry sector. Regrettably, despite the importance of funds for timber and non-timber production, the National Government and Central Bank of Nigeria excluded the forestry sector from most of the Credit Schemes provided. Central Bank established the Commercial Agriculture Credit Scheme (CACS), and this fund complemented other special initiatives such as the Agricultural Credit Guarantee Scheme (ACGS), which is mainly for small-scale farmers, the Interest Draw-back Programme, Agricultural Credit Support Scheme, and other similar development initiatives (CBN, 2018). The Central Bank of Nigeria funded participating banks to finance commercial agricultural enterprises. Studies have shown that the agriculture sector received financial assistance from the Government through the participating commercial banks. Agricultural farmers, individuals, and organizations were reported to have benefited from these initiatives. Unfortunately, little or no private forest plantation investors have benefited from these initiatives (Fasoro, 2018).

The above discussions show that afforestation and reforestation projects receive little or no attention from the National Government. It is important to note that forest plantations are long-term investments, with the cost of establishment occurring in the first several years of the production cycle, while the significant share of the yield and revenue is expected at the end of the rotation period, which in most cases for Indigenous species is between 20 and 40 years. Still, fast-growing exotic species may be harvested in less than ten years, depending on the proposed products (Enters *et al.*, 2004). Therefore, incentives such as soft loans, tree seedlings, technical advice, and tax relief are required to encourage small- and medium-sized private forest plantation owners.

In this regard, FAO (2008) suggested financing mechanisms for private investment in forest plantation development, including microfinance, out-grower schemes, foreign direct investment, and remittances. In other regions of the world, with exceptionally high forest cover in Latin American countries, other private sector financing mechanisms have been developed, such as environmental stock exchanges, private equity investment funds, and forest-backed securities purchased by institutional investors like pension funds. Unfortunately, West African financial markets are

generally not yet developed enough to offer such products, and most countries' forest sector is not large enough to stimulate such developments (FAO, Ibid).

POSSIBLE FINANCING MECHANISMS FOR PRIVATE FOREST PLANTATION OWNERS IN NIGERIA

1 Microfinance

Microfinance has played a crucial role in financing small enterprises and rural development. It involves providing financial services to low-income investors generally excluded from the commercial banking sector (FAO, 2011). These financial services include credit, savings, and, increasingly, micro-insurance. Microcredit typically consists of small short-term loans (12 months or less) that are given against collateral. Regulated formal financial institutions, NGOs, member-owned organizations, and informal financial services providers, such as traditional kinship networks, rotating savings and credit associations, and moneylenders, provide microfinance services to investors. FAO (Ibid) stated that these institutions vary in their mission, with some focusing strongly on their financial viability and others emphasizing their social missions. The interest rate also varies across institutions. For example, some institutions, particularly NGOs, provide loans at subsidized rates, while some institutions are commercial entities that need to cover their operating costs through revenues from interest on loans.

Many constraints have been reported to affect private investors' free access, especially small-medium scale forest plantation investors to microfinance. These constraints include the long gestation periods for plantation activities, lack of clear land tenure, fluctuation in market prices, and marketing of timber and non-timber forest products. Small-medium scale private forest plantation owners may have to wait several years before plantations mature. The long period between initial investment and harvest calls for long-term financing because various optimal silvicultural practices must be carried out to give a productive outcome (timber quality). This long-term financing is unavailable primarily, further increasing uncertainty and risk. High interest rates also become more demanding on longer-term loans.

High interest rates by Banks may pose a great challenge and discouragement to potential private investors with no or little alternative source of income. There must be improved linkages between the forestry and finance sectors to ensure the development of financing products suited to the industry on the one hand and the improved understanding of financial opportunities and regulation by the forestry sector on the other.

2 Out-grower Schemes

FAO (2011) reported that out-grower schemes, or contract farming, represent a form of integrated value-chain financing, whereby a buyer higher up the chain provides funding for a producer lower down the value chain. Under such schemes, producers allocate land and other resources to produce and manage trees or other agro-forestry products for a processing company. The processing company provides a guaranteed market and facilitates the investments necessary for the plantation. A contractual agreement between the growers and the processing company defines the responsibilities and benefits of each party. Out-grower schemes respond to the forest sector's constraints regarding long gestation periods. They allow smallholders to access finance for investment in plantations and to access input supplies, they often provide some technical production support, and finally, they offer smallholders a guaranteed, if not always equitable, market for their production. Financing for investments by the smallholder farmers often comes in the form of loans

(cash advance payments or in-kind loans, with or without interest) that are repaid upon harvest when the smallholder sells the produce as agreed to the contractor.

FAO (Ibid) confirmed that Liberia has the most extensive experience with out-grower schemes, with the Firestone out-grower scheme in the rubber sector being operational since 1926 and having attracted its share of criticism. A more recent large-scale scheme in Liberia concerns the oil palm sector. Equatorial Palm Oil, a Roundtable on Sustainable Palm Oil member, launched production with smallholders on 169,000 hectares of land. Other countries such as Côte d'Ivoire, Ghana, and Nigeria also have examples of out-grower schemes.

Landell-Mills and Ford (1999) in FAO (2005) stated that Sappi, an international pulp and paper company and the second largest private forest owner in South Africa, was the first company in South Africa to experiment with partnership arrangements with local communities as a way of increasing its access to forest resources. The original Scheme, "Project Grow," was started in Kwazulu-Natal in 1982 and has since been managed by an NGO called Lima Development Foundation, an NGO with a track record in community development. Under this Scheme, local communities sign a contract with Sappi, which entitles them to free expertise, training, and seedlings, advanced payment for work, and a guaranteed market for their tree at current market prices. When the trees are finally ready, Sappi pays the participants the value of the produce, deducting any advance payments. This Scheme has worked well despite farmers not owning the land they plant. Generally, individuals are granted rights to community-owned land for plots averaging less than one hectare per family. By1999, 6 800 ha had been planted by 7 600 farmers, generating 2.4 million rands (R) (U.S. $545 000) per year. Participants earn about U.S. $205 per hectare per year, which compares favorably with ranching or sugar production alternatives. In 1990, Sappi introduced a second outgrower scheme for title deed holders called the Management Associated Programme (MAP). MAP offers free seedlings and technical advice, a loan of up to R1 200 (U.S. $275) per hectare at the prime bank interest rate, and a guaranteed market price for timber. Up until 1999, 28,000 ha had been planted. The average income in the U.S. is $115 per hectare per year. The grower must follow the harvesting practices prescribed by Sappi and cannot sell the timber grown to anyone else.

In Nigeria, the British America Tobacco Company practices this Scheme. Farmers are employed to plant tobacco for the company. The company provides a guaranteed market and facilitates investments necessary through incentives. Remarkably, many registered private wood industry companies in Nigeria are heavy users of forest resources, e.g., saw millers, timber exporters, pulp and paper companies, furniture, kitchen, and pallet manufacturers, etc. hence These companies can stimulate investment in forest plantation development through out-grower schemes. Companies, industries, and organizations involved in using timber and non-timber forest products in Nigeria can support forest plantation development in various forms. Still, they may include minor and mediumholder farmers receiving loans from these private companies to establish plantations on their land in return for selling the timber to the supporting private companies. Although many private companies, e.g., Obasanjo Holdings, Bisrod Company, and British America Tobacco Company, are significant investors in forest plantation development in Nigeria, the timbers produced are, in one way or another, utilized personally and cannot readily meet the demand of the county at large (Fasoro, 2018).

3. Foreign Direct Investment

Gondo (2010) stated that foreign direct investment (FDI) flows are new investments foreign enterprises make during a given period. The report further revealed that in recent years, there has been an increase in foreign investment in forest plantations and the associated wood processing industries, especially in East, South, and some West African countries. This has been spurred by the

growing demand for industrial timber on the continent and abroad (FAO, 2011). Feldstein (2000) identified the provision of diversification opportunities in other countries through the international flow of capital to reduce the risk faced by owners of capital in their home countries as one of the advantages of FDI. This shows that FDI is made by foreign companies operating in a country under the proper framework and, when well-managed, can provide employment opportunities, finance (throughout-grower schemes or other mechanisms), and transfer skills and technical know-how to smaller local companies. FDI is also attractive as it does not require fixed repayment and does not contribute to debt burdens.

In Africa, most FDI to forestry is unevenly distributed and concentrated in forest-rich, stable, low-risk countries. West Africa's industrial forestry activity level is shallow compared to other regions, notably Asia and Latin America, and it attracts relatively little forestry FDI. Gondo (2010) reported that in recent years, Eastern and Southern Africa have recorded an increase in foreign direct investment in forest plantations and the associated wood-processing industries, while few West African countries such as Liberia, Sierra Leone, Ghana, and Côte d'Ivoire with relatively rich forest have an increase in FDI. The study revealed that data on FDI in Africa's forest sector are complex, and industrial timber production has a poor track record. Conversely, the growing global concern about sourcing wood from sustainably managed forests has seen forest plantation development as a solution to increasing timber production. Therefore, there is a need for private investment.

Nigeria is now one of Africa's largest recipients of foreign investment, but its overdependence on the oil and gas sector has remained a significant challenge to its economy (Ajibola *et al.*, 2018). The economy lacks the drive to divert attention towards the non-oil sub-sectors, including mining, manufacturing, services, agriculture, and forestry. As a result, a more significant percentage of about 60% of the FDI that flows into the Nigerian economy is made into the extractive (oil) industry (Ajibola *et al.*, 2018), while the non-extractive industry remains on a declining path except for the telecommunication sector which has progressed over time.

Many notable factors limit FDI from raising rural populations out of poverty or contributing in other meaningful and sustainable ways to local development. This is attributed to several factors, including low timber pricing, illegal activities and corruption, weak governance systems, low level of in-country processing, low wages, marginalization of rural communities: little re-investment in managing natural forests, and no consideration for private forest plantation investors. Thus, the Nigerian Government must create environments that attract foreign private investment in forest plantation development. Also, there is a clear need for better coordination and more careful targeting of FDI in the forestry sector because the sector has been undermined in budgetary allocation and FDI disbursement.

4. Remittances

Remittances are another vital source of financing for small and medium enterprises. Remittances from migrants to their home countries have been a great source of funds for developing countries. The remittances of the diasporas, despite being a show of attachment to the country of origin, serve as a vehicle towards the economic growth of such a country. FAO (Ibid) reported that 2006 global remittances were estimated at US$300 billion, of which $10.4 billion went to West African countries. In Sierra Leone, Liberia, and Cape Verde, remittances account for 12%, 26% and 34% of GDP respectively. IFAD (2007) estimated Nigeria's remittance to be 5% of the GDP.

Ikechi and Anayochukwu (2013) stated that migrants' remittances were found to have a positive impact on the economic growth of the economies studied, though to varying degrees. IFAD (2007) revealed that recipients use most remittances to finance the consumption of essential goods and

services – food, clothing, lodging, health care, and education. Remittances provide a necessary source of revenue for several recipients in rural communities that are excluded from the banking sector. In Ghana, it was estimated that two-thirds of remittances were destined for recipients in rural areas (IFAD, Ibid). However, Brown and Ahlburg (1999) argued that remittances undermine productivity and growth in low-income countries as they are readily spent on consumption rather than productive investments. Hence, remittances should be directed to productive investments in developing countries to boost their economy through job creation.

FAO (2011) revealed no specific cases of forestry initiatives funded by remittances were found in the literature. Still, there may thus be some potential for tapping into this source of funds to finance forest plantation development. A rise in remittances directed towards productive investments, such as private investment in forest plantation development, will strengthen and secure access for small and medium enterprises to a once reliable source of financing.

5 Commercial Banks

Akpansung and Babalola (2010) affirmed the essential role of the banking sector in actual sector development by mobilizing resources from the savers and allocating such savings as loans to credit-worthy customers to promote economic growth and sustainability. Udih (2014) opined that if financial resources were adequately made available to the Agricultural sector by banks, it would not only cure food scarcity but also attract new and existing investors into the economy, thereby creating room for employment. Ijaiya and Abdulraheem (2000) also stated that credit is a financial resource obtained from a financial institution within a specified period based on agreed terms with the promise of paying back as and when due.

The Central Bank of Nigeria, in collaboration with the Federal Ministry of Agriculture and Water Resources, established the Commercial Credit Scheme (CACS) in 2009 to deepen access to finance and reduce the exclusion rate. The fund was made available to participating banks to finance commercial agricultural enterprises. CBN (2018) reported that one hundred and ninety-one (191) benefiting businesses comprised cooperative groups, partnerships, private and public limited liability companies, and sole proprietorships. N147.87 billion was disbursed to the 191 firms between 2009 and 2016. State governments also served as channels for certain groups of beneficiaries. Over the years 2011 and 2015, the highest uptakes of CACS loans were recorded. Most (79.1%) of the 191 businesses are private liability companies, 7.3% are government-owned, 6.8% sole proprietorships, and 4.2% are public liability companies. Unfortunately, the forestry sector cannot apply for such a loan because the Scheme only includes Agricultural commodities such as production (cash crops, food crops, poultry, livestock, and aquaculture), processing (feed mill development, threshing, etc.), storage, farm input supplies, and marketing.

The importance of forest products cannot be overemphasized because studies have shown that the demand for timber and non-timber forest products in Nigeria is extremely high, and the market does not match the supply of products. Hence, bank loans and advances can influence the forestry sector through forest production. It is believed that if banks fund forest plantation development, it will, in turn, increase forest products and attract new investors into the system. Sufficient loan facilities granted by banks and the Government will increase productivity and promote citizen welfare through job creation. Hence, private funding can be one of the most veritable instruments for sustainable forestry development.

Conclusion

Public funding for forest initiatives and programs has been insufficient and delayed at both the federal and state government levels, and the country's current forest resources cannot sustainably meet its needs. This trend may continue for some time unless appropriate initiatives, such as encouraging private investment in forest plantation development, are taken. Forest plantation development is an essential activity in forestry development that can increase wood supply and stem the pressure in the natural forest; thus, generating innovative ways of funding private forest plantation development will be a significant way of achieving sustainable forest development, income generation, increasing wood supply, and reducing the pressure on natural forests in Nigeria. Thus, the Central Bank of Nigeria should include timber and non-timber output in the Commercial Agriculture Credit Scheme, or a separate portfolio should be developed for the forestry sector to provide small and medium-sized forest plantation investors with access to loans. It is also critical for all private forest plantation owners to understand that when assessing possible investments, forest investors weigh expected profits against risks. Investment flows are heavily influenced by tree-growing conditions, market access, growth potential, physical and institutional infrastructure, and the business environment, which includes political and economic stability and land tenure security. The main barriers to financing private investments in SFM in developing countries include high, natural, and perceived risks such as those related to land tenure; a lack of both domestic and foreign equity and loan financing; unfavorable financing terms; and, finally, high up-front costs associated with forestry investment projects. To encourage more excellent forest investment, the Government can improve the investment environment, including policy and legislation, governance, transparency, and infrastructure. There are numerous methods for the public sector to support long-term investments in sustainable wood production. These include expanding the information base on forest resources and finance, collecting and publicizing data on domestic investments, and boosting access to private financing.

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SUB-THEME: VALORIZATION AND SUSTAINABLE UTILIZATION OF FOREST PRODUCTS

Relaionship between anatomical and acoustic properties of *Gmelinaarborea* wood

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Abstract

Wood is considered a special material for musical instruments and other acoustic applications due to its unique acoustic traits. However, since the anatomical structure of wood also determines its suitability for various applications, hardwood being different in their wood microscopic structure from softwoods makes it difficult to select wood species suitable for acoustic purposes, thus, we aimed to establish the relationship between the anatomical and acoustic properties of *G .arborea* wood to know the anatomical traits enhancing acoustic performance. Three fifteen-year-old *Gmelinaarborea* trees were felled and samples of $20 \times 20 \times 20\ mm^3$ and $20 \times 20 \times 300\ mm^3$were obtained axially and radially for anatomical (fiber characteristics and micrographic analysis)and acoustic properties testing [Fundamental Frequency (FF), Sound velocity (V), Longitudinal Elastic Modulus (E), Specific Longitudinal Elastic Modulus (Es), Acoustic Coefficient (K), Damping Factor (tanδ), Sound Quality (Q), Impedance (Z), and Acoustic Conversion Efficiency (ACE)]respectively. The significantly correlated variables were as follows; fiber diameter (FD), cell-wall thickness (CWT), ray width (RW), and ray ratio (RR) with FF (0.73, 0.67, -0.60, 0.66); FD, CWT with E (0.69, 0.65); FD with Es (0.69); FL with K (-0.62); FD with V (0.69); FD and CWT with Z (0.60, 0.61). Our result implies that wood rays, FD, and CWT had a better relationship with acoustic properties. Notwithstanding, we found out that the relationship between these properties is diverse, as such, it can be unstable and species dependent.

Keywords: Micrographic analysis, Damping factor, correlation, *G. arborea*

Introduction

Generally, the anatomical properties of wood contribute immensely to the characteristics, properties, traits, and performance of wood in service(Baar *et al.*, 2016). Ross and Pellerin (1994)and Bucur (2006)opined that it is appropriate to assume that there is a relationship between microstructure and wave propagation, energy storage, and/or dissipation properties of wood since microstructure also influences the mechanical properties of wood. Thus, the characteristics of wood cells can be related to the same mechanism that determines the static behavior of wood. Furthermore, the relationship between anatomical properties (vessel elements, fiber, ray, and axial parenchyma) and wood acoustic quality for xylophone bars was examined by Brancheriau *et al.*, (2006)who noted the importance of regular and homogeneous anatomical structures for acoustic quality classification.

Wood can produce sound (by direct striking) and amplify or absorb sound waves originating from other bodies. This sound can be partially absorbed or reflected. As such, wood is considered a special material for musical instruments and other acoustic applications. Due to these unique acoustic traits, wood has gained relevance in the production of several musical instruments such as violin, xylophone, piano, guitar, and percussion instruments.

Hardwoods are different in their wood microscopic structure from softwoods. This implies that the variation in the microstructure of hardwoods influences product quality differently, thus making it complex to select wood species suitable for acoustic purposes. Also, (Bucur, 2006)stated that the difference in the microscopic structure of hardwood usually makes it difficult to provide hardwood for the production of figures (e.g. hourglass-shell) for general functions.

Since the anatomical structure of wood also determines its suitability for various applications (Bucur, 2006), it is important to consider a wood's anatomical structure for every specific purpose, especially where quality product is required. Hence, it is necessary to know the anatomical traits of a wood germane to enhance acoustic performance. For these reasons, this research endeavors to study the relationship among anatomical and acoustic properties of *G. arborea* wood.

Olaoye *et al*. (2016) established a relationship between fiber characteristics and selected acoustic properties but without consideration of other aspects of wood anatomy such as the vessel and parenchyma cells. More so, there is a need to provide information on the relationship between the anatomical and acoustic properties of Nigeria's preferred wood species for acoustic functions.

Gmelinaarborea is an essential exotic species that has found wide acceptance, cultivation, and distribution in Nigeria due to the benefits derived from its wood.

Sample Collection and Preparation

Three fifteen-year-old *Gmelinaarborea* trees with straight boles were purposively selected and felled at Onigambari Forest Reserve, Ibadan, Nigeria. From each tree, bolts of 60cm in length were collected from the base and top at 10% and 90% positions of the merchantable height, respectively. From the bolts, wood sample cubes of $20 \times 20 \times 20\ mm^3$ (R x T x L) and $20 \times 20 \times 300\ mm^3$(R x T x L) were obtained axially (base and top at 10% and 90%, respectively) and radially (inner wood and outer wood), for selected anatomical and acoustic properties testing respectively. A total of 36 samples were used for this experiment.

Anatomical Properties

The anatomical property tests of the selected samples collected were conducted at the Wood Anatomy Laboratory, Department of Forest Products Development and Utilization, Forestry Research Institute of Nigeria (FRIN), Ibadan, Nigeria.

Preparation of Wood Samples for Micrographic Analysis (Sectioning).

To prepare the stem discs for sectioning, samples were cut into blocks of 2 x 2 x 2 cm for easy clamping on microtome holders and carefully labeled for easy identification. The wooden blocks were soaked in water for 17-24 hours to soften for easy sectioning based on the density of the wood. The wood blocks were oriented to show these dimensional planes or axes: transverse, tangential, and radial sections.

The sections were stained with Safranine-O for 30 minutes and then rinsed with distilled water. The sections were immersed in 50% and 95% Ethanol. The ethanol was used to extract the excess stain on the sections. The ethanol solvent was cleared by covering the sections with several drops of clove oil for 5 minutes and later transferred into xylene for dehydration and differentiation. Later, the Sections were mounted on the slides with the use of Canada balsam. The function of the Canada balsam was to help place the cells intact, without shrinking or collapsing for a very long period, and with clarity. The descriptive terminology and measurements followed the International Association of Wood Anatomists (IAWA, 1989).

Lastly, the samples were examined under the microscope to view the cell differentiation of the species along the dimensional planes (transverse, tangential, and radial sections), and the photomicrographs for rays and vessels were taken, measured, and counted at x40 magnification. Ten (10) rays and vessels were measured (length and width).

Thus, ray height, ray width, vessel width, number of vessels per mm^2, and number of rays were measured. Ray ratio (R) was calculated using equation 1 (Baar*et al.*, 2016)

$$R = \frac{H}{W} \qquad 1$$

$$where: H = height\ and\ W = width\ of\ a\ particular\ ray\ on\ tangential\ section$$

Fibre Measurement

The fiber measurements were carried out following ASTM, (2007a)and ASTM, (2007b). Samples were collected from inner wood and outer wood at the top and base along the merchantable height and prepared into slivers of 3mm x10mm. Maceration of the slivers was carried out using acetic acid and hydrogen peroxide (1:1) and placed in an oven for 2 hours at a temperature of 100°C then the solution was vigorously agitated to enable the separation of the individual fibers. The macerated fibers were randomly selected and dropped on a standard slide, 7.5cm x 2.5cm using a procedure adopted by Dutt *et al.*(2012).

All the fiber characteristics namely: fiber length, fiber diameter, and lumen width were viewed under a stage micrometer mounted on a Zeiss light microscope (Standard of 25 fibers) under 40× magnification in the swollen state. Twenty-five (25) fibers were measured from each sample slide while Cell wall thickness (CWT) was obtained mathematically using equation 2, as adopted by Oluwadare and Sotannde (2007);

$$CWT = \frac{FD - LW}{2} \qquad 2$$

The ray, vessel, and fiber characteristics were investigated at the Wood Anatomy Laboratory, Department of Forest Products, Development and Utilization, Forestry Research Institute of Nigeria, Ibadan

Acoustic Property Test (Longitudinal free vibration test)

Samples $(20 \times 20 \times 300\ mm^3)$collected were oven-dried to constant weight and then stored at relative humidity 65±5% and temperature 20±2˚C for one month before testing. The experiment was set up according to the Jalili *et al.* (2014)method. Hence, selected wood acoustic properties [Sound velocity (V), Longitudinal Elastic Modulus (E), Specific Longitudinal Elastic Modulus (Es), Acoustic Coefficient (K), Damping Factor (tanδ), Sound Quality (Q), Impedance (Z), and Acoustic Conversion Efficiency (ACE)] were measured using the longitudinal free vibration test methods.

The experiment was also set up as shown in Figure 1. However, after generating many sounds by striking the wood, the first bending natural frequency (fundamental frequency) was obtained from the FFT. Hence, equation 3 was used to determine the dynamic modulus of elasticity.

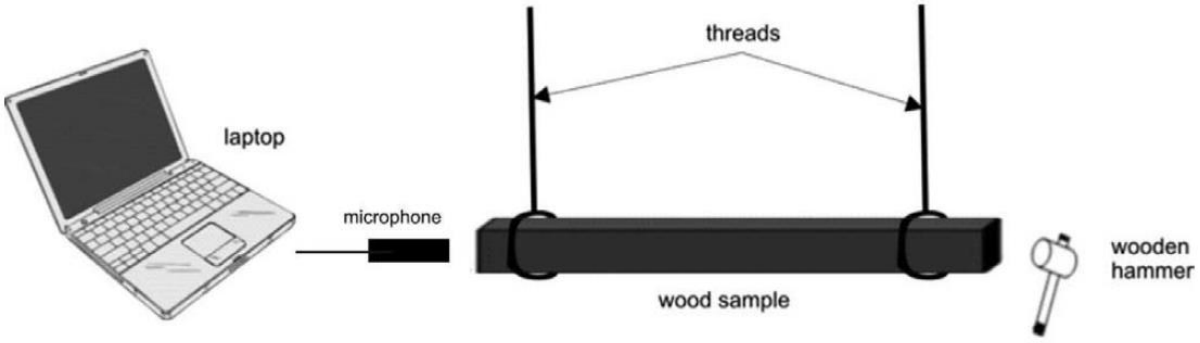

Figure 1 The set-up of the longitudinal free vibration test
(Jalili *et al.,* 2014)

$$E = \left(\frac{2f_n}{\gamma_n \pi}\right)^2 \frac{mL^3}{I} \qquad 3a$$ (Baar *et al.*, 2016)

Where m is the specimen weight, f_n is the First bending natural (fundamental) frequency, n is the mode number, and L is the length of the sample. γ_n is for the first mode 2.267, and *I* is inertia.

$$I = \frac{(bh^3)}{12} \qquad 3b$$

Where b is the width and h is the thickness of the specimen

Having obtained the dynamic elastic modulus, equations 4-10 were used to calculate other selected acoustic parameters.

Note: the experiment was conducted in an enclosed place at room temperature having ensured total silence, and the FFT analyzer showed no sign of a sound signal.

Specific longitudinal elastic modulus (Es);

$$Es = \frac{E}{\rho_s} \qquad 4a$$

$where\ \rho_s = Relative\ Density\ (Specific\ gravity)$

$$\rho_s = \frac{\left[\frac{oven\ dried\ mass}{green\ volume}\right]}{density\ of\ water} \qquad 4b$$

To calculate the Acoustic co-efficient of the vibrating body (K):

$$K = \left(\frac{E}{{\rho_s}^3}\right)^{0.5} \qquad 5$$

$where\ E = longitudinal\ elastic\ modulus, and\ \rho_s = specific\ gravity$
(Roohnia, 2005)

After each impulse, the sample will start vibrating. Due to the internal friction, the vibration energy will reduce after a while. This attenuation occurs due to the material damping which is affected by the type of material. Therefore, a decrement in vibration energy as a function of time could lead to damping of sound.

$$Damping\ factor\ due\ to\ internal\ friction\ (tan\delta) = \frac{\lambda'}{\pi} \qquad 6$$

$where\ \lambda^1 = logarithmic\ vibrating\ decrement\ factor$

$$\lambda^1 = \left(\frac{1}{n}\right) ln\left(\frac{X_1}{X_{n+1}}\right) \qquad 7$$

$where\ n = number\ of\ successive\ peaks,$

$X_1\ and\ X_{n+1}\ are\ the\ first\ and\ (n+1)th\ amplitude\ of\ vibration\ respectively$
(Roohnia, 2005)

To calculate sound quality factor (Q) and acoustic conversion efficiency (ACE);

$$Q = \frac{1}{tan\delta} \qquad 8$$

$$ACE = \frac{K}{tan\delta} \qquad 9$$

$where\ K\ is\ the\ acoustic\ coefficient\ of\ the\ vibrating\ body$

$z = c\rho$

$z = impedance$

$c = velocity$ 10

(Ross & Pellerin, 1994)

Results and Discussion

The mean values of the selected anatomical properties tested for *G. arborea*wood are represented in Table 1. Thus FL, FD, LW, CWT, V.W, No. of vessels/mm^2, No. of ray/mm^2, RH, RW, and Ray Ratio were 1.14 mm, 27.62 µm, 14.83 µm, 6.40 µm, 136.40 µm, 4.10, 7.51, 395.97 µm, 58.59 µm and 6.93 respectively. Table 2 showed the acoustic properties of G.arborea wood tested; the mean values for FF, V, E, tanδ, Es, K, Q, ACE, and Z were 1095Hz, 4848.58m/s, 9.34GPa, 0.0039, 23.57GPa, 12.30 $m^4kg^{-1}s^{-1}$, 279.64, 3435.66 $m^4kg^{-1}s^{-1}$ and 1.92 $km^{-2}s^{-1}$, respectively. Plates 1-3 showed samples of the fiber, transverse, and tangential sections of the *G.arborea* wood.

Table 1. Mean values of selected anatomical properties of *G. abroea* wood

Anatomical Properties	Mean Values
Fibre Length	1.14 ± 0.12 mm
Fibre Diameter	27.62 ± 2.93 µm
Lumen Width	14.83 ± 1.44 µm
Cell Wall Thickness	6.40 ± 1.09 µm
Vessel Width	136.40 ± 24.32 µm

Number of Vessels/ mm²	4.10 ± 0.70
Number of rays/ mm²	7.51 ± 1.20
Ray Height	395.97 ± 34.67 µm
Ray Width	58.59 ± 9.16 µm
Ray Ratio	6.93 ± 1.38

Mean ± S.D.

Plate 1 Sample of fibers measured for *G. arborea* wood (x40)

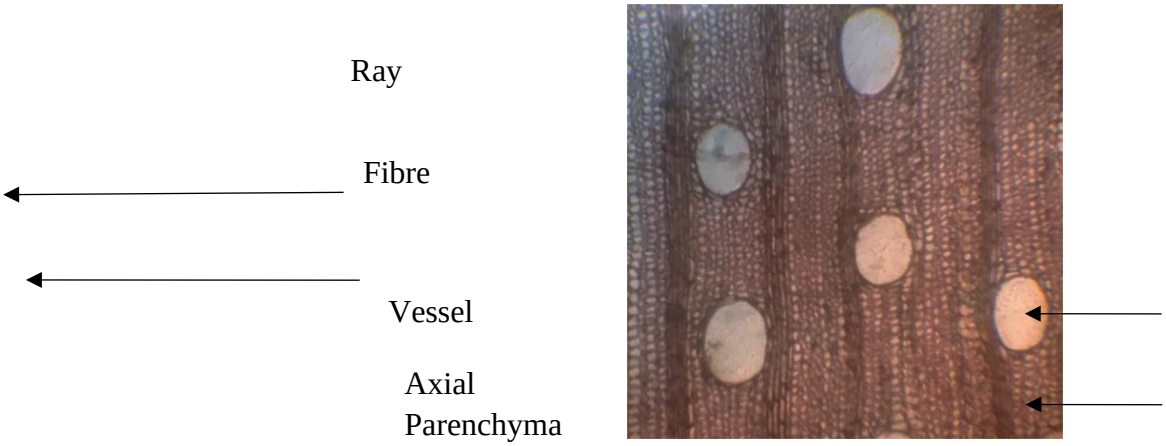

Plate 2. Transverse section of a sample of *G. arborea* wood (x40)

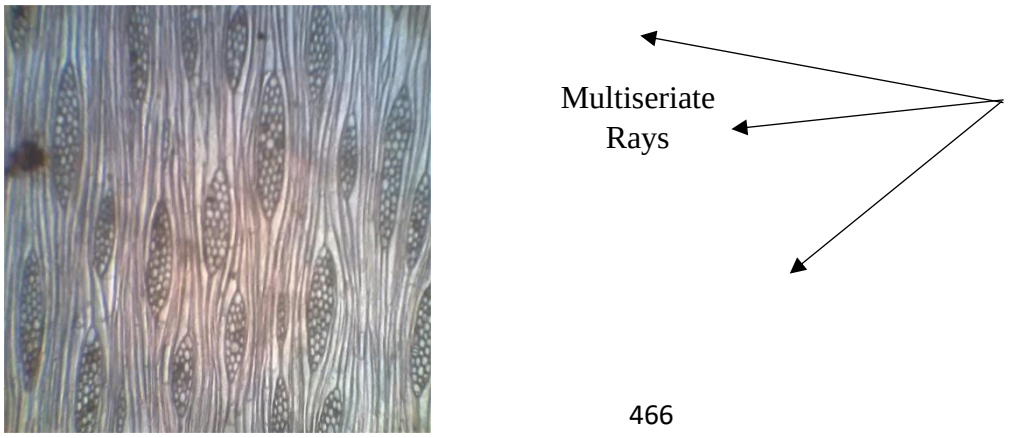

Plate 3. Tangential section of a sample of *G. arborea* wood (x40)

Table 2. Mean summary of selected acoustic properties of *G. arborea* wood

Acoustic properties tested	Mean
Fundamental frequency 'FF' (Hz)	1095.02
Velocity of sound 'V' (m/s)	4848.58
Longitudinal elastic modulus 'E' (GPa)	9.34
Damping factor 'tanδ'	0.0039
Specific longitudinal elastic modulus 'Es' (GPa)	23.57
Acoustic coefficient 'K'($m^4kg^{-1}s^{-1}$)	12.30
Sound quality factor 'Q'	279.64
Acoustic conversion efficiency 'ACE' ($m^4kg^{-1}s^{-1}$)	3435.66
Impedance 'Z' x10^6 ($kgm^{-2}s^{-1}$)	1.9199

Furthermore, Table 3 presents the correlation of anatomical properties with acoustic properties. The significantly correlated variables were as follows; FD, CWT, RW, and RR with FF (0.73, 0.67, -0.60, 0.66); FD, CWT with E (0.69, 0.65); FD with Es (0.69); FL with K (-0.62); FD with v (0.69); FD and CWT with Z (0.60, 0.61).

Meanwhile, Table 4. Showed the significant stepwise regression analysis between these two properties. Only a few anatomical properties had a significant regression with ACE and Z. The VW and CWT had the higher R^2 (0.558) for ACE, with VW being the highly contributing variable (R^2 change of 0.366). Whereas, RW and LW were the only anatomical properties significantly predicting Z at R^2 of 0.593 and 0.298 respectively.

Table 3. Pearson correlation analysis among anatomical and acoustic properties of *G. arborea* wood

	FL	FD	LW	CWT	VC	VW	RC	RH	RW	RR
FF	-0.45	**0.73***	0.46	**0.67***	0.44	0.07	-0.14	0.17	**-0.58***	**0.66***
E	-0.02	**0.69***	0.43	**0.65***	0.04	0.10	-0.40	-0.14	-0.40	0.22
Es	-0.32	**0.69***	0.56	0.56	0.11	0.28	-0.42	-0.16	-0.28	0.14
K	**-0.62***	0.25	0.42	0.07	0.14	0.47	-0.17	-0.14	0.11	-0.12
V	-0.31	**0.69***	0.55	0.56	0.11	0.27	-0.42	-0.16	-0.28	0.14
ACE	0.08	-0.01	-0.28	0.17	-0.16	0.43	0.36	-0.13	0.03	-0.04
Z	0.18	**0.60***	0.30	**0.61***	-0.01	-0.05	-0.35	-0.08	-0.42	0.25
tan$\boldsymbol{\delta}$	-0.37	0.10	0.40	-0.13	0.26	-0.20	-0.37	0.06	-0.04	0.07
Q	0.26	-0.04	-0.38	0.19	-0.20	0.31	0.39	-0.08	-0.00	0.00

Table 4. Stepwise multiple regression analysis of significant models between acoustic and anatomical properties of *G. arborea* wood

Acoustic properties	Predictor(s)	Models		R^2	R^2 change	SEE	Model sig.
ACE							
	x_1	VW	198.02^a 23.736^{b1}	0.366	0.366	716.73	0.013
	x_1, x_2	VW, CWT	2295.59^a 25.24^{b1} -360.08^{b2}	0.558	0.192	620.84	0.005
Z							
	x_1	RW	2510188.54^a -10074.83^{b1}	0.296	0.296	133654.46	0.029
	x_1, x_2	RW, LW	3604669.73^a -12074.87^{b1} -65884.60^{b2}	0.593	0.298	105402.73	0.003

Equation: $y = a + b_1x_1 + b_2x_2 + \cdots b_nx_n$ a – constant, b – standard coefficient SEE – Standard Error of Estimate y = acoustic properties x_1, x_2 … = anatomical properties R^2 – Coefficient of Determination

Discussion

Of all the anatomical properties determined, FD, CWT, and RR had a positive correlation with FF while RW had a negative relationship. This, therefore, implies that a wider fiber diameter, thicker cell wall, and more rays contributed to a higher fundamental frequency recorded for the wood, whereas the negative significant correlation between RW and FF means that a wider ray will lead to a lower fundamental frequency in *G. arborea* wood.(Brancheriau *et al.,* 2006)highlighted the importance of a regular and homogenous anatomical structure of wood rays for good acoustic properties was highlighted by (Brancheriau *et al.,* 2006). This reference may have been responsible for the significant negative correlation between RW and FF of *G. arborea* observed in this study.

Similarly, fiber diameter had a positive correlation with longitudinal elastic modulus and specific elastic modulus while cell wall had a positive correlation with longitudinal elastic modulus only. As such, the wider the fiber diameter, the better the elasticity. Also, a thicker cell wall contributes to better longitudinal elasticity. This finding supports(Basson, 1987)and (Alves *et al.,* 2008)who stated that wood elasticity is strongly influenced by the volume of fiber. By implication, since fibers with wider diameters occupy more fiber per space, then the significant relationship between elasticity with fiber diameter and thicker cell wall may have been connected to the high fiber volume that ensued.

On the other hand, the acoustic coefficient is also known as the radiation ratio, and a higher value is essential for overall acoustic performance. Therefore, since there was a negative significant correlation between K and fiber length, then the shorter the fiber length the better the radiation ratio. Thus, suggesting that a shorter fiber length may be of advantage for better acoustic conversion efficiency of wood provided internal friction is lower. Contrarily, Baar *et al.*,(2016) opined that longer fibers may be required for a better ACE but however pointed out that provided the fibres are not strongly deflected by the presence of rays. Also, there are indications from the step-wise regression model that VW and CWT are more instrumental to the prediction of ACE up to 56%, than any other anatomical properties.

The significant positive correlation recorded between velocity and fiber diameter implies that a wider fiber diameter equals more velocity of sound in wood. This relationship may be attributed to the availability of space in fibers of wider diameter (material medium) that is needed for sound to travel in wood.

Additionally, the study showed that the FD, and CWT of *G.arborea*had a major relationship with impedance (Z). The significant positive correlation they recorded means impedance of wood is expected to be higher concerning an increase in FD, and CWT. Meanwhile, it is only the combination of RW, and LW that had the highest coefficient of determination of a significant regression with Z. The results thus imply that RW and LW were suspected to contribute to the regression models predicting Z up to 59%.

Baar *et al.,* (2016)opined that higher ray volume or frequency can result in lesser favorable acoustic properties, thus supportingBrancheriau *et al.* (2006)who stated that short, structurally homogeneous, and a minimal number of rays are important for good acoustic quality, and opined that fiber morphology does not seem to have a major impact on acoustic quality. Meanwhile, Baar *et al.* (2016)opined that longer fibers could improve internal friction in some species. Notwithstanding, our study showed that RR had a favorable relationship with FF thus opposing their findings.

However, we observed a diverse variation in the relationship of anatomical and acoustic properties of the different wood species studied by Baar *et al.,* (2016)such that RW was significantly correlated with tan$\boldsymbol{\delta}$, E, Es and ACE for Afzelia *sp*., but similar relationships were not found forMillettia*sp*. We, therefore suspect that the relationship between anatomical and acoustic properties of wood may be species dependent.

Similarly, correlation as observed for Millettia*sp.,* in the work of Baar *et al.* (2016) was also obtainable for *G. arborea* wood in this study. This could mean that the anatomical structure responsible for the type of relationship obtained forMillettia*sp*. maybe the same for *G. arborea* wood.

In addition, microfibril angle (MFA), and chemical composition especially specific extractive compounds can strongly affect the internal friction of wood(Matsunaga *et al.,* 1999; Minato *et al.,* 2010), such that the variability of these extractives can reduce the influence of anatomical characteristics on internal friction Baar *et al.* (2016). Since the chemical composition and extractives of the wood in the study were not examined, it may also have been a reason no significant correlation was observed between any anatomical properties and internal friction.

Conclusion

In this study, a relationship between the anatomical and acoustic properties of *G. arborea* wood was established. It was found that the relationship between these properties is diverse, as such, it can be unstable and species-dependent owing to the different structures of individual wood species' tissue and organization which probably conditioned the establishment of a relationship between anatomical

features and acoustic properties. Therefore, more data from more samples of different wood species would be required to make a holistic conclusion about the relationship between these properties. Nevertheless, fiber length, fiber diameter, cell wall thickness, ray width, and ray ratio have been highlighted to correlate with some of the acoustic properties of *G. arborea* wood determined in this study.

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SUSTAINABLE UTILIZATION OF NON-TIMBER FOREST PRODUCTS IN NIGERIA: A REVIEW

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ABSTRACT

Non-timber forest products (NTFPs) contribute to the livelihoods of rural people in Nigeria. The sustainable use of NTFPs is critical for preserving biodiversity, sustaining livelihoods, and promoting economic development. This paper discusses the concept of NTFPs, the current state of NTFP utilization in Nigeria, the challenges associated with NTFP utilization, and possible solutions for sustainable NTFP utilization. NTFPs refer to a wide range of forest resources other than timber, such as medicinal plants, fruits, nuts, and fibers. NTFPs play an important role in the cultural and economic livelihoods of Nigerians. However, the current state of NTFP utilization in Nigeria presents several challenges that threaten their continued existence. Rapid population increase, urbanization, and unsustainable harvesting practices all contribute to the misuse and decline of NTFP resources. Poor regulatory frameworks, weak policies, and limited access to markets worsen the problem, resulting in land use disputes and environmental damage. A diverse approach is required to solve these problems. Community participation, capacity building, legislative reforms, and market linkages are critical measures for supporting sustainable NTFP use. The objective of management and sustainability of NTFPs should be developed by engaging local populations in decision-making processes, training people on sustainable harvesting techniques, strengthening regulatory frameworks, and increasing market access. Hence, sustainable utilization of NTFPs requires the support of stakeholders at all levels and the implementation of new policies and initiatives by stakeholders. Nigeria can harness the economic, social, and environmental benefits of NTFPs while conserving its rich forest resources for future generations.

Keywords: Forest, Non-Timber Forest Products, Sustainable Utilization, Sustainable Forest Resources Management

INTRODUCTION

Non-timber forest products (NTFPs) constitute a range of biological resources derived from forests, excluding timber. In developing nations, particularly in Africa and Asia, non-timber forest products (NTFPs) contribute to the income generation and healthcare of rural households (Esther *et al.*, 2019). Non-timber forest Products (NTFPs) encompass diverse forest-derived goods and services, including fruits, nuts, medicinal plants, resin, dye, and bushmeat, among others. According to Chamberlain *et al.* (1998), these encompass "plants, parts of plants, fungi, and other biological material harvested from within and on the edges of natural, manipulated, or disturbed forests". Wickens (1991) further defines NTFPs as "all biological material, excluding industrial round wood and related products like sawn timber, wood chips, wood-based panel, and pulp." These materials can be extracted from natural forests or managed plantations, serving various purposes within households; being marketed, or holding social, cultural, and religious significance. These include

plants and plant materials used for food, fuel, storage and fodder, medicine, cottage and wrapping materials, and biochemical, as well as animals, birds, reptiles, and fishes, for food and feathers (Rana, 2019).

NTFPs contribute significantly to food security, income generation, healthcare, and cultural heritage preservation, particularly for rural and indigenous communities (Shackleton *et al.,* 2011). In Nigeria, these encompass a plethora of natural treasures, from medicinal plants like Neem and Moringa to wild fruits such as bush mango and baobab, as well as fibers like raffia and bamboo. Embedded in the cultural tapestry of local communities, NTFPs serve many purposes, from traditional medicine and food sources to craft materials and sources of income. The utilization of NTFPs is interwoven with the daily living and household economies of many Nigerians, particularly those in rural areas. Medicinal plants are essential for healthcare in communities with limited access to modern medicine, while wild fruits, vegetables, and nuts contribute to dietary diversity.

Additionally, fibers from the forest are transformed into traditional crafts, sustaining artisanal livelihoods. Non-Timber Forest Products (NTFPs) are integral to the socio-economic development of Nigeria, providing sustenance, income, and cultural significance to many people in Nigeria (Ogundipe *et al.,* 2018). With a rich diversity of forests and ecosystems, Nigeria boasts a wide array of NTFPs, including fruits, nuts, medicinal plants, and other forest resources (Ajayi *et al.,* 2019). However, the sustainable management and utilization of these resources face various challenges, ranging from overharvesting to inadequate governance frameworks (Chukwuemeka *et al.,* 2020).

The utilization of Non-Timber Forest Products (NTFPs) in Nigeria has been on for years and is interwoven with our culture and household economy. NTFPs are essential sources of food, medicine, and income for rural communities across Nigeria. However, with increasing population pressures, rapid urbanization, and unsustainable harvesting practices, the sustainable management of NTFPs has become a challenging issue. The degradation of forest ecosystems, loss of biodiversity, and economic vulnerability of local communities underscore the need for comprehensive research and action to address these challenges (Fakayode and Omoju, 2007).

Non-Timber Forest Products (NTFPs) play a crucial role in Nigeria's economy, culture, and ecosystem. Nigeria has many different natural environments, each with its own types of plants and animals. Using these non-wood forest products wisely can help protect these environments, fight climate change, and help the country's economy by creating jobs and new markets, especially for people who don't have many job opportunities. But there are some big problems to solve. Right now, there's too much taking of these products, which can lead to them running out. There's also not enough support from the government or enough research on how to use these resources in a way that keeps them around for a long time. Plus, the people who collect and sell these products need better ways to do this so they can make more money and keep their traditions alive (Onyekwelu and Nwude, 2009).

This paper focuses on strategies for sustainable utilization of forest resources that are not wood, like plants used for medicine, fruits, nuts, and honey, without harming the environment. These non-timber products contribute to the livelihood of a large number of people in Nigeria. NTFPs serve as sources of income, food, and healthcare for many families. However, this resource is being depleted due to over-exploitation. Furthermore, the utilization of non-timber forest products sustainably requires the support of all stakeholders in the production and distribution chain of NTFPs including local communities, the government, scientists, and businesses. They should listen to each other and use both traditional knowledge and scientific research to find the best ways to use this resource judiciously. It is also important for the government to make policies that will protect this resource from over-exploitation and support the people involved in the production and distribution chain.

Doing all this can help make sure that Nigeria's forests and the benefits they provide can last for many generations to come. Hence, this review examines the concept, status, challenges, and potential solutions for the sustainable utilization of NTFPs in Nigeria.

Concept of Non-Timber Forest Products (NTFPs)

NTFPs refer to a wide range of forest-derived goods and services that are harvested, processed, and traded for various purposes other than timber production (Shackleton *et al.*, 2011). These encompass a diverse array of products, including edible plants, medicinal herbs, fibers, resins, and ornamental plants, among others. NTFPs play a vital role in supporting the livelihoods of forest-dependent communities, providing food, income, and traditional medicines, while also contributing to biodiversity conservation and ecosystem resilience.

NTFP contributes significantly to rural economies and cultural practices (Dovie *et al.,* 2015) by serving as sources of essential commodities including food, medicine, crafts, and cosmetics. However, challenges such as overexploitation and habitat degradation exist. Sustainable strategies like certification schemes and community-based management are proposed to address these issues.

In Africa, NTFPs are integral to socio-economic development, providing food, income, and traditional medicines. However, challenges such as inadequate governance and unsustainable practices threaten their long-term viability (Nnadozie *et al.,* 2017). Collaborative efforts are essential for promoting sustainable NTFP management in Africa.

NTFPs play a significant role in Nigeria's rural economy, contributing to food security, income generation, and cultural practices (Ajayi *et al.,* 2019). Studies have shown that NTFPs constitute a substantial portion of rural household income in Nigeria, particularly in forested regions (Ajayi *et al.,* 2019). However, unsustainable harvesting practices and inadequate market access pose significant challenges to the long-term viability of NTFP utilization in the country (Nnadozie *et al.,* 2017). Also, the lack of effective governance frameworks and policy support exacerbates these challenges, leading to overexploitation and habitat degradation (Ogundipe *et al.,* 2018). Policy interventions and community involvement are necessary to ensure sustainable NTFP utilization in Nigeria. Addressing these issues requires multi-stakeholder collaboration, policy interventions, and community-based management approaches tailored to the specific socio-economic and ecological contexts of Nigeria (Chukwuemeka *et al.,* 2020).

NTFPs encompass a diverse range of goods obtained from forests excluding timber. They include medicinal plants, fruits, nuts, fibers, and resins, among others. In Nigeria, NTFPs have long been an integral part of the socio-economic fabric, particularly in rural and forested areas where they serve as essential sources of livelihood for millions of people. Furthermore, in Nigeria, NTFPs have been integral to traditional livelihoods and serve as important sources of income and biodiversity. The origin of NTFP conservation and utilization emanates from the assumption that: NTFPs much more than timber, contribute to different ways of improving livelihoods and welfare of populations living in and adjacent to forests, providing them with food, medicines, and other material inputs and as a source of employment and income, particularly in hard times, and the exploitation of NTFPs is less ecologically destructive than timber harvesting and therefore provides a more sound basis for sustainable forest management (Ndulue *et al.,* 2021).

Current Status of NTFP Utilization in Nigeria

The present state of NTFP utilization reveals a delicate balance of resource extraction and environmental conservation. As demand for these products rises the need for sustainable utilization becomes paramount. Unregulated harvesting, driven by economic pressures, poses a threat to biodiversity and ecosystem health. The delicate balance between meeting the needs of present

generations and preserving these resources for the future underscores the urgency of adopting sustainable practices. Several challenges impede the sustainable use of NTFPs. Despite the advantages derived from non-timber forest products (NTFPs), numerous communities face ongoing threats from illegal activities, widespread forest fires, land conversion for cultivation, deforestation, urbanization, encroachment, and the transformation of land into agricultural uses. These factors collectively contribute to the substantial loss of forested areas (Rana, 2019).

Also, Overharvesting, driven by increasing demand, poses a direct threat to certain plant species and ecosystems. Additionally, inadequate regulation and enforcement exacerbate the risk of exploitation. Climate change further compounds these challenges, altering the distribution of species and impacting the availability of NTFPs (Rana, 2019). Despite these challenges, NTFPs remain a cornerstone of local economies and livelihoods. Indigenous communities heavily rely on these products for sustenance, income generation, and cultural practices. Recognizing the importance of NTFPs in supporting rural communities underscores the need for a balanced approach that safeguards both environmental and socio-economic interests. As a result of the challenges enumerated above, there is a need for conservation of these NTFPs. The interest in NTFPs has grown with increasing awareness of tropical Forest deforestation and rising acknowledgment of the need to add value to forest resources, to compete with other land uses (Martinez and Beneficiario, 2004).

Challenges

The utilization of NTFPs in Nigeria is widespread across various sectors, including agriculture, medicine, handicrafts, and cosmetics. Examples of commonly harvested NTFPs in Nigeria include shea butter, bushmeat, palm oil, honey, and medicinal plants. Despite their significance, the utilization of NTFPs in Nigeria faces various challenges. Rapid population growth, urbanization, unsustainable harvesting practices, inadequate policies, and weak regulatory frameworks contribute to the unsustainable exploitation of NTFPs. Furthermore, the lack of awareness about sustainable harvesting techniques and market dynamics exacerbates the situation. The challenges facing the utilization of NTFPs in Nigeria include but not limited to the following:

Firstly, Overexploitation and Unsustainable Harvesting Practices; Overexploitation refers to the excessive harvesting or extraction of NTFPs beyond sustainable levels, leading to depletion of natural resources and degradation of forest ecosystems. Numerous NTFPs in Nigeria are subject to overexploitation and unsustainable harvesting practices, leading to the depletion of natural resources, loss of biodiversity, and degradation of forest ecosystems. (Nnadozie *et al.,* 2017). Rapid population growth, increasing demand for NTFPs, and unsustainable harvesting practices contribute to overexploitation. Without proper management and regulation, overexploitation can result in the decline of NTFP species, loss of biodiversity, and disruption of ecosystem services vital for local communities and the environment.

Secondly, Limited Market Access and Value Chain Development; Access to markets and value chains for NTFPs in Nigeria is often constrained by factors such as poor infrastructure, limited market information, and lack of market linkages, which hinder the economic potential of NTFPs and limit income opportunities for producers (Chukwuemeka *et al.,* 2020). Limited access to markets and low prices discourages sustainable harvesting practices among local communities. Limited access to markets and value chains constrains the economic viability of NTFP-based enterprises, discouraging sustainable harvesting practices among local communities. Inadequate infrastructure, transportation networks, and market information systems impede the efficient distribution and marketing of NTFP products, particularly in remote and marginalized areas. Unfair trade practices,

price fluctuations, and lack of market incentives further undermine the economic incentives for sustainable NTFP utilization.

Thirdly, Land Use Changes and Deforestation; The expansion of agricultural activities, urbanization, and land conversion for infrastructure development pose significant threats to forest habitats and NTFP availability in Nigeria, exacerbating the vulnerability of forest-dependent communities and ecosystems (Angelsen *et al.,* 2014).

Fourthly, Land Use Conflicts; Competition for land between agriculture, logging, and conservation often leads to the degradation of forest ecosystems. Competition for land between agriculture, logging, conservation, and other land uses often leads to conflicts over NTFP resources and land tenure rights. Encroachment of agricultural activities, expansion of logging concessions, and establishment of protected areas can restrict access to NTFP-rich forests, exacerbating poverty and food insecurity among local communities. Resolving land use conflicts requires balancing the needs of different stakeholders, promoting participatory approaches to natural resource management, and ensuring equitable access to NTFP resources while conserving forest ecosystems.

Furthermore, Lack of Legal Recognition and Institutional Support; The legal and policy frameworks governing NTFP utilization in Nigeria are often inadequate, fragmented, or poorly enforced, resulting in limited recognition, protection, and support for NTFP-dependent communities and enterprises (Ogundipe *et al.,* 2018).

Lastly, Lack of Regulation; Inadequate enforcement of regulations contributes to illegal logging and unsustainable practices. The lack of effective regulatory frameworks and enforcement mechanisms exacerbates the unsustainable exploitation of NTFPs. Weak governance, corruption, and inadequate institutional capacity hinder the implementation and enforcement of policies aimed at promoting sustainable NTFP utilization. Illegal logging, unauthorized harvesting, and unregulated trade pose significant challenges to the conservation and sustainable management of NTFP resources.

Addressing these challenges facing NTFP utilization in Nigeria requires a holistic approach that integrates sustainable forest management practices, community-based conservation initiatives, policy reforms, community engagement, capacity building, market development initiatives, and stakeholder engagement to promote the sustainable utilization of NTFPs while safeguarding the ecological integrity and socio-economic well-being of forest-dependent communities.

Possible Solutions

To ensure the sustainable utilization of NTFPs, a multifaceted approach is imperative. Strengthening regulatory frameworks, promoting community-based conservation initiatives, and investing in research for sustainable harvesting techniques are integral components. Strategies for promoting sustainable NTFP utilization include enhancing legal and policy frameworks, promoting community-based management, improving market access and value chain development, fostering sustainable harvesting practices, and building capacity among stakeholders (Shackleton *et al.,* 2011). Collaboration between government agencies, local communities, and environmental organizations is crucial for implementing and enforcing these strategies effectively. The possible solutions include:

Firstly, Community Engagement; Involving local communities in decision-making processes and resource management fosters stewardship and promotes sustainable practices.

Secondly, Capacity Building; Providing training and education on sustainable harvesting techniques, value addition, and market access empowers local communities and enhances livelihoods.

Thirdly, Policy Reforms; Strengthening regulatory frameworks, enforcing laws, and implementing sustainable forest management practices are essential for protecting NTFP resources.

Fourthly, Market Linkages; Facilitating market linkages, promoting fair trade practices, and creating value chains for NTFPs incentivize sustainable utilization and conservation efforts.

Lastly, Research and Innovation; Investing in research and innovation to identify new NTFPs, improve harvesting methods, and develop alternative livelihood options contributes to the long-term sustainability of forest resources.

Conclusion and Recommendation

In conclusion, the sustainable utilization of Non-Timber Forest Products (NTFPs) is essential for promoting livelihoods, biodiversity conservation, and sustainable development in Nigeria and beyond. This review provided a framework for policymakers, researchers, and practitioners to develop strategies, and initiatives and implement possible solutions aimed at promoting sustainable utilization of NTFPs and conservation in Nigeria. Concerted efforts are needed to address governance gaps, enhance market access, and promote community-based management approaches to ensure the long-term sustainability of NTFP resources in Nigeria and contribute to poverty alleviation and environmental conservation goals. Achieving sustainable utilization of NTFPs in Nigeria requires concerted efforts from stakeholders at all levels. State Governments should set up appropriate forest management strategies and policies that can help to conserve our forests. By addressing the challenges and implementing innovative solutions, Nigeria can harness the economic, social, and environmental benefits of NTFPs while ensuring the conservation of its rich forest resources for future generations.

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Bioethanol Production from *Eucalyptus camaldulensis* Dehnh Wood Waste Using *Bacillus subtilis* and *Escherechia coli* Isolated from Soil in Afaka Forest Reserve, Kaduna State Nigeria

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ABSTRACT

The economic and ecological problems associated with fossil fuels have raised interest in biofuel research in recent times in different parts of the world. The use of *Eucalyptus* waste biomass with no appreciable value to industries or for food as an alternative and cost-effective feedstock for bioethanol production was evaluated in this study. *E. camaldulensis* biomass (leaves, bark, and bark and leaves) were pretreated separately with acid (2M H_2SO_4) and Microwave irradiation (250V, 50Hz) before fermentation with *Bacillus subtilis* and *Escherichia coli* isolated from surrounding soil. Higher yields of reducing sugar were obtained from bark (43 %) and leaves (38.5 %) pretreated by microwave irradiation as compared with acid-treated plant biomass. Similarly, Bioethanol volume and concentration of 34.89 g/l and 0.51 % respectively were higher in Microwave irradiated bark of *E. camaldulensis* at 21 days of fermentation when *E. coli* and *B. subtilis* were used in synergy. The least bioethanol volume yield of 18.79 g/l and concentration of 0.12 g/l when bark and leaves of *Eucalyptus camaldulensis* were combined was obtained on day 7 of fermentation using *E. coli.* The study concludes that the number of dried wastes generated (37.8 kg) from one average stand of *Eucalyptus* tree could yield a significant volume (131,884.2 g/l) of bioethanol when *Bacillus subtilis* and *Escherichia coli* are used in synergy.

Keywords: Eucalyptus, Biomass, Bioethanol, Fermentation

INTRODUCTION

The world is facing the crisis of global warming and environmental degradation which has been associated with excessive use of fossil fuels. Alternative sources of energy are being explored the world over to reduce oil dependence and increase energy production (Berndes *et al.,* 2003). Among the various sources explored, biofuels offer one of the best alternative options as they have much lower life-cycle greenhouse gas (GHG) emissions compared to fossil fuels (Kumar, 2012). Biofuels which could be solid, liquid, or gaseous fuel derived from biological materials can be used to generate energy (Agba *et al.,* 2010). Energy produced through these processes could help to reduce the world's dependence on oil and therefore cut CO_2 emissions, thus mitigating global warming. In addition, biproducts of biofuel production can provide new income and employment opportunities in rural areas (Stevens and Verhe 2004). Bioethanol which is one of the biofuels derived from plant biomass is an ethyl alcohol, grain alcohol, $CH_3–CH_2–OH$, or ETOH. It is a liquid biofuel that is produced from several different biomass feedstocks and conversion technologies. Bioethanol has been reported as an attractive alternative fuel because of its renewable bio-based resource and its oxygenation which provides the potential to reduce particulate emissions in compression–ignition engines (Millan, 1997). It is one of the promising future energy alternatives that could contribute to the reduction of negative environmental impacts generated using fossil fuels (Zheng *et al.,* 2009). Bioethanol has been produced from a variety of raw materials containing fermentable sugars.

Eucalyptus species is one of the commercially important fast-growing trees in Nigeria. It provides the raw material for papermaking and is widely used in the construction industries, although large amounts of wood residue, such as bark, leaves, cork residue, cross-cut ends, edgings, grinding dust, and saw have not been efficiently utilized (Galbe, and Zacchi 2012). Considering the high cellulose content, the fast growth of Eucalyptus camaldulensis, and the fact that waste generated during wood processing has no human and animal food values, the plant could serve to provide the much-needed feedstock for bioethanol production in Nigeria.

METHODOLOGY

Study Area

Afaka Forest Reserve occupies about 7,093.1366 hectares of land and lies on latitudes 10^0 33'N and 10^0 42'N and longitudes 7^0 13'E and 7^0 24'E. The Forest Reserve provides a mixture of both natural and man-made vegetation suitable for guinea savannah vegetation. *Eucalyptus*

Sample Collection and Processing

One kilogram (Kg) of each bark and leaf of *E. camaldulensis* was collected separately in clean polyethylene bags from Afaka Forest Reserve, Kaduna State, and transported immediately to the Centre for Energy and Environment, Nigerian Defence Academy - Kaduna. Samples collected were washed several times to remove adhering dirt and later chopped into small pieces using a sharp knife. Chopped samples were oven-dried in an oven at 150 ^{0}C for 6 hours, pulverized to powder using mortar and pestle, and stored in capped wide-mouthed plastic containers until needed (Musliu, and Salawudeen 2012).

Isolation and Identification of Fermenting Bacteria from Soil

Collection and Preparation of Soil Sample for Serial Dilution

Collection and preparation of soil samples for serial dilution were carried out following the standard methods. Briefly, five (5) grams of upper soil layer were collected at 5 different locations within Afaka Forest Reserve using clean, dry plastic sample tubes with the aid of a sterile spatula. Soil samples collected were mixed to form composite soil from which 1g was suspended in 10 ml of sterile water in a ratio of 1:10 (10^{-1}). Further dilution of 10^{-3}, $10^{-4,}$ and 10^{-5} were prepared from the stock (10^{-1}) preparation.

Preparation of Media

The preparation of nutrient agar media was carried out following the standard procedure described by [9]. Twenty-eight (28) grams of nutrient agar was added to 1000ml of distilled water in a beaker, stirred vigorously and dissolved using a hot plate. This was later sterilized by autoclaving for 15 minutes at 121 ^{0}C and allowed to cool before dispensing in petri dishes. The preparations were allowed to solidify at room temperature.

Inoculation of Media

Media inoculation was done by streaking different dilutions (10^{-3}, 10^{-4} and10^{-5}) on solidified nutrient agar in petri dishes and incubated at 37 ^{0}C for 24 hours (Manga and Oyeleke, 2008). Each petri dish was later observed for the appearance of colonies.

Fermentation Test

Each bacterium isolated from the soil was screened for fermentation ability by Carbohydrate

Fermentation Test using Triple Sugar Iron agar (TSI) prepared as agar slope (Chitra *et al.,* 2014). Test organisms were inoculated by stabbing and streaking the medium with the aid of a sterilized straight wire loop and then incubated at 37 ^{0}C for 24 hours. Gas production was determined by cracking of the medium while H_2S formation was determined by the blacking at the slant butt junction. Determination of glucose fermentation was achieved by yellowing of the butt. Fermentation of lactose or sucrose or both was determined by yellowing of both the butt and the slant, and the motility was determined by observing the line of inoculation where a sharply defined line of inoculation indicates positive motility.

Morphological and Biochemical Characterization of Bacteria Isolates from Soil Samples

Colonies of bacteria with fermenting ability were characterized and identified based on morphological and biochemical characteristics using standard techniques described by Nivedita *et al.,* 2013.

Pretreatment of E. Camaldulensis Wood Waste

Microwave Irradiation

Ten grams of dried bark, leaves, bark, and leaves of *E. camaldulensis* were taken separately in glass beakers and microwaved (model no-QMWO-25L) for 3 minutes at 250V, 50Hz. One hundred milliliters of distilled water were added to both the bark and leaves of *E. camaldulensis* and autoclaved at 121 ^{0}C for 15 minutes. The mixtures were then filtered through No1 Whatman filter paper into a conical flask and the hydrolysate was collected for further analysis.

Acid (2M H_2SO_4) Pretreatment

Ten grams of dried bark, leaves, bark, and leaves of *E. camaldulensis* were separately soaked in 100 ml of 2M H_2SO_4. The mixtures were allowed to stand for 4 hours and autoclaved at 121 ^{0}C for 15 min. The mixtures were then filtered into a conical flask through a Whatman No.1 filter paper. Hydrolysates collected were subjected to further analysis.

Hydrolysate Detoxification

The hydrolysate from bark, leaves, bark, and leaves of *E. camaldulensis* collected from both microwaves irradiated, and acid-treated biomass were separately heated to 60 ^{0}C and basified by adding at intervals 0.5g solid NaOH until a pH of 5.5 was achieved. To the solution, 1g of Ca $(OH)_2$ was added to detoxify harmful materials present in the hydrolysate and then filtered through a Whatman No.1 filter paper to remove insoluble residues. The filtrates containing fermentable sugars were then stored in capped plastic containers for determination of reducing sugar (Miller, 1959).

Determination of Reducing Sugar

The reducing sugar content of the hydrolysates was assayed by adding 3ml 0f 3, 5 - dinitrosalicylic acid (DNS) to 3 ml of each hydrolysate sample. The mixture was heated in a hot water bath for 10 minutes until a red-brown color was observed. To the mixture, 1 ml of 40 % potassium sodium tartrate solution was then added to stabilize the color and the mixture cooled to room temperature under a running tap. The absorbance of each sample was measured at 491 nm using a UV-VIS spectrophotometer. The reduced sugar content was subsequently determined by reference to a standard curve of known glucose concentration (Oyeleke and Jibrin, 2009).

Fermentation of the Hydrolysate

Fifty (50) milliliters of bark, leaves, and a combination of bark and leaves of *Eucalyptus camaldulensis* hydrolysates were separately dispensed into three 100 ml capacity conical flasks and

each flask was replicated three times. The flasks were then covered with cotton wool, wrapped in aluminum foil, and autoclaved at 120 ^{0}C for 15 minutes. The flasks were allowed to cool at room temperature and aseptically inoculated with the fermentative organisms (6.00×10^2cfu/ml) isolated from the soil as follows:

a) *Bacillus subtilis*
b) *Escherichia coli*
c) *Bacillus subtilis + E.coli*

All flasks were incubated anaerobically at 30 ^{0}C and each was examined at seven days intervals for 3 weeks. The fermented broth was distilled at 78 ^{0}C and the distillate was collected for determination of bioethanol concentration in the fermented medium.

Determination of Concentration of Bioethanol

The concentration of bioethanol in distillate was carried out using UV-VIS quantitative analysis of alcohols using chromium VI reagent according to the methods described by (Humphrey and Caritas, 2007). This involves taking 1 ml of standard ethanol and diluting it with 100 ml of distilled water to produce 1% stock solution. To obtain 0%, 0.2%, 0.4%, 0.6% and 0.8% of the stock ethanol solution, 0 ml, 2ml, 4ml, 6ml and 8ml of the stock solution was diluted in 10ml of distilled water. To each of the varying ethanol concentrations, 2 ml of chromium reagent was added and allowed to stand for an hour and the absorbance of each concentration was measured at 588 nm using a UV-VIS spectrophotometer. Readings obtained were used to develop a standard ethanol curve. To determine the concentration of bioethanol produced, 4 ml of each bioethanol sample was transferred into a test tube and treated with 2 ml of chromium reagent. The mixture was allowed to stand for an hour and the absorbance was measured at 588 nm using the UV-VIS spectrophotometer.

Quantification of Ethanol

To determine the quantity of ethanol produced, distillate from hydrolysate of bark, leaves, and a combination of bark and leaves fermented with *B. subtilis*, *E. coli,* and a combination of the two bacteria were collected over a slow heat at 78 ^{0}C. The quantity of ethanol produced in g/l was then obtained by multiplying the volume of distillate collected at 78°C by the density of ethanol (0.8033 g/ml) (Arumugam, and Manikandan, 2011).

Statistical Analysis

Data obtained were statistically analyzed by one-way analysis of variance. A comparison of means was done by the New Duncan's multiple range test ($P = 0.05$).

RESULT

The amount of waste generated from one average fell stand of the *Eucalyptus* plant in the Afaka forest Reserve is presented in (Fig 1). Fresh Bark, leaves, and unused branches of felled *Eucalyptus* plant produced 38.0 kg, 7.0 kg, and 26.0 kg respectively while the dried bark, leaves, and unused branches produced 32.0 kg, 5.8 kg, and 20.8 kg respectively.

The reducing sugar yields from the hydrolysates of bark, leaves, bark, and leaves of *E. camaldulensis* pretreated with acid (2M H_2SO_4), microwave irradiation, and untreated biomass are presented in Figure 3. Microwave irradiation produces the highest (38.5% - 43%) yield of reducing sugar compared with untreated (7% - 8%) and acid (2M H_2SO_4) (35.5% - 38%) pretreated biomass. Although there was no significant difference in reducing sugar yields of acid (2M H_2SO_4) treated and microwave irradiated biomass ($P>0.05$), the difference in reducing sugar yield between treated and untreated biomass is statistically significant ($P<0.05$).

Table 1 shows the quantity in volume (g/l) of ethanol produced over 3 weeks from microwave-treated *E. camaldulensis* wood waste biomass using bacteria isolated from the soil. Although the performance of individual fermenting bacteria was lower when both were used in synergy, the volume of ethanol produced by these organisms irrespective of plant biomass used increased steadily over the 3 weeks. However, the highest volume (31.22 ± 0.54g/l – 34.89 ± 0.07g/l) of ethanol production was achieved when microwave irradiated bark was fermented by *B. subtilis* + *E. coli* than leaves (25.95 ± 0.04g/l – 33.95 ± 0.02g/l) or bark + leaves (26.18 ± 0.50g/l – 29.05 ± 0.02g/l) using the same fermenting organisms.

Similarly, there was an increase in percentage concentration of bioethanol produced from day 7 to day 21 irrespective of plant part or fermenting organism used. However, microwave irradiated bark biomass when fermented by *B. subtilis* + *E. coli* had a higher percentage concentration of bioethanol produced at day 7 (0.42 ± 0.02), day 14 (0.47 ± 0.03), and day 21 (0.51 ± 0.02) than either of the plant parts fermented by individual bacteria (Table 2).

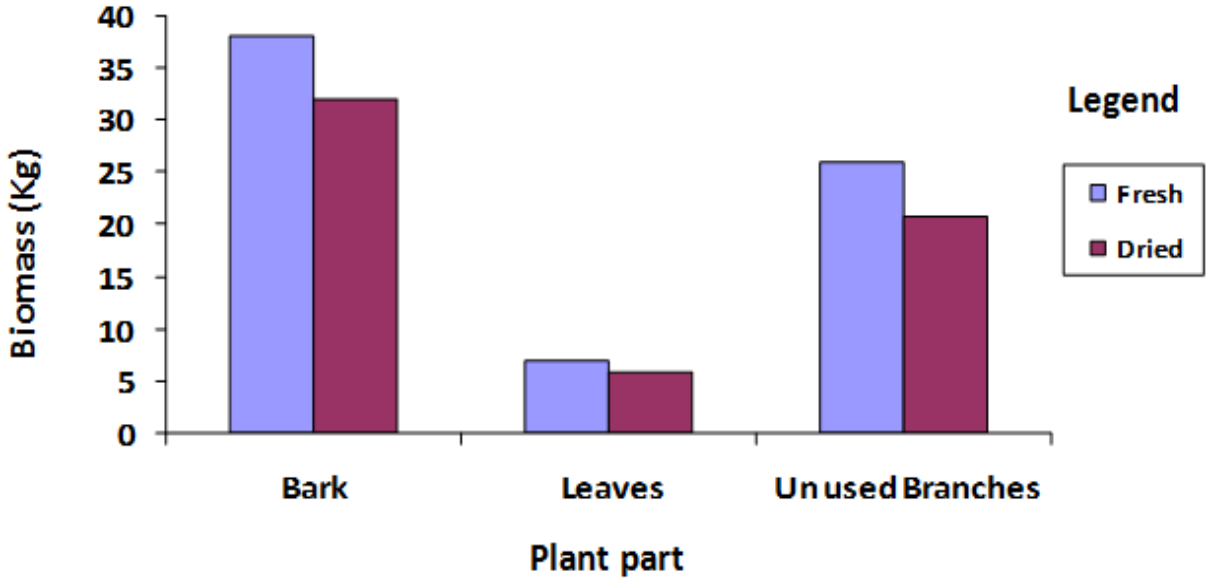

Figure 2. *Biomass by weight generated from an average fell stand of E. camalendulensis in Afaka Forest Reserve, Kaduna*

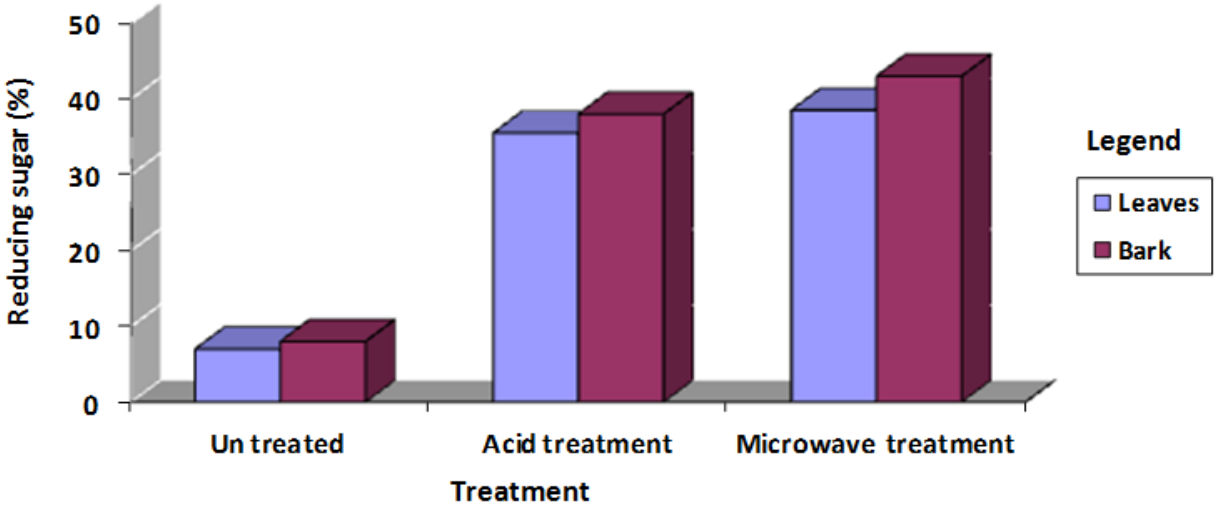

Figure 3. *Percentage yield of reducing sugar from E. camaldulensis waste using different treatment methods.*

Table 1. The volume of bioethanol (g/l) produced from E. camaldulensis biomass using bacteria isolated from soil at Afaka Forest Reserve Kaduna, Nigeria.

		Fermentation days		
Plant part	**Fermenting Organisms**	**7**	**14**	**21**
	B. subtilis	$19.28^{a} \pm 0.02$	$21.13^{a} \pm 0.01$	$25.18^{a} \pm 0.05$
Bark and leaves	*E. coli*	$18.79^{a} \pm 1.10$	$20.09^{b} \pm 0.04$	$22.88^{b} \pm 0.51$
	B.subtilis+ E.coli	$26.18^{b} \pm 0.50$	$27.70^{c} \pm 0.06$	$29.05^{c} \pm 0.02$
	B. subtilis	$21.09^{a} \pm 0.04$	$25.28^{a} \pm 0.07$	$27.82^{a} \pm 0.01$
Leaves	*E. coli*	$19.80^{b} \pm 0.06$	$25.72^{a} \pm 0.07$	$27.28^{a} \pm 0.09$
	B.subtilis+ E.coli	$25.95^{c} \pm 0.04$	$30.58^{b} \pm 0.01$	$33.93^{b} \pm 0.02$
	B. subtilis	$25.84^{b} \pm 0.06$	$27.50^{c} \pm 1.04$	$28.93^{b} \pm 0.05$
Bark	*E. coli*	$25.26^{b} \pm 0.02$	$26.25^{bc} \pm 0.08$	$27.55^{b} \pm 0.09$
	B.subtilis+ E.coli	$31.22^{e} \pm 0.54$	$31.77^{d} \pm 0.41$	$34.89^{c} \pm 0.07$

a,b,c, means within a raw in each plant part with different superscripts are significantly different ($P<0.05$). Values are means ± standard deviation

Table 2. *Percentage concentration of bioethanol produced from E. camaldulensis wood waste biomass at Afaka Forest Reserve Kaduna, Nigeria.*

		Fermentation days		
Plant part	**Fermenting Organisms**	**7**	**14**	**21**
	B. subtilis	$0.13^{a} \pm 0.01$	$0.16^{a} \pm 0.01$	$0.25^{a} \pm 0.02$
Bark and leaves	*E. coli*	$0.12^{a} \pm 0.03$	$0.15^{a} \pm 0.02$	$0.22^{b} \pm 0.02$
	B.subtilis+ E.coli	$0.23^{b} \pm 0.02$	$0.30^{b} \pm 0.02$	$0.39^{c} \pm 0.01$
	B. subtilis	$0.16^{a} \pm 0.01$	$0.25^{a} \pm 0.02$	$0.33^{a} \pm 0.02$
Leaves	*E. coli*	$0.14^{a} \pm 0.02$	$0.23^{a} \pm 0.02$	$0.31^{a} \pm 0.02$
	B.subtilis+ E.coli	$0.27^{b} \pm 0.01$	$0.42^{b} \pm 0.03$	$0.47^{b} \pm 0.01$
	B. subtilis	$0.25^{a} \pm 0.03$	$0.34^{a} \pm 0.02$	$0.38^{a} \pm 0.01$
Bark	*E. coli*	$0.22^{a} \pm 0.03$	$0.32^{a} \pm 0.02$	$0.36^{a} \pm 0.03$
	B.subtilis+ E.coli	$0.42^{b} \pm 0.02$	$0.47^{b} \pm 0.03$	$0.51^{b} \pm 0.02$

a,b,c, means within a raw in each plant part with different superscripts are significantly different ($P<0.05$). Values are means ± standard deviation.

DISCUSSION

The basic structural framework of plants consists of cellulose, hemicellulose, and lignin. The close and complex association between these three lignocellulosic materials causes physical and chemical barriers that have to be broken to release fermentable sugars for bioethanol production. The differences observed in the yield of reducing sugar in microwave and acid pretreatment of *E. camaldulensis* biomass are to be expected. Yields of reducing sugar from lignocellulose biomass processed by different pretreatment methods including microwave irradiation, and concentrated and dilute acids are well documented (Lima *et al.,* 2013; Chaturvedi, and Verma, 2013). Microwave irradiation is known to enhance the digestibility of cellulosic biomass, increase surface area, decrease the degree of polymerization and crystallinity of cellulose, enhance hydrolysis of hemicelluloses, and result in partial depolarization of lignin. This was in contrast to acids which though powerful agents for cellulosic hydrolysis result in the formation of degradation products and release natural inhibitors that affect the yields of fermentable sugars (Nikzad, 2013).

The high volume of bioethanol obtained from bark of *E. camaldulensis* in the present study using B. subtilis + E. coli in synergy at days 21 was higher than the volume of ethanol obtained for other plant biomass such as guinea corn husk (Humphrey, C.N and Caritas, 2007); Sweet potato peels, rice husk (Mohd *et al.,* 2011); and empty fruit branches of palm oil tree ((Deutscher *et al.,*2002). These differences in the volume of bioethanol obtained from the different plant biomass could be associated with the major composition of the various feedstocks in addition to the fermenting organisms involved in the production process. *B. subtilis* and *E. coli* are excellent organisms that are resistant to salt/ toxic inhibitors in addition to being good anaerobic fermenters. According to (Brooks, 2008), *B. subtilis* and *E. coli* are organisms that grow very fast and can utilize pentose (C_5) and hexoses (C_6) including glucose, xylose, mannose, and cellobiose among other simple sugars. They are also reported to possess native hemicellulases. Although both *B. subtilis* and *E. coli* have excellent fermentation ability, *B. subtilis* is reported to produce a larger number of polysaccharide degrading enzymes such as α amylase, pullulanase, endo β-1-4 mannase, levenase, pectate lyases, β-1-4-endogluconase, β- 1.3-1,4-endogluconase, and endo-1,4- β- xylanases. The ability of *B. subtilis* to efficiently break down polysaccharides into soluble carbohydrates was reflected in the relatively high volume of bioethanol produced when these organisms were used individually in the present study.

Conclusion

This study revealed that *B. subtilis* and *E. coli* isolated from soil have great potential in the fermentation of *E. camaldulensis* biomass into bioethanol. The amount (34.89 g/L) of bioethanol produced from 10g of *E. camaldulensis* biomass after 21 days of fermentation using *B. subtilis* and *E. coli* in synergy translates into about 131,884.2g/L of bioethanol derivable from waste generated from an average stand (37.80 kg) of *Eucalyptus spp*. Further studies would however be needed to enhance the performance of these organisms through genetic manipulation of the bacteria to achieve higher yields thus reducing over-dependence on fossil fuel.

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Effect of Agro-Waste (*Arundo Donax* L.) Particles on Physical and Mechanical Properties of Polymer Composites

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Abstract

The dimensional stability and strength properties of Wood Plastic Composites (W.P.C.) produced from *Arundo donax* and recycled high-density polyethylene (RHDPE) were investigated in this study. The stems of the *Arundo donax* plant were milled into particles and thoroughly sieved with wire mesh of size 250 µm and oven-dried to attain a shallow moisture content of 2 per cent at a controlled temperature of 103 ^{o}C for 24 h. The fine particles of *Arundo donax* and plastic were compounded at 1:1, 1:2 and 1:3 (w/w). The W.P.C. samples were treated with a maleic anhydride polyethene coupling agent at a 5% constant proportion. The composite specimens produced were subjected to physical and mechanical properties per ASTM standards. The dimensional properties were investigated, including water absorption, linear expansion and thickness swelling at 24 h. The density, flexural modulus and strength were also determined. The results indicate that there were significant variations among the group at a 5 % level of probability. It was observed that as the proportion of plastic increases to plants, the density and dimensional properties of the boards decrease. Also, in mechanical properties, as the proportion of plastic increases, the modulus of the board increases while the strength decreases. The boards produced in this study were remarkably good in dimensional stability and mechanical properties. They show better utilization strength based on the density relationship to the strength values. Based on this study, agro waste like *Arundo donax* can be used to manufacture wood plastic composite.

Keywords: - *Arundo donax*, Density, Dimensional, Mechanical, Plastic,

INTRODUCTION

Wood-plastic composites (W.P.C.) are biopolymer composites that are made from a combination of wood flour, thermoplastic resin, and chemical additives under specific conditions (Pressure and temperature) (Clemons 2002). W.P.C. is designed as a direct wood substitute in polymer. W.P.C. currently dominates structural and non-structural residential building product market share (Wolcott 2003). The advantages displayed by these products are low moisture absorption, high dimensional stability, low wet/dry traction, good workability, high resistance to decay, termite attack and ultraviolet (U.V.) radiation. The challenges of the products include relatively lower tensile strength and lower stiffness, but most importantly, longer-term creep deformations

and creep rupture properties (Smith and Wolcott 2006). The mechanical and physical properties of W.P.C.s may be engineered to some extent by changing the component characteristics and proportions, compatibilizer type, and fine-tuning the processing parameters (Zabihzadeh *et al*., 2009). Wood as a filler constitutes one of the significant components in the production of W.P.C. and has a direct relationship with the properties of the composites. Wood particles are hydrophilic and incompatible with hydrophobic thermoplastic polymers. The incompatibility between wood and polymer matrix is a significant problem for interfacial adhesion between these two-component materials, which is of critical importance for the mechanical properties of the composite (Bledzki *et al*., 1998; Jiang and Kamdem, 2004).

Many research studies have been conducted on using various wood species and plants to produce W.P.C. (Jayaraman and Bhattacharyya 2004, Gnatowski 2005, Klyosov 2007, Kim *et al*. 2008). Pine, maple, and oak are the most used wood species for commercial W.P.C. production. Preference in selecting wood species for the W.P.C. production was based on regional availability and cost (Kim *et al*., 2008). The availability of wood species can be regionally restricted. Berger and Stark (Berger and Stark 1997) investigated the mechanical properties of P.P. filled with wood flours of different species (ponderosa pine, loblolly pine, maple, and oak). The following properties were measured: Izod impact energy (notched and unnotched), flexural strength and M.O.E., tensile strength and modulus, tensile elongation, mould shrinkage, and heat deflection. The species' effects on the resulting composites' performance were examined. It was concluded that hardwood flours provided an improvement in tensile properties and heat deflection temperature (the temperature at which a polymer or plastic sample deforms under a specified load) over softwood flour; however, ponderosa pine wood flour provides the best overall mechanical property enhancements compared with other species.

It has been noted that the art of making composites is restricted mainly to synthetic polymer and synthetic reinforcing fibres like glass, carbon, and nylon. The potentiality of natural fibre-based composites using other plants, such as jute, kenaf, hemp, sisal, pineapple, coir, etc., as reinforcing fibre in a thermosetting resin matrix has received considerable attention among scientists all over the world because of their excellent specific properties. Some of them have already been used as industrial products. Due to global demand and environmental awareness, plant materials have increased. (Nourbakhsh and Ashori 2010) investigated the use of corn stalks, reed stalks, and oil seed stalks in combination with thermoplastic. It was concluded that with the addition of agro-waste materials, the tensile and flexural properties of the composites are significantly enhanced. Reis *et al*. (2011) supplemented the findings by also studying the mechanical properties of composites using agro-waste materials.

Based on these previous findings, further research is needed to investigate the characteristics of W.P.C. produced from agro waste (*Arundo donax*), which is readily and abundantly available.

MATERIALS AND METHOD

The materials used in this project were *Arundo donax* stems, plastic packaged water bags (known as sachet water), lubricant, an extruder, a hydraulic hot press, and a milling machine. *Arundo*

donax stems were collected from National Horticultural Research Institute (NIHORT) plantations in Ibadan. The stems were cut into smaller pieces and air-dried for 14 days to reduce the moisture content to 12 %. The dried *Arundo donax* stems were milled into fine particles and thoroughly sieved with 1µm mesh. The plastic sachets were collected from dumping sites, washed thoroughly, dried and milled into fine particles using an industrial pulverizing machine available at M.T.N. waste recycling factory at Aleshinloye Market, Oyo-state, Nigeria.

Production of the Experimental Samples

Before sample production, fine particles of *Arundo donax* were further oven-dried at 103 ^{0}C to attain 4 % moisture content. The fine particles of *Arundo donax* and plastic were fed into an extruder at the temperature of 165^{0}C to produce compounded strand W.P.C., which was pelletized and fed into a mould of 200 mm x 200 mm x 6 mm and hot pressed at 145 ^{0}C for 45 minutes. The samples were produced in a combination of plastic/wood ratio of 1:1 (50% + 50%), 1:2 (33.33% + 66.66%) and 1:3 (25% + 75%) (Agro waste: plastic) w/w basis, respectively. After that, the boards were removed and dimensionalized into specific test samples to determine the physical and mechanical properties (ASTM D 790, ASTM D 570, ASTM D 792).

Determination of properties

The weight, thickness and length of samples dimensions 50 mm x 50 mm x 6 mm were subjected to cold water immersion treatment for 24 (hours) respectively. Furthermore, other samples were also subjected to cold water immersion treatment at 20 (^{o}C) respectively. These samples were laid horizontally in water treatment with their surfaces covered with water. After each soak, the sample was drained using dried cloth, and measurements such as thickness, length, and weight were taken before and after immersion to determine the water absorption, thickness swelling, and linear expansion (ASTM D 570). The target density for the board was computed as follows (ASTM D 792). A static bending test was conducted on the sample following (ASTM D790). All data was subjected to descriptive and statistical analysis using analysis of variance (ANOVA) to determine the significant difference among the group at a 5 % probability level. The treatment means were separated using Duncan's Multiple Range Test (DMRT). The experimental design adopted in this study was done in a Completely Randomized Design. Each board produced at mixing ratios of 1:1, 1:2 and 1:3 (agro waste/plastic) was replicated four (4) times.

RESULTS AND DISCUSSION

Physical Properties

The mean values for densities of the boards were 0.78, 0.64 and 0.63 (g/cm^3) for ratios 1:1, 1:2 and 1:3 (fibre: plastic) respectively. These density values agree with the previous findings of other studies by Aina *et al*., (2016), Izekor and Mordi (2014), Aina and Ajayi (2008), Fuwape and Aina (2008), Klyosov (2007) but slightly lower than the values obtained in some studies too. This reason could be attributed to the raw materials used. The variation in the density of W.P.C.

has been reported to be due to particle use and polymer type. The density of the wood or polymer used can affect the density of W.P.C. product (Aina *et al*., 2016; Aina *et al*., 2013; Fabiyi and McDonald, 2010; Fabiyi *et al*., 2009; Fuwape *et al*., 2009). However, the densities of W.P.C. made from wood particles also differ from the density of W.P.C. made from agro waste. These findings also agree with the previous findings of (Aina and Ajayi 2008), who used *Bambusa vulgaris.* It was observed in this study that the densities obtained were high, and this could be the effect of the bulker and higher density of the *Arundo donax* particle after milling. It was observed in Fig. 1 that the boards' densities decreased as the composition's plastic content increased. This shows that the interaction bond between the filler and matrix was more significant in the ratio 1:1 than the others. A close interaction bond between a particle and the binder increased the board's compatibility, leading to a denser board than others. As the binder expands, the fillers gradually lose their compatibility. The mean values of water absorption, thickness swelling, and linear expansion were 4.85, 3.76, 3.37, 0.00, 0.00, 0.00; and 0.07, 0.00, 0.01 in (%) for ratios 1:1, 1:2, and 1:3, respectively.

The values obtained in this study are like those obtained in other studies (Ajigbon and Fuwape, 2015; Fuwape *et al*., 2010; Aina *et al*., 2016; Izekor and Mordi, 2014). It was observed in this study that the water absorption and linear expansion of the boards decreased with an increase in plastic proportion to the agro-waste proportion (Fig. 2 and 3). However, no values were recorded for the boards' thickness swelling. These observations could be a result of plastic in nature being hydrophobic. It resists water and encapsulates the hydrophilic filler, quickly absorbing water. The increase in the proportion of plastic to filler in the composition helps to fill up the available pores. These pores allow water to penetrate the board's matrix on the brand's surface. However, when the pores are filled with plastic, it becomes difficult for the water to penetrate the board. This observation agrees with the previous studies by (Izekor and Mordi 2014, Aina and Fuwape 2008, Fuwape *et al*., 2010, Ajigbon and Fuwape 2015). The result of the variance analysis at a 5% probability level to test for significant differences among the boards produced from different agro-waste/ plastic ratios is presented in Table 1. The results show significant differences in density, water absorption and linear expansion obtained among the boards produced at a 5% probability level. The board made from an agro-waste/plastic ratio of 1:3 had the lowest density value, while the plastic/agro-waste ratio of 1:1 had the highest density value (Fig 1). W.P.C., made from a ratio of 1:1, had the highest values for water absorption and linear expansion, showing that the board at 1:1 could still absorb water more than the others (Figs. 2 and 3).

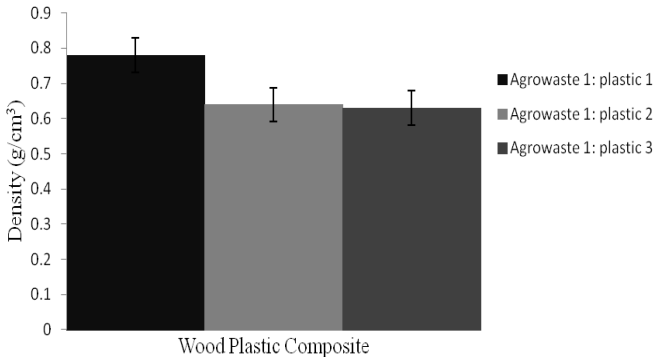

Fig 1: Effect of the Agro-waste: plastic on the density of the wood plastic composites

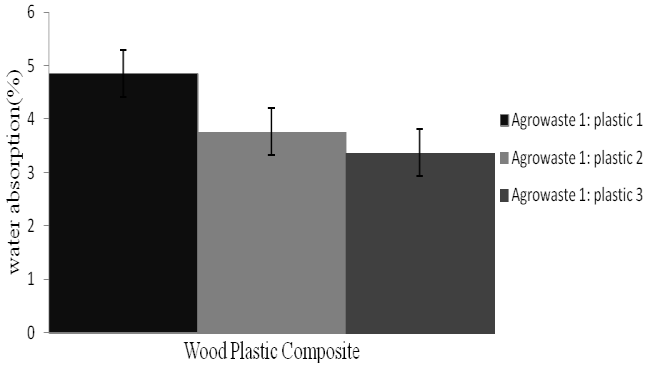

Fig 2: Effect of the Agro waste/plastic on the water absorption of the wood plastic composites

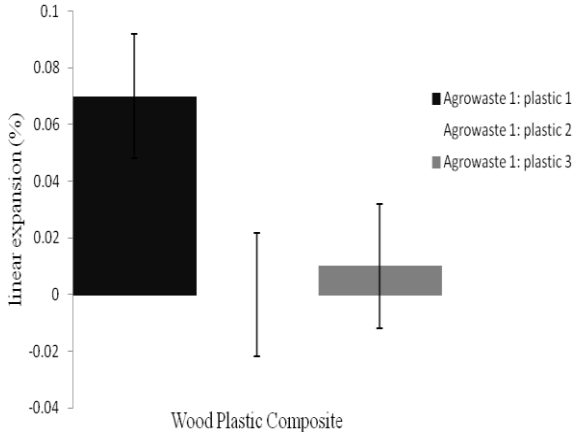

Fig 3: Effect of the Agro waste/plastic on the linear expansion of wood plastic composites

Flexural strength

The mean values of modulus of rupture were 10.09, 7.43 and 6.44 (N/mm^2) for ratios 1:1, 1:2 and 1:3 respectively. The moduli of rupture values obtained in this study are within the same range of values obtained in the previous research by Izekor and Mordi (2014) and Aina and Fuwape (2008). The values

were also smaller than some earlier studies (Wechsler *et al*., 2008; Aina *et al*., 2016; Klyosov, 2007; Stark and Rowland, 2003; Colom *et al*., 2003). It was observed that the modulus of rupture for the boards decreased with an increase in plastic proportion to the agro-waste proportion (Fig 4). This observation might be attributed to the interfacial adhesion between the matrix and the filler. The filler dispersion in the matrix improved the interfacial bond, leading to better stress distribution. As the matrix increases, the filler will be freely loose within the matrix, leading to less restriction to the deformation capacity of the matrix in the elastic zone. This observation agrees with the previous finding by (Yadav and Yusoh 2015). With high plastic proportion to wood, the stress dispersion was not balanced, so the stress distribution was reduced, leading to a decrease in M.O.R. The mean values of the modulus of elasticity of the boards were 3035.50, 5113.00 and 5291.00 (N/mm^2) for ratios 1:1, 1:2 and 1:3, respectively. The value obtained agrees with other studies by 9Izekor and Mordi 2014, Behzad 2012). These values were still higher than those obtained in some studies (Wechsler et al., 2008; Klyosov, 2007; Stark and Rowland, 2003). It was observed that the modulus of elasticity of the boards increased with an increase in plastic to the agro-waste (Fig 5). This might be attributed to the filler used in this study. As the filler proportion increases, the interrelationship bond increases with less stress concentration within the matrix. The reaction will enhance the strength but also affect the board's rigidity. This observation agrees with previous findings by (Kim *et al.*, 2008, Stark and Rowland 2003, Chen *et al*., 2006, Adhikary 2008, Ajigbon and Fuwape 2015). (Ayrilmis *et al*., 2013) reported that an improvement in the elastic proportion of the boards could be due to the power of the adhesion bond between the filler and reinforcement.

The result of the analysis of variance conducted at 5% probability level to test for significant differences among the boards made from the agro waste/plastic is presented in Table 1. Table 1 shows a significant difference among the boards produced at a 5% probability level (Table 1). The board with agro waste/plastic 1:1 had the best strength than the others (1:2 and 1:3). Still, these two ratios were not significantly different to each other (Fig 4), meaning they are not different to each other in terms of strength either of the two can be used to replace one another. The result of the analysis conducted at 5% probability level to test for significant differences among the modulus of elasticity of the boards made from the agro waste/plastic is presented in Table 1. The results show a significant difference among the boards made at different ratios at a 5% probability level (Table 1). The board made from an agro-waste/plastic ratio of 1:1 had the lowest value, while an agro-waste/plastic ratio of 1:3 had the highest value of modulus of elasticity (Fig 5).

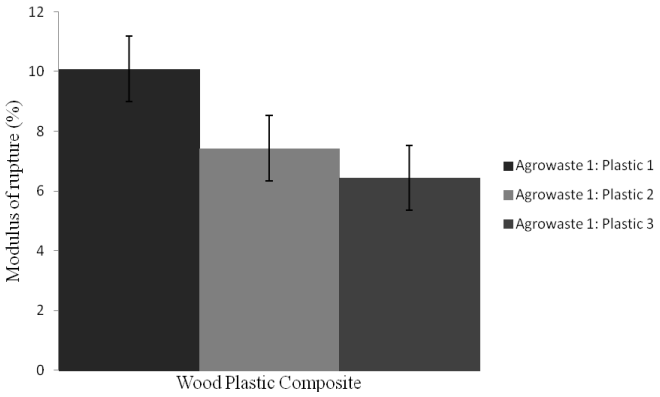

Fig 4: Effect of the Agro-waste/plastic on the modulus of rupture of the wood plastic composites

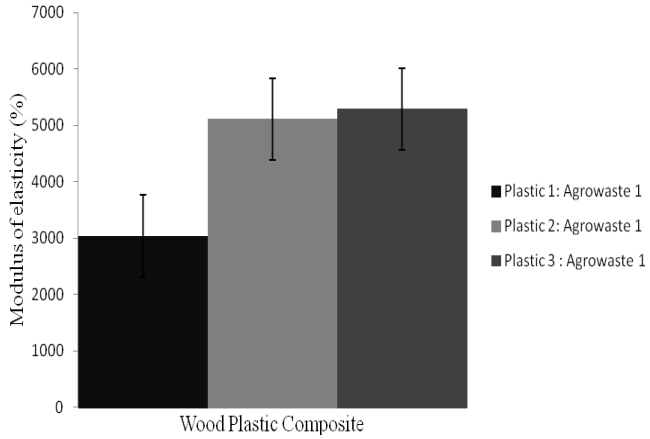

Fig 5: Effect of the Agro-waste/plastic on the modulus of elasticity of the wood plastic composites

Table 1: Result of analysis of variance conducted for physical properties of the wood plastic composite

Source of variance	Df	Physical properties						Mechanical properties			
		Density (g/cm^3)		Water absorption (%)		Linear expansion (%)		Modulus of rupture (N/mm^2)		Modulus of elasticity (N/mm^2)	
		F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.
Between Groups	2	87.573	0.000*	87.573	0.000*	86.000	0.000*	35.174	0.000*	12.320	0.003*
Within Groups	9										
Total	11										

*Means significant (P≤0.05) level of probability

CONCLUSION

Wood plastic composites were successfully produced from particles of *Arundo donax* at a fibre/plastic ratio (1:1, 1:2 and 1:3). The mixing proportions of fibre/plastic influenced the characteristics of the W.P.C. products from this agro waste. As the plastic proportions increased, there was a significant improvement in the properties, except for density and modulus of rupture. From this research work, it can be concluded that the particles of *Arundo donax* and recycled plastic were suitable for producing W.P.C. items. However, W.P.C.s produced from this agro waste performed well in load application and dimensional stability.

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COMPOSITION OF BIOGAS FROM COW DUNG AND EUCALYPTUS (*Eucalyptus camaldulensis. Dehnh*) WASTE

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ABSTRACT

Concerns about climate change, global warming, and the growing price of conventional fuel make it necessary to look into alternative, affordable, sustainable energy sources, particularly in Nigeria's Sudano-Sahelian area. One of the most abundant tree species in the area is Eucalyptus, which produces CO_2 when its leaves burn after they fall every day and litter the surroundings. Hence, a study was carried out on biogas production using cow dung, eucalyptus wastes and a mixture of cow dung/Eucalyptus to evaluate biogas composition produced from different substrates. Utilizing locally manufactured digesters (10 L plastic buckets), slurries were created with varying ratios of waste to water (cow dung 3 kg: 3000 cm^3, eucalyptus 1 kg: 5000 cm^3, and mixed (2 kg: 4000 cm^3). Anaerobic digestion was carried out in a digester that was fed each sample. The biogas generated was gathered into 1000cm^3 urine bags, one for each substrate. The NDIR Gas Analyzer was then used to determine the proportion of various gases, including CO, CH_4, H_2, and CO_2, and the corresponding caloric values of each substrate. The methane content and caloric value of the Eucalyptus, a combination of cow dung and Eucalyptus, and cow dung were found to be 7.34 /249.58 KJ/m^3, 5.94 /125.98 KJ/m^3, and 5.92 /124.60 KJ/m^3, respectively. Throughout the time, weekly temperatures were reported between 29.1 ^oC and 32.1 ^oC. According to this study, biogas made from Eucalyptus have a significantly greater methane content and caloric value than those made from cow dung or a combination of cow dung and Eucalyptus.

Keywords: *Eucalyptus camaldulensis*, composition, biogas, cow dung.

INTRODUCTION

Climate change, environmental degradation, and global human health problems are caused by using fossil fuels as a primary energy source (Adeniran *et al.*, 2014). Improper waste management is also one of the significant problems confronting every development. This is due to an increase in industrial, commercial, agricultural and environmental activities, which has resulted in the generation of large quantities of waste (Adeniran *et al.*, 2014). When improperly managed, these wastes contribute to unhygienic environmental conditions that breed pathogenic microorganisms (Ogbene *et al.*, 2019). Apart from the health implications, wastes make an environment unpleasant and unattractive. However, these wastes can be adequately managed by conversion into practical and more environment-friendly forms called biogases. Biogas is a gas

that breaks organic matter without oxygen (Anunputtikul and Rodtong, 2004). It is a renewable energy source, like solar and wind energy. Furthermore, biogas can be produced from regionally available raw materials and recycled waste, and it is environment-friendly and carbon IV oxide (CO_2) neutral. Biogas is produced by the anaerobic digestion or fermentation of biodegradable materials such as manure, sewage, municipal waste, green waste, plant material, and crops (Kigizi *et al*., 2014).

Biogas is a flammable gas produced when organic materials are fermented under anaerobic conditions. It contains methane and carbon (IV) oxide with traces of hydrogen sulphide and water vapour. It burns with a pale blue flame and has a calorific value of 25.9-30J/$m^{3,}$ depending on the percentage of methane in the gas. The gas is also known as dung, marsh, gobar, sewage, and swamp (Sagagi *et al.*, 2009). In biogas production, the conversion of complex organic matter to methane and carbon dioxide is possible mainly by the actions of different groups of microorganisms, with the microbial community of biogas comprised essentially of bacteria and fungi and other groups of protozoan (Idi *et al.,* 2020) The essential microbial complex is comprised of hydrolytic bacteria, fermenting bacteria, acetogenic bacteria and methanogenic bacteria and these groups of microorganisms have been reported to establish synthrophic relationships where the later members of the food chain depend on the previous for their substrate but may also have significant metabolic products (Arinze *et al*., 2005).
A non-dispersive infrared sensor (NDIR sensor) is a simple spectroscopic sensor often used as a gas detector. It is non-dispersive in optical dispersion since the infrared energy can pass through the atmospheric sampling chamber without deformation. The main components of an NDIR sensor are an infrared source (lamp), a sample chamber or light tube, a light filter and an infrared detector. The IR light is directed through the sample chamber towards the detector. In parallel, another chamber with an enclosed reference gas, typically nitrogen. The gas in the sample chamber causes absorption of specific wavelengths according to the Beer-Lambert law, and the detector measures the attenuation of these wavelengths to determine the gas concentration. I.e. The gas is pumped (or diffuses) into the sample chamber, and gas concentration is measured electro-optically by its absorption of a specific wavelength in the infrared (IR). The detector has an optical filter that eliminates all light except the wavelength that the selected gas molecules can absorb. (Korotcenkov, 2013)

Eucalyptus camaldulensis. Dehnh is widely planted as an exotic in many parts of Nigeria. It is the most grown tree species in semi-arid and arid environments. *It is a solid, durable, and valuable timber that can be used for various purposes.* Much attention has been focused on biomass from grass. However, *Eucalyptus* species is one of the most promising types of cellulose feedstock for biogas production due to its high cellulose content (Galbe and Zacchi 2007). In addition, these biomasses do not form human and animal food sources. In Nigeria, it is primarily grown to produce fuel wood, poles, and posts, and it is also in mixture with other tree species such as *Azadirachta indica* (Neem) for the establishment of shelterbelts. (Midgley *et al.,* 1989). In this study, an analysis was carried out to determine the percentage of CH_4 and other unwanted gases in the biogas. The volume of biogas produced from different substrates (Cow dung, Eucalyptus) and cow dung/eucalyptus mixture were also compared.

METHODOLOGY

Samples Collection

Cow dung was collected in a clean bag from the Kofar market area of Sokoto and transported to Sokoto Energy Research Center, Usmanu Danfodiyo University Sokoto, Nigeria—E*ucalyptus camaldulensis. Dehnh* waste was collected in a clean bag from Savanna Forestry Research StationSamaru–Zaria, Kaduna State and transported to Sokoto Energy Research Center, Usmanu Danfodiyo University Sokoto, Nigeria, where it was dried under the sun for seven days and pulverized into powder using mortar and pestle (Galbe and Zacchi 2007).

Pretreatment of Eucalyptus Waste

The ground powdered sample of the Eucalyptus waste was put in polythene bags and buried underground for 14 days (Nnaji 2015).

Preparations of Slurry

Three thousand grams (3000 g) of fresh cow dung was mixed with 3000 ml of water in a ratio of 1:1. The mixture was agitated thoroughly. One thousand grams (1000 g) of pulverized Eucalyptus was mixed with 5000 ml of water in a ratio of 1:5. For the mixture, one thousand five hundred grams (1500 g) of fresh cow dung and five hundred gram (500 g) of pulverized Eucalyptus was mixed with 4000 ml of water in a ratio of 2:4. All were agitated thoroughly and transferred into separate digesters (10 litters) and tightly covered with silicon sealant and araldites to create anaerobic condition. Each sample was replicated three times (kigozi *et al.* 2014), (Sagagi *et al.,* 2009) and (Akhator *et al.,* 2016). pH records of the slurries were also taken before and after digestion.

Non-Dispersive IR Gas Analysis

Biogas samples (4000cm^3) were collected using two urine bags (2000cm^3) that were connected to two separate digesters for each of the three samples and were taken to the Department of Chemical Engineering, Ahmadu Bello University, Zaria, for NDIR analysis using a Gas Analyzer (Gasboard-3100P). The analyzer measured the concentration of CO, CO_2, CH_4, H_2 and O_2 in the sample simultaneously and calculated caloric value automatically. Gas analysis was carried out according to the manufacturer's instructions. The biogas sample was pumped into the sample chamber, and gas concentration was measured electro-optically by absorption of a specific wavelength in the infrared (IR). The IR light was directed through the sample chamber towards the detector. The detector has an optical filter that eliminates all light except the wavelength the selected gas molecule can absorb. Ideally, other gas molecules do not absorb light at this wavelength and do not affect the amount of light reaching the detector. The detector measures the attenuated signal depending on the amount of gas absorption and is proportional to the measured gas concentration (Barati, 2017) (Rajaefar *et al.*, 2017).

Statistical analysis

Urine bags were used to collect the biogas produced from the three distinct substrates, and the formula for square root transformation was used to modify the data.

$Y^1=\sqrt{Y}+0.5$ (Steel and Torrie 1960).
Where
Y^1= Transformed data
Y= Original data and 0.5= Constant.

Transformed data was then subjected to ANOVA using SAS Statistical software. Mean differences for a percentage of gases in the biogas produced were separated using the least significant difference (LSD) at a 5% level. The correlation coefficient was also carried out to ascertain the relationship among the different compositions of gases from the biogas produced. We were using pea sin's correlation coefficient.

RESULTS AND DISCUSSION

When biogas is made from cow dung and Eucalyptus and mixed, many gases are produced; they may be measured using a gas analyzer (Gasboard-3100P) that can detect only five different gases, and these include CO, CO_2, CH_4 and H_2 as shown in table 1. Biogas generated from Eucalyptus leaves recorded the highest methane content (7.34), followed by a mixture of the two substrates (5.94), and then cow dung (5.92), which shows there is a significant difference in the methane content produced from the different substrates used. This agrees with the work of (Joao *et al.,* 2011). These could be due to the nature and composition of Eucalyptus species. The gas analyzer (Gasboard-3100P) also measured the calorific value of the biogas.

Table 1: Mean values for the percentage of some gases in the biogas produced.

Treatment	CO	CO_2	CH_4	H_2
Cow dung	0.73b	3.24c	5.92c	0.99b
Eucalyptus	0.87a	3.46a	7.34a	0.71c
Mixture	0.71c	3.37b	5.94b	1.27a
SED±	0.003	0.003	0.001	0.005
LSD	0.0080	0.0066	0.0034	0.0124

Means followed by the same letter(s) within the same treatment column are not different statistically at *P=0.05* level of probability using LSD.

Table 2. Correlation values for CO, CO_2 and CH_4 have a (+VE) sign, which shows that values of these gases from the biogas increase simultaneously, while values for H_2 with a (–VE) sign show that it decreases when the other gases increase.

Table 2: **Correlation matrix of biogas composition as affected by different substrates.**

Biogas	CO	CO_2	CH_4	H_2
CO	1.0000			
CO_2	0.72442*	1.0000		
CH_4	0.98915**	0.81472**	1.0000	
H_2	-0.92339**	-0.40798^{NS}	-0.86160**	1.0000

NS = r-value not significant N = 9
*= r-value significant at ($P \leq 0.05$) Df = N-2 = 7
**= r-value significant at ($P \leq 0.01$)

The caloric values for the biogas from different substrates using a Dashboard 3100p analyzer are shown in Table 3. This indicates a higher heating value from biogas produced from *Eucalyptus camaldulensis. Dehnh.* (249.58KJ/m^3) and lowest from Cow dung (124.60KJ/m^3). Eucalyptus leaves contain highly nutritious, rich organic substances suitable for sustaining microbial life in an anaerobic fermentation process, transforming substrates into biogas. These results were following the work of Joao *et al.* (2011). The high caloric value is due to the high methane content from Eucalyptus's biogas, which shows the potentiality of biogas generated from Eucalyptus leaves as a cooking gas.

Table 3: Caloric Values of Biogas Production from the Substrates

Sample	Caloric value (KJ/m^3)
Cow dung	124.60
Eucalyptus	249.58
Mixture	125.98

pH of the sample is another factor that affects biogas production. pH value is paramount, especially during digestion, to provide an environment for biogas production. Table 5 shows the pH values before and after the substrate samples. However, the optimum pH range for biogas production has been reported as 6.0 – 7.8 before digestion and 5.6 – 7.8 after digestion. (Garba and Sambo 1992). Based on this, the results of pH, as shown in Table 5 above, indicate that the samples used in this research had pH, which provides a favourable environment for effective bio-digestion of the substrate. The pH values agreed with the work of Garba and Sambo (1992).

Table 4: pH values of the substrates

Samples	Before digestion	After digestion
Cow dung	7.12±0.01	5.14±0.01
Eucalyptus	7.83±0.01	6.73±0.01
Mixture	6.71±0.01	5.79±0.01

Results are mean of triplicate ± SD

CONCLUSION AND RECOMMENDATIONS

Conclusion

Results from Non-Dispersive IR (ND-IR) analysis revealed high methane content and caloric value from Eucalyptus (7.34) (59.65Kcal/m^3) and least from cow dung (5.92) (29.78Kcal/m^3). Significant CH4 differences among the three substrates revealed the quality of biogas generated from leave litters of *Eucalyptus camaldulensis. Dehnh.* pH of the substrates recorded were within the recommended value of 6.0 – 7.8 before digestion and 5.6 – 7.8 after digestion. This has proven the noble potentiality of the said plant as a source of biogas, which has not been well exploited in the study area.

Recommendation

The use of biological waste materials is receiving attention for their effectiveness in biogas production because of less or zero carbon emission. Therefore, based on this research, the following further works are recommended:

1. Research on the applications of biogas produced by the substrates.
2. Large-scale production of efficient digesters, cylinders, and burners for domestic activities
3. Similarly, based on the observations and encouraging results from this research, the use of Eucalyptus wastes for biogas generation should be given more attention in areas where the wastes are abundant.

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Unlocking the Green Potential: A Comprehensive Exploration of Innovations in Sustainable Wood Waste Utilization for a Greener Tomorrow

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ABSTRACT

This study delves into sustainable wood waste utilization, highlighting environmental implications. Addressing industry-generated wood waste, it advocates judicious forest resource management. Wood, a vital resource, yields significant residues—sawdust, wood chips, bark, and shavings. Focusing on sustainable strategies, the exploration transforms wood waste into goods—engineered wood products, energy, mulch, and animal bedding. Scrutinizing practices from recycling to pyrolysis, the analysis evaluates wood waste's role in bioenergy production, emphasizing contributions to the green economy. Results showcase recycled wood integration in construction materials, highlighting structural integrity. Case studies unveil sustainable wood waste utilization models, and the regulatory framework proposes enhancements. Examining economic viability considers cost-effectiveness, employment, and market dynamics. The conclusion outlines challenges, envisions prospects, and underscores the research imperative. Recommendations emphasize global agenda advancement through sustainable wood waste utilization, aligning with the green economy.

Keywords: Wood waste, sustainability, bioresources, recycling, green economy.

INTRODUCTION

Wood, a natural product, boasts renewable, biodegradable, mechanical, and thermal advantages. It undergoes processing in various wood industries—sawmills, plywood mills, furniture, pulp and paper, and particleboard mills (Mijinyawa et al. 2010). It contributes to materials for farming tools, building, fuel, weapons, construction, and energy generation. Wood's versatility extends to crafting tool handles, sports equipment, weaving tools, utensils, and toys (Sekumade & Oluwatayo, 2011). Wood waste emerges as byproducts from forestry, wood, and construction activities. Originating from wood packaging, demolition, construction, and other sources like households and railway projects (Van Bethem et al. 2007), sawmills generate the highest wood waste volume during log processing. Factors influencing this production include log diameter, saw type, product specifications, and worker skill. Wood waste includes sawdust, off-cuts, trims, slabs, shavings, bark, and split wood (Figures 1-3). Sawdust results from cutting, sizing, and

edging, while trims and shavings follow trimming and smoothing processes (Stecher et al., 2013).

Urbanization significantly contributes to increased wood waste, stemming from the disposal of unwanted wood in construction, demolition projects, or urban and transition areas between urban and traditional forests (forest interface areas). Urban wood waste is typically used in low-value products like mulch or firewood (Brashaw et al. 2012). Sustainable wood waste utilization involves employing wood briquettes as firewood substitutes, utilizing wood waste for industrial energy, employing bark in adhesives and foam production, and creating medium-density fiberboard and engineered wood products from locally generated wood waste. These practices hold the potential for economic growth and sustainable development, stimulating interest in their management (Ogunwusi, 2014). Following separation, cleaning, and processing, wood waste finds diverse applications, serving as feedstock for engineered woods, landscape mulch, soil conditioner, animal bedding, compost additive, sewage sludge bulking medium, and boiler fuel (Stewart et al. 2012).

Figure 1: Wood bark

Figure 2: Wood off-cuts

Figure 3: Wood shavings

CATEGORIES OF WOOD WASTE:

Wood waste categorization involves two classes: avoidable and unavoidable wastes. Unavoidable wastes, like sawdust, slabs, wanes, and bark, cannot be prevented. In contrast, avoidable wastes arise from inadequate saw maintenance, improper sawing, and a lack of proper log impaction before sawing, highlighting operational inefficiencies (Lucas, 1995). Wood waste was identified in categories in selected sawmills, differentiating between those generated within wood-based plants during conversion and those from timber harvesting and transportation (Gawali et al. 2022). Another classification, based on Grade A, Mixed, and Low Grade, defines wood waste quality. Grade A has minimal contaminants, while Mixed Grade contains significant contaminants in low quantities. Low-grade comprises contaminated wood with tar and other chemicals (Owoyemi et al. 2016).

SOURCES OF WOOD WASTE:

Primary wood waste sources include forests during timber harvesting and wood industries during processing. Wood waste generated from sawmills, furniture industries, and plywood industries includes sawdust, wood backs, plain shavings, wood rejects, off-cuts, sander specks of dust, wood chips, and veneer wastes (Ogunwusi & Jolaoso, 2012; Cambero & Sowlati, 2014).

Table 1: Sources of wood and the types of residues generated

S/N	Source	Type of Residue
1.	Forest operations	Branches, needles, leaves, stumps, roots, low Grade and decayed wood, slashings and sawdust
2.	Sawmilling	Bark, sawdust, trimmings, split wood, planer shavings, sander dust
3.	Plywood production	Bark, core, sawdust, veneer clippings and waste, panel trim, sander dust
4.	Particle board production	Bark, screening fines, panel trim, sawdust, sander dust

WOOD WASTE UTILIZATION:

Wood waste finds sustainable applications, minimizing environmental pollution. It is used in producing wood-based insulation materials, chemicals, medicines, and essential products such as tannins, adhesives, quinine, flavouring, aphrodisiacs, antibiotics, and latex materials sourced from bark extracts (Metsämuuronen et al. 2019). Wood waste, including sawdust and wood shavings, serves as animal bedding for poultry, while wood chips provide clean and comfortable enclosures for livestock (Ahn et al., 2020). Slabs are sold as firewood in local markets for sustainable livelihoods (Holding et al. 2006).

Engineered Wood Products, created from glued-together wood pieces, offer versatile applications, with Medium Density Fibreboard (MDF) being a crucial raw material for superior products (Pandey, 2022). Briquettes and wood pellets, derived from wood waste, are used in household cooking, water heating, ceramics, clayware firing, and energy production (Aiyeloja et al., 2013). Wood waste contributes to alternative daily landfill covers, biofuels, and wood-based composites (Ogunwusi, 2014).

EFFECTS OF SUSTAINABLE WOOD WASTE UTILIZATION:

Wood waste management influences environmental outcomes, presenting both positive and negative effects. Improper disposal pollutes aquatic and terrestrial ecosystems, leading to fire hazards and potential flooding during the rainy season (Owoyemi et al. 2016). Additionally, wood waste burning emits green gases, posing health risks such as respiratory infections and skin issues (Naeher et al. 2007). Exposure to wood dust, especially in specific industries, increases the risk of adenocarcinoma, a rare nasal cancer (Vallières et al., 2015). However, when well-utilized, wood waste contributes to economic growth, wealth creation, and employment while preventing open burning, deforestation, and climate change (Akhator et al. 2017).

FACTORS LIMITING WOOD WASTE UTILIZATION:

Several factors hinder wood waste utilization, including the lack of incentives, knowledge, technological know-how, vertical and horizontal integration, and insufficient information on economic benefits. Poor enforcement of environmental regulations and the absence of wood waste management policies further impede progress (Pandey, 2022).

CONCLUSION AND RECOMMENDATION:

Sustainable wood waste utilization aligns with sustainable development goals, addressing household energy needs. Effective management diminishes environmental and health impacts, reducing air pollution, respiratory infections, and river contamination. Implementing policies and incentives to encourage wood waste utilization and prevent indiscriminate disposal is crucial for long-term success. Government and forestry stakeholders must collaborate to promote the efficient use of sawmill wood wastes, fostering economic development and environmental cleanliness.

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***Theme:** Promoting Innovative Research in Forestry Sector: Prospects and challenges*

ASSESSMENT OF CHARCOAL PRODUCTION IN TORO LOCAL GOVERNMENT AREA OF BAUCHI STATE, NIGERIA

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Abstract

Charcoal is one of Nigeria's cheapest fuel sources for small to middle-income households. This study examined charcoal production in the Toro Local Government Area. Four communities (Toro, Magama, Tulu and Rishi) were selected based on information from the State Charcoal Dealers Association. Thirty questionnaires were administered. The data obtained were analyzed using descriptive and inferential statistics. The results revealed that among 435 tree species identified to produce charcoal in the study area, *Anogeissus leiocarpus* had the highest percentage of 16.10 followed by *Detarium microcarpum* (8.90%) and *Diospyros mespiliformis* (7.90%). The results further revealed a strong positive correlation between the respondents and charcoal production as a sustainable business. The results observed that one of the significant challenges of charcoal production was the non-selective harvest of tree species. Almost 84% of the producers depend on either government or community forests as their source of wood. It is therefore recommended that charcoal producers, through their association and other stakeholders, should invest in private woodlot plantations to ensure the sustainability of the business, as other alternative sources of fuel are too expensive, especially for the lower and middle-class households in the area.

Keywords: charcoal; fuel wood; tree species; savanna

Introduction

Tree biomass is the principal source of fuel wood in rural communities. About 13% of the world's primary energy is from the forest. People in the world's developing countries derived at least 90% of their energy requirement from wood and charcoal (Fuwape and Akindele 1997). The increase in population and industrialization in some developing countries has resulted in a scarcity of indigenous tree biomass and fuel supply. Many forest resources have been destroyed through excessive forest exploitation for timber, pulp, firewood, and charcoal. Fuwape (2001) and Klasnja *et al.* (2002) asserted that there is no feasible alternative to wood as an energy source in some underdeveloped and developing African and Asian countries. The central role of fuel wood in the domestic energy budget is primarily due to socio-economic reasons, which include low income, large family size, high cost of alternative sources of energy, etc. The solution to fuel wood crises in some African, Asian countries and Latin American countries lies in afforestation and reforestation (Tella and Fuwape, 2005).

Fuel wood management has motivated the calculation of biomass equations, whereas timber management has mainly driven volume equations. Today, the accurate estimation of forest

biomass is crucial for many applications, from the commercial use of wood to the global carbon cycle (Bombelli *et al.*, 2009). Almost all charcoal is produced in rural areas, especially in forested areas surrounding the urban centres, and it contributes significantly to the deterioration of the environment, resulting in increased carbon dioxide in the atmosphere (Tunde *et al.*, 2013). The growing demand for charcoal has resulted in deforestation in vulnerable areas (Salau and Keshinro, 2015). To improve the availability of wood and reduce deforestation due to over-exploitation of forests, especially in rural and semi-urban areas, there is a need to identify the common tree species used, the method of harvesting and the size of the wood being harvested. The main objectives of this study were to identify common tree species used for charcoal production, assess the demographic characteristics of charcoal producers, and determine the prospects and challenges of charcoal production in the study area.

Materials and Methods

Study area

This study was conducted in four (4) Toro Local Government Area communities of Bauchi State: Rishi, Tulu, Toro and Magama (Figure 1). Toro is topographically hilly and located on a latitude 10º11′48″ N – 10º32′59″ N and longitude 8º55′3″ E – 9º33′34″ E (fig.4). It has generally favorable weather with temperature ranging from 21ºC (69.80 ºF) to 32 ºC (89.60 ºF) and average annual rainfall of 820.7mm. Toro Local Government occupies a total land area of about 6,932 km^2. The Local Government has a population of 486,100 as of 2016 (Thomas, 2017) with a growth rate of 3.6%, and the projected population is about 503,600 people in 2019 (NPC, 2006). Most people in the study area are farmers growing food crops such as maize, guinea corn, rice, sweet potatoes, cassava, etc.

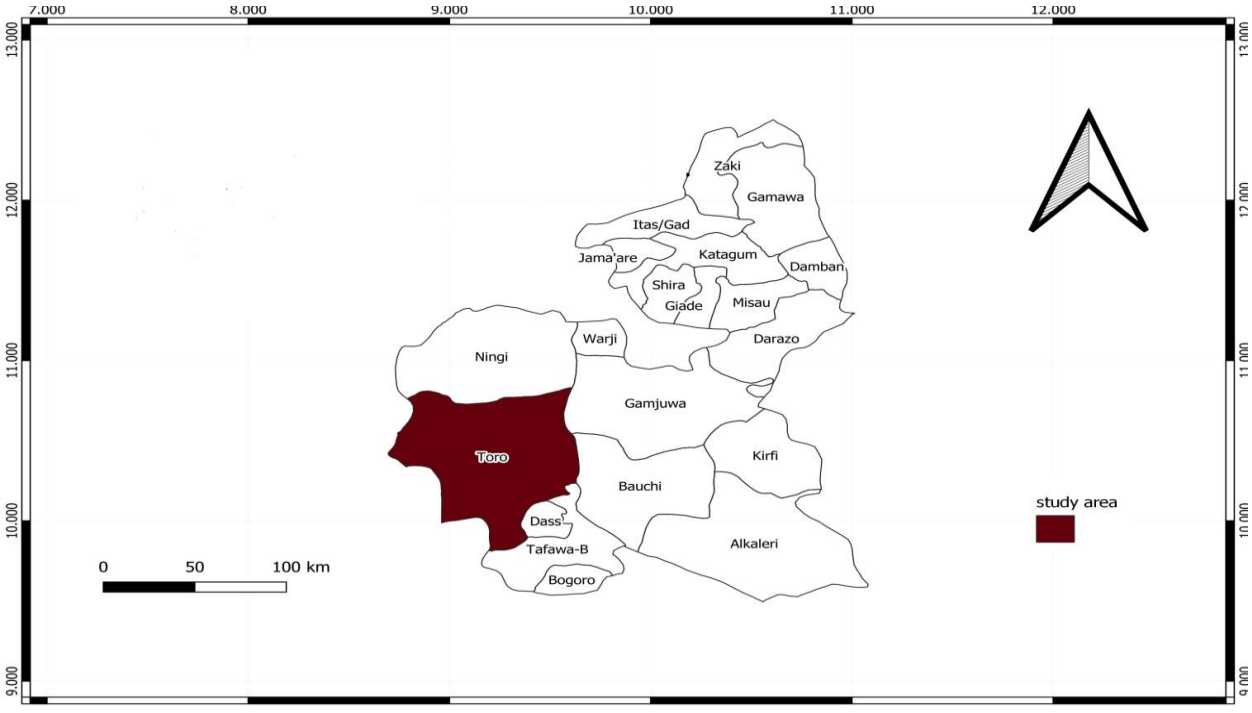

Figure 1: Map of Bauchi State showing Toro LGA (Study Area)

Method of data collection

Questionnaire design

A reconnaissance visit was conducted in the study area to familiarize and interact with the charcoal producers. Questionnaires were developed to assess information about the tree species used for charcoal production in the study area. Four communities were selected, and thirty (30) questionnaires were administered to each community. The respondents were selected through the Charcoal Dealers Association in the State. The questionnaire was open- and closed-ended and administered face-to-face and paper-and-pencil methods.

Data analysis

Descriptive statistics and chi-square were used to summarize the data obtained from the respondents. The demographic characteristics of the respondents, dbh and height classes of tree species, and part of the trees used for charcoal production were also assessed.

Results

Tree species used for charcoal production

A total of 483 trees distributed among 30 species and 13 families were encountered using a questionnaire in the study sites. The proportion of the trees varies significantly across the communities of the study area. Toro had the highest number of trees (156), followed by Rishi (138), whereas Tulu had the lowest number of trees (56). Among the tree species identified, *Anogeissus leiocarpus* was the most dominant tree species found in all the communities, followed by *Detarium microcarpum*, which was also evenly distributed among the Toro Local Government of Bauchi State communities. Other tree species are site-specific, but they are essential for charcoal production.

Table 1: Tree species used for charcoal production

Family	Tree species	Freq.	Percentage
Anacardiaceae	*Lannea microcarpa*	17	3.50
Combretaceae	*Anogeissus leiocarpus*	78	16.10
	Combretum nigricans	10	2.10
	Guiera senegalensis	13	2.70
Chrysobalanaceae	*Parinari macrophylla*	6	1.20
Ebenaceae	*Diospyros mespiliformis*	38	7.90
Fabaceae	*Acacia albida*	7	1.4
	Acacia nilotica	8	1.70
	Albizia chevalieri	4	0.80
	Albizia lebbeck	2	0.40
	Andira inermis	4	0.80
	Burkea Africana	19	3.90
	Daniellia oliveri	11	2.30

	Detarium microcarpum	43	8.90
	Entada Africana	18	3.70
	Isoberlinia doka	15	3.10
	Parkia biglobosa	5	1.00
	Piliostigma reticulatum	11	2.30
	Prosopis africana	28	5.80
	Pteracarpus erinaceus	25	5.20
	Acacia sieberiana	14	2.90
	Tamarindus indica	5	1.00
Lamiaceae	*Vitex doniana*	2	0.40
Meliaceae	*Azadirachta indica*	21	4.30
Moraceae	*Ficus trichopoda*	12	2.50
Myrtaceae	*Syzygium guineense*	26	5.40
Rhamnaceae	*Ziziphus spina-christi*	10	2.10
Sapotaceae	*Vitellaria paradoxa*	10	2.10
Ulmaceae	*Celtis integrifolia*	10	2.10
Zygophyllaceae	*Balanites aegyptiaca*	11	2.30
Total		**483**	**100.0%**

Demographic characteristics of the charcoal producers

The demographic characteristics revealed that out of 120 respondents interviewed, 105 were males, while only 15 were female. Most charcoal producers in the study area fall between 20 – 40 and 41 – 60 years. Business and farming formed the principal primary and secondary occupation of the charcoal producers, sixty-four (64) and fifty-three (53) respondents with business and agriculture as the Primary occupation, while fifty-two (52) and fifty-one (51) respondents were Businessmen/women and Farmers as Secondary occupation respectively. The educational status of the respondents revealed that 48 respondents had primary education, only 35 had secondary education, and only 10 attained tertiary education. The respondents' family size comprised 299 total adult males, 286 total number of adult females and 254 total numbers of children.

Table 2: Distribution based on the Demographic characteristics of the respondents

Variable	Classes	Freq.	Percentage (%)
Gender	Male	105	87.50
	Female	15	12.50
Age group	<20 years	2	1.67
	20 – 40 years	57	47.50
	41 – 60 years	59	49.17

	Over 60 years	2	1.67
Edu. Status	No formal Edu.	26	21.67
	Primary Edu.	48	40.00
	Secondary Edu.	35	29.17
	Tertiary Edu.	10	8.33
	Adult Literacy	1	0.83
Pri. Occupation	Farming	53	44.17
	Business	64	53.33
	Students	3	2.50
Sec. Occupation	Farming	51	42.50
	Business	52	43.33
	Others	17	14.17
Household size	No. of Adult male	299	35.64
	No. of Adult female	286	34.09
	No. of children	254	30.27

Prospects and Challenges of Charcoal Production

The results of why the respondents were into charcoal production showed that about 75% of the respondents considered charcoal production a business. In contrast, only a low proportion (8%) of the respondents thought it was an avenue to earn a living. The quantity and price of charcoal produced per plant range between 11 – 15 bags and 1000 – 1200 NGN, respectively.

The results also revealed the forest ownership where charcoal is obtained; community forests accounted for 40.83%, community and government plantations 55.83, while private forests accounted for only 1.17%. Another prominent challenge in charcoal production is the part of the plant used to make charcoal; tree stems and branches accounted for 35.83%, shrub and branches 25.83%, and branches only accounted for 7.5%. Other challenges of charcoal production include transportation problems (67.5%), lack of capital (59.2%), high cost of labour (43.3%), scarcity of wood resources (33.3%), and inconsistent government policies (31.7%), among others.

Table 3: Reasons for joining charcoal producers

Community	Business	Lack of employment	To augment income	To earn living	Total
Toro	16	1	10	3	30
Rishi	27	0	2	1	30
Magama	17	0	12	1	30
Tulu	15	7	5	3	30
Total	75	8	29	8	120

Table 4: Source of wood raw materials

Forest Ownership					PART OF THE PLANT USED					
Comm	Private	Comm.	Govt.	Comm. & Govt.	Tree stem	Branches	Tree stem & branches	Shrubs & Branches	All	Total
Toro	2	16	2	10	5	9	15	1	0	30
Rishi	0	14	0	16	0	0	5	1	24	30
Magama	0	1	0	29	0	0	0	29	1	30
Tulu	0	18	0	12	5	0	23	0	2	30
Total	2	49	2	67	10	9	43	31	27	120

Table 5: Diameter and height distribution of the tree species used for charcoal production

Variable	Class	Freq.	Percentage (%)
Diameter (cm)	5 - 15	3	2.5
	16 - 25	14	11.7
	26 - 35	70	58.3
	> 35	33	27.5
Length (m)	<1	17	14.2
	1 - 5	38	31.7
	6 - 10	59	49.2
	>10	6	5.0

Table 6: Quantity of charcoal produced in bags

Community	Quantity of charcoal (bag)				
	5 - 10	**11 – 15**	**16 – 20**	**> 20**	**Total**
Toro	6	22	2	0	30
Rishi	3	16	11	0	30
Magama	23	7	0	0	30
Tulu	5	18	3	4	30
Total	37	63	16	4	120

Table 7: Price of charcoal per bag (naira)

	Price of charcoal (bag/naira)				
Community	**500 - 1000**	**1001-1500**	**1501 - 2000**	**> 2000**	**Total**
Toro	11	19	0	0	30
Rishi	20	10	0	0	30
Magama	0	30	0	0	30
Tulu	0	20	9	1	30
Total	31	79	9	1	120

DISCUSSION

Tree species used for charcoal production

The analysis showed that *Anogeissus leiocarpus* is the most familiar species used for charcoal production across all regions of the study area, Followed by *Detarium microcarpum, Diospyros mespiliformis, Prosopis africaa* and *Syzyguim guinensis* (Table 1). This is because apart from being the area's most diverse tree species, they also produce charcoal with high calorific value. Adebayo *et al.* (2019) reported similar results in the identical study area of this research (Saki West and Ibarapa North of Oyo State), where *Anogeissus leiocarpus* had (77.5% and 66.3%), followed by *Vitellaria paradoxa* (68.8%, 85.0%), *Bridelia ferruginea* (58.8%, 65.0%) *and Terminalia spp* (41.3%, 56.3) in the two locations. The respondents prefer these trees because of the uniqueness of good quality charcoal produced by them. This study also corresponded with Tunde *et al*. (2013), that trees such as Axle wood (*Anogeissus leiocarpus*), Burkea (*Burkea Africa na*), Shea butter (*Vitellaria paradoxa*) have dense wood that produces good quality charcoal. This research also aligns with the Netherlands Programmes Sustainable Biomass study, which shows that charcoal producers prefer tree species with slow-burning features for charcoal. However, these species are essential economic trees and, therefore, vulnerable to over-exploitation (BTG, 2020).

Demographic characteristics of charcoal producers

The demographic characteristics of the respondents are presented in Table 2 through Table 7. The result shows that there were more males (105) than females (15) in the charcoal business; this is not disconnected from the rigorous activity involved in charcoal production. The age group of the respondents falls between 20 – 40 and 40 - 60 age groups; this denotes that respondents within this group suit the enterprise because of the energy exertion required during charcoal production. The study also revealed that most of the respondents had primary (40%) and secondary education (29.2%), and only a few had tertiary education (8.3%), which implies a low level of formal education %) in the study area. Business and farming are two major primary occupations (64 and 53) and secondary occupations (52 and 51), respectively. This result supports Adejumobi and Eniola's (2011) findings about charcoal producers in Oke-Ogun, which state that their level of education is low. The finding is also similar to what Adeniji *et al.* (2015) reported, that the active age group for charcoal production in Niger State was 20-39 years. Adebayo *et al.* (2019) reported a similar result in Saki West and Ibarapa North Local Government Areas of Oyo state that 57.5% of the respondents were male, 32.5% were within the age group of 40-49 years, while 45.0% and 42.5% had primary and secondary school education, respectively. Also, 32.5 % of the respondents had 16 - 20 years experience in charcoal production.

Prospects and Challenges of Charcoal Production

The results showed that about 62.5% of the respondents in the study area had considered charcoal production as a business. In contrast, only 8% of the respondents thought it an avenue to earn a living (figure 2). The Chi-square analysis result further revealed a significant relationship between the respondents in the four communities ($\chi 2 = 11.938$, df = 3, $P<0.05$) and charcoal production as a sustainable business. In contrast, all other reasons for charcoal production were not significant. This result is similar to what Adebayo *et al.* (2019) reported in some selected

communities of Oyo State with a chi-square value of 11.94. The quantity and price of charcoal produced per plant also encouraged the respondents; most respondents reported that there are about 11 – 15 bags of charcoal produced per tree from an average height of 11 – 30m. The average bag price was 1200 (NGN), and it also keeps appreciating.

Despite the prospects, there are a lot of challenges associated with charcoal production in the study area. The results show that the ownership of the forest where charcoal is obtained is either from the government or community forests. The private forest accounted for only 2% of charcoal production. This shows that almost all the charcoal producers don't have/developed their plantations where these can be harvested sustainably because most private investments are well managed/kept compared to public and government plantations/forests. Adeniji et al. (2015) reported similar challenges to the total dependence of charcoal producers on the government and community forests for production. Another prominent challenge in charcoal production is cutting down the entire tree. Only nine respondents out of 120 harvests had branches to make charcoal; the rest either felled tree as a whole and branches to make charcoal.

Other challenges of charcoal production include transportation problems (67.5%), lack of capital (59.2%), high cost of labour (43.3%), scarcity of wood resources (33.3%), inconsistent government policies (31.7%) among others (Table 7)

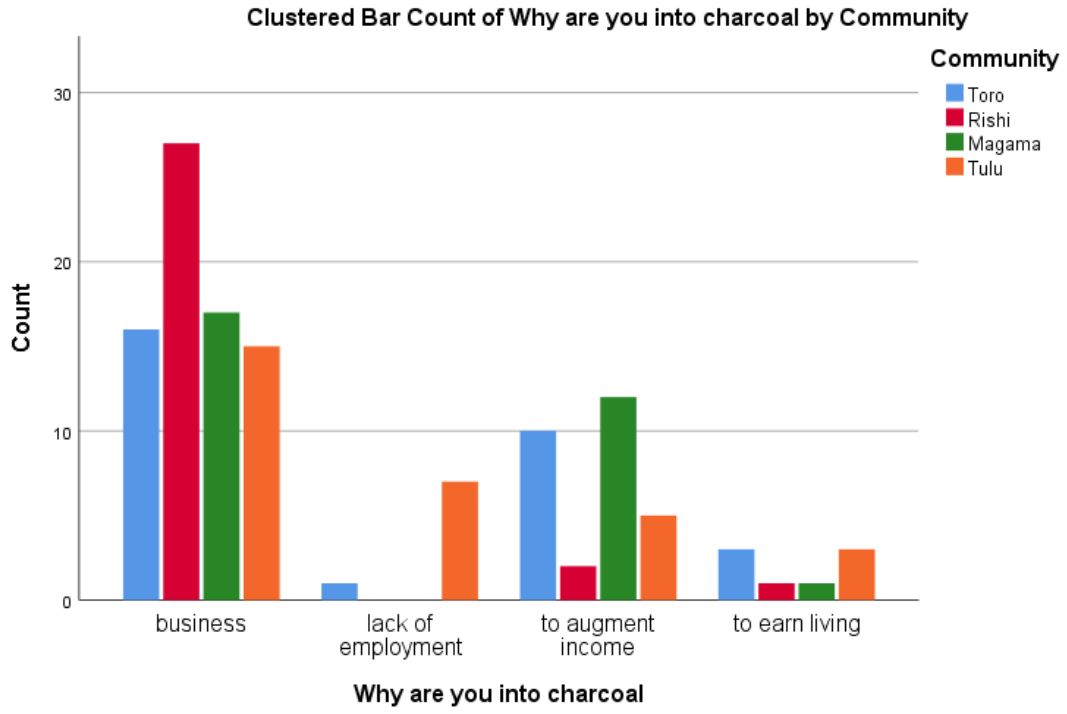

Figure 2: Distribution of the respondents for purposes of charcoal production in the study area

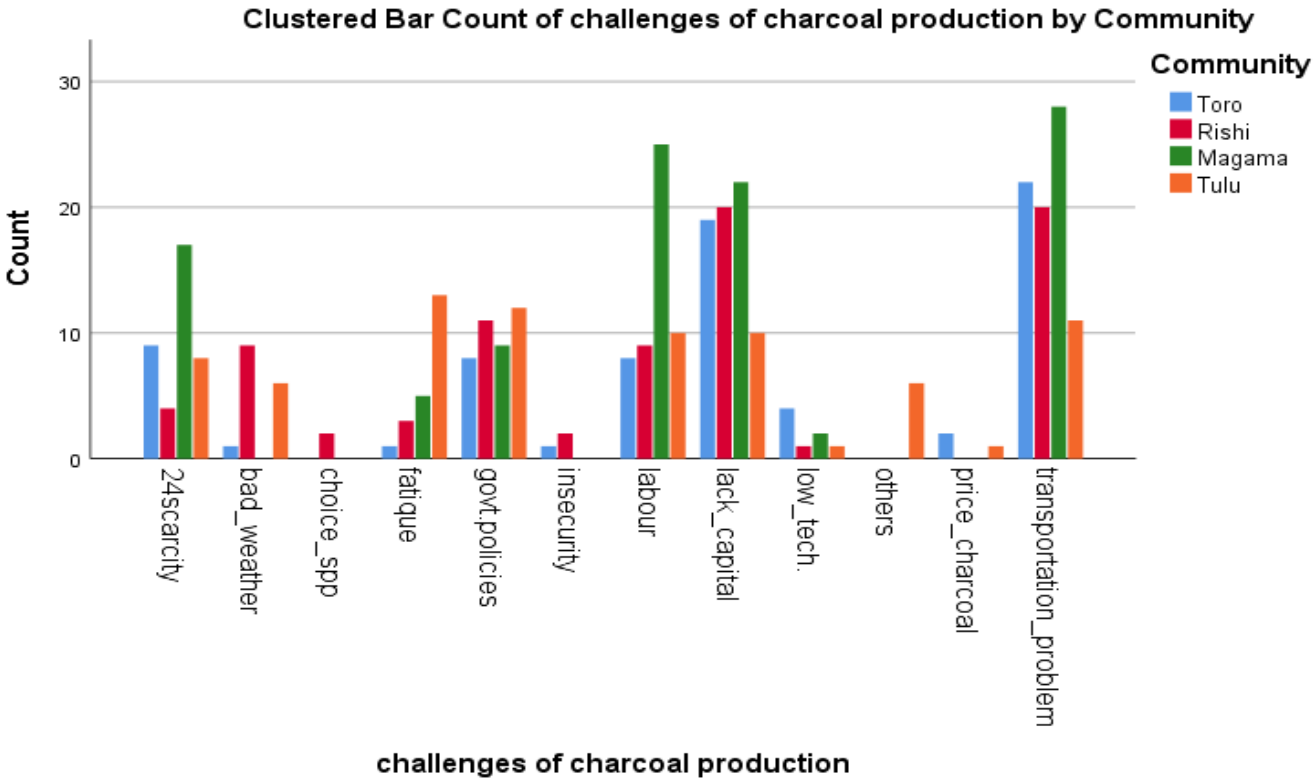

Figure 3: Distribution of the respondents on challenges of charcoal production in the study area

Conclusion and Recommendation

Charcoal production is one of the most profitable businesses in local communities, including semi-urban cities in Nigeria. It's one of the cheapest energy sources for household consumption and small to medium-scale enterprises. There is a vast number of tree species in the savanna that are suitable for charcoal production; however, the method of harvesting is crude and wasteful. The whole tree species would be harvested instead of cutting down the branches, especially the savanna tree species, where the branches of some tree species are equivalent to or even higher than the tree stem. The charcoal makers cut down the entire tree to maximize the profit, thereby depleting the scarce resources of wood materials, often leading to deforestation and land degradation. It's therefore recommended that the charcoal producers focus more on the tree branches rather than cutting the entire stem to make carbon, since most of the savanna tree species have big branches capable of producing charcoal equivalent or even higher than that of stem/bole. There should also be more emphasis on establishing private woodlots rather than over-dependence on the government and community forest for the charcoal.

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Natural Durability Assessment of *Elaeis guineensis Jacq.* Wood Exposed to Termite Attack

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Abstract

Selecting naturally durable wood for structural purposes can help reduce the pressure on our forest. This study aimed to evaluate the weight loss from termite attacks on the wood of *Elaeis guineensis*. For this evaluation, three matured *E. guineensis* trees that have stopped fruiting over 30 years of age were felled from Ogunsiji Village, Ido Local Government Area of Oyo State, Nigeria. Bolts of 50cm long were removed from the felled trees along the axial direction at the base (10%), middle (50%) and top (90%). Samples were then collected along the radial position (peripheral, inner and centre) for the base, middle and top according to ASTM D 1758-74. A natural durability test (using weight loss from termite attack) was carried out, and data were analyzed using descriptive statistics and Inferential statistics such as Analysis of Variance (ANOVA). From the results, the weight loss from termite attack of the *E. guineensis* wood samples ranged from 20.17 to 41.64%, with an increase from base to top, increasing weight loss from termite attack of the *E. guineensis* wood. Results further showed that weight loss increases radially from the bark (peripheral) to the inner part of the wood of E. guineensis. Samples of *E. guineensis* wood obtained at the peripheral base exhibited the highest resistance to termite attack. Based on the result, samples obtained from the base and peripheral of *E. guineensis* wood were more naturally durable.

Keywords: *E. guineensis*, natural durability, weight loss, termite, lesser-used species

INTRODUCTION

As the world's population grows, so does the demand for wood for construction and furniture. Nigeria's tropical forest is disappearing at an alarming rate, and the demand for timber has continued to rise in proportion to the human population (Aigbe and Oluko, 2012; Ogutuga *et al*., 2016; Oyetunji *et al*., 2020). Wood is expected to remain in high demand due to its versatility and lower cost than other construction materials. The high demand for wood would lead to the overexploitation of natural and plantation forests, which would have serious environmental consequences (Geomatic, 1998; Youngquist and Hamilton, 1999; Fuwape, 2001; Falemara, 2012). One way to tackle over-exploitation and shortage of wood supply involves utilizing lesser-used species, such as oil palm trunks, as replacements. Oil palm trunk lumber is a well-known material used for centuries in low-cost, medium- to low-performance markets. The oil palm (*Elaeis guineensis*) is a monocotyledonous plant from the palm family Arecaceae. It is a monoecious species that produces unisexual male and female inflorescences in alternate cycles (Barcelos *et al*., 2015). Oil palm is, without a doubt, the wealthiest tree on the planet in terms of natural endowments. It is one of the best trees God has given man in the

tropics for his survival and all his vegetable oil and other needs. It has been referred to as the 'Tree of Life' (Okolo *et al*., 2019) not only because every part of the tree benefits humans but also because it lives and thrives for many years. The oil palm is widely believed to have originated in Africa, specifically in the tropical rainforest region of West Africa, which is known to have wild and semi-wild palm groves along the coastal belt (Poku, 2002). The wood of *E. guineensis* is recognized for construction use. To adequately promote the proper utilization of *E. guineensis* at local and international levels, comprehensive research on the natural durability of the species must be embarked upon.

However, wood faces a significant threat known as bio-deterioration, which shortens its life (Acanakwo *et al*., 2019). Bio-deterioration significantly influences consumers' preference for wood over steel and concrete. As a result, researchers have been motivated to investigate the inherent resilience of various local commercial wood species (Liu *et al*., 2015). Natural resistance refers to a wood species' intrinsic ability to resist bio-deterioration without artificial preservatives. This resistance is frequently caused by extractives in the heartwood region (Mounguengui *et al*., 2016). Notably, even among hardwood species, the sapwood of all known trees remains highly susceptible to decay unless thoroughly removed (Owoyemi *et al*., 2017).

The natural durability of wood, which quantifies its ability to withstand the onslaught of biodegradation agents, is a dynamic characteristic that transforms as trees mature. Their central wood cells evolve into heartwood (Jebrane *et al*., 2014). Within this diverse spectrum of wood species, some display only mild resistance to insect attacks, making them vulnerable to the relentless appetite of termites. In contrast, others boast robust heartwood laden with potent natural compounds that act as an effective deterrent against termite infestations (Stallbaun *et al*., 2017). In this complex dance of adaptation and evolution, the complicated interplay between tree species and the natural environment determines the level of protection wood can provide against the relentless forces of bio-deterioration. These varying levels of resistance highlight the importance of researching and identifying wood species with better termite resistance, as they hold the key to increasing the longevity and sustainability of wood-based products in an ever-expanding world that relies on wood for various purposes. However, there is little information on the natural durability of *E. guineensis* wood to bio-degrading agents such as termites in Nigeria. Thus, adequate information is needed on the natural durability (weight loss from termite attack) of the wood of *E. guineensis* to ensure its suitable and appropriate utilization.

MATERIALS AND METHODS

Three matured *E. guineensis* trees of over 30 years of age that have stopped fruiting were selected and felled from Ogunsiji Village, Ido Local Government Area of Oyo State, Nigeria, located on latitude $7^0$30'7.83" N and longitude $3^0$47'12.81"E. Bolts 50cm long were cut from the felled trees along the axial direction (sampling height) at the base (10%), middle (50%) and top (90%) of the merchantable length (Figure1). The bolts were then taken to the Department of Forest Products Development and Utilization of Forestry Research Institute of Nigeria, Ibadan, for further conversion to test samples. Samples were collected along the radial position (peripheral, centre and inner) for the base, middle and top.

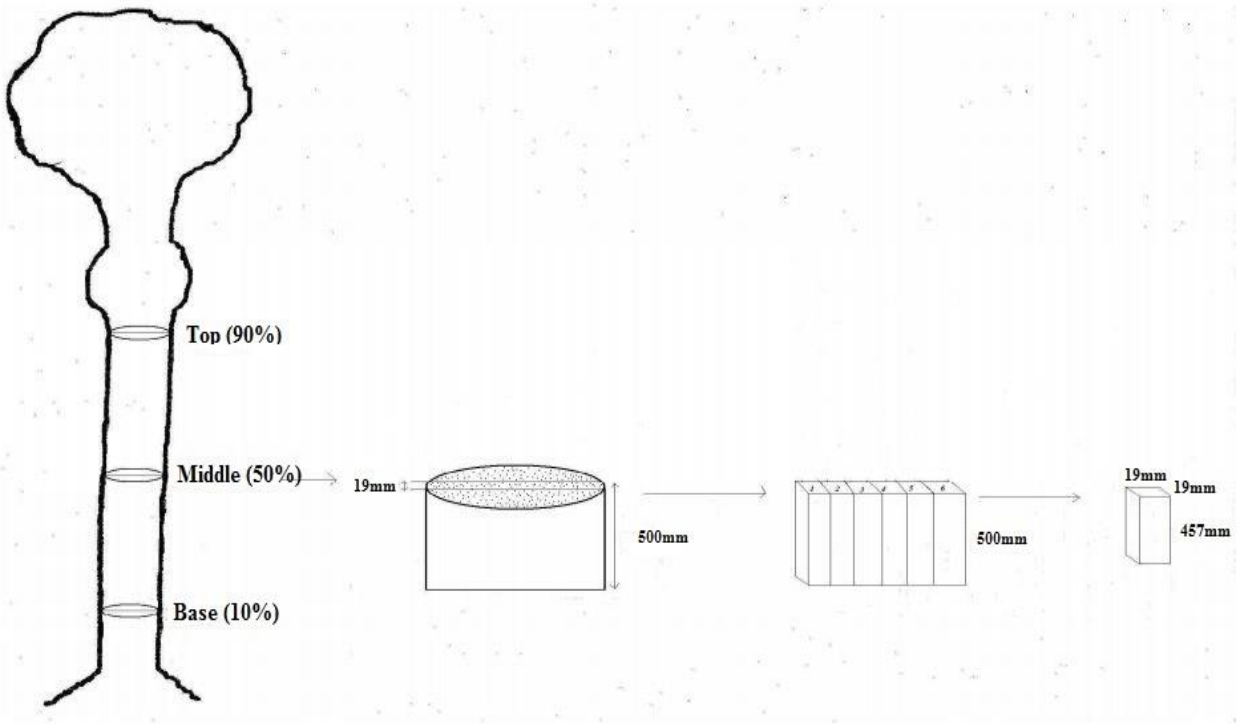

Figure 1: Schematics Sampling Procedure for Obtaining Test Sample for Durability Test

Testing of the Samples

Samples were cut to 19mm x 19mm x 457mm for weight loss determination following ASTM D 1758-74. Each treatment, a combination of sampling height and radial position, was replicated five times, and 45 samples were obtained for the weight loss test. The data obtained were analyzed using Analysis of Variance (ANOVA) and separated using Duncan Multiple Range Test at a 5% significance level.

Graveyard Test

The graveyard experiment was carried out for 24 weeks (6 months). *E. guineensis* wood samples were buried in a graveyard with evidence of infestation by termites with spacing not less than 300 mm between samples and not less than 600 mm between rows following ASTM D 1758- 74. The initial weight of samples was first determined before they were buried in the graveyard, and the final weight after 24 weeks was assessed. Weight loss was determined using the formula below following ASTM D 3345-08 (2008).

$$W = \frac{W_1 - W_2}{W_1} X100 \quad \text{.....(1)}$$

Where:

W= % Weight loss

W_1= Initial weight before termite attack

W_2= Final weight after attack (after oven dried)

RESULTS AND DISCUSSION

Weight Loss (W.L., %) of *E. guineensis* wood from Termite Attack

The results of the graveyard test conducted on the *E. guineensis* wood samples placed in ground contact for 24 24-week period is presented in Figure 2. The weight loss of *E. guineensis* wood was found to be lowest at the base to the top due to termite exposure.

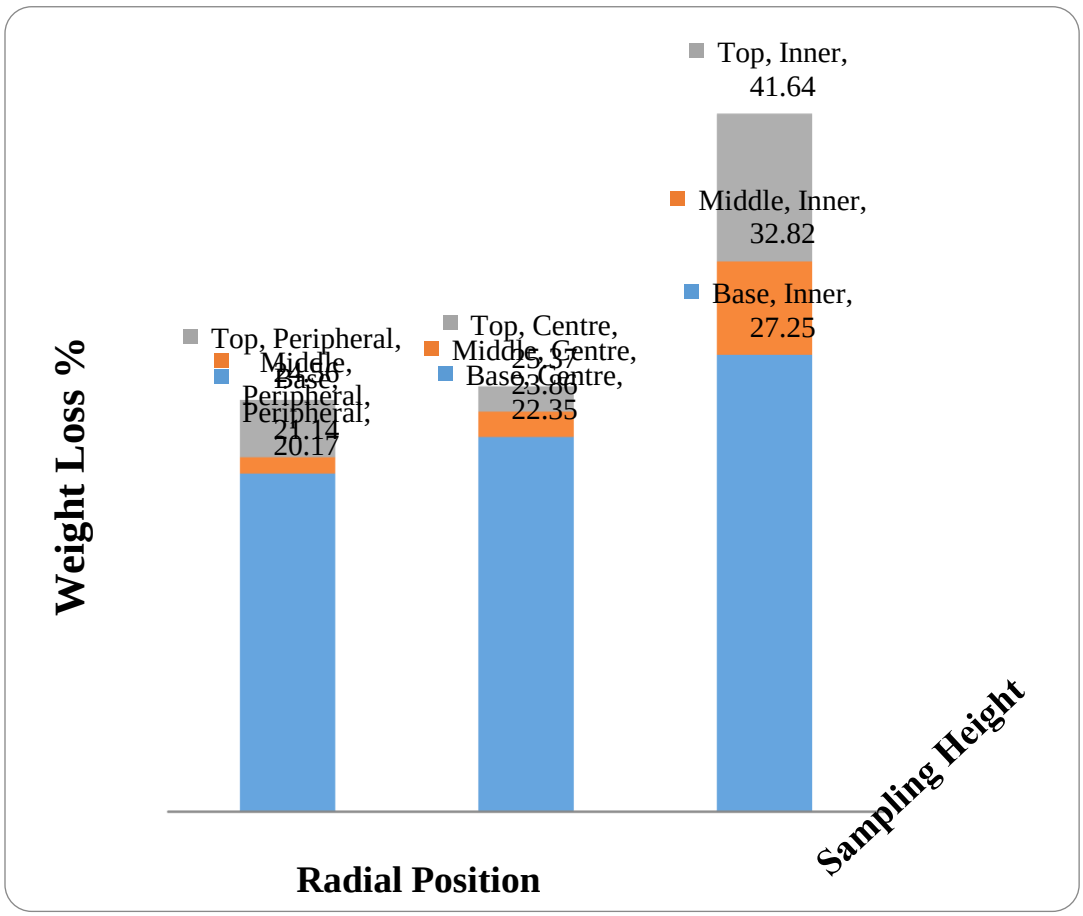

Figure 2: Weight Loss (%) from Termite Attack of *E. guineensis* Wood

The finding of this study agrees with the position of Lukmandaru (2011), Namujehe and Orikiriza (2013) and Ogutuga *et al.* (2020) that weight loss from termite attack is minimal at the base to the top. The lowest weight loss percentage recorded at the base of *E. guineensis* wood might be due to the highest ratio content of mature-to-juvenile wood. Across the bole (Radial Position), weight loss from termite attack was least at the peripheral, followed by timber obtained at the centre. At the same time, the innermost part of the wood of *E. guineensis* had the highest weight loss from termite attack (Figure 2). This indicates that the wood samples of *E. guineensis* obtained at the peripheral exhibited the highest resistance to termite attack. The relatively high resistance to termite attack of the *E. guineensis* samples obtained at the peripheral base, middle and top could be a result of their density, which is a factor that enhances durability. Stirling *et al.* (2015) stated that decay resistance varies within the stem, which tends to

increase radially from the pith to the heartwood-sapwood boundary and longitudinally from crown to base.

Statistically, there is a significant difference in the weight loss from termite attack of the *E. guineensis* wood along the sampling height, radial position, and their level of interaction (Table 1) at $p<0.05$. The follow-up test presented in Table 2 showed that sampling height and radial position differed. The samples from the base and peripheral showed more resistance to termite attack and were thus more naturally durable.

Table 1: Analysis of Variance for Weight Loss from Termite Attack

Source of Variation	**df**	**W.L. Sig.**	**W.L.**
Sampling Height	2	0.000*****	212.74
Radial Position	2	0.000*****	649.27
Sampling Height*Radial Position	4	0.000*****	51.93
Error	36		
Total	44		

Sig.: Significance, WL: Weight Loss and *****: Significant at $p<0.05$

Table 2: Follow-up Test for Sampling Height and Radial Position

Variables	**W.L. (%) Mean±SDV**
Sampling Height	
Base	23.26^{c}±3.11
Middle	25.94^{b}±5.24
Top	30.52^{a}±8.23
Radial Position	
Peripheral	21.96^{c}±2.10
Centre	23.86^{b}±1.51
Inner	33.91^{a} ±6.23

The mean in the column is significantly different ($p<0.05$).

CONCLUSION

The study showed that weight loss differed along sampling height and radial position. The study revealed that weight loss was more radially across the bole of *E. guineensis* from the bark (peripheral) to the inner part. The study further revealed high weight losses along the axial direction from base to top.

The study showed that the samples obtained from the base were more naturally durable than those obtained at the middle and top portion of the wood of *E. guineensis*. The study also showed that samples obtained radially at the peripheral were more naturally durable and had the best resistance to termites than those obtained at the centre and the inner part of the *E. guineensis* wood.

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THE SIGNIFICANCE OF EXTRACTIVES IN ENHANCING THE NATURAL DURABILITY OF WOOD SPECIES

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Abstract

This paper explores the pivotal role of extractives in conferring natural durability to certain wood species. Extractives, comprising a diverse array of secondary metabolites, have long been recognized for their contributions to the resistance of wood against decay and deterioration. Through a comprehensive literature review, this paper examines the chemical composition, distribution, and mechanisms of action of extractives in naturally durable wood species. Furthermore, it investigates the potential applications of extractive-rich wood materials in various industries, including construction, furniture, and outdoor structures. By elucidating the relationship between extractives and wood durability, this paper aims to provide insights into sustainable strategies for utilizing naturally resistant wood resources and inform future research directions in the wood science and technology field.

Keywords: Extractives, natural durability, decay resistance, secondary metabolites, chemical composition, wood species, wood science and technology

INTRODUCTION

Wood has been an essential material for human civilization since immemorial, serving as a fundamental resource for shelter, tools, and myriad other applications. As a natural, cellular, and renewable resource, wood offers outstanding strength-to-weight properties, affordability, and ease of production, making it highly desirable for many applications (Hingston *et al.*, 2001). Its distinctive structural and chemical properties further augment its versatility in various applications. The polymers in wood (cellulose, hemicellulose, and lignin) possess distinct properties that contribute to wood's overall functionality and performance. In addition to these major components, wood contains extractive compounds, varying from one tree to another, from one region to another, and according to the tree's age. Although these compounds constitute only a tiny portion of the wood, they are crucial for its unique properties (Fengel and Wegener, 1989; Rowell, 2012; N'Guessan *et al.*, 2024)

Extractive organic substances represent about 2 to 5 per cent of the composition of softwoods, 3 to 8 per cent of temperate hardwoods, and up to 18 to 22 per cent of tropical woods (Mosedale *et al.*, 1998). These species-specific molecules, despite their low concentration in the wood compared to the three structural polymers, are responsible for the variability of several properties both within various species and within the same tree (Schultz *et al.*, 1995; Mosedale *et al.*, 1998; Schultz and Nicholos, 2000; Lacandula, 2002; Amusant *et al.*, 2007). These metabolites, essential to the adaptation and survival of the tree, serve a defensive role by forming a chemical

or physical barrier against wood degradation agents. However, not all wood species possess equal resistance to decay and deterioration, leading to variations in their durability and longevity. Among the factors contributing to wood's natural durability, extractives have emerged as a critical determinant, influencing the material's ability to withstand environmental stresses and biological attacks.

Extractives encompass diverse secondary metabolites synthesized by trees and stored within their heartwood, bark, and other tissues (Schultz and Nicholas, 2012). These compounds, ranging from phenolics and terpenoids to flavonoids and tannins, play multifaceted roles in wood's biological, ecological, and mechanical properties (Taylor and Gartner, 2017). They are pivotal in influencing the wood's ability to withstand environmental stresses and biological attacks, contributing significantly to its natural durability. While extractives have long been recognized for their contributions to wood colouration, odour, and chemical defence against pests and pathogens, their significance in enhancing wood durability has garnered increasing attention from researchers, industries, and policymakers alike (Kuusinen *et al.,* 2016; Gao *et al.,* 2017; Zhang *et al.,* 2018; Adebawo, 2019; Adegoke *et al.,* 2021). In recent years, there has been growing interest in understanding the chemical composition, distribution, and mechanisms of action of extractives in naturally durable wood species (Gao *et al.,* 2017). Through interdisciplinary efforts encompassing wood science, chemistry, microbiology, and ecology, significant strides have been made in elucidating the intricate interplay between extractives and wood durability (Kuusinen *et al.,* 2016).

Against this backdrop, these efforts have expanded our fundamental understanding of wood biology and opened new avenues for harnessing the inherent resistance of select wood species for sustainable applications in construction, furniture manufacturing, and outdoor environments (Zhang *et al.,* 2018). This review paper endeavours to comprehensively explore the role of extractives in enhancing the natural durability of wood species by synthesizing and critically analyzing existing literature, aiming to shed light on the chemical diversity, biological functions, and industrial applications of extractive-rich wood materials. Furthermore, it identifies critical research gaps and proposes directions for future investigations, thereby fostering advancements in wood science and technology.

In the subsequent sections, the paper will look into the chemical constituents of extractives, their distribution within wood tissues, and their mechanisms of action against decay fungi, insects, and other wood-damaging organisms. The practical implications of extractive-rich wood materials regarding sustainable resource utilization, environmental conservation, and economic development will also be discussed. The paper will further contribute to the collective knowledge base and inspire innovative approaches towards harnessing the innate resilience of wood for the benefit of present and future generations.

CHEMICAL CONSTITUENTS OF EXTRACTIVES: ITS BIOLOGICAL AND BIOCHEMICAL IMPORTANCE

Extractives are a diverse group of secondary metabolites produced by trees, encompassing various chemical classes and structural complexities. Synthesized in living tree cells, these compounds are stored in heartwood, sapwood, bark, and other tissues. Their chemical composition varies among wood species and individual trees, influenced by genetic, environmental, and physiological factors. Four main categories of extractives can be identified:

1. Terpenes and Terpenoids

Terpenes: Derived from isoprene units, found in resin canals, and play roles in disease resistance, odour creation, and pathogen protection. Examples include tropolones, sterols, and phytol. Terpenes are vital in defending plants and wood against various pathogens, including moulds, fungi, and bacteria. They also serve to attract pollinating insects or repel herbivores. When parasites or predators attack a plant, the levels of these compounds increase. Tropolones contribute to the natural durability of certain woods. According to Saniewska and Jarecka (2008), hinokitiols (β-thujaplicin) significantly inhibit the growth of fungi such as *Coriolus versicolor*, *Phanerochaete chrysosporium*, *Poria placenta*, and *Gloephyllum trabeum* (Saniewska and Jarecka, 2008; Nuutinen, 2018).

Terpenoids: Oxygenated terpene derivatives with anticancer properties, classified into mono, di, oligo, and polyterpenes. Examples include betulinic acid, camphene, and geraniol. Garcia *et al.* (2008) showed that L-carvone from *Pinus sylvestris* significantly inhibits fungal growth. Similarly, Turley *et al.* (2006) found that these compounds effectively destroy *Escherichia coli*. Betulins, pentacyclic triterpenes found in birch bark (*Betula spp.*), possess specific antimicrobial properties, including antimold and antibacterial effects. Lupeol, another triterpene, has chemopreventive, cytotoxic, and antioxidant properties.

2. Aliphatic compounds

Aliphatic compounds include fatty acids, alkanes, fatty alcohols, triglycerides, palmitic acid, and stearic acid. Fatty acids are hydrophobic aliphatic chain carboxylic acids, either saturated or unsaturated, found in vegetable oils and wood extractives. They influence pulping and wettability. Organic acid derivatives have been reported to make them promising chemicals for transferable durability (Barbero-Lopez *et al.*, 2018, 2020). Schmidt (1984) evaluated the influence of saturated fatty acids on the spore germination of brown- and white-rot basidiomycetes. He determined that caprylic or octanoic (C8), pelargonic or nonanoic (C9), and decanoic (C10) acids at a concentration of 100 ppm destroyed the spores of test fungi.

In contrast, dodecanoic acid (C12) was effective against brown-rot fungal spores but not white ones. Schmidt's findings indicated a high degree of specificity depending on the fatty acid concentration and the type of test fungus. Clausen *et al.* (2015) reported that several fatty acid formulations and propionic acid inhibited mould test fungi. They also found that L-lactic acid and selected adjuvants enhance the antifungal properties of these formulations.

3. Phenolic compounds

These are diverse compounds with an aromatic ring and hydroxyl groups, originating from biosynthetic pathways and classified into families like simple phenols, flavonoids, quinones, stilbenes, lignans, and tannins. Given that some of these compounds exhibit antioxidant and antimicrobial activities, there is growing interest in their extraction (Fernandez Agullo *et al.*, 2015; Zhang *et al.*, 2015).

Flavonoids: Abundant phenolic compounds with antioxidant capacities found in plants and exhibiting antifeedant, antiviral, antitumor, anti-inflammatory, and antibacterial activities. Several researchers have demonstrated that the natural durability of certain woods is attributed to the presence of flavonoids. For instance, dihydromorin and aromadendrine found in the extractives of Acacia species contribute to this durability (Schultz *et al.*, 1995). Sirmah *et al.* (2009a) identified -(-) mesquitol as the compound responsible for the natural durability of

Prosopis juliflora. Other scholars, such as Adebawo and Adegoke (2019) and Adegoke *et al.* (2015), have also reported the presence of flavonoids.

Lignans: Dimers are composed of two phenylpropane units, widespread in wood knots, and exhibiting antitumor, antimitotic, antioxidant, and antiviral properties. Some lignans have demonstrated toxicity towards wood-destroying agents and exhibit resistance to degradation. The antifungal, antibacterial, and insecticidal properties observed in several lignans suggest their potential role in plant defence mechanisms, and they may also contribute to regulating plant growth (Mijnsbrugge *et al.*, 2000; Kawamura et al., 2004; Céspedes *et al.*, 2006). For instance, syringol, a lignin pyrolysis product found in hardwoods, is the primary chemical responsible for imparting a smoky flavour (Bari *et al.*, 2009). Additionally, research by Adegoke *et al.* (2020) and Okanlawon *et al.* (2020) suggests that pyrolytic oil derived from wood residues enhances wood resistance to bio-deteriorating agents. Furthermore, these compounds may exhibit antifungal activities against fungi, as demonstrated by various structures identified in the bark of *Obvata species* (Pandey and Pitman, 2004).

Tannins: Phenolic natural products with astringent and antioxidant properties, divided into hydrolyzable and condensed tannins found in wood, bark, leaves, fruits, and galls. Tannins have been identified for their potential anticarcinogenic and antimutagenic properties, along with antimicrobial effects. Numerous studies have highlighted tannins' antioxidant and antiradical activities (Bate-Smith, 1977; Amarowicz, 2007). The presence of tannins has been noted for their resistance against fungi and termite attacks on certain tropical hardwoods (Adebawo and Adegoke, 2019).

Stilbenes: Metabolites consist of two benzene rings, mainly found in softwoods, with antioxidant, antifungal, and pharmacological properties, and play a crucial role in fungicide and insect protection. Various species of Combretum, which are rich in stilbenes, exhibit resistance to termites. Stilbenes play a vital role in conferring resistance to wood rot fungi, and research has been conducted on inducing stilbene biosynthesis by irradiating seedlings to enhance wood resistance against biodegradation (Norin, 1981). They significantly influence the technological properties of wood. Stilbenes such as pinosylvine and its mono- or dimethylated forms, isolated from *Picea glauca, Pinus resinosa*, or *Pinus banksiana*, demonstrate potent inhibition against white rot fungi such as *Phanerochaete chrysosporium* and *Trametes versicolor*, with a lesser inhibitory effect on brown rot fungi including *Poria placenta*, *Gloeophyllum trabeum*, and *Neolentinus lepideus* (Célimene *et al.*, 1999; Lu *et al.*, 2015).

Quinones: Oxygenated compounds derived from phenol oxidation with a restricted distribution and classified as benzoquinones, naphthoquinones, and anthraquinones. In the natural durability of teak wood, 40, 50-dihydroxyepiisocatalponol plays a significant role in resisting fungal attacks (Niamké *et al.*, 2011, 2012). Niamké *et al.* (2012) demonstrated that this compound acts as a fungicide, effectively inhibiting the growth of *Trametes versicolor*. Additionally, in the wood of *Diospyros virginiana*, 7-methyl juglone and its derivatives exhibit termiticidal activity (Carter *et al.*, 1978).

Alkaloids: Cyclic organic compounds containing nitrogen atoms, with limited distribution, and possessing therapeutic and civic interest as a source of novel lead compounds for drug development. Alkaloids function as protective agents against fungi, insects, and herbivores, as

well as serving as a nitrogen source essential for plant development and growth-regulating agents akin to hormones. Additionally, they offer protection against ultraviolet radiation. Alkaloids exhibit toxicity towards insects, effectively paralyzing or killing those that consume them (Trematerra and Sciarretta, 2002; Bouchelta *et al.,* 2005). Adebawo and Adegoke (2019) conducted research revealing that alkaloids found in neem seed oil exhibit antifungal properties against biodeteriorating agents.

DISTRIBUTION OF EXTRACTIVES WITHIN WOOD TISSUES

Extractives are unevenly distributed throughout the various wood tissues, with concentrations varying radially and longitudinally within a tree. The distribution of extractives within wood tissues is influenced by factors such as:

Heartwood and Sapwood: One of the most well-known patterns of extractive distribution occurs between heartwood and sapwood (Bhat and Chandrashekar, 2014). Heartwood, the innermost portion of the tree, typically contains higher concentrations of extractives than sapwood, contributing to its natural durability and decay resistance (Martinez-Alvarez *et al.*, 2017). This is because heartwood has a higher concentration of phenolic compounds, which are toxic to fungi and insects, protecting against decay and insect attack (Kuusinen *et al.,* 2016). This makes heartwood highly sought after for outdoor applications and high-value products. The presence of extractives in heartwood strongly influences wood's natural durability olfactory, physico-mechanical, and acoustic properties (Stevanovic and Perrin, 2009).

Radial Variations: Within the same tree, extractive concentration often varies radially from the pith to the bark (Hillis, 1987; Ziegler, 1989; Magel and Hillis, 1993). This variation is characterized by a general pattern of higher extractive content in the innermost annual rings (closer to the pith) and a gradual decrease towards the outer rings (closer to the bark) (Taylor *et al.,* 2006; Santana *et al.,* 2010). This radial gradient reflects the gradual accumulation and deposition of extractives as the tree matures, with the innermost rings representing the earliest stages of heartwood formation (Hillis, 1987). The exact pattern and extent of radial variation vary depending on tree species, age, and growth conditions (Ziegler, 1989; Magel and Hillis, 1993).

Longitudinal Variations: Extractive distribution can also vary along the longitudinal axis of the tree (Petrasso and Edlund, 1990). For instance, extractive content may be higher in the lower trunk and decrease towards the upper canopy, resulting from differences in physiological activity, environmental exposure, and hydraulic transport mechanisms within the tree (Gartner *et al.,* 2004). This longitudinal gradient may be influenced by factors such as tree age, growth rate, and environmental conditions (Zhang *et al.,* 2018).

Vascular and Non-Vascular Tissues: Extractives are found in both vascular (xylem) and non-vascular (rays, parenchyma) tissues of wood (Chen *et al.,* 2019). While some extractives are primarily concentrated within specific cell types, such as phenolic compounds in ray cells (Kuusinen *et al.,* 2016), others are more evenly distributed throughout the various tissue types, contributing to the overall chemical and mechanical properties of wood (Gao *et al.,* 2017).

Environmental Influences: Environmental factors, such as soil composition, temperature, moisture availability, and biotic interactions, can influence the distribution of extractives within

wood tissues (Martinez-Alvarez *et al.,* 2017). Trees growing in nutrient-poor or water-stressed environments may allocate more resources towards extractive production to defend against biotic and abiotic stressors (Zhang *et al.,* 2018). For example, trees growing in areas with high fungal activity may produce more antifungal compounds to protect against decay (Bhat and Chandrashekar, 2014).

MECHANISMS OF ACTION AGAINST DECAY FUNGI, INSECTS, AND OTHER WOOD-DAMAGING ORGANISMS

Wood extractives protect trees against various biological threats, including decay fungi, insects, and other wood-damaging organisms. These natural compounds exhibit multiple mechanisms of action that deter or inhibit the proliferation of pests and pathogens, thereby enhancing the durability and longevity of wood materials (Taylor *et al.,* 2002).

Antimicrobial Properties: Extractives in wood play a crucial role in defending against decay fungi, insects, and other wood-damaging organisms due to their antimicrobial properties. Trees synthesize these natural compounds as a defence mechanism against pathogens and pests. Many extractives possess inherent antimicrobial properties that inhibit the growth and activity of decay fungi and other microorganisms. Phenolic compounds, such as tannins and lignans, are known for their ability to disrupt cellular membranes, inhibit enzyme activity, and interfere with metabolic processes in fungi. Terpenoids, particularly sesquiterpenes and diterpenoids, exhibit broad-spectrum antimicrobial effects against bacteria, fungi, and moulds by disrupting cell wall integrity and membrane permeability (Scheffer and Morrell, 1998; Yang, 2009; Singh and Singh, 2012).

Decay fungi are among the most significant threats to wood integrity, causing structural damage and compromising the durability of wooden structures. Antimicrobial extractives hinder fungal growth by disrupting cellular processes or forming physical barriers. Recent research by Schmidt *et al.* (2021) highlighted the role of terpenoids and phenolic compounds in inhibiting fungal proliferation through various mechanisms, including membrane disruption and enzyme inhibition. In a research carried out by Adebawo and Adegoke (2019) and Adegoke *et al.* (2021), it was also discovered that alkaloids, phenols, terpenoids, tannins, saponins and flavonoids present in neem seed oil have antifungal properties against biodeteriorating agents. Insects, such as termites and wood borers, pose another challenge to wooden structures, leading to extensive damage if left unchecked. The antimicrobial properties of extractives act as a deterrent to these wood-damaging organisms. Studies by Gao *et al.* (2023) demonstrated the efficacy of sesquiterpene lactones and flavonoids in repelling wood-boring insects by disrupting their physiological functions or acting as feeding deterrents. Many researchers have reported the effectiveness of extractives from wood, seed oil, and leaves against insect attacks (Adebawo *et al.,* 2015; Adebawo *et al.,* 2018; Adegoke *et al.,* 2015, 2020, and 2021). Moreover, extractives not only inhibit the growth of pathogens but also contribute to wood's overall durability by enhancing its resistance to decay and degradation. Recent investigations by Li *et al.* (2022) emphasized the synergistic effects of different classes of extractives in conferring resistance against a wide range of wood-degrading organisms, thus prolonging the lifespan of wooden materials.

Antifeedant and Repellent Effects: Some extractives act as antifeedants or repellents against wood-boring insects and other herbivores, deterring them from feeding on or ovipositing in wood

materials. Terpenoids, resin acids, and alkaloids are among the most common classes of extractives known for their insecticidal and deterrent properties. These compounds may affect insect behaviour, disrupt feeding mechanisms, or induce physiological stress responses, thereby reducing the likelihood of insect infestation and damage (Henagamage *et al.,* 2023; Cushnie and Lamb, 2005; Adebawo, 2019)

Wood extractives' antimicrobial properties disrupt insects' feeding behaviour by making the wood less palatable or inducing toxicity upon ingestion. Recent studies have elucidated the mechanisms behind these effects, highlighting the role of specific compounds such as sesquiterpene lactones and flavonoids. For instance, research by Gao *et al.* (2023) demonstrated the antifeedant activity of sesquiterpene lactones against wood-boring insects, inhibiting their feeding behaviour and thereby protecting wooden structures from damage. In addition to antifeedant effects, wood extractives exhibit repellent properties, deterring insects from approaching or settling on treated wood surfaces. This repellent action can be attributed to the volatile organic compounds (VOCs) emitted by wood extractives, which create an inhospitable environment for pests. Schmidt *et al.* (2021) investigated the repellent effects of VOCs against wood decay fungi, highlighting their role in preventing fungal colonization and decay.

Furthermore, the effectiveness of wood extractives as antifeedants and repellents can vary depending on factors such as extractive composition, concentration, and the target organism. Research into the synergistic effects of different extractive compounds has shown promising results in enhancing the overall efficacy of wood protection strategies. Li *et al.* (2022) emphasized the importance of understanding the interactions between various classes of extractives in conferring resistance against wood-degrading organisms, including fungi and insects.

Enzyme Inhibition: Enzyme inhibition is a crucial mechanism by which wood extractives exert their protective effects against decay fungi, insects, and other wood-damaging organisms. These natural compounds can interfere with the activity of critical enzymes involved in the degradation of wood polymers, thereby slowing down the decay process and preserving the structural integrity of wood (Laks and Coote, 2020).

Extractives can also interfere with the enzymatic activities of wood-degrading organisms by inhibiting critical enzymes involved in lignocellulose degradation. Phenolic compounds, in particular, have been shown to inhibit the activity of ligninolytic enzymes (e.g., lignin peroxidase, manganese peroxidase) produced by decay fungi, thereby hindering the depolymerization of lignin and the subsequent degradation of cellulose and hemicellulose. Decay fungi secrete various enzymes, including cellulases, hemicellulases, and ligninases, to break down wood polymers into simpler compounds that can be utilized as nutrients. Wood extractives can inhibit these enzymes through various mechanisms, such as competitive or non-competitive inhibition. For example, certain phenolic compounds in wood extractives can bind to the active sites of fungal enzymes, blocking their access to substrate molecules and hindering the degradation of wood polymers (Schmidt *et al.,* 2021).

In addition to inhibiting fungal enzymes, wood extractives can interfere with the enzymatic processes involved in insect digestion and metabolism. Studies have shown that certain extractive compounds, such as terpenoids and alkaloids, can inhibit the activity of digestive enzymes in wood-boring insects, impairing their ability to extract nutrients from wooden

structures (Gao *et al.,* 2023). This enzymatic inhibition reduces wood-boring insects' feeding and growth rates, thereby minimizing damage to wooden materials.

Furthermore, enzyme inhibition by wood extractives can have synergistic effects when combined with other mechanisms of action, such as chemical complexation and binding (Smit and Tudzynski, 2021). By targeting multiple pathways involved in wood degradation, extractives can provide comprehensive protection against decay fungi, insects, and other wood-damaging organisms.

Indirect Defense Mechanisms: Indirect defence mechanisms in wood rely on the interactions between wood extractives and the surrounding environment to protect against decay fungi, insects, and other wood-damaging organisms. Unlike direct defence mechanisms involving direct interactions with pathogens or pests, indirect defences harness secondary processes or interactions to enhance wood resistance. In addition to direct effects on pests and pathogens, extractives may stimulate indirect tree defence mechanisms, such as induced resistance and allelopathy. Induced resistance involves upregulating defence-related genes and producing secondary metabolites in response to biotic stressors. In contrast, allelopathy consists of releasing allelochemicals that inhibit the growth of competing organisms in the surrounding environment.

One indirect defence mechanism is allelopathy, where wood extractives release chemical compounds into the surrounding environment that inhibit the growth or development of competing organisms. These compounds can have allelopathic effects on nearby plants, fungi, or microbes, creating a hostile environment for potential wood-degrading organisms. For example, studies have shown that certain wood extractives possess allelopathic properties that inhibit the germination and growth of fungal spores, thereby reducing the risk of fungal colonization and decay (Biedermann *et al.,* 2019).

Research has demonstrated the role of VOCs emitted by wood extractives in attracting predatory insects or parasitic fungi that prey on wood-boring insects or compete with wood decay fungi for resources (Kandasamy *et al.,* 2020). Wood extractives can alter soil or microclimate conditions around wooden structures, creating an environment less conducive to the growth of decay fungi or wood-boring insects. By modifying environmental factors such as moisture content or pH, wood extractives indirectly suppress the growth and activity of wood-degrading organisms (Martini *et al.,* 2021).

Synergistic Interactions: Synergistic interactions among wood extractives are crucial to understanding the comprehensive defence mechanisms against decay fungi, insects, and other wood-damaging organisms. These interactions involve the combined effects of multiple extractive compounds, which often enhance the overall efficacy of wood protection beyond the individual contributions of each compound. It is important to note that the effectiveness of extractives in wood protection usually depends on the synergistic interactions among different compounds and their concentrations within the wood matrix. Synergism between extractives and other components of wood, such as lignin and carbohydrates, may enhance wood materials' overall durability and resistance to biotic and abiotic stresses (Mori *et al.,* 1987; Hwang *et al.,* 2007).

One aspect of synergistic interactions is the combination of different classes of extractive compounds, each with unique modes of action against wood-degrading organisms. For example, phenolic compounds may disrupt enzymatic activity in decay fungi, while terpenoids are

repellents against wood-boring insects. Together, these compounds can provide broader and more robust protection against a more comprehensive range of pests and pathogens (Li *et al.*, 2022). Furthermore, synergistic interactions can occur within the same class of extractive compounds, where certain compounds enhance the activity or stability of others. For instance, studies have shown that the presence of certain flavonoids can increase the antimicrobial potency of phenolic compounds by promoting their uptake or retention within wood tissues (Schmidt *et al.*, 2021; Adebawo *et al.*, 2015; Adebawo *et al.*, 2018 and Adegoke *et al.*, 2021). Similarly, terpenoid compounds may synergistically enhance the repellent effects of other volatile compounds, thereby increasing their efficacy in deterring wood-boring insects (Martini *et al.*, 2021).

PRACTICAL IMPLICATIONS OF EXTRACTIVE-RICH WOOD MATERIALS

Practical implications of extractive-rich wood materials extend across forestry, wood processing, and product manufacturing sectors, offering opportunities for enhanced durability, reduced chemical treatments, improved performance, and biodiversity conservation. Recent research provides insights into these implications, guiding sustainable resource utilization strategies.

Enhanced Durability and Resistance: Extractive-rich wood, abundant in natural compounds like resins and phenols, exhibits superior resistance to decay fungi and pests (Hägerdal *et al.*, 2020; Adebawo, 2019). Extractive-rich wood, characterized by high concentrations of natural compounds such as resins and phenols, offers notable advantages in terms of enhanced durability and resistance against decay fungi and pests. This attribute significantly impacts various industries, particularly in construction and outdoor applications. Research by Hägerdal *et al.* (2020) reveals the superior resistance of extractive-rich wood to decay fungi and pests. These natural compounds act as potent inhibitors, hindering the growth and proliferation of wood-degrading organisms. As a result, wood products made from extractive-rich species exhibit prolonged lifespans compared to those made from less resistant wood types (Kabir, 2007; Stirling, 2010).

In construction, where durability is paramount, using extractive-rich wood can lead to structures that withstand environmental stresses and maintain their integrity over time. Whether used in framing, siding, decking, or outdoor furniture, extractive-rich wood offers longevity and reliability, reducing the need for frequent maintenance and replacement. Moreover, extractive-rich wood excels in resisting decay and pest infestations in outdoor applications exposed to moisture, humidity, and insect activity. This resilience translates to reduced material consumption and lower lifecycle costs, making extractive-rich wood an economically and environmentally sustainable choice for outdoor projects. Beyond immediate cost savings, using extractive-rich wood contributes to broader resource conservation efforts. Extending the lifespan of wood products consumes less material over time, reducing overall resource demand and environmental impact. Additionally, naturally resistant wood species can reduce reliance on chemical treatments, minimizing ecological harm associated with wood preservation practices.

Reduced Chemical Treatment Requirements: The innate preservative properties of extractive-rich wood significantly mitigate the need for extensive chemical treatments, as highlighted by research conducted by Rautkari *et al.* (2021). These natural compounds in extractive-rich timber, such as resins, tannins, and phenols, act as potent inhibitors against decay fungi, insects, and other wood-damaging organisms. As a result, the reliance on synthetic chemical treatments for wood preservation is significantly reduced. Reducing chemical treatment requirements has far-

reaching implications for environmental sustainability and promotes more sustainable forestry practices. By minimizing the use of chemical preservatives, extractive-rich wood contributes to lower environmental impact, as the production and application of synthetic chemicals often entail energy-intensive processes and can release harmful pollutants into the environment.

Furthermore, by reducing the demand for chemical inputs in forestry operations, extractive-rich wood supports sustainable forest management principles. Sustainable forestry practices aim to maintain the ecological integrity of forest ecosystems while meeting the social, economic, and environmental needs of present and future generations. Minimizing the use of chemical treatments aligns with these goals by reducing the risk of pollution, protecting biodiversity, and preserving soil and water quality within forest ecosystems. Additionally, the reduced reliance on chemical treatments in wood preservation promotes human health and safety, as exposure to potentially hazardous chemicals is minimized for workers involved in forestry and wood processing operations. This is particularly relevant in the context of occupational health and safety regulations, which prioritize the well-being of workers in the forestry and wood products industries.

Improved Product Performance: Incorporating extractive-rich wood into engineered products enhances dimensional stability and water resistance (Laine *et al.,* 2022). Engineered wood products, like laminated veneer lumber, benefit from these qualities, offering higher performance and longevity in various applications. Research by Laine *et al.* (2022) demonstrates that extractive-rich wood enhances dimensional stability and water resistance when used in engineered products such as laminated veneer lumber. These qualities are highly desirable in various applications, including construction, furniture manufacturing, and outdoor structures. By improving product performance, extractive-rich wood contributes to higher quality, longer-lasting products that meet the demands of diverse industries and consumers.

Furthermore, extractive-rich wood species often command premium prices in the marketplace due to their superior quality and performance characteristics (Laine *et al.,* 2022). Stakeholders can capitalize on this value-added opportunity by selectively harvesting and processing extractive-rich species. By capturing more excellent economic value from forest resources, stakeholders are incentivized to invest in sustainable forest management practices, thereby promoting forest ecosystems' long-term health and productivity. In addition to economic benefits, the conservation of extractive-rich wood species is essential for biodiversity conservation. Some extractive-rich wood species serve as keystones in biodiverse ecosystems, playing crucial roles in supporting a wide range of plant and animal species (Hägerdal *et al.*, 2020). Conservation efforts aim to preserve these species and their habitats, promoting ecosystem health, resilience, and the preservation of biodiversity for future generations.

Value-added Opportunities: Extractive-rich wood species often command premium prices due to their superior quality (Laine *et al.*, 2022). By selectively harvesting and processing such species, stakeholders can capture more excellent economic value from forest resources, incentivizing sustainable management practices. Using extractive-rich wood species presents significant value-added opportunities for stakeholders in the forestry and wood products industries. Research conducted by Laine *et al.* (2022) highlights that extractive-rich wood often commands premium prices in the marketplace due to its superior quality and performance characteristics. Stakeholders, including forest owners, logging companies, and wood product manufacturers, can capitalize on these value-added opportunities by selectively harvesting and processing extractive-

rich wood species. By targeting these species, stakeholders can capture more excellent economic value from forest resources than less valuable wood species.

Biodiversity Conservation: Some extractive-rich wood species are keystones in biodiverse ecosystems, highlighting the importance of their sustainable management (Hägerdal *et al.*, 2020). Conservation efforts aim to preserve these species and their habitats, promoting ecosystem health and resilience. Biodiversity conservation is a critical consideration in the utilization of extractive-rich wood species. Research by Hägerdal *et al.* (2020) and Yang (2009) emphasizes the importance of sustainable management practices to preserve extractive-rich wood species and their associated habitats within biodiversity ecosystems.

Extractive-rich wood species often play critical roles as keystones in ecological communities, supporting various plant and animal species. These species contribute to ecosystem health, resilience, and stability by providing habitat, food sources, and other ecosystem services. Their conservation is essential for maintaining biodiversity and preserving the functionality of natural ecosystems.

CONCLUSION

Wood extractives represent a promising avenue for enhancing the durability and resistance of wood materials against biological threats. Wood extractives play a pivotal role in shaping wood's natural durability and functional properties, revealing their significance in various ecological, industrial, and societal contexts. The chemical diversity and distribution of extractives within wood tissues contribute to their resistance against biological degradation agents and environmental stresses, making certain wood species highly sought after for outdoor applications and high-value products. Their multifaceted mechanisms of action, including antimicrobial properties, antifeedant effects, enzyme inhibition, and indirect defence mechanisms, provide comprehensive protection against decay fungi, insects, and other wood-damaging organisms. The practical implications of extractive-rich wood materials extend across various sectors, offering reduced chemical treatment requirements, improved product performance, and biodiversity conservation opportunities. However, further research is needed to explore novel extractive compounds, optimize wood preservation techniques, elucidate biochemical mechanisms of extractive action, assess environmental impacts, and develop sustainable forest management practices. By advancing a complete understanding of wood extractives and their applications, we will promote the sustainable utilization of forest resources and contribute to developing environmentally friendly wood products for future generations.

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UTILIZATION OF HONEYBEE PRODUCT IN POVERTY ALLEVIATION OF RURAL COMMUNITIES OF TOUNGO LOCAL GOVERNMENT AREA OF ADAMAWA STATE

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ABSTRACT

This study assessed utilization of honeybee products in poverty alleviation of rural communities in Toungo Local Government Area Adamawa State, Nigeria. Questionnaire and interviews were used to collect data from the respondents. Three wards were purposively selected (Toungo I, Toungo ii and Kiri I), the area known to wildly used for honey business. Descriptive statistics was used for data analysis. Results showed that 31-40 years has the highest 84.3% respondents. Results reveal widespread use of honeybee product, honey 91% highest and least bee wax 58.5% were used by the communities. The multifaceted applications of honey, spanning nutritional supplementation (33.5%), traditional medicine (74.5%), food ingredient (44%), and preservation (50.8%), underscore its cultural significance and economic potential. Poverty alleviations include: employment (77.8%), income diversification (91.7%), entrepreneurship opportunities (96.5%) and market development (33%). Despite positive economic opportunities: challenges in honeybee utilization, including a lack of training and education (86.2%), limited market access (77.8%), environmental factors (24.5%), and financial constraints (61.8%), necessitating targeted interventions. Lack of training and education is the major challenges in honey bee products utilization among the communities. Government policies of honeybee products are economic landscape, suggesting that strategic interventions can harness their potential for poverty alleviation and sustainable development. Government should engage with policymakers to create an enabling environment for the sustainable growth of the honeybee production and also create local and regional marketing networks, providing training on market-oriented production, and exploring e-commerce platforms to reach a broader consumer base

.

.**Keywords:** Honeybee products, Poverty alleviation, rural communities and Utilization

INTRODUCTION

Honey is a natural sweet substance produced by bees using nectar from flowers. It is a viscous liquid with a golden or amber color, known for its rich taste and various health benefits. Honey is commonly used as a sweetener, ingredient in cooking, and as a remedy for certain ailments (Heathmont, 2013). Man has been collecting honey from wilderness for thousands of years,

honey is the natural sweet substances produced by honey bees *Apis mellifera* from the nectar of blossom or from the secretion of living part of plant. The best primary products of honey bee are honey, wax, pollen, royal jelly and venom (American Bee Journal, 2015). The history use of honey is parallel to the history man and virtually every culture can be found of its use of honey as a food source and as a symbol of employment in religious magic and therapeutic ceremonies (Flottum, 2016).

Honey is composed of sugar (about 76%) water (18%) and other ingredients that make up about (6%) (*United States Department of Agriculture*, 2018). Sugar gives the main characteristics of honey (sweetness) water folous (the liquid), and components that are found in small quantities determine the different between various types of honey. These different are the colour, aroma and taste sugar account in honey is not a single species, but consist of three kinds of sugar. These are the fruit sugar (fructose) which has among the highest (41) grape sugar (glucose) which has about 34% of ordinary sugar (sucrose) which is between 1 and 2%. The ratio of one types of sugar to other deepened of the source (Wiston, 2018). Flowers pasture and to same extend on enzyme invertase, which breaks down regular sugar in grape and fruit. This enzyme is located in the flower which the bee collect nectar but it is also present in present in the bee bully (Baglio, 2018). Honeybees are important pollinators for flowers, fruits, and vegetables. The live on stored honey and pollen all winter and cluster into a ball to conserve warmth. All honeybees are social and co-operative insect. Members of the hive are divided into the three types.

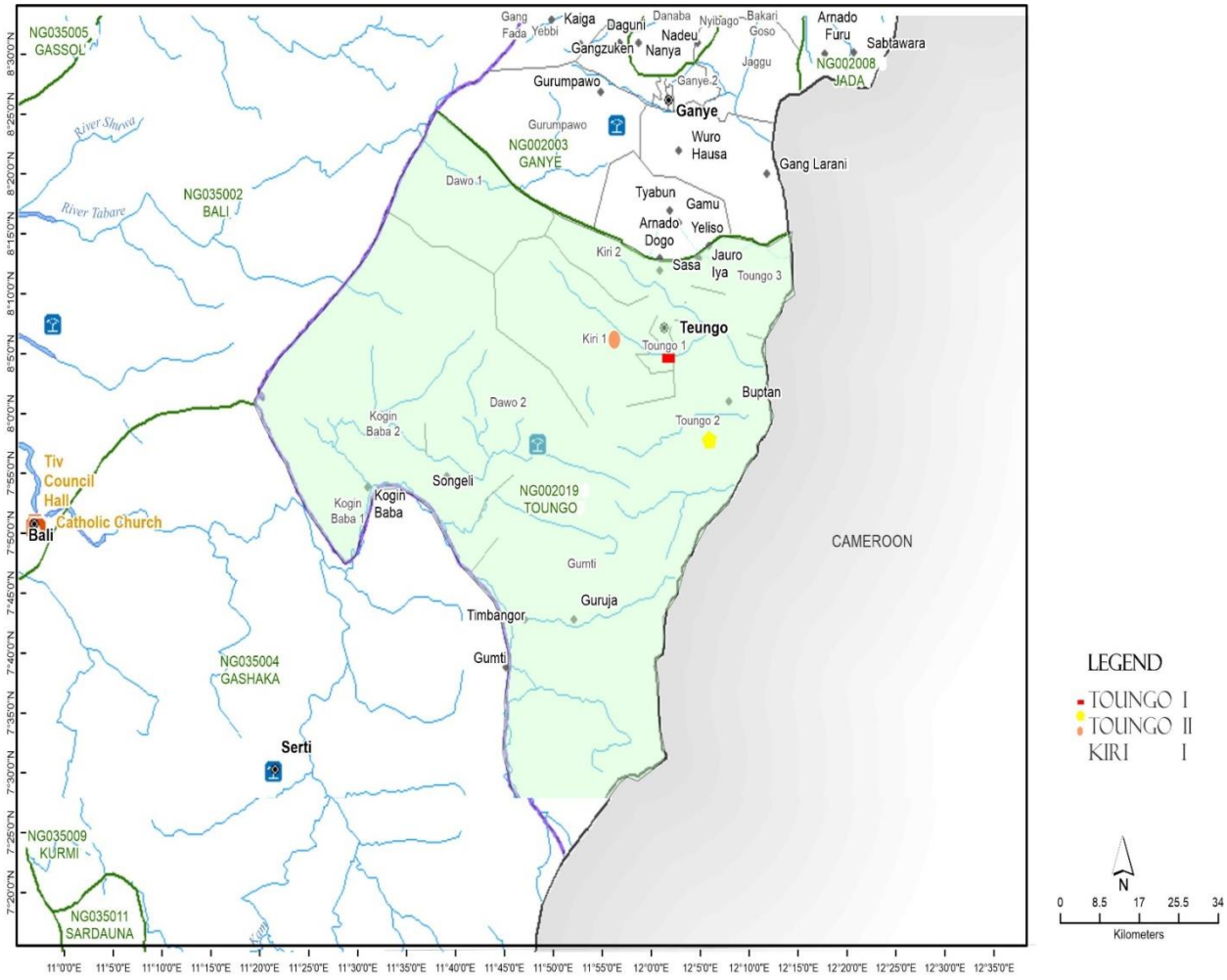
i. Members forage for food (Pollen and Nectar from flowers) build and project the hive, clean, and circulate air by beating their wings.
ii. The Queens job is simple laying of eggs that will spawn the hives next generation of bees. There is usually only a single queen in hives. If the queen dies, workers will create a new queen by feeding one of the workers females a special food called "Royal Jelly" this enables the worker to develop into a fertile Queen. Queen regulates the hives activities by producing chemical that guide the behavior of the other bees. Male bees are called drones.
iii. The third class of honeybee are called drones, several hundred drones live each hive during the spring and summer but they are expelled for the winter months when the hive goes in to lean survival mode (Ahmad *et al.,* 2021).

MATERIALS AND METHOD

Study Area

Toungo Local Government Area lies within latitudes 08° 05′ N to 08° 09′ N and longitudes 12° 03′ E and 12° 06′ E. it constitutes part of sheet 238 Southwest on a scale of 1:50,000. Toungo LGA has an estimated population of about 180, 911 with the land size of 5,665.37sq km. The area is primarily occupied by members of chamba, Hausa, and the Fulani ethnic groups. The notable landmark includes the Gbuni cave and the Gashaka gumti national park (Local government Diary, 2013). The area form part of Yola Arm of the Upper Benue trough. The area is characterized by moderate to high relief; marked by isolated hills and valley, and towards the central part there are few hills which stand out with the general elevation, with boulders and minor hills surrounding it. The elevation rises from 1,400 to 1,750 m above mean sea level; the area is well drain by ephemeral rivers and streams which gather most of the runoff from the hills. The drainage system exhibits a dendritic drainage pattern and it is dominated by the river Kom which flows from Northeast to Southwest (*Nigeria Media, 2023*).

Toungo LGA has Northern Guinea and Sudan Savannah zones having two season rainy and dry seasons, it is heavily forested and has approximately minimum of 15.1° C with maximum of 38.8° C from March to April, harmattan (November-February), an average humidity level of about 29 percent with the average of wind speed in the area calculate at about 11km/h. small hills and small mountain can be found in the Toungo L.G.A. (Toungo Local Government Area, Nigeria, 2024). The average annual Rainfall ranges from 1100 to 1600mm and the raining season



Map of Toungo L.G.A Showing Study Area

Sources: DTM RXVII, DWC, eHealth Africa, IHP, ITOS, Government of Nigeria (OSGOF), OSM, UNCS, WFP

lasted for months. Precipitation is lowest in January, with an average of 0 minutes. Most of the precipitation here falls in August, Averaging 156mm at average Temperature of 32.7°C (Toungo Adamawa, 2023).

Method of Data Collection

The data collection for this study is descriptive statistic through the use of questionnaire as primary data. other methods, such as surveys, interviews, observations, and existing records or documents were used.

Sampling and Sample Size

Purposive sampling was used for this study, three wards were selected at random out of the 10, which include Toungo I, Toungo II and Kiri I, this is because the wards are widely known for honey business in the Local Government. A total of 400 questionnaires was distributed across the three wards. The sample size for which questionnaire administered across the wards in the study area was determined using the equation by Yamane (1967). This is shown in Table 1.

$n = N/ (1 + (Ne^2)$

Where n = sample size

N = Population size

e = error limit

In this case, the population of Toungo is 180,911

Therefore, N = 180,911

e = assumed to be 0.05

Hence, $n = 180,911 / (1 + 180,911 *(0.05)^2)$

$= 180,911 / 1+ 180,911 * 0.0025$

$= 180,911 / 800.9$

$= 400$

$n = \underline{400}$

Data Analysis

Frequencies and percentages_used to analyse the collected data. The findings were presented in (descriptive narratives) to provide a table graph clear and concise representation of the data.

Table 1 shows the number of questionnaires distributed across the three wards based on the population and proportion of the wards. Toungo I has the highest respondents with frequency and percentage of 180 (45%), Toungo II has 120 (30%) respondents while Kiri ward has 100 (25%) respondents.

Table 1: Sample Size

Ward	Population	Sample Size
Toungo I	33,100	180
Toungo II	21,540	120
Kiri I	15,600	100
Total	**70,240**	**400**

RESULTS

Demographic Characteristics of Respondents

Gender distribution shows that male has 60.75% while female has less with 39.25% among the respondents. This suggested that males are more involved in Honey Bee products business than

the females in the study area. Age group with the highest respondents of 44.25% between 31-40 years of the total respondents, 41-50 with 34.75%, while 20-30 (20%) and above 50 (1%). The representation suggest that the honey product business is dominated by young individuals that are agile and strong.

Marital status shows that married people have 209 (52.2%) respondents while single have 191 (47.8%) respondents. Marital status of respondents determines the level of usage of honey products. Married people use honey bee products because of variety of needs of honey bee products that arises from the family. Occupation of the communities shows that farmers have 231 (55%) of the respondents, students 81 (20%), business owners 30 (28%) while civil servants have 28 (7%) respondents. Farming is the one of the major occupations of the people of the communities (Table 2).

Table 2: Demographic Characteristics of Respondents

Gender of Respondents		
Gender	**Frequency**	**Percentage (%)**
Male	243	60.75
Female	157	39.25
Total	**400**	**100**
Age Group of Respondents		
Age Group	Frequency	Percentage (%)
20 – 30	80	20
31 – 40	177	44.25
41 – 50	139	34.75
Above 50	4	1
Total	**400**	**100**
Marital Status of Respondents		
Marital Status	**Frequency**	**Percentage (%)**
Single	191	47.8
Married	209	52.2
Total	**400**	**100**
Respondents' Occupation		
Occupation	**Frequency**	**Percentage (%)**
Farmers	221	55
Business Owners	30	8
Civil Servants	28	7
Students	81	20
Unemployed	40	10
Total	**400**	**100**

Source: Field work, 2023

Years of Experience of Respondents in Honey Bee Product Usage

Results from table 3 shows the number of years respondents have been using and selling honey bee products in Toungo Local Government Area. It indicated that 42% of respondents have experience with honey bee products in selling and usage for 16-20years, 35.5% above 20 years, 19.5% from 11-15years, 2% for 1- 5 years while 1% 6-10years. This shows that the respondents have good knowledge of various honey products which contributes in alleviating poverty in the communities (Figure 1).

Table 3: Respondents' Years of Experience

Years of Experience	Frequency	Percentage (%)
1 – 5	8	2
6 – 10	4	1
11 – 15	78	19.5
16 – 20	168	42
Above 20 years	142	35.5
Total	**400**	**100**

Source: Field Work, 2023

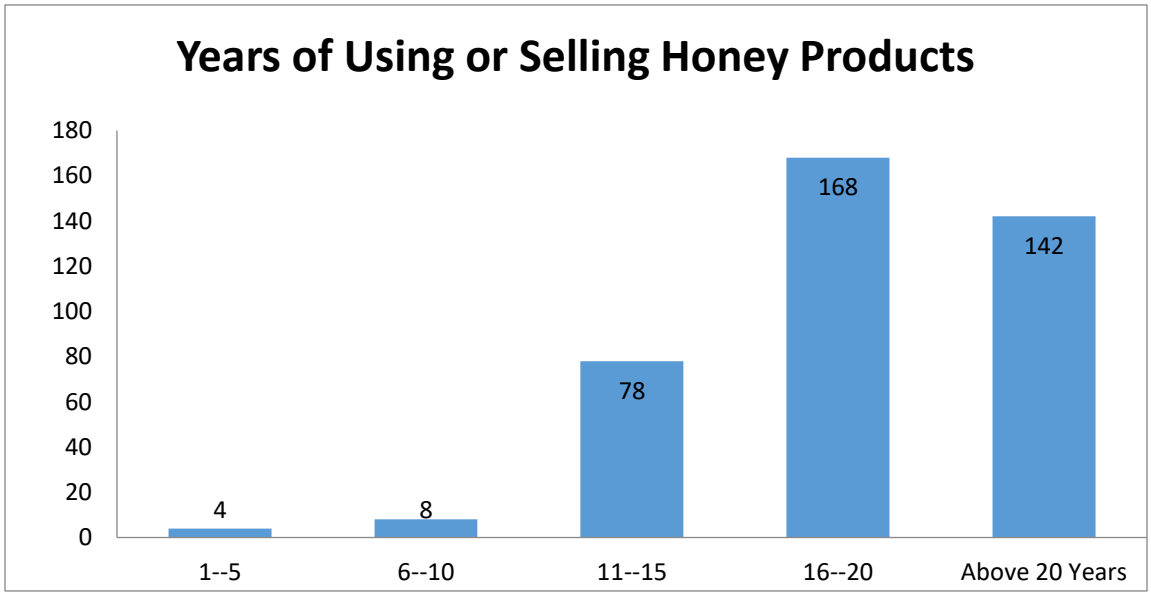


Figure 1: Respondents' Years of Usage and Selling Honey Products

Honey Bee Products Available in Toungo

Most Used Honeybee Products

Table 4 shows the most used honeybee products of available in the study area. Honey bee products identified include Honey, Beeswax, Bee Pollen, Propolis, Bee Venom and Royal Jelly. Honey is the most used product in the study area, 91% of the respondents used honey. This entails economic and nutritional value of honey, making it a potential driver for income generation and improved food security in the community. Furthermore, 75.5% of the respondents uses. Royal Jelly as product derived from honey, Royal jelly valued for its nutritional, cosmetic properties, local consumption and commercial exploitation. Propolis account for 69.5% of

respondents used which provide health-related products to a broader market. Bee Pollen 64.3% of the respondents which serve as income stream for beekeepers, contributing to their overall financial stability through selling. Beeswax 58.5% of the respondents due to high frequency market demand for beeswax-based products. Bee venom with a utilization rate of 71.5%, points to a community familiar with apitherapy. The extraction and sale of bee venom, known for its medicinal applications contribute to income generation and in turn poverty alleviation (Figure 2).

Table 4: Most Used Honey-bee Products in Toungo

Product	Frequency	Percentage (%)
Honey	364	91.0
Beeswax	234	58.5
Bee Pollen	257	64.3
Propolis	278	69.5
Royal Jelly	302	75.5
Bee Venom	286	71.5

Source: Field Work, 2023

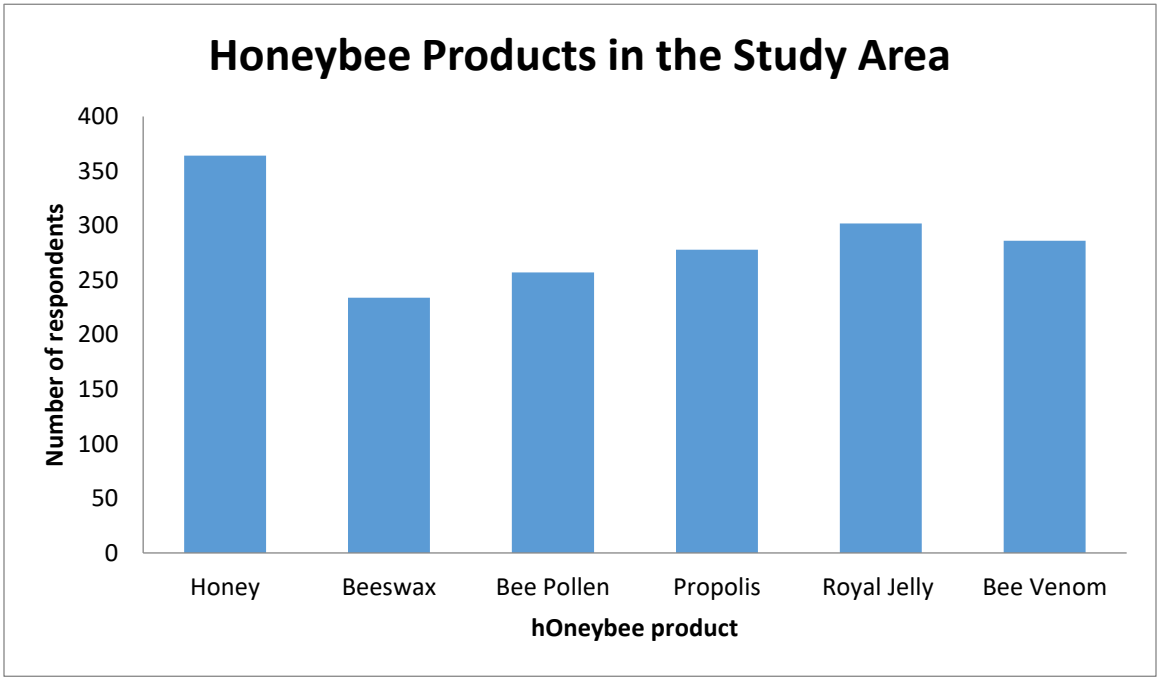


Figure 4.: Honey Bee Product in the study area

Usage of *Honey* among *Respondents*

Results from table 5 shows the various uses of honey in the study area. The percentage distribution of honey applications including nutritional supplement, traditional medicine, food ingredient, and preservative. Nutritional supplement 33.5% as a source of essential nutrients, potential and promoting health. Honey as a traditional medicine 74.5% found in the communities which in herbal practice and cultural heritage. Honey is used as a food ingredient 44% as an integral part of the local culinary landscape, enhancing dishes positions in the community. Honey is used as preservative 50.8% signifies its role of extending shelf life of certain food items, reducing waste and contributing to food security in the community.

Table 5: Uses of Honey in Toungo Local Government

Use	Frequency	Percentage
Nutritional Supplement	134	33.5
Traditional Medicine	298	74.5
Food Ingredient	176	44
Preservative	203	50.8

Source: Field Work, 2023

Value and Roles of Honeybee Products Utilization in Toungo

Income from Honeybee Products

Table 6 provides an overview of monthly income percentage generated from bee products. The percentage distribution of income brackets, ranging from 5,000 to above 30,000 Naira, offer insights into the economic contributions of honeybee activities in the region. At 21.5%, a considerable number of individuals in Toungo generate monthly incomes ranging from 5,000 to 10,000 Naira through honeybee products which is modest, it signifies a baseline economic contribution for the community. Community income 29% falls within the bracket of 11,000 to 15,000 Naira some individuals achieving a higher level from the sales of honeybee products, this indicates the potential economic development and improved livelihoods. An income of 18% generated within 16,000-20,000 Naira range this shows the scalability and profitability of honeybee activities. Beekeepers generating 13.5% monthly income between 21,000 and 25,000 Naira contribute significantly to the local economy, reinforcing economic sustainability of honeybee product ventures which constitute a noteworthy segment in improving living standards and increased financial resilience. Honey bee products of 10.5% falls between 26,000-30,000 Naira. Furthermore, 7.5% of respondents generate monthly incomes above 30,000 Naira from honeybee products. This represents a small yet influential group of beekeepers who have achieved a commendable level of financial success. As beekeepers generate higher incomes, they are better positioned to meet their basic needs, thus contributing to the overall reduction of poverty in the community.

Table 6: Monthly Income Generated from Honeybee Products

Monthly Income (Naira)	Frequency	Percentage
5000-10,000	86	21.5
11,000-15,000	116	29
16,000-20,000	72	18
21,000-25,000	54	13.5
26,000-30,000	42	10.5
Above 30,000	30	7.5
Total	**400**	**100**

Source: Field Work, 2023

Honeybee Product assist in Poverty Alleviation

Results from table 7 outlines the various ways in which honeybee product initiatives create economic opportunities in the community. Employment generation 77.8% as a consequence of honeybee product initiatives, fostering economic stability and reducing unemployment rates through honey extractions. Income diversification 91.7% helps in transformative individual livelihoods through reducing dependency on a single revenue stream. Entrepreneurial opportunities 96.5% which makes individuals to establish and expand businesses within the honeybee activities sector, contributing not only to personal financial growth and

broader economic development. Market development 33% enhance the rich of honeybee products beyond local boundaries, tapping into regional, national, and international markets, thereby amplifying economic opportunities for the community.

In the pursuit of economic opportunities, honeybee initiatives encounter various challenges that impact their growth and sustainability. Table 7 outlines these challenges, encompassing factors such as lack of training and education 86.2% signifies gap in knowledge and skills which hinder beekeepers to adopting modern practices. Limited access to market 77.8% which brings about market linkages and distribution channels. Insufficient infrastructure 84.3% serves as barrier to efficient honeybee product processing, storage, and transportation. Environmental factors 24.5% such as climate change, habitat loss, and pesticide affect bee populations and honey production. Inadequate finance 61.8% brings lots of difficulties in accessing funds for investment, expansion, and addressing immediate financial needs.

Beneficial support beekeepers seek to tackle the challenges inherent in honeybee activities which includes: Training and capacity building 17.5%, access to financial resources 58.8%. market Linkages 7.2%, infrastructure development 5.2% Government policies and incentives 11.3%.

Government policies implementation to support honeybee product initiative table 7 the perspectives of individuals engaged in honeybee product initiatives in Toungo regarding the most important government policies to support their endeavors. The result shows providing financial incentives 75.3%, offering training programs 11.3%, establishing quality 5.7%, and facilitating market access 7.7% to be encourag for honey bee keeper.

Table 7: Honeybee product initiatives create economic opportunities in the community

Option	**Frequency**	**Percentage (%)**
Employment generation	311	77.8
Income diversification	367	91.7
Entrepreneurship opportunities	386	96.5
Market development	133	33
Beekeepers Challenges		
Challenges	**Frequency**	**Percentage (%)**
Lack of training and education	345	86.2
Limited access to markets	311	77.8
Insufficient infrastructure	337	84.3
Environmental factors	98	24.5
Inadequate Finance	247	61.8
Beneficial Support for Beekeepers		

Support	**Frequency**	**Percentage (%)**
Training and capacity building	70	17.5
Access to financial resources	235	58.8
Market linkages	29	7.2
Infrastructure development	21	5.2
Government policies and incentives	45	11.3
Total	400	100

Government Policies to Support Honeybee Product Initiatives

Government Policies	**Frequency**	**Percentage (%)**
Providing financial incentives	301	75.3
Offering training programs	45	11.3
Establishing quality standards	23	5.7
Facilitating market access	31	7.7
Total	400	100

Source: Field Work, 2023

DISCUSSION

Honey plays a vital role as bee product to alleviate poverty among the communities of Toungo Local Government Area which dominated other bee product in terms of uses and utilizations such as traditional medicine, preservatives and food ingredient among the community. Findings showed that daily consumption of oral royal jelly (1000mg) for eight weeks is effective in alleviating menopause symptoms. It's also used for hay fever, diabetes, premenstrual syndrome (PMS), obesity, dry eye, and many other purposes. Bee venom has traditionally been used to treat inflammatory diseases such as rheumatism. However, bee venom has also been known to be used as an adjunct in the treatment of neurological disorders, asthma, and infectious diseases such as malaria. Propolis fight against bacteria, viruses, and fungi. It contains anti-inflammatory effects and help skin healing. Propolis is rarely available in its pure form. It's usually obtained from beehives.

Bee pollen is a mixture of flower pollen, nectar, enzymes, honey, wax and bee secretions. Bee pollen has gained traction in the health community because it’s loaded with nutrients, amino acids, vitamins, lipids and over 250 active substances, agrees with finding of (Vit, 2018). Bee pollen granules consist of approximately; **Carbohydrates:** 40%**, Protein:** 35%**, Water:** 4–10%, **Fats:** 5% and **other substances:** 5–15%

Beeswax is a waxy substance created by young honey worker bees. In beehives, *beeswax* is used by worker bees to create cells. In foods and beverages, as stiffening agents. In manufacturing, as thickeners, emulsifiers, and as stiffening agents in cosmetics. Beeswax absolute is used as a fragrance in soaps and perfumes. Beeswax helps lower cholesterol levels, prevent infections, and protect the stomach from ulcers caused by non-steroidal anti-inflammatory drugs. **This is in line to the finding of (**Marcelo et al., 2011; Bonvehi *et al.,* 1987)

Income generated from honey product differs within the study location but is increasing due to the high demands of bee product in the community. This agrees with find of (Agera, 2011) that Bee product help to safety net, providing households with extra income from the sales of honey and other beehive products. At the same time, bee products are nutritious food that can be an extra source of energy and nutrients.

Poverty alleviation through employment, income generation, entrepreneurship and market development. this is in line with findings of (Agera, 2011) it improves community techniques, increase production and strengthen their position on the market. The returns for beekeeping will eventually contribute to the wellbeing of the whole community. It also encounters challenges in the community such as training and education, limited access to market, insufficient infrastructure, environmental factor and inadequate finance. This study conforms with (**Addisu** and Desalegn, 2021) stated that bee colony decline, absconding and swarming, honeybee pests and predators, and lack of training and extension were identified as major challenges.
Beneficiary support and government policies to be provided for beekeepers in terms of training and capacity building, access to finance, market linkages, infrastructure development and incentives. Government should also provide policies such as offering training programs, establishing quality standard and facilitating market access. This is in line the Assent and Benjamin, 2002 Act.

Conclusion

In conclusion, the study highlights the integral role of honeybee products in the economic and nutritional landscape of Toungo Local Government Area. The community perceptions coupled with the identified challenges and beneficial supports, ensures the potential for honeybee initiatives to contribute significantly to poverty alleviation and sustainable development in the community.

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Assessment of the Training Needs of Extension Staff in Climate Change and its Impact on Agricultural Activities in Edo State, Nigeria

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Abstract

The study assessed the staff members at agricultural extension who needed to be trained on climate change and its impact on agricultural activities in Edo State. A simple random sampling procedure was used to choose about one hundred and twenty (120) agricultural extension staff, to collect data; the data collected were then summarized using percentages, frequency counts, and the mean. The findings indicated that male agricultural extension staff comprised a majority (65.0%) of the state's extension staff, 70.0% were between the ages of 31 – 50years with the average length of 13 years employment. Also, the study area indicated there is an increase in diseases and pest infestation (93.3%), erosion occurrences (91.7%), excessive heat (85.0%), flooding (77.5%), extreme cold temperature (75.0%), drought (65.8%), and high humidity (58.3%). Furthermore, it was shown that extension staff were avoiding indiscriminately bush burning, soil enrichment measures, planting of cover crop, irrigation scheme utilization, bush fallowing, etc. which were considered a training need by the extension staff sampled. The major constraints to the training need of extension workers of climate change includes inadequate fund by Government to support climate/weather recording facilities needed by their organization, irregular electric power supply, no knowledge of Nigerian Meteorological Agency (NiMET) services and products, obsolete/unavailability of weather/climate recording facilities and gadget, etc. The study concluded that they are major constraints to accessing climate information and there is a need for training in multiple areas of climate change. It is recommended that the Agricultural Development Program in the state should utilize regular Forth Nightly Training (FNT) meetings to educate extension staff about climate change issues.

Keywords: Extension staff, Training Needs, Climate Change, Observation, Agricultural activities

Introduction

The consequences of climate change occurrences are becoming more obvious as it intimidates the economy situation, culture, and societal institutions in addition to having profound effects on the physical environment and people's daily living. The Intergovernmental Panel on Climate Change (IPCC) of the United Nations resolved that human-caused greenhouse gas emissions are accountable for global warming and that this phenomenon is endangering ecosystems, civilizations, cultures, and economies of the entire world (IPCC, 2012). The amount of greenhouse gases in the earth's atmosphere is a main factor contributing to climate change.

The IPCC term climate change as a "change in the state of the climate that can be identified by changes in the variability of its properties which persists for an extended period, typically decades or even longer" (IPCC, 2011). IPCC further asserted that natural internal processes known as external forces or persistent anthropogenic changes in the composition of the atmosphere or land use can contribute to climate change (IPCC, 2011). In Nigeria, climate change has newly become particularly solemn, with terrible consequences now and then. Series of impacts of climate change around now include floods, landslides, droughts and famines.

As noted by Wangwe (2020), that the diverse impact of climate change, as it affects Nigerians populace is a lack of awareness about it as they still need to be educated and informed about it. When the weather worsens and storms become more frequent and intense, there are serious socioeconomic consequences to the livelihood of the people. Nigeria, though relatively fortunate with nature, experienced severe flood disasters in 2012 and 2022 which led to countless destruction of lives and properties (Odunayo, J., 2015). Sustainable forest management in Nigeria is being overwhelmed with many trials directly related to forest utilization and indiscriminate human activities in many of the state in Nigeria (Chandran K.P. &Sandya, P., 2022).

According to the Intergovernmental Panel on Climate Change (IPCC) (2017), climate change is manifested by rising temperatures, changes in rainfall, rising sea levels and intensification of natural disasters such as hurricanes, floods, droughts, and landslides. The extension sector must awake or rise, notwithstanding in collaboration with other stakeholders, to the challenge of improving the knowledge, attitudes and skills of extension agents and the clientele concerning issues that affect agricultural development in the country, including adaptation to the effects of climate change.

There is a need to regularly analyze the technical competence and job performance of agents who mediate between agricultural extension institutions and target farmers on all agricultural related issues. Antwi-Agyei & Stringer (2021) defined training need as the difference between the required level of individual competence and his present level of competence. Unfortunately, in Nigeria, the agricultural extension service system has failed to live up to this expectation in terms of climate change adaptation (Ebenehi, Ahmed and Barnabas, 2018), owing to the

extension agents' lack of climate change knowledge and capacity, who are the system's primary information disseminators to the farmers.

Most agricultural extension agents in Nigeria are of lower knowledge on climate change issues and its occurrences, impeding their ability to effectively deliver information and services to farmers in the same (Godson-Ibeji, et. al., 2020; Mustapha, et. al., 2012). The extension agent in forestry requires additional training to gain a better understanding of climate change issues and to be able to communicate effectively this to farmers (Ifeanyi-obi, Etuk&Jike-wai, 2012; Mustapha, Undiandeye&Gwary, 2012).

There is an increased need for extension agents to enlarge their capacity and role in order to meet the existing needs of rural farmers in the country. Involving extension agents in climate change training will positively influences their active participation in disseminating climate smart agricultural initiatives in many parts of the country (i.e. Nigeria), implying that extension agents will be willing to get involved in climate change issues efficiently.

This study aims to contribute to the body knowledge by closing the gap in assessing extension agents' climate change training needs in order to identify possible areas of training for extension agents.

Objectives of the study

The broad objective of the study was to assess training need of extension staff in climate change and its impact on agricultural activities in Edo State, Nigeria.

The specific objectives were to:

Describe the personal characteristics of agricultural extension staff in study area.

Determine the climate change observations by the agricultural extension staff in the study area.

Determine the areas of training needs on climate change by extension staff in the study area and;

Identify constraints to training needs on climate change among extension staff in the study area.

Hypotheses of the study

Ho1: There is no significant relationship between the male and female extension staff and area of training needs on climate change by in the study area.

Ho2: There is no significant relationship between the male and female extension staff and the constraints to training needs on climate change among extension staff in the study area.

2.0 Methodology

Edo State is an inland state in central southern Nigeria, with its capital – Benin City. It lies within the geographical co-ordinates of longitude 6º 04'E and 6o 43'E and latitude 5o 44'N and 7o 34'N of the equator. It is bounded in the south by Delta State, in the West by Ondo State, in the North by Kogi State and in the east by Kogi and Anambra States. The state occupies an area of 17,802km2 (6, 8773 sqmi) with a population of over 3million people. Edo State is situated in

the rainforest zone of Southern Nigeria. The annual precipitation is between 1500mm and 3000mm with rainfall days of about 200. The three distinct vegetation types are mangrove forest, fresh swamp, savannah. The state is divided into three agro–ecological zones: Edo North (comprises of 7 LGAs), Edo Central (comprises of 5 LGAs) and Edo South (comprises of 6 LGAs) with a major occupation of the people is agriculture (Levy& Kenneth E., 2024).

A multistage process was used to select respondents for the study. The first stage was the total selection of entire LGAs in the three (3) agro-ecological zones in Edo state, at this stage Edo north, south and central were selected. They were totally selected because the extension agent was spread across the state and equal representation is required in this study. This was followed by the random selection of at least ten (10) extension agent across the LGAs in Edo state giving a total of one hundred and eighty (180) extension agents across the LGAs in the state. At the end nine (9) respondents (i.e., extension agents) from each of the LGAs were able to be reached out to and this give a sample size of 126 respondents.

However, only 120 questionnaires were considered valid at the end of administering the research instrument. The primary data were collected from the respondents through the use of a structured questionnaire. Data from the study were analyzed using descriptive Statistics which involved frequency, percentage, mean, standard deviation. Inferential Statistics: Chi-square and Pearson's product moment correlation coefficient (PPMC) was used to test the hypothesis at 5% significant level.

Result and Discussion

3.1 Socioeconomic characteristics of the respondents

Result in Table 1 shows that majority (70.0%) of the respondents were between the age of 31 – 50 years of age with the mean age of 45years which shows that the extension workers were within the productive age and are likely adventurous in the search for information. 65.0% of the respondents were males, male dominance in extension work may result in a gender-blind approach to information and innovation dissemination (Adeola & Ayoade, 2011). Majority (68.3%) were married, 50.8% and 41.7% of the respondents practiced Christianity and Islamic religion respectively. Majority of respondents (44.1%) had B.Sc or B. Agric/HND, 21.7% had M. Agric, 30.8% had ND or NCE certificate and 3.3% of them had Ph.D qualification level. Above half (55.8%) of respondents had working experience of between 10 – 15 years.

The extension staff sampled cut across the hierarchy in extension service: majority (60.8%) of them were Extension agents, while 10.8% and 10.0% were Block Extension Supervisors and Block Extension agents respectively, 5.0% were Subject Matter Specialist, 3.3% were Director of Extension and Head of Women in Agricultural Extensions (HWIA) respectively and 6.7% of them were Chief Extension Officer. This reveals that there is still shortfall in the number of extension worker in the state. The ratio of 1:3 of Extension Agent to Block Extension supervisors.

Climate change observations by the agricultural extension staff

Findings in Table 2 reveals that extension staff climate change observations in the study area. The observations made by over 50% of the respondents indicated that there is increase in diseases and pest infestation (93.3%), erosion occurrences (91.7%), excessive heat (85.0%), flooding (77.5%), extreme cold temperature (75.0%), drought (65.8%) and high humidity (58.3%). The findings corroborate the report of Iwuchuku and Onyeme's (2013) that extension agents were aware of the effects of climate change on natural resources such as agricultural produce. The recent adverse effect of climate change events in Nigeria in terms of excessive rainfall, flooding and drought in the extreme north and some parts of the country may not be unconnected with respondents drive to meet information deficiencies in this regard.

As noted by (Koja-Odongo and Mostert, 2013), an information need may arise when an individual recognizes that his or her current state of knowledge is inadequate to meet up with the task at hand, or to resolve encounters, or to fill a void in some area of knowledge where necessary. According to Odunayo (2015), the multifarious impact of climate change, as it affects Nigerians is a lack of awareness about it as they still need to be educated and informed about it. When the weather worsens and storms become more frequent and intense, there are serious socioeconomic consequences. Malnutrition and disease become common occurrences (Fatile, 2013).

3.3 Areas of training needs on climate change by extension staff in the study area.

Result in Table 3 shows climate change training needs of extension staff towards climate change in the study area. The respondents affirmed that they need training in almost all the climate change practices itemized for this study. Dis-aggregating the data, result discloses that; forecasting of weather for planting was with the mean value ($\bar{x}$ = 1.88) and planting of wind breaker ($\bar{x}$ = 1.98) were not considered a training need by the extension staff in the study area. Iit could be noted that majority of the respondents had one form of education or the other as revealed in Table 1, they may be knowledgeable and aware of weather forecasting done by the weather forecasters and as such do not consider it a training need, likewise, have means of controlling wind outcome.

Some of the major training needs on climate change were avoiding uncontrolled bush burning ($\bar{x}$ =2.85) was considered a training need by the extension staff , soil enrichment measures ($\bar{x}$ =1.03), planting of cover crop/agroforestry ($\bar{x}$ = 2.40), irrigation scheme utilization ($\bar{x}$ =2.36), avoidance of bush burning practices ($\bar{x}$ = 2.33), bush fallowing ($\bar{x}$ =2.28), Planting of early maturing species ($\bar{x}$ =2.26), planting of trees for wind breakers ($\bar{x}$ =2.25) as training needs for climate change practices. This shows that respondents in the study area are not only involved in one aspect of production but are also involved in the other aspect of agriculture (i.e. processing and marketing) that could have impact of climate. This agrees with the findings of Ebenehi et al. (2018) who observed that men and women perform different tasks in agricultural activities or production, while the female are more into marketing and processing the males are more of production.

Table 1: Distribution based on personal characteristics of the respondents (n=120).

Variables	Frequency	Percentages (%)	Mean/std. deviation

Age (years)			
< = 31	19	15.8	
31 – 40	32	26.7	
41 – 50	52	43.3	44.55/ 10.23
51 – 60	17	14.2	
Sex			
Male	78	65.0	
Female	42	35.0	
Marital status			
Single	29	24.2	
Married	82	68.3	
Separated	9	7.5	
Religion			
Christianity	61	50.8	
Islam	50	41.7	
Traditional	9	7.5	
Educational level			
ND/NCE	37	30.8	
BSc, B. Agric/HND	53	44.1	
M. Agric	26	21.7	
Ph.D	4	3.3	
Working experience (years)			
<= 10	18	15.0	
11 – 15	67	55.8	13.4/5.32
16 – 20	35	29.2	
Job rank			
Directors of Extension	4	3.3	
CEO	8	6.7	
WIA	4	3.3	
EAs	73	60.8	
BES	12	10.0	
BEA	13	10.8	
SMS	6	5.0	

A United Nations Development Programme (UNDP) report (2010) on Gender and Climate change capacity development series evidenced that climate change has an adverse effect on the lives and livelihood of men and women differently because of their gender-based roles and this exacerbate existing gender inequalities. The vulnerability of women to climate change is also because large record of rural women engages in livelihood activities that are highly dependent on natural resources and these natural resources are highly climate sensitive as noted by FAO

(2020) For instance, agriculture, a highly climate sensitive sector supports the livelihood of 70-80% of farmers in Nigeria bulk of which are women.

Table 2: Distribution based on the climate change observation.

Climate change observation	Yes (%)	No (%)
Drought	79 (65.8)	41 (34.2)
Extremely cold temperature	90 (75.0)	30 (25.0)
Flooding	93 (77.5)	27 (22.5)
Excessive heat	102 (85.0)	18 (15.0)
Erosion occurrences	110 (91.7)	10 (8.3)
Increased pest and infestation	112 (93.3)	8 (6.7)
High humidity	70 (58.3)	50 (41.7)
Increased wind storm	41 (34.2)	79 (65.8)
Acid rain	12 (10.0)	108 (90.0)
Reduce natural vegetation	18 (15.0)	5.0)

Table 3: Areas of training needs on climate change by extension staff in the study area.

Training needs	Mean	Std. Deviation
Appropriate spacing of crop plants on the farm field	2.21*	.825
Avoidance of bush burning practices	2.33*	.803
Soil enrichment measures	2.52*	.660
Soil enrichment measurement like application of fertilizer	2.06*	.860
Irrigation scheme utilization	2.36*	.798
Zero tillage of the soil	2.19*	.818
Planting of cover crops/ agroforestry	2.40*	.769
Mulching of the soil and plants	2.07*	.798
Planting of trees for wind breakers	2.25*	.837
Pest management integration	2.20*	.822
Forecasting of weather for planting	1.88	.638
Bush fallowing	2.28*	.744
Farming program adjustment	2.14*	.853
Planting date adjustment	2.02*	.860

Planting of early maturing species	2.26*	.982
Manuring application	2.09*	.733
Planting drought tolerant species	2.16*	.792
Avoid indiscriminate bush burning	2.85*	.512
Planting wind breakers	1.98	.783
Improved weeding method (i.e. use of herbicide)	2.08*	.801
Clearing of the land with improved tools/machine	2.06*	.738
Harvesting information (i.e. timeliness and method)	2.13*	.682
Marketing information	2.22*	.724
Maintenance of equipment	2.18*	.733

3.4. Constraints to training needs of climate change among extension staff

Results in Table 4 show the seriousness of the constraints to extension staff' access to climate change matters in the study area. The major constraints to training needs of climate change by the respondents were revealed with their mean value ($\bar{x}$.) Inadequate fund by Government to support 11 climate/weather recording facilities needed by their organization ($\bar{x}$ =2.32), irregular electric power supply ($\bar{x}$=2.28), no knowledge of NIMET services and products ($\bar{x}$=2.14), obsolete weather recording facilities ($\bar{x}$ =2.11), unavailability of climate facilities and gadget ($\bar{x}$ = 2.09), wrong timing in climate information and data (= 2.07) and inaccessibility of climate information ($\bar{x}$ = 2.05) poor network/reception ($\bar{x}$=2.36) were the serious constraints identified by the extension staff sampled. Others minor constraint identified were; lack of technical know-how in operating climate equipment ($\bar{x}$=1.82) and extension staff lack of interest in climate matters ($\bar{x}$=1.93) were not serious constraints to the respondents.

Hypotheses of the study

Hypotheses one: There is no significant relationship between the male and female extension staff and area of training needs on climate change by in the study area.

This could be attributed to the fact that extension workers are not directly responsible for taking weather data in the ADP but the Monitoring and Evaluation staff assigned to metrological stations. However, adequate information should be made available and accessible to the extension staff through their in-house interactions (training, meetings, seminars etc.). Most agricultural extension workers need to be properly informed about crucial issues related their field such as climate changes, climate/weather situations of their environment. As noted by Ebenehi, et al. (2018) who stated that extension workers and farmers need to have access to agro-climatic information such as weather forecasts, adaptive technology innovations, or market-through extension and information system.

Table 4: Constraints to training needs of climate change among extension staff

Constraints	Major (%)	Minor (%)	Not a constraint (%)	Mean
Lack of fund by government to support climate facilities	70(58.3)	18 (15.0)	32 (26.7)	2.32
Irregular electric power supply	54 (45.0)	45(37.5)	21 (17.5)	2.28
Obsolete weather recording facilities	38 (31.7)	47(39.2)	35 (29.2)	2.11
Poor networking for electronic media	45 (37.5)	32 (26.7)	43 (35.8)	2.02
Inaccessibility of climate information	42 (35.0)	42 (35.0)	36 (30.0)	2.05
Unavailability of climate facilities and gadget	38 (31.7)	55 (45.8)	27 (22.5)	2.09
Wrong timing in climate information and data	44 (36.7)	40 (33.3)	36 (30.0)	2.07
Lack of technical know-how of staff in operating climate equipment	25 (20.8)	48 (40.0)	47 (39.2)	1.82
No knowledge of NIMET services and products	53 (44.2)	31 (25.8)	36 (30.0)	2.14
Extension staff lack of interest in climate matters	36 (30.0)	40 (33.3)	44 (36.7)	1.93

Source: Field Survey 2022, * Major constraints (mean ≥ 2.00)

The Nigerian Meteorological Agency (NiMET) has the mission to observe Nigerian weather and climate and provide meteorological, hydrological, and oceanographic services in support of national needs and international obligations (Anuforom, 2009). NiMET provides various agro-climate info services/products for managing hazards/food crisis. These services could not be said to be accessible to research and extension institutions consequently the extension workers let alone the farmers.

Gender differences on training needs to climate change

Table 5 shows the result of t-test analysis of the difference between the gender categories with respect to training needs on climate change among the extension staff in the study area. No significant difference exists between male and female respondents (65.032<66.332). This is an indication that both genders require additional training on climate change to the extent in which they are involved in disseminating agricultural information to farmers, this difference is not statistically significant.

Table 5: Difference between male and female on training needs to climate change in the study area

Variables (i.e. sex)	N	Training need score Mean	Difference	t-value	Decision
Male	78	65.032	0.342	0.432	Not significant
Female	42	66.332			
Total	120				

Source: Field survey, 2022 NS (Not significant) Critical value at 5% = 1.96

Ho2: There is no significant relationship between the male and female extension staff and the constraints to training needs on climate change among extension staff in the study area.

Difference between the male and female extension staff and the constraints to training needs on climate change

Result in Table 6 shows the result of t-test analysis of the difference between gender categories with respect to constraints to training needs on climate change among extension staff in the study area. There is significant difference existing between male and female respondents (44.65< 47.96) to constraints to training needs on climate change in the study area. This is an indication that staff females require more training than their male counterparts in the study area. The susceptibility of women to climate change is also because large record of rural women engages in livelihood activities that are highly dependent on natural resources and these natural resources are highly climate sensitive as noted by (FAO, 2020).

Table 6: Difference between the male and female extension staff and the constraints to training needs on climate change among extension staff in the study area.

Variables (i.e. sex)	N	Training need score Mean	Difference	t-value	Decision
Male	78	44.65	4.852	8.103	Significant
Female	42	47.96			
Total	120				

4.0 Conclusion and Recommendations

The study showed that the extension staff made climate change observation relevant to the people. The most serious constraints to accessing climate information were poor funding, lack of attention to climate information among others. The studies clearly show that there is a need for training in multiple areas of climate change and in the agricultural sector. In order to have a training program that meets all aspirations of extension staff and to promote the agricultural sector, there must be a training program with the training needs identified to avoid loss of time, effort, and money without achieving training objectives. Male and female extension staff perceived several climate changes as relevant.

Training needs expressed about climate change were similar for both gender but females perceived serious constraints to climate change training in the study area. Extension staff sampled had broad spectrum of information needs covering several areas and sought information to meet training needs on climate change in Edo State. Agricultural researchers collaborated with extension workers in meeting their information needs is of important to improve agricultural activities of the farmers in area.

The following recommendations are made based on the findings of this study:

Climate change information should be established, better harmonized and related to local agricultural activities on a regular basis for extension staff to access at the State and Local Government level.

Agricultural Development Program in the state should utilize regular Forth nightly training (FNT) meetings to educate extension staff about climate change issues.

Availability of fund by the government to purchase the necessary weather recording facilities needed in the ADPs in order to complement NIMET effort at State and local level should be implemented.

Efforts should be directed by the government to ensure stable electricity in order to guarantee direct access and use of facilities (ICTs) to access proven climate information and training;

NIMET services and products should be accessed directly by the ADPs through the internet as immediate information which could be complemented by their locally obtained data;

Extension staff should be sensitized in the use of ICTs (as formal sources) so as to have access to recent development and to have up-to-date global information relevant to their tasks;

Also, there is a need for ongoing studies to find out training needs in any area of climate change or any hitch that will affect negatively the performance of agricultural extension staff should be efficiency, skills, knowledge and information that makes the employee unable to perform the appropriate career.

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Ethnobotanical Survey of Medicinal Plants in Daura Local Government, Katsina State, Nigeria

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Abstract

The study Ethnobotanical Survey of medicinal plants used in the Daura Local Government area of Katsina State was conducted to examine and catalogue the traditional methods of preparation, dosing, and administration of medicinal herbs. Purposive sampling techniques were used to select the target respondents, while structured questionnaires were used to collect the data. Descriptive statistics was used to analyse the data obtained from the study. The result revealed that most respondents (82%) were males, while 18% were females. The result shows that 40% of the respondents are 40 years and above, while 18-25 years is the most minor age, with 8%. The result also shows that 54% of the respondents were married, while 10% were single. The majority of the respondents, 76%, were herbal medicine practitioners, while 24% were herbal medicine vendors. The majority of the respondents, 48%, possessed a Primary school education, while 2% obtained a Degree. The findings revealed that 12 medicinal plants were used to treat Sexually Transmitted Diseases. These plants belong to the families of *Anacardiaceae, Caricaceae, Amaryllidaceae, Malvaceae, Musaceae, Sapotaceae, Moraceae, Arecaceae, Moringaceae, Rhamnaceae*, and *Leguminosae*. The majority of the respondents, 86%, believed that using traditional medicine does not cause any side effects, while 24% opposed it. This research documented the medicinal plants used in the Daura Local Government area of Katsina State, their preparation mode, and the parts of the plants used. The study also recommended that the government encourage and support the sale and use of medical plants due to their efficacy in curing people's ailments and relatively lower cost.

Keywords: Ailments; Medicinal Plants; Traditional medicines

Introduction

The term ethnobotany was initially used in 1896 by American botanist John Harshburger to describe his attempts to discover more about the plants used by aboriginal and primitive people (Qureshi *et al.,* 2009). Since then, it has come to be recognised as the traditional knowledge that indigenous cultures possess about the variety of plants and how various people use the local plants that are endemic to their places (Ali-Shtayeh *et al.,* 2008). Ali-Shtayeh *et al.* (2008) state that plants are significant sources of drugs that cure various human ailments. In the past, all kinds of therapy, manufactured from essential plant components or more complex forms like mixtures, crude extracts, etc., came from plants. These days, many drugs that work against a wide range of ailments are made from plants (Farnsworth & Soejarto, 2006).

Medicinal herbs have significant benefits for both modern and conventional medicine. Based on their proven real value, these plants provide primary healthcare for over 80% of the rural population (Preethi *et al.,* 2011). For a very long time, people have used plants as sources of healing to treat a wide range of illnesses, but this is especially true for individuals in Africa (Sofowora, 2006). Despite significant breakthroughs in synthetic organic medicinal chemicals over the 20th century, approximately 25% of prescribed drugs in industrialised nations come directly or indirectly from plants (Preethi *et al.,* 2011). According to Bussmann *et al.* (2010), there is still not enough study on the plants used in traditional medicine. In developing countries like Nigeria and other parts of West Africa, where many people cannot afford synthetic drugs, up to 80% of people turn to medicinal plants for healing (Elujoba *et al.*, 2005). The World Health Organization (WHO) describes traditional medicine as the collection of all applicable knowledge, whether explicable or not, that is relied upon exclusively for the observation and practical experience that is transmitted verbally or in writing from generation to generation to diagnose, prevent, and treat physical, mental, or social imbalances (Abd El-Ghani, 2016). Plant-based remedies and traditional healers significantly impact the health of millions of people in Africa (Antwi-Baffour *et al.,* 2014). According to the WHO, conventional medicine is one of the most dependable strategies to guarantee that everyone globally has access to healthcare (Antwi-Baffour *et al.,* 2014). Many treatments have been developed from the expertise of people in tropical forests, and more will undoubtedly come about.

It is well known that most developing countries employ traditional medicines and medicinal plants as therapeutic agents to preserve good health (WHO, 2003). The main component of conventional medicine is medicinal plants, sold in marketplaces or administered by traditional healers in their houses (Okigbo *et al.,* 2009). The word "herbal drug" designates the plant parts or components (leaves, flowers, seeds, roots, barks, stems, etc.) used to make remedies. A medicinal plant is described by the World Health Organization (2002) as an herbal preparation created by subjecting plant parts to physical or biological processes such as extraction, fractionation, purification, concentration, or other techniques. These preparations might be made for immediate consumption or as a foundation for additional herbal products.

Due to a lack of access to modern healthcare facilities, the majority of people, especially those who live in rural areas, are still forced to treat common illnesses using ancient medicines. Thus, in the trade of medicinal plants, these individuals frequently constitute the weakest link (Ketula, 2007; Dharani, 2012). There may be a wealth of information regarding the use of plants against various illnesses in areas where their use is still highly valued (Muthee *et al.,* 2011). According to Igoli *et al.* (2005) and Gabriel *et al.* (2019), ethnobotanical surveys are essential for selecting plants for pharmacological screening. It stimulates continued research into natural plant-based pharmaceuticals.

This research aimed to examine and catalogue the traditional methods of preparation, dosing, and administration of medicinal herbs. Additionally, the study assessed the medicinal plants' viability in the research area and their potential for discovery.

Material and Method

Study Area

Daura is a town and local government area in northern Nigeria's Katsina State. According to Itamah and Amshi (1970), the Hausa people consider it their spiritual home. As one of the "seven true Hausa states" (Hausa Bakwai), the emirate was ruled by the offspring of Bayajidda's first wife, Daurama, along with Biram, Kano, Katsina, Zazzau, Gobir, and Rano. The region is between latitudes 120 30' and 130 30' North and longitudes 80 19' and 90 2' East (Smith, 1978). According to the 2006 population census (N.P.C., 2007), the area is home to 715,586 people. Rainfall ranges from 400 to 560 mm annually for four to five months. Low as 130 c occurs during the harmattan period, while high as 430 c occurs during the hot season (www.sunmap.en/weather/katsina/Daura). Major crops planted in the area that receive rain are millet, sorghum, cowpea, groundnuts, sesame, and others; crops that receive irrigation during the dry season include vegetables, wheat, rice, and cowpea. The majority of the population in the area work in agriculture, blacksmithing, trading, pastoralism, and animal rearing. The Hausa-Fulani group comprises most of the local population (Smith 1978).

Study Design

This study adopted a cross-sectional survey design. Cross-sectional study design is a type of quantitative research design. In a cross-sectional study, the investigator simultaneously measures the outcome and the study participants' exposures. This method utilised a semi-structured questionnaire. The study was primarily descriptive because it combined quantitative and qualitative data collection and analysis techniques to survey medicinal plants used to treat various ailments in the Daura Local Government Area.

Population of the Study

The target population was made up of traditional medical herbalists. An ethnobotanical survey of medicinal plants was conducted, and it involved 100 traditional medical herbalists. Herbalists were selected based on location (study area) and professionalism. Several people interviewed include Traditional Medicine Practitioners (T.M.P.) (those who practice traditional medicine popularly known as herbalists, Herb Sellers (those who sell herbs in shops or stalls, Herb Hawkers (those who hawk herbs and already prepared herbal mixture for dispensing) and older people who knew medicinal plant use. Informed consent was obtained verbally from all participants being interviewed. These informants were selected based on their vast knowledge of medicinal plants and many years of experience treating diseases (Common cold disease, including) using medicinal plants found in and around their areas.

Sampling Technique

A purposive sampling method was used to select respondents from the study area. Purposive sampling is a non-probability method for obtaining a sample where researchers use their expertise to choose specific participants to help the study meet its goals (Etikan *et al.,* 2016). The

choice of Daura L.G.A was informed by the fact that the population is sufficient for a good sample size.

Data Collection

Data was collected from August 2023 to September 2023. Herb sellers in marketplaces, motor parks, and popular bus stops in the central town of Daura were individually interviewed. Structured questionnaires and oral interviews were adopted to gather ethnomedicinal data. The questionnaire was administered directly to those who could read and write, while others were filled out after being interviewed orally using an interpreter. Information collected includes knowledge on the use of the medicinal plant species, the local names of the plant species, parts of plant used, dosage, methods of herbal preparation, mode of administration, duration of treatment, and other traditional uses. One hundred herb sellers were interviewed while a field survey was done on farmlands and forest reserves to identify the plants.

Data Analysis

The socio-demographic data of the respondents were analysed using descriptive statistical methods via frequency and percentages. The results obtained from the ethnobotanical survey will be analysed using the Relative Frequency of Citation (R.F.C.).

Result and Discussion

Results

Demographic Information of the Respondents

The result in Table 4.1 revealed that most respondents (82%) were males, while (18%) were females. The table also indicated the age range of the respondents, where 40 years and above represent 40% while 18-25 years has the most minor age with 8%. The results show that 54% were married, while 10% were single. The majority of the respondents, 76%, were Herbal Medicine Practitioners, while 24% were Herbal Medicine Vendors. This enables us to gather information about the medicinal plants used to treat various ailments in Daura L.G. The religious affiliations of the respondents, as shown in Table 4.1, indicated that 80% were Muslims, Christianity was 12%, and other religions available in the study area were traditional African religions 8%. This further suggests that Daura is a multi-religious L.G.A, as people can associate with their desired religions. The result depicted that the majority, 48% of the respondents, possessed a Primary education, and 36% had a secondary school education. Also, 6% of the respondents have either a diploma or a national certificate in education (N.C.E.), 2% obtained a degree and above, while the remaining 8% had none of the above educational qualifications.

Table 4.1: Demographic Information of the Respondents

VARIABLES	FREQUENCY	PERCENTAGE
GENDER		
Male	82	82%
Female	18	18%

Total	100	100%
A.G.E.		
18-25	8	8%
26-32	18	18%
33-40	34	34%
40 and above	40	40%
Total	100	100%
MARITAL STATUS		
Married	54	54%
Single	10	10%
Widowed	36	36%
Total	100	100%
OCCUPATION		
Herbal medicinal practitioner	76	76%
Herbal medicinal vendors	24	24%
Civil servant	0	0%
Business	0	0%
Total	100	100%
RELIGION		
Islam	80	80%
Christian	12	12%
Traditional African religion	8	8%
Total	100	100%
QUALIFICATION		
Primary education	36	36%
Secondary education	8	8%
Diploma/N.C.E.	6	6%
Degree and above	2	2%
None of the above	48	48%
Total	100	100%

Medicinal plants used for the treatment of various ailments

Medicinal plants used for the treatment of Sexually Transmitted Diseases (S.T.D.s)

Based on the ethnobotanical survey, Table 4.2 shows the plants used for treating Sexually Transmitted Diseases (S.T.D.s) in Daura. Also, their scientific names, common names, the plant part used, the preparation method used, and the mode of administration are depicted in the table. The findings of this study indicated that 12 medicinal plants were used to treat Sexually Transmitted Diseases in Daura L.G. The result showed most of the plants effective in curing STDS belong to the families of Anacardiaceae, Caricaceae, Amaryllidaceae, Malvaceae, Musaceae, Sapotaceae, Moraceae, Arecaceae, Moringaceae, Rhamnaceae, and Leguminosae.

Table 4.2 Medicinal plants used for the treatment of Sexually Transmitted Diseases (S.T.D.s) in Katsina Local Government Area

S/N	Family Name	Scientific name	Common name	Parts of plants use	Form of preparation	Mode of administration
1	*Anacardiaceae*	*Anacardium occidentale*	Cashew	Leaves	Decoction	External use (1x1) till recovery
2	*Anacardiaceae*	*Mangifera indica*	Mango	Leaves	Decoction	Internal use (3x1)
3	*Caricaceae*	*Carica papaya*	Paw Paw	Root	Tincture	Internal use (2x1)
4	*Sapotaceae*	*Chrysophyllum albidum*	Star apple	Seeds	Decoction	Internal use (1x1)
5	*Moraceae*	*Ficus exasperata*	Ficus	Leaves &root	Powder	Internal use (1x1)
6	*Arecaceae*	*Hyphaenethebaica*	Doum	Leaves	Decoction	Internal use (2x1)
7	*Moringaceae*	*Moringa oleifera*	Moringa	Leaves	Decoction	Internal use (3x1)
8	*Rhamnaceae*	*Ziziphusmucronata*	Buffalo-thorn	Leaves &flower	Decoction	Internal use (1x1)
9	*Leguminosae*	*Tamarindus indica L.*	Tamarind	Leaves	Decoction	Internal use (2x1)

Medicinal Plants Used for the Treatment of Common Cold among Children in Daura Local Government Area.

Table 4.8 indicates the plants used to treat the Common cold among children in Daura. The findings revealed that ten medicinal plants were used to treat the common cold in Daura. Most plants effective on common cold were from *Lamiaceae, Amaranthaceae, Combretaceae, Fabaceae, Liliaceae, Zingiberaceae, Rubiaceae*and*Myrtaceae*families.

Table 4.3 Medicinal plants Used for the treatment of common cold among children in Daura Local Government Area

S/n	Family	Scientific name	Local name	Plant part use	Form of preparation	Mode of administration
1	Amaranthaceae	Aervalanata	Efun	Leaves	Decoction	Internal (oral)
2	Combretaceae	Anogeisusleiocarpus	Marke	Bark &Leaves	Decoction	Internal (oral)
3	Fabaceae	Abrusprecaturius	Idon Zakara	Whole plant	Decoction	Internal (oral)
4	Liliaceae	Aliumsativum	Tafarnuwa	Bulb	Decoction/Powder	Internal (oral)
5	Zingiberaceae	Zingiber officinale	Chitta	Rhizom	Dccoction/infusion	Internal (oral)

6	Rubiaceae	Payettacrissipe	Rubatari	Leaves	Decoction	Internal (oral)
7	Myrtaceae	Zyzygiumaromaticun	Kanumfari	Flower buds	Powder/Decoction	Internal (oral)
8	Lamiaceae	Mentha piperita	Na'aNa'a	Leaves	Infusion/decoction	Internal (oral)
9	Rutaceae	Citrus limon	Lemuntsami	Fruits	Raw edible	Internal (oral)

Medicinal Plants Used for the Treatment of Malaria in Daura Local Government Area.

The most often used ethnobotanical plant species for the treatment of malaria were *Allium sativum, Croton macrostachyus, Carica papaya, and Lepidium sativum.* Leaves were used more frequently as a therapeutic preparation than other parts. Plant extracts were found to have very good, sound, and moderate anti-malarial activity in mice with rodent Plasmodium species.

Table 4.4: Medicinal Plants Used for the Treatment of Malaria

s/n	Botanical Name	Local name	Family name	Part of plant use	Mode of preparation
1	*Cochlerspernumtinctorium*	Rawaya	Cochlospermeceae	Dried leaves	Grinded & infusion
2	*Erythrina senegalensis*	Minjirya	Papilionaceae	Dried leaves	Grinded & infusion
3	*Ficusthoningii*	Chediya	Moraceae	Leaves and dried stem bark	Grinded & infusion
4	*Azadirachta indica*	Dogonyaro	Meliaceae	Leaves and dried stem bark	Decoction & infusion
5	*Carica papaya*	Gwanda	Caricaceae	Dried leaves	Decoction & infusion

Medicinal Plants Used to treat Sickle cell anaemia in Daura Local Government Area.

Researchers analysed the therapeutic potential of extracts from the leaves and seeds of *Cajanus cajan* (Pigeon Pea), leaves of *Zanthoxylum zanthoxyloides* (artar root), *Moringa oleifera* (leaves) and leaves of *Carica papaya* (Paw Paw) by extracting molecules in the structures and applying them to blood samples from S.C.D. patients. Other plants used to treat sickle cell anaemia are presented in table 4.5.

Table 4.5 Medicinal plants for management of sickle cell anaemia

S/n	Botanical name	Local name	Family	Part of plant us	Mode of preparation
1	*Syzygiumaromaticum*	Kanunfari	Myrtaceae	Buds/leaves	Dried & Infusion
2	*Carica papaya*	Gwanda	Caricaceae	Leaves dried	Infusion/Decoction
3	*Moringa oleifera*	Zogale	Moringaceae	Leaves dried	Decoction/Infusion

Medicinal Plants Used for the Treatment of Diabetes in Daura Local Government Area.

Table 4.6 indicated that the leaves and fruit of *Carica papaya* (papaya), *Mangifera indica*, leaves of *Azadiractaindica, Terminnaliacatapa*, bulb of *Allium sativum* and whole plant of Aloe vera by extracting molecules in the structures and applying them to blood samples from S.C.D. patients

Table 4.6 Medicinal plants for the management of diabetes

s/n	Botanical name	Local name	Family	Part of plant use	Mode of preparation
1	*Anisopusmannii*	Sakayau	Asclepiadaceae	Stem and leaves	Infusion
2	*Guierasenegalensis*	Sabara	Combretaceae	leaves dried	Infusion/Decoction
3	*Annona senegalensis*	Gwandar-daji	Annonaceae	stem-bark, root, leaves	Decoction/Infusion
4	*Aristolochiaalbida*	Dumandutse	Aristolochiaceae	Whole Plant	Decoction/Infusion
5	*Anogeissusleiocarpus*	Marke	Combretaceae	Stem-bark	Infusion
6	*Bauhinia thonningii*	Kalgo	Leguminosae	Whole plant	Decoction/Infusion
	Carica papaya	Gwanda	Caricaceae	leaves, fruit pulp, seed	Decoction/Infusion

Factors that influence the use of medicinal plants

The 4.7 below revealed that most respondents (86%) never found any side effects in using traditional medicine, while 24% suggested that they found side effects in using traditional medicine. The side effects of conventional medicine include diarrhoea, vomiting and dizziness. These side effects may result from non-proper administration and dosage of conventional medicine. Sometimes, many traditional medicines have adulterations with other ingredients; some traditional medicines are mixed with orthodox drugs and other heavy metals that may cause vomiting, diarrhoea and other side effects.

Table 4.7: Side Effects of Traditional Medicine

Response	Frequency	Percentage
Yes	24	24%
No	86	86%
Total	100	100%

Discussion

The findings revealed that most of the medicinal plants used for the treatment of Sexually Transmitted diseases in Daura L.G were *Anacardiumoccidentale, Chrysophyllum albidum, Musa paradisiaca L., Tamarindus indica L., Ficus exasperate, Hyphaenethebaica, Carica papaya, Moringa oleifera, Allium schoenoprasum L., Ziziphusmucronata, Gossypiumhirsutum,* and *Mangifera indica L.* out of which *Mangifera indica L*. has the highest value. This study is in line with that of Aanuoluwa and Omonike (2021), who reported that 52 Species of plants representing 34 families as reported by 80 traditional medicine practitioners as remedies for treating Sexually transmitted diseases in Ibadan of Oyo state, Nigeria. The families that were highly used include *Anacardiaceae, Fabaceae and Cucurbitaceae.*

Based on the ethnobotanical survey carried out in Daura, the findings revealed that most of the medicinal plants used for the treatment of the common cold in Daura L.G were *Aervalanata, Anogeisus leiocarpus, Terminalia avicennoids, Abrusprecaturius, Allium sativum, Zingiber officinale, Pavettacrissipe, Syzygiumaromaticum, Menthapiperita* and *Citrus limon.* This study conforms with that of Dolatkhahi and Nabipour (2014), who suggested that *Abrusprecaturius* and *Allium sativum* were used to treat the common cold in Iran. *Citrus limon* and Pavettacrissipe plants were utilised in southwest Iran to treat the common cold.

Allium sativum, Croton macrostachyus, Carica papaya, and *Lepidium sativum* were treated for malaria treatment. Leaves were used more frequently as a therapeutic preparation than other parts. Leaves and seeds of *Cajanus cajan* (pigeon pea), leaves of *Zanthoxylum zanthoxyloides* (artar root), *Moringa oleifera* (leaves) and leaves of *Carica papaya* (papaya) were used by extracting molecules in the structures and applying them to blood samples from S.C.D. patients.

People use herbal medicines to maintain or improve their health. Many believe that products labelled "natural" are always safe and sound. This is not necessarily true. Herbal medicines do not have to go through the testing that drugs do. Discussions on herbal medicine were associated with either mild/moderate diseases or using herbal medicine as a starting treatment before applying conventional medicine. In this context, participants emphasised the limits of herbal medicine for severe illnesses. Dissatisfaction with traditional treatment, past good experiences, positive aspects associated with herbal medicine, and family traditions were the most commonly-mentioned reasons why herbal medicine was preferred as treatment. Concerning information sources, independent reading and family traditions were found to be equally or even more important than consulting medicinal experts. Conversely, some factors discourage some people from using herbal medicine, such as inappropriate dosage, uninformed providers, poor packaging and labelling, fake products, fear of dangerous effects and unreliable herbal service vendors and practitioners.

Conclusion

Traditional medicinal plants provide an alternative therapy for treating many diseases in the significant number of people in the population under the direction of herbalists. Plant material can provide alternative treatment at a lower cost. This ethnobotanical survey has revealed high knowledge and use of medicinal plants in Daura L.G, Katsina State. This study has medicinal documented plants that can potentially treat or prevent different ailments. The information from this study can guide the discovery of new antiviral agents from the plants.

Recommendations

There is a need for an ethnobotanical survey in every state of the nation on medicinal plants used in the treatment of different ailments to preserve knowledge on medicinal plants and to update existing information; most of the medicinal plants used are from the wild, there is a need to encourage and enforce cultivation of medicinal plants, to reduce exploitation of plants growing in the wild. Otherwise, the extinction of valuable medicinal plants in the wild may occur.

Based on the findings of this research, I therefore recommend the following:

2. To preserve knowledge on medicinal plants and to update existing information, most of the medicinal plants used in Daura L.G are from the wild; there is a need to encourage the cultivation of medicinal plants to reduce the exploitation of plants growing in the wild. Otherwise, the extinction of valuable medicinal plants in the wild may occur.
3. The government should encourage and support the sale and use of medical plants due to their efficacy in curing people's ailments and relatively lower costs.

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228	Dr	Osunsina	Israel Oluyinka Oloyede	ISTF/NG/2020/228
229	Mr	Osuolale	Adesope Owoade	ISTF/NG/2020/229
230	Ms	Otemoye	Oluwaseun esther	ISTF/NG/2020/230
231		Owojori	KAFAYAT Abimbola	ISTF/NG/2020/231
232		Oyebade	Bukola	ISTF/NG/2020/232
233	Mr	Oyediji	Olalekan Mathew	ISTF/NG/2020/233
234	Mrs	Oyediran	Rofiat Ifeoluwa	ISTF/NG/2020/234
235	Mr.	Oyegbami	Akinleye Isaac	ISTF/NG/2020/235
236	Dr	Oyemade	Oyekanmi Olawale	ISTF/NG/2020/236
237	Mr	OYENIYI	Oreoluwa John	ISTF/NG/2020/237
238	Dr	Oyewo	Oyekunle Isaac	ISTF/NG/2020/238

239	Mrs	Oyewumi	Ronke Victoria	ISTF/NG/2020/239
240	Mr	Oyibotie	Godgift Oghenekeme	ISTF/NG/2020/240
241	Dr	Pelemo	John O.	ISTF/NG/2020/241
242	Mr	Popoola	Olayinka Daniel	ISTF/NG/2020/242
243	Mr	Quadri	Abiodun	ISTF/NG/2020/243
244		Riliwan	Mosobala Abiodun	ISTF/NG/2020/244
245	Mr	Saheed	Olanipekun Debo	ISTF/NG/2020/245
246	Ms	Saidat kemi	Oribolawale	ISTF/NG/2020/246
247	MS.	SALAUDEEN	ISLAMIYAT BUSOLA	ISTF/NG/2020/247
248	Mr.	Salisu	Faruq	ISTF/NG/2020/248
249	Mr	Sanni	Habeebullahi A	ISTF/NG/2020/249
250	Prof.	Sanusi	Yekeen Adeeyo	ISTF/NG/2020/250
251	Mr	Shittu Oluwaseun	John	ISTF/NG/2020/251
252	Dr	Shomkegh	Simon	ISTF/NG/2020/252
253	Mr	Shoneye	Oluwatayo Jide	ISTF/NG/2020/253
254	Mr	Simpson	Victor Bamidele	ISTF/NG/2020/254
255	Mr	Soroye	Sodiq Oladapo	ISTF/NG/2020/255
256	Mr	SULEIMAN	ABDULHAMEED BASHIR	ISTF/NG/2020/256
257	Prof.	Tee	Terver Norbert	ISTF/NG/2020/257
258	Dr	Tembe	Emmanuel Terzungwe	ISTF/NG/2020/258
259	Mr.	Thomas	MARVELLOUS	ISTF/NG/2020/259
260	mr	Tinuoye	kehinde	ISTF/NG/2020/260
261		Titilayo	Hassan habibat	ISTF/NG/2020/261
262	Dr	Titus	Ampitan	ISTF/NG/2020/262
263	Mr.,	Tope Mukaila	Kazeem	ISTF/NG/2020/263
264	Nurse	Tunji	Aladeyelu	ISTF/NG/2020/264
265	Ms.	Udekwe	Maryprecious Anwulika	ISTF/NG/2020/265
266	Mr	Udoh	Samuel	ISTF/NG/2020/266
267		UGBOH	Ephraim Nduka	ISTF/NG/2020/267
268	Mr	Umar	Lawan Alhaji	ISTF/NG/2020/268

269	Mrs	Umeh	Chisom Leticia	ISTF/NG/2020/269
270	Mr	Unigwe	Godwin Nnanedum	ISTF/NG/2020/270
271	Mr	Urim	Beshel Ato	ISTF/NG/2020/271
272	Mr	Victor	EZEANYA chukwuebuka	ISTF/NG/2020/272
273	Mr.	Victor Idinmachukwu Vincent	Anoliefo	ISTF/NG/2020/273
274	Mr	Victor. O	Elaigwu	ISTF/NG/2020/274
275	Mr	wahab	wasiu	ISTF/NG/2020/275
276	Dr	Williams	Olufunmilola Atoke	ISTF/NG/2020/276
277	Ms.	WOGHIREN	IMUWAHEN AIMUFUA	ISTF/NG/2020/277
278	Mr	Yager	Gabriel Ortyom	ISTF/NG/2020/278
279	Mr.	Yahaya	Usman	ISTF/NG/2020/279
280	Ms	Yebovi	Dede KpataNyon	ISTF/NG/2020/280
281	Mr	Yusuf	Adams Adebayo	ISTF/NG/2020/281
282	Mr	Zakariyyah	Dhikrullah Toyin	ISTF/NG/2020/282
283	Mrs		Olayinka Victoria Arowolo	ISTF/NG/2020/283
284	Mr		Abbas Abubakar	ISTF/NG/2020/284
285	Mr		Abdulaziz Umar	ISTF/NG/2020/285
286	Mr.		abdullahi saidu muhammad	ISTF/NG/2020/286
287	Mr		Abdullahi	ISTF/NG/2020/287
288	Mr		Abdullahi Bature	ISTF/NG/2020/288
289	Mr		Abdullahi Mukhtar	ISTF/NG/2020/289
290	Mr.		Abdullahi Usman	ISTF/NG/2020/290
291	Mr		Abdulmoroof Adedotun	ISTF/NG/2020/291
292	Mr		Abdulrahman sani	ISTF/NG/2020/292
293	Mr		Abdulrashid Inuwa	ISTF/NG/2020/293
294	Miss		Abdurrasheed	ISTF/NG/2020/294
295	Mr		Abegunrin	ISTF/NG/2020/295
296	Mr		Abiodun Abdulkabir, Yusuf	ISTF/NG/2020/296
297	Mr		Abubakar alhassan	ISTF/NG/2020/297

298	Dr		Abubakar Ali	ISTF/NG/2020/298
299	Mr		Abubakar Ali Yakasai	ISTF/NG/2020/299
300			Abubakar Dauda	ISTF/NG/2020/300
301	Mr		Adamu Muhammad Auwal	ISTF/NG/2020/301
302	Mr		Adamu sulaiman	ISTF/NG/2020/302
303			Yaduma Zacharia B. (Ph.D.)	ISTF/NG/2020/303
304	Mr		Adebayo Samson ADEOYE	ISTF/NG/2020/304
305	Dr		Adeboyin Funmi ADEROUNMU	ISTF/NG/2020/305
306	Mr.		Adekunle Oluwaseun	ISTF/NG/2020/306
307	Engr.		Adeniyi Michael Aderemi	ISTF/NG/2020/307
308	Mr		Adeniyi Okanlawon Basiru	ISTF/NG/2020/308
309	Mr.		Adewole, Adesiyan Tobi	ISTF/NG/2020/309
310	Mr		Ahmad Hafiz magaji	ISTF/NG/2020/310
311	Eng		Ahmed Kayode Aluko	ISTF/NG/2020/311
312	Mr		Aina-Oduntan	ISTF/NG/2020/312
313	Miss		Aisha Ibrahim Kabir	ISTF/NG/2020/313
314	Dr.		Ali	ISTF/NG/2020/314
315	Mr		Ali Gujja	ISTF/NG/2020/315
316	Mr		Ali mati	ISTF/NG/2020/316
317	Mrs.		Alice Titilayo Ademigbuji	ISTF/NG/2020/317
318			Aliyu Tukur Ibrahim	ISTF/NG/2020/318
319			Amarachi Esther Asiegbu	ISTF/NG/2020/319
320	Mr		Aminu	ISTF/NG/2020/320
321	Dr		Ancha Ukper Paul	ISTF/NG/2020/321
322	Dr		Areo Olusola Samuel	ISTF/NG/2020/322
323	Mr.		Atanda	ISTF/NG/2020/323
324	Mr		Austin Adedayo Adewoye	ISTF/NG/2020/324
325	Miss		Ayomide Rachel Oladipupo	ISTF/NG/2020/325
326	Mr		Babangida	ISTF/NG/2020/326
327	Alh		Bashar Muhammad	ISTF/NG/2020/327

328	Other		Bashir Haruna	ISTF/NG/2020/328
329	Mr		Bello Abdulhamid	ISTF/NG/2020/329
330	Mrs		Bernice Nwanna Francis	ISTF/NG/2020/330
331	Mrs		Bukola Hannah Ugege	ISTF/NG/2020/331
332	Mr		Chibuike Romanus Eze	ISTF/NG/2020/332
333	Mrs		Christiana Amokeye Andeshi	ISTF/NG/2020/333
334	Others		Christiana Omakiche SAMUEL	ISTF/NG/2020/334
335	Mr.		Musa Daniel	ISTF/NG/2020/335
336	Dr		Daniel Edet	ISTF/NG/2020/336
337	Prof		David Finchiwa Jatau	ISTF/NG/2020/337
338	Mr		David Sunday Richard	ISTF/NG/2020/338
339	Mrs		Deboah Akharume Adewole	ISTF/NG/2020/339
340	Miss		Deborah Elesie	ISTF/NG/2020/340
341	MR		DENIS AKINJIDE, ADENUGA	ISTF/NG/2020/341
342	Mr.		Dickson Olofu Oodo	ISTF/NG/2020/342
343			Dorcas Samuel	ISTF/NG/2020/343
344	Mrs		Doreen Keziah Osazuwa	ISTF/NG/2020/344
345	Mr		Ebuka Augustine ugwu	ISTF/NG/2020/345
346	Miss		Eccepacem Chukwudebe	ISTF/NG/2020/346
347	Dr		Edith Chinyelu Odozie	ISTF/NG/2020/347
348	Mrs		Emilia Ugochukwu Nnamani	ISTF/NG/2020/348
349	MR		EMMANUEL AYEGBA ABALAKA	ISTF/NG/2020/349
350	Mr		Emmanuel Kolawole Abodunrin	ISTF/NG/2020/350
351	Hon Chief Mrs		Esa	ISTF/NG/2020/351
352	Malam		Faisal muazuvHasheem	ISTF/NG/2020/352
353	Mr.		Faith Oluseye Oyedeji	ISTF/NG/2020/353
354	Miss		Faith Sumaduniya	ISTF/NG/2020/354
355	Miss		Faizat Yetunde Musa	ISTF/NG/2020/355
356	Mrs		Fatima Oluwaseun Kazeem-Ibrahim	ISTF/NG/2020/356

357	Mrs		Fatimah Lawal	ISTF/NG/2020/357
358	Dr		Francis Akinyele Faruwa	ISTF/NG/2020/358
359	Mr		Friday	ISTF/NG/2020/359
360	Mrs		Funmilayo Busola Okanlawon	ISTF/NG/2020/360
361	Dr		Gailyson Yelwa Jamala	ISTF/NG/2020/361
362	Mr		Gaius Adejuyigbe Adebusuyi	ISTF/NG/2020/362
363	Mr		Ganiyu Olosasa BABA	ISTF/NG/2020/363
364	Mr		Garba Abubakar Muazu	ISTF/NG/2020/364
365	Mr		Haastrup	ISTF/NG/2020/365
366	Miss		Hafsat Magori Muktar	ISTF/NG/2020/366
367	Mr		Hamza Yunus Adam	ISTF/NG/2020/367
368	Mr.		Haruna Alhassan	ISTF/NG/2020/368
369	Mr		Ibrahim Muazu Dankama	ISTF/NG/2020/369
370	Mr.		Ibrahim Muhammad Abdul	ISTF/NG/2020/370
371	Dr		Idorenyin Gideon	ISTF/NG/2020/371
372	Miss		Igho-Osagie	ISTF/NG/2020/372
373	Mr		John Ikpegbu	ISTF/NG/2020/373
374	mrs		ILIYASU AISHATU LADIDI	ISTF/NG/2020/374
375	Dr		Iroko	ISTF/NG/2020/375
376			Isaac Akuji	ISTF/NG/2020/376
377	Mr		Isaac Amonjenu	ISTF/NG/2020/377
378	Mr		Isah	ISTF/NG/2020/378
379	Mr		Ismail Babatunde Faniyi	ISTF/NG/2020/379
380	Mr.		Ismaila Abubakar	ISTF/NG/2020/380
381			Ismaila Yunusa	ISTF/NG/2020/381
382	DR.		J. Y jamala	ISTF/NG/2020/382
383	Mr		Jatto	ISTF/NG/2020/383
384	Mr		Jide Adedipe	ISTF/NG/2020/384
385	Mr		John Oseyomon Aigbokhan	ISTF/NG/2020/385
F386	Madam		Jojo Elhassan	ISTF/NG/2020/386

387	Dr		Joyce Okama AMADI	ISTF/NG/2020/387
388	Mr		Kabir Magaji	ISTF/NG/2020/388
389	Mr		Kabiru Galadima Hassan	ISTF/NG/2020/389
390	Mr		Kamal	ISTF/NG/2020/390
391	Dr.		Kaseem Dele Salami	ISTF/NG/2020/391
392	Miss		Lawal	ISTF/NG/2020/392
393	Mr		Lawal	ISTF/NG/2020/393
394	Miss		Lawal	ISTF/NG/2020/394
395	Mr.		Lawan Alhaji Umar	ISTF/NG/2020/395
396	Mal.		Maigari	ISTF/NG/2020/396
397	Malam		Maigari Malala	ISTF/NG/2020/397
398	Mrs		Mangodo	ISTF/NG/2020/398
399	Mrs		Medina Raji	ISTF/NG/2020/399
400	Mr		Mohammed Abdullahi	ISTF/NG/2020/400
401	Mr.		Mohammed Gomna BUKAR	ISTF/NG/2020/401
402	Mr		Mohammed Tarikh Abdullahi	ISTF/NG/2020/402
403	Miss		Msendoo Maureen Tondo	ISTF/NG/2020/403
404	Mr		Muammar Aminu	ISTF/NG/2020/404
405	Mr.		Muhammad Babale Garba	ISTF/NG/2020/405
406	Mr		Muhammad Sabiu	ISTF/NG/2020/406
407	Mr		Muhammad umar guri	ISTF/NG/2020/407
408	Mr		Muhammad Zayyanu Dalhatu	ISTF/NG/2020/408
409	Mr		Mujahid Sa'id Nura	ISTF/NG/2020/409
410	Mr		Murshiddin Suleiman	ISTF/NG/2020/410
411	Malam		Murtala Isyaku	ISTF/NG/2020/411
412	Mr		Musa	ISTF/NG/2020/412
413			Naseer Nuraddeen	ISTF/NG/2020/413
414	Mr		Nasir Yahuza Tukur	ISTF/NG/2020/414
415	Mr		Ngutor Barnabas Mbakuuv	ISTF/NG/2020/415
416	Mrs		Nkemdirim Ebubeoniso Odoya	ISTF/NG/2020/416

417			Nyalli	ISTF/NG/2020/417
418	Mrs		Odeleye Sifon Victoria	ISTF/NG/2020/418
419	Miss		Ogaji Hadiza Adamu	ISTF/NG/2020/419
420	Mr		Oke	ISTF/NG/2020/420
421	Dr.		Okosodo Ehi Francis	ISTF/NG/2020/421
422	Mr		Oladele Nathaniel AMOO-ONIDUNDU	ISTF/NG/2020/422
423	Mrs		Olajiire-Aja	ISTF/NG/2020/423
424	Mr		Olanipekun M Dahunsi	ISTF/NG/2020/424
425	Dr		Olasumbo Monsurat Wahab	ISTF/NG/2020/425
426	Mr		Olasuyi	ISTF/NG/2020/426
427	Dr Mrs		OLUBUNMI PAULINE ADEJOH	ISTF/NG/2020/427
428	Dr		Olufunlola Odunayo Akinola	ISTF/NG/2020/428
429	MISS		OLUOMA PERPETUAL ORJI	ISTF/NG/2020/429
430	Dr		Oluronke Olubunmi Sobola	ISTF/NG/2020/430
431	Miss		Oluwatoni Honour Afinjuomo	ISTF/NG/2020/431
432	Dr.		Oluwatoyin Opeyemi 3	ISTF/NG/2020/432
433	Mr		Oluwole Oke	ISTF/NG/2020/433
434	Mrs		Oluyemisi Babatunde	ISTF/NG/2020/434
435	Mrs		Omolabake Okon-Akan	ISTF/NG/2020/435
436	Mrs		Omolola Taiwo Adams	ISTF/NG/2020/436
437	Dr		Onyema	ISTF/NG/2020/437
438	Miss		Opeyemi Adesuyi	ISTF/NG/2020/438
439	Mrs		Oyedeji Marufat	ISTF/NG/2020/439
440	Mrs		Oyedele Yetunde	ISTF/NG/2020/440
441	Mr		Patrick Gregory Boni	ISTF/NG/2020/441
442	Mr		Patrick Monday Sule	ISTF/NG/2020/442
443	mr		peter ogah mathias	ISTF/NG/2020/443
444	Mr		Popoola Joseph Adekola	ISTF/NG/2020/444
445	Miss		Rabiu Aisha Darma	ISTF/NG/2020/445
446	Mrs		Rasheedah Suleiman	ISTF/NG/2020/446

447	Mr		Abubakar Sada Rufa'i	ISTF/NG/2020/447
448	Mr		SADIQ HASSAN ABBA	ISTF/NG/2020/448
449	Mr		Sadiq ismail	ISTF/NG/2020/449
450	Mr		Sagir Ado Danturai	ISTF/NG/2020/450
451	Mr		Sa'idu Murtala	ISTF/NG/2020/451
452	PROF		SALE	ISTF/NG/2020/452
453	Mr		Samsideen Olabiyi Rufai	ISTF/NG/2020/453
454	Mr		Samuel Olusola Oyewole	ISTF/NG/2020/454
455	Other		Sani abubakar muazu	ISTF/NG/2020/455
456	Mr		Sani Madugu	ISTF/NG/2020/456
457	Mr		Sanusi	ISTF/NG/2020/457
458	Mr		Sanusi Lawal	ISTF/NG/2020/458
459			Abubakar Shehu	ISTF/NG/2020/459
460	Mrs		Shekarau Bishiriyya Dahiru	ISTF/NG/2020/460
461	Mr.		Sheriffdeen Abiola Alli	ISTF/NG/2020/461
462	Mr		Simpson	ISTF/NG/2020/462
463	Mr.		Sonigitu Asibong EKPE	ISTF/NG/2020/463
464	Mr		Tijjani Abubakar Abu	ISTF/NG/2020/464
465	Mr.		Tirmizi Gbolagade Imran	ISTF/NG/2020/465
466	Mr		Tomiyosi Bola	ISTF/NG/2020/466
467	Miss		Ubaekwe Rosemary	ISTF/NG/2020/467
468	Dr		Ugochi Eucharia Ekwugha	ISTF/NG/2020/468
469	Mr.		Umar Mohammed Gidado	ISTF/NG/2020/469
470			Usamatu Buhari	ISTF/NG/2020/470
471	Engr.		Victor Sunday Gushe	ISTF/NG/2020/471
472	Mrs		Vivian Idu	ISTF/NG/2020/472
473	Mr		Yahaya Abdulazeez	ISTF/NG/2020/473
474	Mr		Yakubu Abubakar	ISTF/NG/2020/474
475	Mr		Yakubu Mustapha	ISTF/NG/2020/475
476	Mal		Yusuf Adamu	ISTF/NG/2020/476

477	Mr	Yusuf	Isyaku karofi	ISTF/NG/2020/477
478	Mr	Zahraddeen	Abdullah Adam	ISTF/NG/2020/478
479	Mr	OBIAJUNWA	Udoka Peter	ISTF/NG/2022/479
480	Dr	Adekunle	Abiodun E.	ISTF/NG/2022/480
481	Mrs	Oyediji	Olubukola Tolulope	ISTF/NG/2022/481
482	Dr	Nwajiobi	Benson	ISTF/NG/2022/482
483	Alhaji	MUHAMMAD	SA'AD HASHIDU	ISTF/NG/2023/483
484	Mr	Adeyemi	Timothy Olugbenga Adedotun	ISTF/NG/2023/484
485	Mrs	AONDONA,	ANITA NGUEMO	ISTF/NG/2023/485
486	Dr.	Oluwafemi	Zacchaeus Olaniyi	ISTF/NG/2023/486
487	Mr	Michael	Adedotun Oke	ISTF/NG/2023/487
488	Mr	Babatunde	Taiye Oluwasola	ISTF/NG/2023/488
489	Prof	Adeboyin	Funmi ADEROUNMU	ISTF/NG/2023/489
490	Dr.	Jibo	A.U.	ISTF/NG/2023/490
491	Prof	Iduma	Felix	ISTF/NG/2023/491
492		MUIBAT	OMOLARA	ISTF/NG/2023/492
493	Prof	Akinyemi	Oladipo	ISTF/NG/2023/493
494	Dr.	Bolaji	Kofoworola Adedigba	ISTF/NG/2023/494
495	Mr	Akintunde	Akintayo	ISTF/NG/2023/495
496	Miss	sola	Bose F.	ISTF/NG/2023/496
497		Oyewole	Adekemi Lizzie	ISTF/NG/2023/497
498	DR	Akintunde-Alo	Daniel Abiodun	ISTF/NG/2023/498
499	Dr.	Chukunda	Franklyn Chukunda	IST/NG/2023/499
500	Dr.	Simbi-Wellington	W.S.	IST/NG/2023/500
501		HALLIDAY	Ann Charles	ISTF/NG/2023/501
502	Mr	Aminu	Abdulhamid Suleiman	ISTF/NG/2023/502
503	Mrs	Ojedokun	Ojetejumola	ISTF/NG/2023/503
504	Mr	Muhammed	Sadiq Dala	ISTF/NG/2023/504
505	Dr	Oluwakemi	Osunderu	ISTF/NG/2023/505
506	Dr	Dishan	Ephraim Edward	ISTF/NG/2023/506

507	Mr	Egubogo	Azuka Chinedum	ISTF/NG/2023/507
508	Mr	Onuwa	Godfrey Chiabuotu	ISTF/NG/2023/508
509	Dr.	Ajala	Olayiwola O.	ISTF/NG/2023/509
510	Mrs.	Anagbor	Amarachukwu Sophia	ISTF/NG/2023/510
511	Dr.	Sowunmi	Linda I.	ISTF/NG/2023/511
512	Dr.	Aleru	Kennedy K.	ISTF/NG/2023/512
513	Dr.	Egwumah	Francis A.	ISTF/NG/2023/513
514	Dr	Fasoro	Oyinlola Abiodun	ISTF/NG/2023/514
515	Miss	Zara	Musa	ISTF/NG/2023/515
516	Mr	Abiodun	T	ISTF/NG/2024/516
517	Mr	Smart	Micheal	ISTF/NG/2024/517
518	Mr	Gambo	Abba	ISTF/NG/2024/518
519	Dr	Lucky	Dartsa Wakawa	ISTF/NG/2024/519
520		Mustapha	Maryam Boluwatife	ISTF/NG/2024/520
521		Olajire-Ajayi	Bolanle	ISTF/NG/2024/521
522		Aboh	Joseph	ISTF/NG/2024/522
523		Mobolaji	Clement	ISTF/NG/2024/523
524	Prof	Fagge	Aminu Umar	ISTF/NG/2024/524
525		Ukpeli	Glory Nnemoma	ISTF/NG/2024/525
526	Dr	Alamu	Olaniyi Thomas	ISTF/NG/2024/526
527		Olayanu	Clement Mobolaji	ISTF/NG/2024/527
528		Bashir	Yakubu Gadaka	ISTF/NG/2024/528
529		Awodutire	Oluwaseun	ISTF/NG/2024/529
530		Roberts	Udo udo	ISTF/NG/2024/530
531		Fanifosi	Gbenga Emmanuel	ISTF/NG/2024/531
532		Ekunola	Joy Nneka	ISTF/NG/2024/532
533		ONYENWEAKU	Levi Ndubuisi	ISTF/NG/2024/533
534	Dr	Anthony	Ikechukwu Onyenso	ISTF/NG/2024/534
535		Yakubu	Adamu Tada	ISTF/NG/2024/535