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FORESTRY AND THE CHALLENGES OF INSECURITY, CLIMATE CHANGE AND COVID-19 PANDEMIC IN NIGERIA

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FORESTRY AND THE CHALLENGES OF INSECURITY, CLIMATE CHANGE AND COVID-19 PANDEMIC IN NIGERIA

P. F. ADEOGUN

Introduction

There is no doubt that we are all familiar with the theme of this keynote address particularly in the recent times it has become a daily occurrence that we are faced with the challenges of **insecurity**, the ubiquitous **climate change** phenomena and of course the most dreaded **Covid-19** pandemic which has taken the lives of millions of people around the globe.

Each of these challenges is unique in its own characteristics and possesses devastating effects on the people, forests and fauna (wildlife). Forestry practice in Nigeria in the recent times has become endangered due largely to widespread incidences of attacks, killings, raping and kidnapping for ransom by harmed men who are supposedly foreigners and their local collaborators who have taken over many of our forest estates in Nigeria. This unsavory development has created so much **fear/terror** and has negatively impacted on forestry and allied activities in Nigeria in the recent times.

The Challenge of Insecurity

This is perhaps the only problem that has hitherto defied all strategic solutions in Nigeria. Strangely, it is pathetic that the military formations are equally helpless in effectively tackling and eradicating this particular monstrous challenge. The monopoly of violence is no longer exclusive right of the military but by the non-state actors. There are instances of security breaches too numerous to mentioned. The front pages of newspapers are daily awash with the news of attacks of bandits in Nigeria while television news headlines are often characterized by the same subject. The most perplexing aspect of this security challenges is that bandits, unknown gun-men or insurgents are majorly occupying many of our national forests in all parts of Nigeria from Sambisa forests in Borno State, Falgore in Kano State, many forests in the southern parts of Nigeria e.g. Oyo State and Ondo State forests, while Lagos and Ogun States are not exempted. Forests in the south east and south-south are not by any means equally exempted from the activities of these marauding criminals.

In a report, an intelligent meeting coordinated by the Defense Intelligence Agency DIA after an attack on an Abuja – Kaduna train identified three locations as destination of bandits after most attacks within that axis. The locations identified by DIA as bandit's dens are Rijana, Katari and Kasarami the forest areas frequently visited by these criminals. This of course is a major challenge of forestry in those areas and the ripple (terror) effect is felt all over other Nigeria forests.

According to Aju and Aju (2018) it was stated that since 2013 when the Boko Haram insurgents found a safe haven in the Sambisa forest from where they launch their attacks on the Nigerian State, neither Nigeria nor the forest has known any peace ever since. Unfortunately, the situation has grown from bad to worse and has continue to metastasis

No wonder therefore, the FAO declare Nigeria forests as one of the most threatened on the planet because of high population growth rates, conversion for subsistence, industrial agriculture and illegal logging and unsafe environment.

Forest establishment is therefore directly affected or impeded as a result of the risk associated with planning and carrying out any planting operations in the forest areas. In some cases, farmers have lost their lives to the sporadic shootings of insurgents, bandits or unknown-gun-men in many parts of Nigeria on their farms, highways and villages.

The Koshebe massacre took place on the 28th November 2020 in the village of Koshebe, in Borno, when as many as 110 civilians and peasant farmers were killed and six were wounded as they worked in rice fields in their village, The attack was thought to be carried out by the insurgents, (Koshebe massacre - Wikipedia). This kind of situation has made practice of forestry a serious challenge in Nigeria, even though most of the attacks are in the northern parts but the ripples effects are felt all over the country. There is no doubt that all this would affect the economic growth (foreign exchange earnings) and stability of the country as well.

Rural Urban Drift/IDPs

Traumatic disorders in affected communities have resulted in displacement of people from their homelands. This has led to exodus of people into the more relatively secure towns and cities. Borno Adamawa and Yobe States have the largest number of IDPs with nearly 1 million persons that have been internally displaced as a result of the insurgency with nearly 530,000 displaced persons in Maiduguri alone. We all know that forestry is rural based, hence the prevailing situation in most part of Nigeria rural areas does not favor practice of forestry and agriculture and if care is not taken the downward economic growth will continue and this will not augur well for the wellbeing of the citizenry. As late as of 2020, Nigeria has a total of 143,110 IDP camps out of which 84% are located in Borno State. The 3rd largest in Africa after DRC and Somalia. The full impact of this development is capable of reducing productivity of forest workers in the affected areas. In Vanguard publication of 8th November 2020, it was reported that over 3,000,000 persons were displaced in he North East alone. (https://www.vanguardngr.com/2021/11/idps-number-in-nigeria-rises-to-3million-refugees-commissioner/) The chief of Staff to Benue's Gov. Samuel Ortom says 1.5 million persons are in various Internally Displaced Peoples (IDPs) camps in the state. He further said

that Many of the States' prime farmers are in IDP camps having been rendered homeless by rampaging bandits. (https://www.vanguardngr.com/2022/06/1-5m-persons-in-idp-camps-in-benue-official/) This number does not exclude forest farmers in the State.

The Governor of Bene State, as a result has moved to create a security outfit for his State and said the State would apply to the FG to authorize purchase military grade weapons such as of AK 47 and AK 49 for Benue State Security Community Volunteer Guards to balance the threat capacity from those categories of Non-state-actors. This is in addition to the WSN code named Amotekun in the SW and other forms and kinds of self-help security arrangements in Nigeria have all indicated the seriousness of security deficiency in the country, the effect of which is all encompassing including especially forestry practice and business in the rural areas and highways.

Climate change challenges and forestry development

Climate change in Nigeria is a global phenomenon. It is felt by all and sundry. Nigeria has been experiencing what the rest of the world is experiencing in the area of socio-economic, agriculture, forestry and animal husbandry challenges.

Plantation establishment is a capital intensive operation in forestry but climate change does not help at all in this area. Particularly, in the arid north where seedling survival could be less than 30% due to effect of drought and erratic rainfall distribution the financial implication of this is weighty on the Federal, State or Local Government budget and performance.

The change in climate has affected the durations and intensities of rainfall which has resulted into runoffs and flooding in many places in Nigeria (Enete IC, 2014). Evidently, precipitation variation has to continue to increase. While in the southern states the precipitations have continue to rise while the northern states particularly the front-line states are experiencing intermittent drought. Which has made forest or plantation establishment a real challenge in these vast lands?

Forest fires

The most devastating effect on forest that could ever be is the forest fire. Fire is better not set or allow to enter a plantation than to mitigate it. Its effect is always permanent and costly in a plantation except it is used deliberately as a management prescription, Bergeron, Y., *et al*. (2002). Fires are adverse events with tangible costs for property and human life, Drew Martin (2016). The onus is on the manager of resources to know when to use and not to use fire in a plantation. In Nigeria and around the world fire has kept on making impact on the ecosystems even in the pristine forest of the amazon fire has been the issue, in California and in the middle east regions, including European countries such as Spain and France recently fire has caused great loses to the ecosystem there.

Therefore, fire is a big challenge to our forest either in the south or in the north of Nigeria. There is however, nothing that man can do to stop the fire from playing a role in ecosystem disturbances because fires do occur naturally on its own from the forces of nature such as volcanic eruption and lightning and in some cases due to mischievous tendency of some animals or birds such as the Firehawks. For decades, people in northern Australia have considered firehawks—the black kite (*Milvus migrans*), whistling kite (*Haliastur sphenurus*), and the brown falcon (*Falco berigora*)—part of the natural order. These birds are key to conservation.)
According to Waipuldanya Phillip Roberts in *I, the Aboriginal*, a 1964 autobiography of Roberts compiled by Australian journalist Douglas Lockwood, He stated that:

> *''I have seen a hawk pick up a smoldering stick in its claws and drop it in a fresh patch of dry grass half a mile away, then wait with its mates for the mad exodus of scorched and frightened rodents and reptiles," "When that area was burnt out, the process was repeated elsewhere."*

Challenges of covid-19 pandemic

By the time the virus spreads to most part of the globe it was almost impossible to contain it and hitherto the virus has caused untold hardship and death to most part of the world without exception.

The virus is unique in its own characteristics in that it was not possible to apply know vaccination technique to tackle it. It took a short while before scientists could break the DNA code and come up with a novel technique of fighting the virus. This in itself was a serious challenge and down the line of forestry and forest resources management the impact has affected all and sundry. The global pandemic due to COVID-19 has brought significant disruption to society and the environment. (Md. Saidur Rahman, *et al.*, 2021).

In Nigeria just like in many other countries, the effects of the incidences of Covid-19 were equally traumatic. The impact of lockdown was felt on both forest and wildlife conservation including the forest dependent people in a country like Bangladesh where detail information was collected. The nationwide lockdown in Nigeria as one would expect has its effect on both forest and non-forest income generation activities of the communities that are living in the forest and fringes of the forests. According to ILO (2020) on the impact of Covid-19 on the forest sector, it was said and I quote:

> *"The COVID-19 pandemic is affecting public health and causing unprecedented disruptions to economies and labor markets, including for workers and enterprises in the forest sector. The sector provides work for at least 54.2 million women and men worldwide, many in the informal economy. Forests are central to mitigating impacts of climate change, and around 1.5 billion people, many of whom are indigenous and tribal peoples, depend on forests for food, income, jobs, energy and shelter"*

If Covid-19 affected this huge number of people in this sector, we can then imagine the significant impact on our economy. Nigeria has a large rural population that is sustaining the country in the areas of food and wood production in the economy. For any successful forest operation, the health of the forester must be guaranteed. In 2020, the global pandemic caused a world-wide uproar in the health sector which reverberated so much in forestry sector.

There was a ban on the movement of people from one place to another. This impacted forestry activities and the like so much. It must be stated that there is no specific sector data on death of forestry workers but the overall death record from National Centre for Disease Control was alarming and inclusive particularly in the epicenter of the pandemic in Nigeria namely Lagos (769 deaths) and Abuja (249 deaths) as at 12/07/22, (NCDC Coronavirus COVID-19 Microsite).

There was a national decree that forced every citizen to stay in-door and where necessary the use of facemask was mandatory. As long as the pandemic continues there was no export or import of goods and services which seriously affected forestry production and export of timber and NTFP. Most countries including Nigeria exempted agri-food systems (including NTFP) from "lockdown" policies introduced to stop the spread of the virus among communities. This has a nation-wide effect on everybody. It caused disruptions to supply chains and falling consumer demand. There was a wider implication of the virus as Federal and State government implemented lockdowns across the country. The first major step taken included closing of all borders and many non-essential businesses which ultimately resulted in severe declining in remittances and export demand and the attendant economic recession.

Conclusion

In conclusion, discussions on forestry and the challenges of insecurity, climate change and covid-19 pandemic in Nigeria is very apt at this particular time in the history of forestry development in Nigeria. There is therefore, the need to strengthen all aspects of our social lives such as: (a) provision of adequate security and defense equipment for our forest guards to protect themselves and our forest estates. (b) mitigating the effects of climate change through the provision and support of mitigation practices and (c) provide health facility and/or health insurance for vulnerable forest workers in case of any event of possible epidemic.

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SUB-THEME 1

SUSTAINABLE FOREST MANAGEMENT AND NATIONAL SECURITY

SUSTAINABLE FOREST MANAGEMENT STRATEGIES FOR REVERSING THE RAPID TRANSFORMATION OF NIGERIA'S PROTECTED AREAS INTO ACTUAL EVIL FORESTS

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The Actual 'Evil' in Our Forests

The concept of 'evil forests' as locations where spiritual and temporal realms are blended and as regions where extra-terrestrials roam freely is well enshrined in Nigerian folklore. The prefix 'evil' is assigned due to the belief that whoever ventures into an area so designated, either willingly or by compulsion, stands to experience a significant level of harm. Several rural communities designate and restrict free access into such areas due to widespread belief that resident animated beings are prone to harming trespassers. In traditional justice systems, it is also the ominous gateway to a painful and shameful eternity where the worst social offenders are banished. This concept is already well illustrated in our homegrown movie industry and more empirically in several scientific reports (Onyekachi et. al. 2019; Green, 2013; Sankawulo, 1971, Njoku *et. al.*, 2017). Several foreign movies also attest to the fact that the concept of evil forests is actually a worldwide phenomenon.

Although usually based on fear, restricted anthropogenic activities in the said areas have helped to keep large swathes of forests in pristine conditions for several decades. However, in recent times, belief in spiritual landlords has rapidly waned to the detriment of biodiversity conservation. In several parts of Nigeria, former 'evil' forests in close proximity to cities have succumbed to infrastructural development. Their erstwhile potency to scare majority of the populace 'into line' has gradually faded with the emergence of younger generations who are more empirical than phantom in thinking. Displacement of so-called evil spirits by humans in traditional reserves and unhindered encroachment into gazetted forest reserves, wildlife sanctuaries, nature reserves and other protected areas, definitely portend multifaceted grave consequences for Nigeria as a whole. While it might be admissible to regard occupation of forests by spirits as fantastic, what is not fantasy nevertheless, is the grim reality facing Nigeria today. Several forest reserves are now best truly described as 'evil'; not because of phantom occupants but because forest reserves are now established bases of terrorists, insurgents, bandits and human-traffickers (Olaniyan, 2018; Olaniyan, 2018; Nsemba et.al., 2021; Popoola, 2014; Freshgist, 2014; Ladan, 2014; Marsai and Tarrósy, 2022, Prinz and Schetter, 2021).

Interestingly, at various fora, I have leeringly advocated for official designation of 'normal' forest reserves as 'evil forests', if only to scare away unrepentant loggers, poachers and their office collaborators from further decimating our common natural heritage. Unfortunately, the normalcy of our forest reserves has been eroded by prevalent violent attacks that are planned and launched from there. Most forest reserves in Nigeria now have a truly evil status. For instance, the very mention of the name 'Sambisa forest' send an immediate shiver down the spine of even the most ardent among field researchers. Several other popular research destinations (**Falgore Forest, Kano; Kamuku Forest, Kaduna; Yan Mangu Forest, Zamfara; Yankari Game Reserve, Bauchi; Sambisa Forest, Borno; several southwestern reserves and Niger Delta Mangroves) are no longer freely accessible or sensible to freely access.** Most researchers and even forest managers have sensibly stayed away from there precious natural estates to the misfortune of other species. As it is, the forests were safer when they were occupied by 'spirits' than now that they are occupied by evil men. Protected areas are no longer managed, and most wildlife have become food for terrorists. As such, we can no longer dutifully pursue the objectives of forest management, famously described by Adeyoju, 2001 and embodied in our National Forest Policy: *Nigeria's natural resources and environment is to be conserved and used for the collective benefit of the people and to be replenished for the benefit of future generations*.

Consequences of Insecurity on Nigeria's Protected Areas

The immediate consequences for biodiversity are that (i) forest managers are denied safe access, (ii) edible resources (flora and fauna) are excessively exploited, (iii) wildlife migration is prematurely triggered, (iv) several ecosystems functions are disrupted (v) the risk of bushfire is heightened and (vi) Access of poachers is made easier. Similarly, in addition to (i) biodiversity loss, other immediate implications for humans are (ii) insecurity of forest guards/managers, (iii) insecurity of life/properties in both nearby communities and urban centres. Concern over ineffective management of forest reserves in different states of Nigeria has taken a different dimension considering the fact that they are now used as hideouts by miscreants who unleash attacks on unsuspecting members of the society as well as public and private properties. Public concern regarding forest management has shifted from the extraction of timber to the preservation of additional forest resources, including wildlife and old growth forests, protecting biodiversity, watershed management, and recreation, protecting areas with fragile ecosystems, maintaining the diversity of life and developing new natural products for medicines (FAO, 2004). Insecurity of forests has dire socio-economic impacts that range from loss of lives, to biodiversity loss, to environmental degradation to economic sabotage. Nwogwugwu *et al*. (2012) highlighting how militancy in Niger Delta creeks decreased in-flow of foreign direct investment from about $20 billion in 2007 to about $6.1 billion in 2010. Loss of human lives have also been high. Similarly, around the country, forest-based insurgents, terrorists, bandits, drug lords and herdsmen have caused much socioeconomic and environmental damages through murder, rape, arson, man-stealing, looting and robbery.

Although forest reserves are public property governed by laws, the regulations of 1953 were merely designed to conserve the forests from illegal loggers, and harvesting of plants. The regulations did not anticipate the emergence of automatic rifle-wielding poachers or bandits and so need to be strengthened to capture present and future sources of danger to the plants and animals in these forests and to their neighbouring communities. In the past, there were patrol guards, armed with dane guns, which were ineffective against the super-fire of violent intruders. Environmentalists are also concerned about the possible transmission of zoonotic diseases if cattle cohabit with wildlife, possibly triggering a new set of medical emergencies. There is dire need to upgrade the laws and regulations to manage the nation's forest reserves and parks to fit the current reality.

Ladan (2014) reported on the modifications of several forest reserves in northern Nigeria due to occupation by violent groups: Balmo Forest Reserve (Bauchi/Jigawa States), Falgore Forest Reserve (Kano State), Idu Forest and Gwagwa Forest Reserves (Abuja FCT), Kabakawa Forest Reserve (Katsina State), Kagoro Forest and Kamuku Forest Reserve (Kaduna State), Ruma/Kukar Jangarai Forest Reserve (Katsina State) and Sambisa Forest Reserve (Borno State). Similarly, the propensity of terrorists to colonise forest reserves has also been reported for various parts of the tropics. In Kenya, gunmen believed to be members of Al-shabab hiding in two forests in Lamu county carried out attacks that kills 60 people, destroyed people houses and farmlands in July 2014. The Kenyan military deployed jets and security personnel to hunt down the attackers that are hiding in Gorji and Balasange forests (Daily Nation, 2014). In India, a guerilla war is going on between the militants and Indian troops stationed in Indian controlled Kashmir since 1989. The militants who have been hiding in Gungerpat, Dhanni and Zab forests and in August 2014 launch an attack that kills four soldiers.

Fierce battles usually take place intermittently across the region as the military tries to defeat the militants (Xinhuanet, 2014). In Colombia, the greatest concentration of FARC guerilla forces is in south eastern region of Colombia's 50,000 square kilometers of forests. The rebels have their bases in the forests from where they launch attacks on government forces, capture people used as soldiers, hostages and engage in illicit drug trade to finance their war. The rebels also hide in remote areas of the forest whenever they lost control of territories under the control. In Democratic Republic of Congo, various armed groups having their bases in the forests have been fighting the national army and United Nations forces for many years in the east. The armed groups from their forest bases ambush government troops and also launch attacks on the civilian population in the vast forests of the country. Besides thus, the series of wars waged in the country armed group took control of national parks where some endangered species are kept and forest rangers were kicked out which results in the death of the species. The armed group also engaged in the deforestation to produce charcoal to finance their illegal activities that serve as security threat to the country. According to UNEP (2010), the Garamba forest has been a rebel stronghold for nearly two decades which has negatively affected the plants and animals that are found there.

It is noteworthy however, that apart from insecurity, other challenges of managing forest reserves in nigeria have been described by several authors: (i) Obscure forest tenures/property rights (Adeyoju, 2005; Larinde and Chima, 2014), (ii) Unimplemented forest management plans (Osemebo, 1988, Akachukwu, 1997), (iii) Low community participation in forest management (Larinde and Chima, 2014), (iv) Inadequate manpower (Alao, 2005; Akindele, 2008; Akande *et al*, 2007; Faleyimu and Arowosoge, 2011; Popoola, 2014), (v) Inadequate funding (Famuyide, *et al*., 2005).

Environmental Consequences of Rebels Using the Forest as Hideout

Forests used as hideouts by rebel groups, are subject to degradation from mineral exploitation, hunting, and collection of fuel wood of these groups. When firearms become widely available in times of warfare this often leads to an eruption of wildlife hunting by armed factions but also by individual poachers that have acquired arms of war. Mineral exploitation activities have proven destructive there where chemicals are used to separate precious stones from rocks and dirt. In some cases, however rebels make efforts to protect the forest, and there with their cover, from large scale exploitation. For instance, in Colombia guerrilla groups use landmines and the threat of violence to prevent outsider penetration into forest areas (Alvarez, 2003). Direct environmental damage is likely as a result of combat related activities. Armies store and abandon ammunition in natural settings which risks water contamination (Westing 1992). By defending forest strongholds with land mines, local population and domestic and wild animals are in continuous life-threatening danger even for many years after the conflict. A more serious threat is when forests are destructed as a counterinsurgency measure. In many of the countries where the forest has been used as a sanctuary for rebel groups, forest destruction has been a deliberate strategy of state armies, paramilitary groups and rebel opposing villagers to destroy rebel fighting capacities. Several means have been deployed towards this end. In Myanmar the government has supported timber operations to open up deep forested mountainous areas where rebel forces sheltered. In Sierra Leone and Liberia villagers in some areas cut away tracks of forest along roads and around villages to protect themselves against ambush and village intrusion of rebels and criminals (Ruben and Doris, 2007).

Most negative damages to forest ecosystems are inflicted through chemical spraying campaigns. In Cambodia, defoliation chemicals are reported to have been used during the days of Khmer Rouge government, International Tropical Timber Organization (ITTO, 2005). Spraying chemicals allegedly causes health problems, loss of productive non-illicit crop areas, ecosystem damage in sprayed areas and - interrelated to these - economic impoverishment and migration of farmers (Sum-Ping 2006). In Mexico Zapatista rebels in 2001 suspected the army to use pesticide spraying programs to control the Mediterranean fruit fly as a disguised attempt to destroy the food security of farming communities suspected of harbouring rebel sympathizers. The government, however, maintained that spraying was purely phyto-sanitary reasons (Pimiento-Chamorro and Hammond 2001).

Strategies for reversing the hazardous impact of terrorism on protected areas

Recent reports (Ojo, 2020; Nsemba et. al., 2021; Prinz and Schetter, 2021; Marsai and Tarrósy, 2022) have highlighted the role of lack of proper governance of protected areas in exacerbating the colonization of the forest reserves commonly termed 'ungoverned spaces' by evil occupants. Hence a major route of recovery is to first recover the spaces by a skillful blend of dialogue and military intervention, thereafter, commence proper governance of the reserves. The following strategies are thus recommended:

i. Decisive military operations to dislodge forests of evil humans
ii. Enhancement of real-time satellite surveillance capacities of Ministry of Environment
iii. Integration of forest protection into the National armed security system
iv. Enactment of stronger legislation and implementation of existing ones
v. Extensive reforestation and enrichment of degraded reserves
vi. Extensive afforestation of new areas to offset recent deforestation
vii. Emphasis of recreation and tourist activities around forest reserves and within national parks
viii. Improved funding for management of protected areas
ix. Increased political will to sincerely tackle corruption issues surrounding forest protection
x. Establishment of military outposts contiguous to national parks and embedded within forest reserves
xi. Greater emphasis on urban forestry to augment total natural forest cover
xii. Subsequent management of all protected areas of Nigeria in line with UNEP's **Ecosystem Approach** to **Sustainable Forest Management** (SFM) and implementation of **Forest Principles** in all Nigeria's protected areas

The Convention for Biological Diversity (CBD) postulated **The Ecosystem Approach for achieving Sustainable Forest Management (SFM).** The postulations were agreed upon and adopted by the conference of the parties to the CBD in 1995. As described in UNEP (2004), the Ecosystem Approach for achieving SFM is thus outlined:

a. The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. Thus, the application of the ecosystem approach will help to reach a balance of the three objectives of the Convention: conservation; sustainable use; and the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources.

b. An ecosystem approach is based on the application of appropriate scientific methodologies focused on levels of biological organisation, which encompass the essential structure, processes, functions and interactions among organisms and their environment. It recognises that humans, with their cultural diversity, are an integral component of many ecosystems.

c. This focus on structure, processes, functions and interactions is consistent with the definition of "ecosystem" provided in Article 2 of the Convention on Biological Diversity: "'Ecosystem' means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit." This definition does not specify any particular spatial unit or scale, in contrast to the Convention definition of "habitat". Thus, the term "ecosystem" does not, necessarily, correspond to the terms "biome" or "ecological zone", but can refer to any functioning unit at any scale. Indeed, the scale of analysis and action should be determined by the problem being addressed. It could, for example, be a grain of soil, a pond, a forest, a biome or the entire biosphere.

d. The ecosystem approach requires adaptive management to deal with the complex and dynamic nature of ecosystems and the absence of complete knowledge or understanding of their functioning. Ecosystem processes are often non-linear, and the outcome of such processes often shows time-lags. The result is discontinuities, leading to surprise and uncertainty. Management must be adaptive in order to be able to respond to such uncertainties and contain elements of "learning-by-doing" or research feedback. Measures may need to be taken even when some cause-and-effect relationships are not yet fully established scientifically.

e. The ecosystem approach does not preclude other management and conservation approaches, such as biosphere reserves, protected areas, and single-species conservation programmes, as well as other approaches carried out under existing national policy and legislative frameworks, but could, rather, integrate all these approaches and other methodologies to deal with complex situations. There is no single way to implement the ecosystem approach, as it depends on local, provincial, national, regional or global conditions. Indeed, there are many ways in which ecosystem approaches may be used as the framework for delivering the objectives of the Convention in practice.

Consequent upon the ecosystem approach for achieving SFM, the following complementary and interlinked **twelve (12) Forest Principles** are also advanced to guide sustainable management of natural resources, especially protected areas:

Principle 1: The objectives of management of land, water and living resources are a matter of societal choice. ***Rationale:*** Different sectors of society view ecosystems in terms of their own economic, cultural and societal needs. Indigenous peoples and other local communities living on the land are important stakeholders and their rights and interests should be recognised. Both cultural and biological diversity are central components of the ecosystem approach, and management should take this into account. Societal choices should be expressed as clearly as possible. Ecosystems should be managed for their intrinsic values and for the tangible or intangible benefits for humans, in a fair and equitable way.

Principle 2: Management should be decentralised to the lowest appropriate level. ***Rationale:*** Decentralised systems may lead to greater efficiency, effectiveness and equity. Management should involve all stakeholders and balance local interests with the wider public interest. The closer management is to the ecosystem, the greater the responsibility, ownership, accountability, participation, and use of local knowledge.

Principle 3: Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems. ***Rationale:*** Management interventions in ecosystems often have unknown or unpredictable effects on other ecosystems; therefore, possible impacts need careful consideration and analysis. This may require new arrangements or ways of organisation for institutions involved in decision-making to make, if necessary, appropriate compromises.

Principle 4: Recognising potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem management programme should: (a) Reduce those market distortions that adversely affect biological diversity; (b) Align incentives to promote biodiversity conservation and sustainable use; (c) Internalise costs and benefits in the given ecosystem to the extent feasible. ***Rationale:*** The greatest threat to biological diversity lies in its replacement by alternative systems of land use. This often arises through market distortions, which undervalue natural systems and populations and provide perverse incentives and subsidies to favour the conversion of land to less diverse systems. Often those who benefit from conservation do not pay the costs associated with conservation and, similarly, those who generate environmental costs (e.g. pollution) escape responsibility. Alignment of incentives allows those who control the resource to benefit and ensures that those who generate environmental costs pay.

Principle 5: Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach. ***Rationale:*** Ecosystem functioning and resilience depends on a dynamic relationship within species, among species and between species and their abiotic environment, as well as the physical and chemical interactions within the environment. The conservation and, where appropriate, restoration of these interactions and processes is of greater significance for the long-term maintenance of biological diversity than simply protection of species.

Principle 6: Ecosystems must be managed within the limits of their functioning. ***Rationale:*** In considering the likelihood or ease of attaining the management objectives, attention should be given to the environmental conditions that limit natural productivity, ecosystem structure, functioning and diversity. The limits to ecosystem functioning may be affected to different degrees by temporary, unpredictable or artificially maintained conditions and, accordingly, management should be appropriately cautious.

Principle 7: The ecosystem approach should be undertaken at the appropriate spatial and temporal scales. ***Rationale:*** The approach should be bounded by spatial and temporal scales that are appropriate to the objectives. Boundaries for management will be defined operationally by users, managers, scientists and indigenous and local peoples. Connectivity between areas should be promoted where necessary. The ecosystem approach is based upon the hierarchical nature of biological diversity characterised by the interaction and integration of genes, species and ecosystems.

Principle 8: Recognising the varying temporal scales and lag-effects that characterise ecosystem processes, objectives for ecosystem management should be set for the long term. ***Rationale:*** Ecosystem processes are characterised by varying temporal scales and lag-effects. This inherently conflicts with the tendency of humans to favour short-term gains and immediate benefits over future ones.

Principle 9: Management must recognise that change is inevitable. ***Rationale:*** Ecosystems change, including species composition and population abundance. Hence, management should adapt to the changes. Apart from their inherent dynamics of change, ecosystems are beset by a complex of uncertainties and potential "surprises" in the human, biological and environmental realms. Traditional disturbance regimes may be important for ecosystem structure and functioning, and may need to be maintained or restored. The ecosystem approach must utilise adaptive management in order to anticipate and cater for such changes and events and should be cautious in making any decision that may foreclose options, but, at the same time, consider mitigating actions to cope with long-term changes such as climate change.

Principle 10: The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity. ***Rationale:*** Biological diversity is critical both for its intrinsic value and because of the key role it plays in providing the ecosystem and other services upon which we all ultimately depend. There has been a tendency in the past to manage components of biological diversity either as protected or non-protected. There is a need for a shift to more flexible situations, where conservation and use are seen in context and the full range of measures is applied in a continuum from strictly protected to human-made ecosystems.

Principle 11: The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices. ***Rationale:*** Information from all sources is critical to arriving at effective ecosystem management strategies. A much better knowledge of ecosystem functions and the impact of human use is desirable. All relevant information from any concerned area should be shared with all stakeholders and actors, considering, inter alia, any decision to be taken under Article 8(j) of the Convention on Biological Diversity. Assumptions behind proposed management decisions should be made explicit and checked against available knowledge and views of stakeholders.

Principle 12: The ecosystem approach should involve all relevant sectors of society and scientific disciplines. ***Rationale:*** Most problems of biological-diversity management are complex, with many interactions, side-effects and implications, and therefore should involve the necessary expertise and stakeholders at the local, national, regional and international level, as appropriate.

Sustainable Forest Management (SFM) offers a holistic approach to ensure activities deliver social, environmental and economic benefits, balance competing needs, maintain and enhance forest functions now and in the future. SFM aims to ensure that forests supply goods and services to meet both present-day and future needs and contribute to the sustainable development of communities. SFM stipulates that forest managers do the following:

- Maintain a stable forest land base
- Maintain or increase forest biodiversity
- Maintain diverse forest size structure and species composition on the landscape
- Maintain or increase the quality and quantity of water from forest ecosystems
- Maintain or increase soil productivity and minimize soil erosion and contamination
- Maintain or increase the capacity for sustained yield of timber and non-timber forest products
- Maintain or increase forest-based employment and community stability
- Maintain and enhance the quantity and quality of forest recreation and other opportunities for people to experience forests
- Maintain a system of institutions, policies, regulations, and incentives that support forest sustainability at multiple spatial scales
- Increase environmental literacy and engage a wide range of stakeholders in sustainable forest management

Similarly, national SFM projects require the following:

- Maintenance, conservation and enhancement of ecosystem biodiversity
- Protection of ecologically important forest areas
- Prohibition of forest conversions
- Recognition of free, prior and informed consent of indigenous peoples
- Promotion of gender equality and commitment to equal treatment of workers
- Promotion of the health and well-being of forest communities
- Respect for human rights in forest operations
- Respect for the multiple functions of forests to society
- Provisions for consultation with local people, communities and other stakeholders
- Respect for property and land tenure rights as well as customary and traditional rights
- Prohibition of genetically modified trees and most hazardous chemicals
- Climate positive practices such as reduction of GHG emissions in forest operations

Good forest governance would enhance peace building and socioeconomic activities

The instrumental role of the forest in conflict for both government and opposition parties calls for their inclusion in peace-negotiations, for the sake of peace-building and for the sake of sustainable forest management. The importance of granting of forests management rights to opposition groups may form an important part of their accommodation in a peace agreement has been discussed by some authors (Kaimowitz, 2005, McNeely, 2007). Kaimowitz (2005) however opined that inclusion of forest management in peace-negotiations is however, no guarantee for their sustainable management. Where management and exploitation rights are granted to former military leaders and ex-combatants, as has been the case in Myanmar and Nicaragua, the new situation of relative stability led to uncontrolled logging and further deprivation of forest dependent indigenous communities. The challenge in such contexts is to carry considerations related to local livelihoods and nature conservation into early stages of peace negotiations and reconstruction activities. Besides conflicts, banditry and terrorism that pose challenges to the nation, the multiple benefits of SFM cannot be over emphasized. The rural poor use forests in many ways, including for subsistence (e.g. fuelwood, medicines, construction wood, bush meat, fodder, mushrooms, honey and edible leaves, roots and fruits); revenue generation (e.g. art, craft, food and wood); formal and informal employment; and other purposes such as security (e.g. as a refuge in war or civil unrest), cultural and spiritual customs, and recreation, (CBD, 2011). Many urban dwellers also derive income from forests, and forests play an essential role in watershed protection and the prevention of land degradation, especially in montane ecosystems, all the benefits mentioned in one way or the other serve as key to improving national security. The multiple demands on forest goods and ecosystem services are unprecedented, but they are set to intensify with the increasing impacts of climate change, population growth and economic crises.

Conclusion

The current morphology of forest reserves into 'evil forests' must be halted. There must be decisive military operations to dislodge forests of evil humans via genuine political will and sustained enhancement of relevant government environmental agencies and apparatus. It is pertinent to enact stronger legislations, implement existing protection policies and integrate forest protection into the National armed security system. The renewed conservation efforts can benefit greatly from technological possibilities such as real-time satellite surveillance, even after sunset. As soon as the forest lands are recovered and access is safe, extensive reforestation, afforestation and enrichment should commence to offset erstwhile deforestation and degradation. It is also crucial to inject significantly higher funds to accommodate the extensive restorative work to be done. Recreation and tourist activities around forest reserves and within national parks should be enhanced to provide funds for sustainability. In the same vein, there must be increased political will to sincerely tackle issues of corruption surrounding forest protection. To forestall resurgence of insecurity and violence, military outposts that are contiguous to national parks and embedded within forest reserves should be established and adequately equipped and funded. To increase forest cover nationally, greater emphasis should be placed on urban forestry, community forestry and participatory forest management. It has become very pertinent to ensure that in actuality, subsequent management of all protected areas of Nigeria should be done in line with UNEP's Ecosystem Approach to Sustainable Forest Management (SFM) and full implementation of Forest Principles.

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PERCEIVED IMPACT OF DEFORESTATION ON RURAL HOUSEHOLDS INCOME: A CASE STUDY OF YEWA SOUTH LOCAL GOVERNMENT AREA OF OGUN STATE

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Abstract

The rate of deforestation and degradation of Nigeria forest resources is alarming. This study was carried out to investigate the impact of deforestation on rural household income in Yewa South Local Government Area of Ogun State. The selection of 180 respondents was done using two stage sampling techniques. Instrument used in data collection was structured questionnaires. Data were analysed and presented in tables using mean, standard deviation, mode, frequency and percentage, hypotheses were tested using inferential statistics (Z- Test, T- test, and Pearson Product Moment Coefficient of Correlation). The major causes of deforestation include; clearing of forest for farming purpose and logging of wood for timber and fuel wood. The perceived consequences of deforestation are decreased rural household incomes and rural poverty among the villagers. There was no significant difference (p<0.05) observed between respondents household income. Deforestation contributes to decreased income of the rural households. This study recommend that Logging plans should be adopted with ecological sound tree felling practices. The benefits such as economic, social, aesthetic and religious of forest people should be preserved. Consultation with the forest people by government agencies or forest resources exploiters should be done – this is to know their socio-economic development need without assuming their needs. Government and logging companies should carry out reforestation exercises to replace extracted tree species in the forests. There should be a zero or light logging in the areas prone to erosion (slopes and stream edges) in the forest.

Keywords: *Deforestation**,** Household income, Demand for agricultural land*

Introduction

In Nigeria, most forests are located in the southern axis and they include; Tropical Rainforests, the Swamp forests and Wooded Savannah. The total forest land cover is 91,077,000 Ha (910,770 km^2) and this represent 12.18% of the total land area (11,089,000 Ha (110, 890 km^2)) of Nigeria. Forest provide varieties of wood and non-wood products such as foodstuffs, medicinal plants, honey, incense, bamboo and so on. Within the Forest are trees, herbs, shrubs, climbers, lianas and other plant species as well as different wild animals that are of great value to the populace.

Forests have both social and economic benefit to the livelihoods of rural households by providing up to 40% of the total household income (Cavendish, 1999b; Mamo *et al.,* 2006). Rural households depend on forests as source of livelihood (WRI, 2005). Majority of rural households in Nigeria have an average land size of <1 hectare with low production and this could be as a result of increased human population (Birhanu, 2009). Due to land fragmentation, farmers are left with option of land clearing for agricultural purposes. Land clearing for agriculture is one of the causes of forest degradation and deforestation. Deforestation is a serious environmental problems that affect the welfare of the people negatively and the overall economy of the country (MoFED, 2002). Other factors like wood fuel harvesting by rural dwellers, logging and expansion of rural areas/villages, policy failure due to implementation and so on are also responsible to deforestation (Mulugeta and Melaku, 2008; Mekonnen and Bluffstone, 2008).

The annual rate of deforestation in Nigeria averaged 3.5% which is one of the highest in the world (Martins and Kuriakose, 2017). The forest area declined from 14.9 million ha.to 10.1 million ha which translates to the loss of 350,000 to 400,000 ha of forest land per annum (Martins and Kuriakose, 2017). Global Forest Assessment reported that Nigeria's forests and woodlands, which currently cover about 9.6 million hectares, have been dwindling rapidly over the past decades. Between 1990 and 2015, Nigeria lost about 35% of its remaining forest resources and over 50% of another wooded land. This situation is pathetic and signaled that the remaining forest area of the country might disappear in the next three decades if nothing is done.

The objective of this study therefore is to examine the impact of deforestation on rural household income and the challenges of deforestation in Yewa South Local Government Area of Ogun State.

Methodology

The Study Area

The study was carried out in Yewa South Local Government area of Ogun State, South-west, Nigeria. Ilaro is the headquarters of Yewa South Local Government with a coordinates of 6°53′00″N 3°01′00″E. The climate of the study area is tropical and characterized with wet and dry seasons. The wet season is associated with the South-West monsoon wind from the Atlantic Ocean while the dry season is associated with the northeast trade win from the Sahara desert. The temperature ranges between 21 ^{0}C and 34 ^{0}C while the annual rainfall ranges between 1500mm and 3000mm. The vegetation is fresh water swamp and mangrove forest.

Sample and Sampling Techniques

The sampling techniques was two stage sampling procedure. The first stage was purposive, which involved selection of six (6) villages (Ilaro, Idogo, Ijanna, Erinja, Ilobi and Owoye). In the second stage, 30 respondents were randomly selected each from the villages. A total of 180 respondents were selected for the study. The respondents comprise of farmers, hunters and educated members of the community.

Statistical Analysis

Data were collected, sorted and presented using mean, standard deviation, frequency and standard deviation. The research hypotheses were tested at $p<0.05$ level of significance using Z-test, independent student's t-test and Pearson Product Moment Coefficient of Correlation (PPMCC) statistics.

Results

The socio-economic characteristics of the rural households was presented in Table 2. Sixty-one percent of the respondents were male while 39% were female. This implies that more males were involved in deforestation than female.

Age distribution of the respondent showed that majority 40% of the respondents were between 31 – 40 years of age, 30% were within the age range of 41 - 50 years of age. Those that were within the age range of 21 – 30 years and above 50 years accounted for 22% and 8% respectively. On the whole, 70% of the respondents fall into the economically active age group of 31–50 years showing that the majority of deforestation actors are in the physically active age group.

About 70% of the respondents were married, 12% were divorced, 10% were widow and 8% were divorced. This assured that married households have a significant influence on deforestation activities as compared to other participants.

The study showed that 43% of the respondents had no level of formal education; 37% had primary school education, 14% had secondary school education while 6% had tertiary level of education. This situation of illiteracy has serious consequences on the level of deforestation and forest degradation in the study area.

Majority (60%) of the respondents had 3-6 members, 22% had 7-9 members, 10% had less than 3 members while only 8% had above 9 person per household. This implies that household with 3-9 persons per household engaged in deforestation activities than their other counterparts.

Majority (75%) of the respondents engaged solely on farming, 10% were teachers who engaged in farming to supplement their salary, 7% were traders who engaged in farming to supplement their income, 5% were motorcyclist who engaged in farming business while 3% who belong to other occupations also engaged in farming business.

Monthly income from income distribution showed that majority 60% of the respondents earned between ₦101,000-150,000 monthly income, 18% of the farm actors were within the monthly income of ₦51,000-100,000, (10%) of the respondents earned between ₦151,000-200000 per month, 7% earned above ₦200,000 per month while monthly income of less than ₦50,000 constituted the least of the respondents with 5%. On the whole 78% of the actors in the study area earned between ₦51,000 - ₦150,000 income monthly.

Table 1: Demography of the respondents (n = 180)

Variables	Frequency	Percentage (%)	Mode
Gender	110	61	Male
Male			
Female	70	39	
Total	**180**	**100**	
Age (year)	40	22	
21 – 30			
31 – 40	72	40	31 – 40 Years
41 - 50	54	30	
Above 50	14	8	
Total	**180**	**100**	
Marital status	14	8	
Single			
Married	126	70	Married
Divorced	22	12	
Widow(er)	18	10	
Separated	0	0	
Total	**180**	**100**	
Ethnicity			
Yoruba	162	90	Yoruba
Igbo	10	6	
Hausa/Fulani	8	4	
Total	**180**	**100**	
Education	77	43	No formal education
No formal education			
Primary education	67	37	

Variables	Frequency	Percentage (%)	Mode
Secondary education	25	14	
Tertiary education	11	6	
Total	**180**	**100**	
Household size	18	10	
Less than 3 persons			
3 – 6 persons	108	60	3 – 5
7 – 9 persons	40	22	
Above 9 persons	14	8	
Total	**180**	**100**	
Major occupation	135	75	Farming
Farming			
Trading	13	7	
Motorcycling	9	5	
Teacher	18	10	
Others	5	3	
Total	**180**	**100**	
Monthly Income	9	5	
₦10,000-50,000			
₦51,000-100,000	32	18	
₦ 101,000-150,000	108	60	₦101,000-₦150,000
₦151,000-200000	18	10	
Above ₦200,000	13	7	
Total	180	100	

Source: Field survey, 2020

The results of practices contributing to deforestation was presented in Table 2. The of forest resources with their mean score and standard deviation were reported as follow; Forest was being cleared for farming purpose (mean = 2.87 and standard deviation = 1.1030); logging for fuel wood was heavily practiced in the forest (mean = 3.27 and standard deviation = 0.9821; mining operation which was very destructive to the forest (mean = 3.86 and standard deviation = 0.8344); setting forest ablaze using wildfire to hunt animals was highly intensive (mean = 3.93 and standard deviation = 0.8175); urbanization to create more cities and towns was done by clearing the forest (mean = 3.55 and standard deviation = 0.9926); poverty that caused most houses to rely on the resources obtained from the forest (mean = 3.18 and standard deviation = 1.0184); low illiteracy level among the populace which often lead to removal of the forest (mean = 3.26 and standard deviation = 1.0157); expanding global market for timber had encouraged forest clearing (mean score = 3.86 and standard deviation = 0.9375; while natural causes such as floods and erosions destroying the forest (mean = 3.78 and standard deviation = 0.7912). This implies that setting forest ablaze using wildfire to hunt animals was a great challenge in the study area.

Table 2: Challenges of Deforestation in the study area

S/no	Contributions of Forest Resources	Sample Size	Mean score	St Deviation	Remarks
1.	Forest is being cleared for farming purpose.	180	2.87	1.1030	Agreed
2.	Logging for fuel wood is heavily practiced in the forest.	180	3.27	0.9821	Agreed
3.	Mining operation is destructive to the forest.	180	3.86	0.8344	Agreed
4.	Setting forest ablaze using wildfire to hunt animals is highly intensive.	180	3.93	0.8175	Agreed
5.	Urbanization to create more cities and towns is done by clearing the forest.	180	3.55	0.9926	Agreed
6.	Poverty caused most houses to rely on the resources obtained from the forest.	180	3.18	1.0184	Agreed
7.	Low illiteracy level among the populace will lead to removal of the forest.	180	3.26	1.0157	Agreed
8.	Expanding global market for timber has encouraged forest clearing.	180	3.86	0.9375	Agreed
9.	Natural causes such as floods and erosions destroying the forest.	180	3.78	0.7912	Agreed

Source: Field survey, 2020

Results in Table 3 showed that the deforestation had the following consequences: loss of bio-diversity (mean =2.92 and standard deviation = 1.0824), depletion of soil and water resources (mean =3.81 and standard deviation = 0.8995), atmospheric pollution (mean = 3.49 and standard deviation = 1.0023), environmental Calamities (Acid rain, Desertification and Flood) (mean = 3.17 and standard deviation =1.0601), decreased rural household incomes (mean = 3.79 and standard deviation =0.8867) while rural poverty among the villagers (mean = 3.53 and standard deviation = 1.1090) concluded the study on consequences of deforestation.

Table 3: Perceived Consequences of Deforestation

S/no	Problems	Sample Size	Mean score	St Deviation	Remarks
1.	Loss of bio-diversity.	180	2.92	1.0824	Agreed
2.	Depletion of soil and water resources.	180	3.81	0.8995	Agreed
3.	Atmospheric pollution.	180	3.49	1.0023	Agreed
4.	Environmental Calamities (Acid rain, Desertification and Flood).	180	3.17	1.0601	Agreed
5.	Decreased rural household incomes.	180	3.79	0.8867	Agreed
6.	Rural poverty among the villagers.	180	3.53	1.1090	Agreed

Source: Field survey, 2020

Table 4: Summary of T-Test Statistics on the Responses of Male and Female Respondents.

Gender	N	Mean	SD	Df	T-cal	T-crit	Prob > T	Decision
Male	110	3.1856	0.1088	178	-0.396	-1.96	0.559	Not Significant
Female	70	3.2078	0.4612					

Source: Field survey, 2020
* P > 0.05

The asterisks indicated that there was no significant difference between the responses of male and female respondents.

Table 5: Summary of F-Test Statistics on Respondents' Responses Based on their Incomes

Sources of Variation	Sum of Squares	Df	Mean Square (Variance)	Fcal	Fcrit	Prob > F	Decision
Treatment	25,030	4	6,257.5	301.26	3.24	0.002	Significant
Error	3,536.007	175	20.771				
Total	28,566.007	179					

Source: Field survey, 2020
* P < 0.05 (significant)

Table 6: Summary of Z-Test Statistics on Forest Resources and Reduction of Crimes

Variables	N	Mean score	St Dev	DF	Zcal	Zcrit	Prob > Z	Decision
Sample	180	3.79	0.8867	179	19.516	1.96	0.0002	Significant
Population		2.5						

Source: Field survey, 2020
* P < 0.05

Table 7: Summary of item-total PPMCC on Deforestation and Rural Poverty

Variables	Pearson r	df	T-cal	T-crit	Prob>T	Decision
Deforestation (x)	0.89	2	2.760	1.96	0.0002	Significant
Rural Poverty (y)						

Source: Field survey, 2020
* P < 0.05

Discussion

Table 4 revealed that no significant difference was observed between the responses of male and female respondents on forest deforestation. This finding also agreed with (FAO, 2015; Aguilar *et al.*, 2011; Agarwal, 2009) who found that men control the most valuable forest resources such as timber while women's control of forest resources could centered on management, use of fuel-wood and non-timber products. The finding was also in corroboration with Kiptot (2015) who asserted that women's forest livelihoods and employment depend on their access to and ownership of forest resources, which are mainly determined by laws and socio-cultural norms.

Result in Table 6 showed a significant difference between the responses of the respondents based on their household incomes. The result showed that absolute value of F-Test computed was 301.26 (significant 0.0002) at .05 alpha level, this indicated a significant difference between the responses of the respondents based on their household incomes (F = 301.26 at p<0.05). This finding aligned with Ayinde *et al.* (2013) who reported a strong correlation between income and its capacity to acquire things that were associated with improved standard of living such as food, clothing, shelter, health care, education and recreation. The finding was also consistent with Debela *et al.* (2012) who maintained that poor households could sell some of their assets such as NTFPs to wealthier households in order to generate income to meet basic household needs. Dewees (2013) concluded that NTFPs can increase household food security and income.

Table 6 showed that deforestation contributes to decreased income of the rural households. The result showed that absolute value of Z-Test computed was 19.516 (significant 0.0002) at 0.05 level of significant, this indicated that deforestation contributes to decreased income of the rural households ($Z = 19.516$ at $p<0.05$). This implied that deforestation contributes to decreased income of the rural households. This finding was in line with Boafo (2013) who found a close relationship between deforestation, decreased incomes and poverty of rural households. This is because increased deforestation means loss of livelihood assets and outcomes. This finding aligned with Bosu *et al.* (2010) who maintained that forest loss could reduce forest communities' contributions to national economic growth and also threatens both the livelihoods and traditions of rural dwelling people.
Table 7 showed that deforestation had significant relationship with rural poverty. The absolute value of T-test computed was 2.760 (significant 0.0002) at 0.05 alpha level, this indicated that deforestation has significant relationship with rural poverty ($T = 2.760$, $r = 0.89$ at $p<0.05$). The finding was in harmony with FAO (2010) who found that NTFPs can address poverty for the marginalized, catchment forest dependent communities through contribution to livelihood outcomes (food security, health and wellbeing) and income. The survival of most households depend on their livelihoods (Chakrabarti, 2005).

Conclusion and Recommendations
Perceived challenges of deforestation among others include forest clearing for farming purpose, logging of wood for timber and fuel wood, the consequences of deforestation are decreased rural household incomes, rural poverty among the villagers among others, there was no significant difference between the responses of male and female respondents, there was significant difference between the responses of the respondents based on their household incomes, deforestation contributes to decreased income of the rural households, and lastly deforestation has significant relationship with rural poverty. Finally, the findings of this study should be considered in the light of its further limitations apart from the ones highlighted in chapter one. Firstly, external validity was limited by the fact that selected participants were from one Local Government. This means that the result apply only to Yewa South Local Government Area of Ogun State.
This study recommend that Logging plans should be adopted with ecological sound tree felling practices. The benefits such as economic, social, aesthetic and religious of forest people should be preserved. Consultation with the forest people by government agencies or forest resources exploiters should be done – this is to know their socio-economic development need without assuming their needs. Government and logging companies should carry out reforestation exercises to replace extracted tree species in the forests. There should be a zero or light logging in the areas prone to erosion (slopes and stream edges) in the forest.

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SEXUAL SYSTEM POLYMORPHISM IN FOREST TREES: A LATENT TOOL FOR SUSTAINABLE FOREST MANAGEMENT IN NIGERIA

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Abstract
Production of progeny in the tropical rainforest starts with flower development, and different tree species have different sexual types and sexual systems. Pollination can occur either within a flower or between flowers of the same tree (cross-pollination) or flowers of different trees (cross-pollination). Mating among relatives results in the loss of heterozygosity that is reflected in phenotypic traits of adaptive or economic significance. However, some tree species have self-incompatibility systems. Out-crossing, which is the movement of pollen from a tree to another tree, often results in increased genetic diversity. Thus, such species' capability for adaptation and survival under hazardous environmental conditions are improved. One major factor influencing intra and inter-population variation in forest trees is the sexual system. Unfortunately, this factor is usually neglected by researchers in Nigeria, yet information on the sexual system of forest trees is needed for sustainable management. Therefore, this review provides information on the sexual types and sexual systems found in forest trees. It also emphasizes the need for adequate knowledge of the sexual characteristics of individual trees in Nigeria's forest reserves to guarantee sustainable forest management

Keywords: *incompatibility system, forest trees, genetic diversity, sustainable forest management*

Introduction

One major factor influencing intra and inter-population variation in forest trees is the sexual system. Unfortunately, this factor is usually neglected by researchers in Nigeria, yet information on the sexual system of forest trees is needed for sustainable management (Duminil *et al.* 2016). Progeny production in forest trees usually begins with bud formation and flower development. Flowers are reproductive structures in forest trees that facilitate reproduction through the union of pollen with ovules.

Moon *et al.* (2013) revealed the sequential stages of flower development to include the early stage that permits the gametes' development through cell differentiation in inconspicuous bud. Flower formation was controlled by selector homeotic genes (Coen and Meyerowitz, 1991).

Different tree species have different sexual types and sexual systems. According to Onokpise and Akinyele (2011), the type of gametes a tree produces is its sexual type of and fertilization can only occur when the stamen and pistil are mature. Since trees are immobile, mechanisms naturally put in place will depend on the flower morphology and structure. However, a tree could be zoochorus or anemochorous (Onokpise and Akinyele, 2011). Pollination can occur either within a flower or between flowers of the same tree (cross-pollination) or flowers of different trees (cross-pollination). Fertilization will occur when mature pollen is transferred to the stigma that is ready to receive it. However, when the pollen does not fall on the ready stigma, no seed will develop (Armbruster *et al.*, 2014).

Pollen exchange within the same tree or among related trees is referred to as selfing (Finkeldey and Hattemer, 2007). Selfing or inbreeding often leads to the loss of heterozygosity, which negatively impacts adaptive and economic traits. Survival, growth rate and stem straightness are some traits in forest trees that are negatively impacted by inbreeding; this negative impact is regarded as inbreeding depression (Finkeldey and Hattemer, 2007).

The ability of tree species to survive in response to environmental changes is related to the genetic variability in that species (Lawal *et al*., 2019). The mating system has since been reported to have an important influence on the amount and distribution of gene difference within and among populations of tree species (Hamrick and Godt, 1989). To ensure intra-specific diversity of forest trees, forest managers must rely on information about the reproductive systems and mechanisms of trees (Doligez and Joly, 1997). Therefore, this review provides information on the sexual types and sexual systems found in forest trees. It also emphasizes the need for adequate knowledge of the sexual systems of individual trees in Nigeria's forest reserves to guarantee sustainable forest management.

Sexual types in forest trees

Finkeldey and Hattemer (2007) discovered that male and female gametes have to come together to produce the zygote. This zygote will then develop through mitosis into an embryo, seed, seedling, and finally, a mature tree that can produce a gamete. A tree sexual type could either be cosexual (female and male gametes are produced) or unisexual (female or male) or sterile (tree not capable of producing any functioning gametes) (Finkeldey and Hattemer, 2007).

Sexual systems in forest trees

As shown in Figure 1, sexual systems comprise gender expression and its occurrence at many levels, such as intra-floral, individual, population, or species levels (Cardoso, *et al*., 2018). A sexual system, according to Leonard (2019), is the pattern of distribution of male and female functions among individuals within a population or species. The reproductive feature of trees is a flower. It can either be unisexual, with just functional male (staminate flower) or female (pistillate flower) components, or bisexual, with both pistils (female organs) and stamens (male organs) (Finkeldey and Hattemer, 2007).

A sexual system known as cosexuality is one in which members of a population only display bisexual blooms with functioning stamens and pistils in the same flower (Barrett and Hough, 2013). A population only displays unisexual (diclinous) blooms in a monoecious sexual system, in which the same individual produces both staminate and pistillate flowers (Kafer *et al.*, 2017).

Individuals of a population with an andromonoecious sexual system display bisexual and staminate flowers, while those with a gynomonoecious sexual system have both bisexual and pistillate flowers (Jong *et al.*, 2008). In a population, trimonoecy (polygamomonoecy) is characterized by the coexistence of bisexual, staminate, and pistillate flowers in the same individual (Torices et al., 2011). Individuals in the dioecy sexual system are completely unisexual, meaning that staminate and pistillate flowers are organized in various plants within a population (Barrett and Hough, 2013; Kafer *et al*., 2017). Androdioecy, which is connected to mutations that cause female sterility, is the coexistence of individuals with bisexual flowers and those who only have staminate flowers (Barrett and Hough, 2013; Kafer *et al.*, 2017). Gynodioecy is the coexistence of individuals with pistillate flowers and those with bisexual flowers (Kafer *et al.*, 2017).

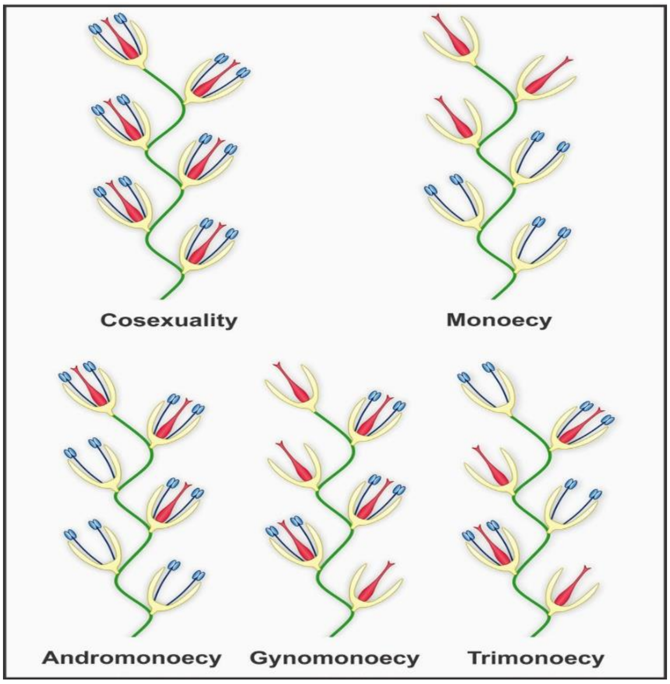

Figure 1: sexual systems that can be found in forest trees.

Stamens and pistils are expressed respectively in blue and red shades (adapted from Cardoso *et al.*, 2018).

Table 1: Sexual system and sexual types of some trees in Nigeria

S/N	Sexual system	Sexual types	Examples
1	Cosexuality (monoecy or hermaphrodic)	f/m	*Albizia feruginea, Barteria fistulosa, Brachystegia enricoma, Chrysophyllum albidum, Mansonia altissima etc*
2	Dioecy	f, m	*Diospyros barteri, Entandrophragma angolense, Khaya grandifolia*
3	Trioecy	f, m, f/m	*Zanthoxylum zanthoxyloides*
4	Gynodioecy	f, f/m	Rhizophora mangle, Ficus species
5	Androdioecy	m, f/m	*Bauhinia ungulate, Terminalia superb*

Sources: Finkeldey, 2005; Ugbogu *et al*., 2016; Guendehou *et al.*, 2018)

Cosexual and dioecious taxa

Finkeldey and Hattemer (2007) made a distinction between two types of cosexuality: (i) hermaphroditic trees have complete blooms that produce both types of gametes in one flower; and (ii) monoecious trees produce both types of gametes but in different flowers. For hermaphroditic trees, Finkeldey and Hattemer (2007) made distinctions between several pollination types. They define autogamy as the fertilization of an ovule using pollen from the same flower, while geitonogamy refers to the fertilization of an ovule using pollen from a different flower. Allogamy includes both antogamy and geitonogamy, but xenogamy entails pollinating a separate tree and causes out-crossing.

Mitchell and Diggle (2005) considered monoecy as a derived condition in angiosperm trees. According to Cardoso *et al.* (2018), the andromonoecy route hypothesis proposes that andromonoecy serves as a transitional stage between cosexuality and monoecy. This hypothesis, according to Jong *et al*. (2008), is supported by the idea that the existence of staminate blooms would make it easier for those bisexual plants to produce strictly pistillate flowers. The other pathway, which uses gynomonoecy as a transition stage, is seen as implausible because it calls for an enormous fruit to be produced by both bisexual and pistillate flowers (Cardoso et al., 2018). According to Weiblen et al. (2000), there are still a few instances where monoecy reverts to cosexuality.

A tree that produces only one type of gamete is termed dioecious. They can either be male or female. According to Renner (2014), dioecious individuals make about 43% of angiosperm families. Ohya *et al.* (2017) highlighted some problems associated with the population growth of cosexual and dioecious taxa. According to them, the populations of coexisting cosexual taxa may expand more quickly than those of dioecious plant species. Due to their inability to self-pollinate and need for a partner to reproduce, dioecious plants are more likely to experience problems with pollination (Xia *et al.*, 2013, Schlessman *et al.,* 2014). Although self-incompatible plants also need a partner to reproduce, all interplant pollinator movement may help produce seeds (Ohya *et al*., 2017). They mentioned that pollinator travel from male to female is necessary for seed formation, hence pollinator movement direction is crucial for dioecious plants. According to studies by Vamosi et al. (2006), De Jong et al. (2005), and Otero-Arnaiz and Oyama (2001), female dioecious trees produced more fruit when surrounded with males trees.

Using mathematical models, Wilson and Harder (2003) investigated how dioecious and cosexual organisms competed for space. They demonstrated that sex differences increased plant variability in seed output and fertilization probabilities, and that reproductive uncertainty decreased the mean recruitment of dioecious species.

Special adaptations for out-crossing in forest trees

There have been several mechanisms identified that could prevent self-fertilization and promote outcrossing in flowering plants. Mechanisms separating the male and female functions, either in time (dichogamy) or in space (herkogamy), are among the most common (Armbruster et al., 2014 and Cardoso et al., 2018).

Self-incompatibility (SI) or self-sterility (SS) in forest trees

In self-incompatibility (SI) or self-sterility (SS), the pollen grain is unable to germinate on its stigma but will germinate on another flower of the same species. That is, when pollen grain produced in a tree with SI or SS reaches a stigma of the same tree, the process of pollen germination, pollen-tube growth, and embryo development will be inhibited, and consequently, no seeds will be produced (Cardoso *et al.,* 2018). In this case, self-pollination becomes impossible. According to Wang et al. (2018), the self-incompatibility mechanism is based on protein-protein interactions and is managed by a single locus known as S, which contains a variety of alleles in the population of the species. The S-locus, according to Wang et al. (2018), has two fundamental protein-coding regions, one of which is expressed in the pistil (female determinant) and the other in the anther and/or pollen (male determinant). Due to their close proximity, S-haplotypes are genetically connected and passed down together (Wang et al (2018). Two proteins that are the translation products of the two regions of the S-locus interact with one another to stop pollen germination and/or pollen tube elongation, which triggers a SI response and prevents fertilization (Gibbs, 2014). Nevertheless, there will be no self-incompatibility and fertilization will take place when a female determinant interacts with a male determinant of a different haplotype.

Pollination is undoubtedly an important part of generative propagation, and the spread of plants is strongly related to pollinators and biodiversity (Yang et al., 2017). Finkeldey and Hattemer (2007) state that pre-fertilization mechanisms are considered incompatibility systems, and that cosexual species lacking incompatibility reactions frequently develop self-sterility systems that cause early termination of the embryo after fertilization. Mixed mating systems are common in seed plants (Goodwillie *et al.,* 2005) because the ability to set seed after selfing is advantageous when mating partners or pollinators are scarce (Kalisz *et al*., 2004). According to estimates, 33% of plant species are intermediate between selfing and outcrossing, while 20% of plant species exhibit significant levels of selfing (Vogler and Kalisz, 2001). However, compared to outcrossed individuals, selfed individuals frequently have worse vegetative and reproductive fitness (i.e. inbreeding depression; Husband and Schemske, 1996). To prevent or limit self-fertilization in blooming plants, many mechanisms have been developed.

Sexual system and forest management

A forest is typically defined as "a land covering more than 0.5 hectares composed of trees with the ability to grow to a minimum height of 2 to 5 meters at maturity in situ and a canopy cover of more than 10%" (Ananta, 2020). Forests in Nigeria have been severely degraded and fragmented (Lawal and Adekunle, 2013). Intra-and inter-specific variation in forest trees could be linked to the ability of the forest manager to maintain the populations of trees with their sexual types and systems in a forest ecosystem.

Selective logging of trees with superior characteristics, which is a common practice in Nigeria, has a negative influence as tree species with inferior characteristics would be left for reproduction (Lawal *et al.* (2019). Eckert *et al*. (2010) revealed that selective logging implies a reduction of "mate" (seed tree) densities, which in theory can affect plant reproductive success. Furthermore, a better knowledge of the sexual systems of forest trees will go a long way to sustain the population of dioecious species. For instance, where a forest reserve is dominated by dioecious species with a few of them producing female gametes, harvesting those female gamete-producing trees will negatively impact the successional status of such species, and a reduction in genetic diversity will result. De Jong *et al.* (2005) and Otero *et al*. (2001) found that female dioecious trees produced more fruit when adjacent males were present. According to Heilbuth et al. (2000), only 50% of the individuals in a population of dioecious species contribute to seed production, which limits their capacity to colonize deserted places. In dioecious tree species, seed dispersal was restricted to the area around female plants, resulting in a densely clumped distribution of seedlings, as discovered by Montesinos *et al.* (2007) and Nanami *et al*. (1999). These drawbacks, according to Baker (1995), would negatively impact the capacity of dioecious trees to colonize new areas.

The majority of tropical tree species are hermophratic (Finkeldey and Hattemer, 2007). Due to the hermaphroditic nature of the majority of tropical forest trees, selfing—the strongest form of inbreeding depression caused by antogamy and geitonogamy—is a possibility. Mechanisms that prevent selfing therefore provide a significant evolutionary advantage. According to Finkeldey and Hattemer (2007), the most crucial mechanisms before fertilization are incompatibility systems. Cosexual species without incompatibility reactions frequently evolve self-sterility systems, which leads to early termination of the embryo following fertilization. Many studies have been conducted in developed countries to estimate selfing rates in forest tree populations (Feres *et al*., 2012; Hamrick, 2011). But in Nigeria, studies on the incompatibility and self-sterility of hermaphroditic species are scarce.

Conclusion and recommendation

There are various sexual systems in forest trees. The production of progenies through pollination depends on the availability of gametes. Hermaphrodite, monoecious, dioecious, trioecious, gynodioecious, or androdioecious trees can be found in the forest ecosystem. Some trees with both gametes may become self-sterile or develop incompatibility systems. Depending on the availability of mating partners and the pollination direction, forest trees will either outcross or self. Often, out-crossing, or the transfer of pollen from one tree to another, leads to an increase in genetic diversity. As a result, such species' adaptability potential and survival under perilous environmental conditions are enhanced. Many tree species in Nigeria are currently being threatened by extinction owing to unsustainable tree harvesting and conversion of forest estates to other land uses. A better knowledge of the sexual systems of individual trees in our forest reserves will help in sustainable forest management and increase the genetic diversity of tree species. Therefore, research to reveal the sexual system of the remnant trees in our forest reserves is recommended.

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SPECIES DIVERSITY AND PUBLIC PERCEPTIONS OF URBAN TREES IN ILORIN METROPOLIS, KWARA STATE, NIGERIA

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Abstract
Urban trees are part of the human environment; they provide direct, indirect, tangible, and intangible ecosystem services. This study was designed to investigate species diversity and public perception of urban trees in Ilorin metropolis, Kwara State, Nigeria. A systematic sampling technique was used to select road networks and houses with trees for enumeration. Socioeconomic data were obtained from 400 randomly selected respondents drawn among students, traders, government workers and marketers. Data were obtained using a structured questionnaire, interview schedule and personal discussions. Eighty-six (86) tree species belonging to 23 families were encountered in the study area. Polyalthia longifolia was the most occurring species, with a frequency of 271 and a relative frequency of 8.40%. The least occurring species were Ceiba pentadra, Ficus carica, and Strychnos spinosa, with frequency and relative frequency of 2 and 0.06% each. The values of Shannon-Wiener and Margalef indices were 3.88 and 10.52, respectively. Majority of the respondents noted that trees beautify the environment, provide shades and help mitigate environmental pollution. On the other hand, the majority also stated that branches of trees litter the environment, and trees reduce visibility on roadsides. The study concludes that the diversity and richness of urban trees was relatively high compared to some urban forests in Nigeria and there was a heightened awareness of the benefits and threats of urban trees in Ilorin metropolis. It recommends that the state government establishes a committee that will look into the conservation and management of urban trees.

Keywords: *Urban trees, ecosystem services, Shannon-Wiener diversity index, Margalef index, environmental pollution*

Introduction

Urban forests are ecosystems characterized by trees and other vegetation associated with human developments. They include all publicly and privately owned trees within an urban area, including individual trees along streets and backyards and stands of the remnant forest (Nowak *et al*., 2001). They are composed of parks, street trees, gardens, river and coastal promenades, greenways, nature preserves, boulevard plantings, and many more (Eckart, 2018).

Urban forests have been regarded as essential elements for improving the green infrastructure network in the urban landscape (Riitters *et al*., 2012). They have become a concomitant aspect of the human environment, generating essential ecosystem services. Ecosystem services are the direct and indirect, tangible and intangible benefits people derive from the ecosystem. According to the Millennium Ecosystem Assessment (MEA, 2005), the ecosystem services are provisioning, regulating, supporting, and cultural services. Hence, urban forests help offset carbon emissions, remove air pollutants, control the microenvironment and mitigate climate change, among other functions (Fuwape and Onyekwelu, 2011).

Urban centres are fast-growing in Nigeria as a result of rural-urban migration. For instance, it was estimated that 43.48% of Nigerians lived in urban areas in 2010, 47.84% in 2015, and 51.96% in 2020 (www.statista.com). This development pattern has resulted in the destruction of urban forests and the development of social amenities, making the urban centres attractive for high migration potentials (Agbelade *et al*., 2016b).

Since urban forests are gradually declining and the quality of life in urban areas are greatly influenced by the amount and quality of their green spaces (Popoola and Ajewole, 2001), it is essential to encourage the people to be involved in their rejuvenation. Therefore, it is necessary to understand the public's shared beliefs and attitudes toward trees that promote their care, management, and protection (Faleyimu, 2014).

Materials and methods

Study Area

The study was carried out in Ilorin, the capital of Kwara State (Figure 1). It lies within latitude 08°26′237″ - 08°31′267″ N and longitude 04°30′02″ - 04°33′77″ E of the equator. It is situated within the North central geopolitical zone and Nigeria's Guinea savanna ecological region. The three major Local Government Areas that form Ilorin are; Ilorin East, Ilorin South, and Ilorin West. The 2006 National Population Census gives the population as 777, 667 with an annual population change of about 3% (NPC, 2006). Ilorin has a tropical climate with dry and wet seasons. The annual rainfall varies from 1000 mm to 1500 mm, with its peak occurring between September and early October; the temperature ranges from 33 ° to 35 °C between November to January and 34 ° to 37 °C from February to April (Ahmed, 2008; Ajadi *et al.*, 2016).

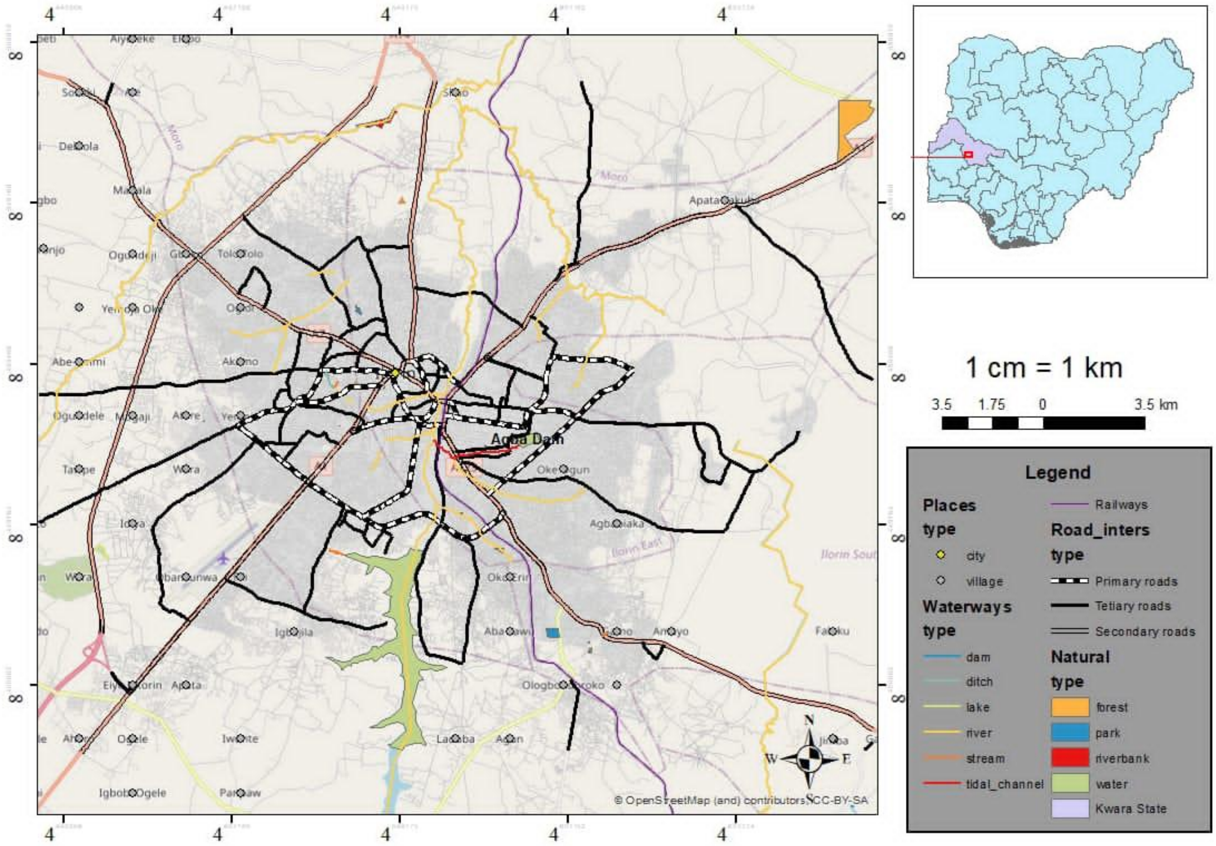

Figure 1: Map of Ilorin metropolis (inset: Map of Nigeria showing Kwara State)

Data Collection

The study purposively selected Ilorin as the study area. Data collection for the study consisted of two parts: (1) a botanical survey based on tree species enumeration and (2) a socioeconomic survey based on questionnaire, interview schedule and personal discussions. The data for tree species enumeration were collected from the central districts covering approximately one-fifth (20%) of the urban areas (Agbelade and Onyekwelu, 2020). The areas covered were: Irewolede (New Yidi Road), Asadam, Taiwo, Muritala Mohammed way, Offa Garage, Ahmadu Bello way, Fate, Tanke, Gaa Akanbi, Sawmill, Adewole, Olohunsogo, Kwara Polytechnic campus, Kwara State College of Education campus, and University of Ilorin campus. The enumeration was done using a systematic sampling to select road networks and houses with trees in the central districts of Ilorin. The service of an experienced taxonomist was employed to identify trees to species level. Socioeconomic survey was employed to collect data on public perception of urban trees in Ilorin metropolis through the use of structured questionnaire administered to four hundred (400) randomly selected respondents. The respondents were drawn among students, traders, government workers and marketers. Interviews and personal discussions were used to support the questionnaire. The questions focused on the demography of the respondents, perception statements using a five-scale Likert, and perception questions with a yes or no response.

Data Analysis

Tree species relative frequency was calculated using:

RF (%) = $\frac{number\ of\ individual\ species}{total\ number\ of\ species} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (I)$

Tree species diversity index was computed using the Shannon-Wiener diversity index:

$$H' = -\sum PiIn(Pi) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where $Pi = \frac{n}{N}$, n = number of individual species, N = total number of tree species, and *In* = natural logarithm

Tree species richness in the area was computed using Margalef index of species richness:

$$d = \frac{S}{\sqrt{N}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where S = the number of species encountered and N = the total number of individuals of all the tree species in the area.

The Likert scale on perception statements was ranked as: Strongly Agreed (5), Agree (4), Undecided (3), Disagree (2), and Strongly Disagree (1).

Microsoft Excel 2016 and Paleontological Statistic (PAST 4.03) were used to enter, clean, and analyze the data. Data were analyzed and summarized using descriptive statistics such as frequency and percentage.

Results and discussion

Urban Trees Composition in Ilorin Metropolis

A total of 86 tree species belonging to 23 families were encountered in the area. *Polyalthia longifolia* was the most occurring species, with a frequency of 271 and a relative frequency of 8.40%. The least occurring species were *Ceiba pentadra*, *Ficus carica*, and *Strychnos spinosa* with frequency and relative frequency of 2 and 0.06% each (Table 1; Figure 2). The species diversity (ShannonWiener) and richness (Margalef) indices for the area were 3.88 and 10.52, respectively (Table 2).

The knowledge of species diversity and composition is vital in comparing the composition of different species (Naidu and Kumar, 2016). Biodiversity assessment in any ecosystem is useful because it indicates the ecological functioning and processes. The Shannon-Wiener diversity index was higher than 3.56 in Abuja urban forests, 3.08 in Minna urban forests (Agbelade *et al*., 2016a), 3.35 in Ibadan metropolis (Agbelade *et al*., 2016b) and 3.39 for Port Harcourt urban forests (Agbelade and Onyekwelu, 2020). It was also higher compared with the findings in some natural forests, where 3.54 was obtained in Old Oyo National Park (Adeyemi and Taofeek, 2020) and 3.74 for Akure Strict Nature Reserve (Adekunle *et al*., 2013). This could be attributed to factors such as socioeconomic conditions, government policy, increased awareness, and perhaps fewer developmental projects that may cause the removal of many tree species. Higher species diversity is expected to contribute to the greenness of the city and help sequester more carbon which will largely influence the atmospheric condition. Fabaceae was the most dominant family in the study area. This agrees with Iheyen *et al*. (2009), Ogwu *et al*. (2016) and Moshood *et al*. (2022). Members of the Fabaceae family largely disperse their seed by the wind. However, the poor representation of some families may be attributed to edaphic and climatic conditions not suitable for the growth of those species or anthropogenic activities such as the construction and expansion of roads.

Table 1: Tree species composition in Ilorin metropolis

Tree Species	**Family**	**Frequency**	**Rel. Freq**
Acacia auriculiformis A.Cunn. Ex Benth.	Fabaceae	12	0.37
Acacia nilotica (L) Willd. Ex Delile	Fabaceae	6	0.19
Acacia polycantha (willd.) Seigler & Ebinger	Fabaceae	16	0.50
Acacia senegalensis (L). Brittton	Fabaceae	5	0.16
Adansonia digitata L	Malvaceae	30	0.93
Afezelia africana SM	Fabaceae	7	0.22
Albizia coriaria Welwex Oliv	Fabaceae	32	0.99
Albizia lebbeck (Lam) Benth.	Fabaceae	79	2.45
Abizia zygia (D.C.) JFMacbride	Fabaceae	43	1.33
Anacardium occidentale L	Anacardiaceae	78	2.42
Annoigeissus leocarpus (DC.) Guill. &Perr	Combretaceae	56	1.74
Annona senegalensis Pers	Annonaceae	8	0.25
Annona muricata L	Annonaceae	87	2.70
Anthocliesta djalonensis A.Chev	Loganiaceae	5	0.16
Anthocliesta nobilis G.Don	Gentianaceae	6	0.19
Atrocarpus altilis (Parkinson)Fosberg	Moraceae	5	0.16
Azadirachta indica A. Juss	Meliaceae	205	6.36
Blighia sapida K.D.Koenig	Sapindaceae	132	4.09
Bridelia ferruginea Benth	Euphorbiaceae	18	0.56
Burkea africana Hook	Fabaceae	6	0.19
Butea superba (Lam.) Taub.	Fabaceae	9	0.28
Bombax constratum	Bombacaceae	4	0.12

Tree Species	**Family**	**Frequency**	**Rel. Freq**
Buhienia veriegata	Fabaceae	10	0.31
Calotropis procera (Aiton) Ait.f	Gentianaceae	11	0.34
Cassia fistula Linn	Fabaceae	48	1.49
Casuarina equisetifolia L	Casuarinaceae	9	0.28
Cedrela odorata L	Meliaceae	23	0.71
Ceiba pentadra L	Malvaceae	2	0.06
Cocos nucifera L	Arecaceae	22	0.68
Combretum molle R.Br. ex G.Don	Combretaceae	16	0.50
Crescentia cujete L	Bignoniaceae	6	0.19
Croton gratissimus Burch.var	Euphorbiaceae	4	0.12
Dalbergia latifolia Roxb.	Fabaceae	8	0.25
Daniella oliveri (Rolf) Hutch & Dalz	Fabaceae	62	1.92
Delonix regia (Hook) Raf.	Fabaceae	6	0.19
Detarium microcarpum	Fabaceae	29	0.90
Erythrina senegalensis Dc	Fabaceae	62	1.92
Erythrina sigmoidea Hua	Fabaceae	18	0.56
Eucalyptus camadalensis Dehn	Myrtaceae	62	1.92
Eucalyptus citrodora Hook.	Myrtaceae	60	1.86
Eucalyptus toreliana F. Muell	Myrtaceae	12	0.37
Ficus benjamina L	Moraceae	39	1.21
Ficus carica L	Moraceae	2	0.06
Ficus capensis Thunb	Moraceae	5	0.16
Ficus exasperate Vahl	Moraceae	37	1.15
Ficus macrophylla Desf. ex Pers	Moraceae	69	2.14
Ficus microcarpa L. Fil	Moraceae	187	5.80
Ficus mucoso Welw ex Ficalho	Moraceae	73	2.26
Ficus sur Forssk.	Moraceae	4	0.12
Ficus sycomorous L	Moraceae	29	0.90
Ficus thoningii L	Moraceae	34	1.05
Gmelina arborea Roxb	Lamiaceae	81	2.51
*Gliricidia sepium (*Jacq.) Walp	Fabaceae	13	0.40
Hildegardia barteri (Mast.) Kosterm.	Malvaceae	7	0.22
Hura crepitans L.	Euphorbiaceae	12	0.37
Khaya grandifoliola C. DC.	Meliaceae	6	0.19

Tree Species	Family	Frequency	Rel. Freq
Khaya senegalensis (Desr) A. Juss	Meliaceae	32	0.99
Kigelia Africana (Lam.) Benth	Bignoniaceae	6	0.19
Lannea acida A. Rich	Anacardiaceae	11	0.34
Lannea barteri (Oliv) England	Anacardiaceae	21	0.65
Leucena leucocephala (Lam.) de wit	Fabaceae	62	1.92
Mangifera indica L	Anacardiaceae	89	2.76
Millieta thonningii. (Schumach.) Baker	Fabaceae	3	0.09
Newbouldia laevis (P. Beauv*)*	Bignoniaceae	22	0.68
Nuclear latifolia. Sm	Rubiaceae	9	0.28
Parinari polyandra. Aubl	Chrysobalanceae	71	2.20
Parkia biglobosa (Jacq)R. Br ex G.Don	Fabaceae	66	2.05
piliostigma thonningii. (Shcum) Milne-Redh	Fabaceae	38	1.18
Plumeria alba L	Apocyanaceae	23	0.71
Polyalthia longifolia (Sonn.) Thwaites	Annonaceae	271	8.40
Prosopsis africana (Guill & Perr) Taub.	Fabaceae	17	0.53
Pterocarpus erinaceus Poir.	Fabaceae	5	0.16
Roystonea regia (H. B. K) F. cook	Arecaceae	45	1.40
Senna siamea (Lam) Irwin & Barneby	Fabaceae	38	1.18
Securidaca longepedunculata. Fresen	Polygalaceae	4	0.12
Spathodea campanulata P. Beauv.	Bignoniaceae	16	0.50
*Spondias mombin.*L	Anacardiaceae	32	0.99
Sterculia setigera. Delile	Sterculiaceae	12	0.37
Strychnos spinosa. Lam	Loganiaceae	2	0.06
Tectona grandis Linn. F.	Lamiaceae	44	1.36
Terminalia catappa L	Combretaceae	110	3.41
Terminalia mantaly H. Perrier	Combretaceae	164	5.09
Terminalia glaucescens. Planch. Ex Benth	Combretaceae	11	0.34
Vitellaria paradoxa C.F Gaertn.	Sapindaceae	43	1.33
Vitex doniana L.	Lamiaceae	35	1.09
Ziziphus abyssinica Hochst.ex A. Rich	Rhamnaceae	6	0.19
TOTAL		3225	100.00

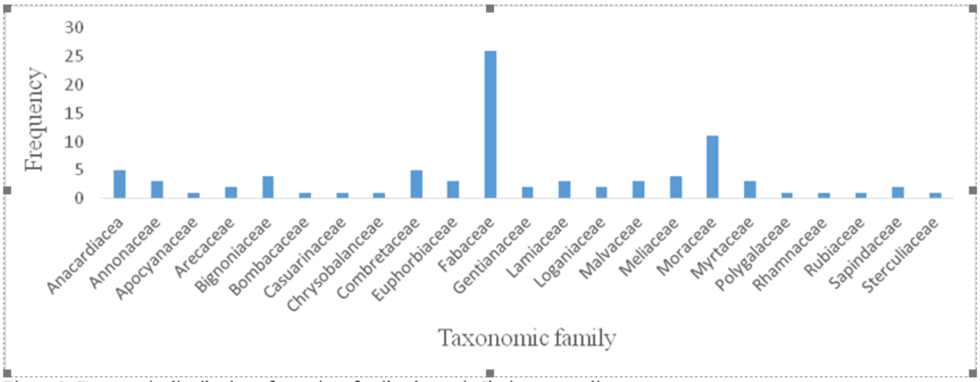

Figure 2: Taxonomic distribution of trees into family classes in Ilorin metropolis

Table 2: Results for Shannon-Wienner and Margalef indices in Ilorin metropolis

S/N	Indices	Value
1	Shannon-Wiener Index of Diversity	3.88
2	Margalef Index of Species Richness	10.52

Demographic Information of Respondents in Ilorin Metropolis

Table 3 presents the demographic information of respondents in the study area. The most of the respondents (75.50%) were within the age bracket of 20-30, while the a few (2.0%) were above sixty years of age (>60). Age classes of 31-40, 41-50, and 51-60 represented 15.0%, 4.5%, and 3.0% of respondents, respectively. The results also show that most of the respondents were male (70.0%), 71.25% were single, and 75.25% practiced Islam. It was further showed that large number of respondents (77.0%) had tertiary education. Some (20.25%) and a few (2.75%) had secondary and primary education, respectively. Two hundred and fifty-seven (257), which represents about 64.25%, were students, 28 (7.0%) were private workers, 82 (20.50%) were government workers, 8 (2.0%) were self-employed, and 25 of them, representing 6.25%, were unemployed.

Given that majority of the respondents were within the age bracket 20-30 disagrees with the findings of Faleyimu and Akinyemi (2014), who observed that most of the respondents in Okitipupa, Ondo State were within the age bracket of 31-40 and had a mean age of 47 years. This is a good indication that most of the respondents were within their productive period and could actively participate should any green programme initiative be introduced in Ilorin metropolis. The level of literacy in the study area was relatively high, which indicates social stability and is fundamental to growth and development. The high literacy level could be attributed to the respondents' awareness of urban forests. According to Etim *et al*. (2012), sensitization and enlightenment programmes will thrive due to high student population indicates that sensitization will be easy provided that proper enlightenment is conducted in schools, and by extension, the students will willingly extend the knowledge to their peer and relatives.

Perception of Respondents on Urban Trees in Ilorin Metropolis

Respondents' perception of urban trees in Ilorin metropolis was accessed by requesting them to respond to some statements (Figure 3) and answer yes or no to others (Table 4). Most (80%) and few (20%) of the respondents strongly agreed and agreed, respectively, to the fact that urban trees beautify the environment. On the provision of shades by trees, some (65.25%) of the respondents strongly agreed that trees provide shades better than other things, while few (1.5%) strongly disagreed. Some of the respondents (62.5%) strongly agreed that trees help mitigate environmental pollution, and about a few (12.5%) disagreed that trees reduce visibility on roadsides. The most agreed that branches and leaves of trees litter the environment, while a few (2%) were undecided. The results further showed that most of the respondents (87.5%) knew of the term "urban forests," while almost all (99.0%) loved trees around them. However, 90.5% of the respondents were not satisfied with the number of trees in their surroundings, further corroborating the majority (97.5%) who showed interest in planting trees in their surroundings. When asked whether or not the government should introduce a new policy banning indiscriminate felling of urban trees in Ilorin, three hundred and sixty-nine (369) of the respondents, equivalent to 92.25%, said yes, while the rest (31 respondents, 7.75%) said no.

Urban forests, like natural forest ecosystems, provide a host of ecosystem services to mankind. The benefits may be tangible or intangible. On the other hand, they pose some dangers to the environment, especially when they are not adequately managed. According to Ajewole *et al*. (2013), some of the common challenges associated with trees are branch and root conflicts with infrastructure and site use and accidental tree fall. It is worthy to note that the respondents were largely aware of urban forestry, environmental services provided by trees, and some of the threats associated with urban forests in Ilorin metropolis. This could be explained by the high literacy level and the fact that most of the respondents were students who might have come across those terms at one point or the other, especially in recent times where virtually every literate has access to the internet. This is similar to the results obtained by Etim *et al*. (2012) in Maiduguri, Borno State.

Table 3: Demographic characteristics of respondents in Ilorin metropolis

Variable	Category	Frequency	Percentage (%)
Age			
	20-30	302	75.50
	31-40	60	15.00
	41-50	18	4.50
	51-60	12	3.00
	>60	8	2.00
Gender			
	Male	280	70.00
	Female	120	30.00
Marital status			
	Married	110	27.50
	Single	285	71.25
	Divorced	4	1.00
	Widowed	1	0.25
Religion			
	Islam	301	75.25
	Christianity	97	24.25
	Others	2	0.50
Education			
	No formal	0	0.00
	Primary	11	2.75
	Secondary	81	20.25
	Tertiary	308	77.00
Employment			
	Unemployed	25	6.25
	Self employed	8	2.00
	Government worker	82	20.50
	Private worker	28	7.00
	Student	257	64.25

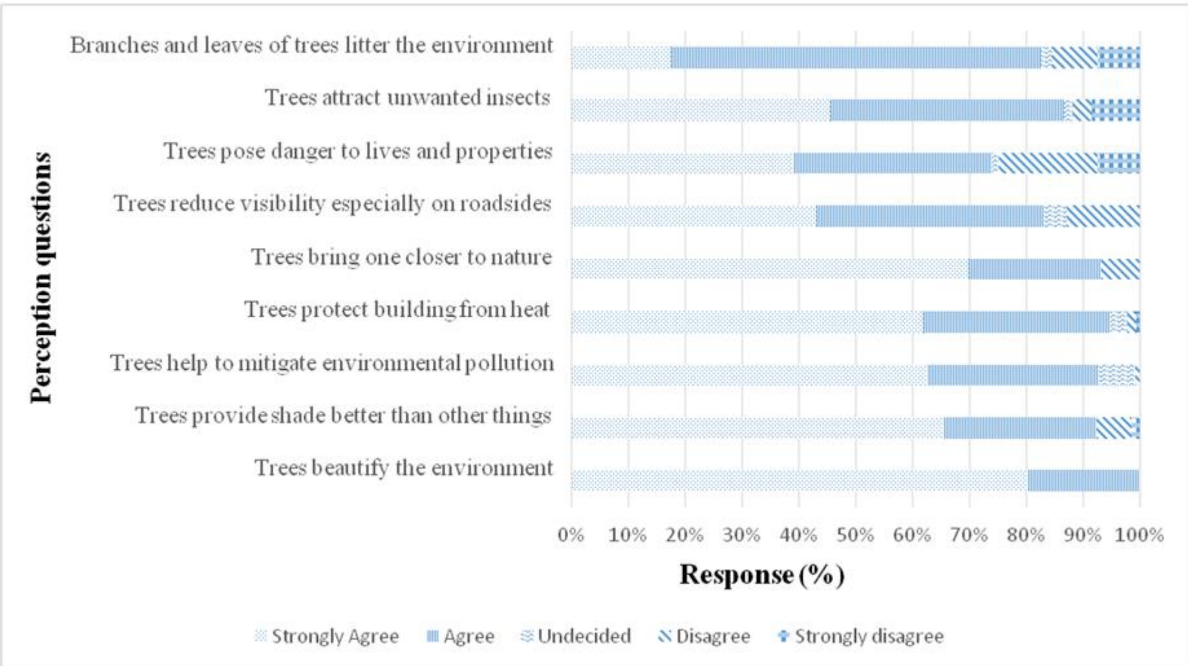

Figure 2: Peoples' perception of urban trees in Ilorin metropolis

Table 4: Respondents' perception of urban trees in Ilorin metropolis

Questions	**YES**		**NO**	
	Frequency	(%)	Frequency	(%)
Are you aware of the term "urban trees"?	350	87.50	50	12.50
Do you love trees around you?	398	99.50	2	0.50
Are you willing to plant trees in your environment?	390	97.50	10	2.50
Are you willing to participate in a tree planting exercise?	356	89.00	44	11.00
Are you satisfied with the present number of trees in your environment?	38	9.50	362	90.50
Should the government bring up a policy to ban the indiscriminate removal of trees in Ilorin?	369	92.25	31	7.75

Conclusion and recommendation

The diversity and richness of urban trees in Ilorin metropolis was relatively high compared to some urban forests in Nigeria. People's perceptions of urban forests in the study area was relatively high compared to other urban centres. The species diversity was higher than in some of the cities in Nigeria, which shows a positive conservation effort. It is praiseworthy that most of the respondents were familiar with the term "urban forest" and were aware of the benefits and threats of urban trees. Hence, the state government and other environmental Non-Governmental Organizations (NGOs) should intensify their efforts in managing and conserving the urban trees in Ilorin metropolis.

The study, therefore, recommends that:

(i) the state government should establish a tree management committee that will look into the conservation and management of urban trees in Ilorin metropolis;

(ii) campaigns and awareness on the importance of tree planting should be taken to the doorsteps of people, and more emphasis should be laid on tree planting in media houses;

(iii) policies prohibiting indiscriminate removal of trees should be put in place;

(iv) inventory of trees should be done at reasonable intervals to note the local status of each tree species.

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EFFECTS OF BANDITRY ACTIVITIES ON FOREST ECOSYSTEMS AND THE HOST COMMUNITIES IN NORTH-EAST GUINEA SAVANNA ECOLOGICAL ZONE OF SANKERA AXIS, BENUE STATE, NIGERIA

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Abstract
The study examined the effects of banditry activities on forest ecosystems and the host communities in the northeastern region of Benue State, Nigeria. It aims to identify the effects of banditry activities on forest ecosystems for effective prevention. Three forest reserves (Ikyo-Nyian, Ukamberagya, and Gundu-Chaha from Katsina Ala, Logo, and Ukum local government areas respectively) were purposely selected for the study. A total of 385 respondents from forest-dependent communities adjacent to these forests were sampled based on the Cochran sampling method. Descriptive statistics, a Likert scale, and Spearman correlation were used to analyze the data. Based on this finding, the majority of the respondents (57.92%) were male farmers who are mostly young and agile. Majority (55.84%) of the respondents significantly (p = 4.56) perceived that bandits use forest estates as major hideout areas. Bandits clash with security agencies in the forest, as significantly (p = 3.84) perceived by most of the respondents (78.18%). Their activities result in biodiversity destruction, degradation, and disturbance. This significantly (p = 4.28), affects the extraction, distribution, and consumption of forest resources and livelihood activities, thereby affecting other ecological, social, and economic activities. The correlation test showed a significant (p = 0.05) positive correlation (between 0.738 and 0.949) between forest ecosystems as banditry hideouts and all the identified ecological and socio-economic implications in the area. There is a need to equip and deploy active security agencies in affected areas for effective prevention, coupled with the provision of more basic infrastructure and amenities, to restore normalcy in the area.

Keywords: *Banditry, Biodiversity, Ecosystem, Forests, Livelihood.*

Introduction

Many rural people depend predominantly on forests and forest resources for food, clothing, housing, medicine, art and crafts, oil, agricultural implements and a host of other requirements (Neelo *et al*., 2015). Guinea savanna natural ecosystems constitute a main source of biodiversity. These species play an important role in the survival of man on earth, thereby providing an array of timber and non-timber forest products (NTFPs) that are significant in sustaining the overall socio-economic wellbeing of humans (Meer, 2018). Forest products have been used by human beings over time for various purposes, such as food, fodder, fiber, traditional medicine, agricultural amenities, domestic materials, construction materials, and many of these reasons are associated with cultures (Talukdar e*t al*., 2020). People are depending upon natural resources to meet a large number of their basic necessities of life. Considering the variability and diverse nature of the NTFPs, a lot of households are able to meet their immediate needs by collecting NTFPs from the forest, while others earn income to meet other needs through the marketing of NTFPs harvested (Abubabkar and Dau, 2019). Rural communities rely heavily on NTFPs as a means of generating income, sources of food and medicine, thereby reducing the poverty level of their people; hence, NTFPs play a vital role in Nigeria (Abubabkar and Dau, 2019). Rural households spend income realized from NTFPs to buy food to maintain their families, hence dependence upon several combined and seasonal activities of NTFPs as the only one-way sure way to ensure household food security (Dau and Elisha, 2013). The types of resources and utilization patterns vary by ecological zone and socio-cultural area. Due to high prevalence rate of banditry in the study area, it is generally believed that, "forest estates have been a suitable hideout for different unlawful activities by different people which is tagged as 'banditry'.

Banditry is an act of robbery and violence committed in areas where the rule of law has broken down (Ladan and Matawalli, 2020). It consists of the organization of armed bands for the purpose of attacking social institutions, enterprises, community, or individuals. Participation in such bands and in the attacks committed by them is equally regarded as banditry (Collins, 2000). Large forested areas allowed for concealment and the formation of camps in the forest by bandits. According to Brenner (2021), vast areas of unregulated forests allow for easy concealment, and security forces have difficulty penetrating the rough terrain of the forests. These effects could have a critical influence on the forest ecosystems and socio-economic stability of rural communities and national development. The invasion of forest ecosystems by bandits is restricting the free access and use of these products. The activities of the bandits have resulted in unimaginable destruction of lives and properties, including biodiversity, displacement of many forest-dependent communities and a growing number of widows, widowers and orphans, who now reside in internally displaced persons (IDP) camps following the continued attacks across different areas in Sankera axis (north-east ecological zone) of Benue State. This necessitates the need to assess the effects of banditry activities on forest ecosystems and the host communities in the study area. Thus, this study aims to identify the nature and patterns of banditry activities, to determine the consequences of banditry activities on forest ecosystems, and to examine the ecological and socio-economic implications of banditry activities on forest-dependent communities for effective prevention or control of banditry activities in the study area.

MATERIALS AND METHODS

Study Area

The North-east ecological zone of Benue State is made up of Sankera and Kwande sub-political blocks located in the north-eastern part of Benue State, Nigeria. Sankera axis comprises of Katsina Ala, Logo, and Ukum local government areas (LGAs). It lies between latitude 6^0 30' to 7^0 40' north and longitude 9^0 4' to 9^0 30' east (Figure 1). Sankera axis shares its north and east boundaries with Nasarawa and Taraba States, respectively. It is also bordered on the south-east by Kwande and Ushongo local government areas and on the south-west by Buruku and Guma local government areas of Benue State. It has a total land area of approximately 5,324 km^2 (IamBenue, 2018). Sankera axis of Benue State is characterized by two (2) seasons: warm-wet and cold-dry. The warm-wet season lasts from April to October, while the dry season begins in November and ends in March. The annual rainfall ranges from 1,200 mm to 1,500 mm (Ani *et al*., 2014). The temperature is generally high, ranging from 22^0 C to 30^0 C in the rainy season (Kakwagh, 2018; Ani *et al*., 2014). According to the National Population Census (NPC, 2006), the population of Sankera was estimated to be 610, 711 with Katsina Ala LGA (224,718), Logo LGA (169,063), and Ukum LGA (216,930).

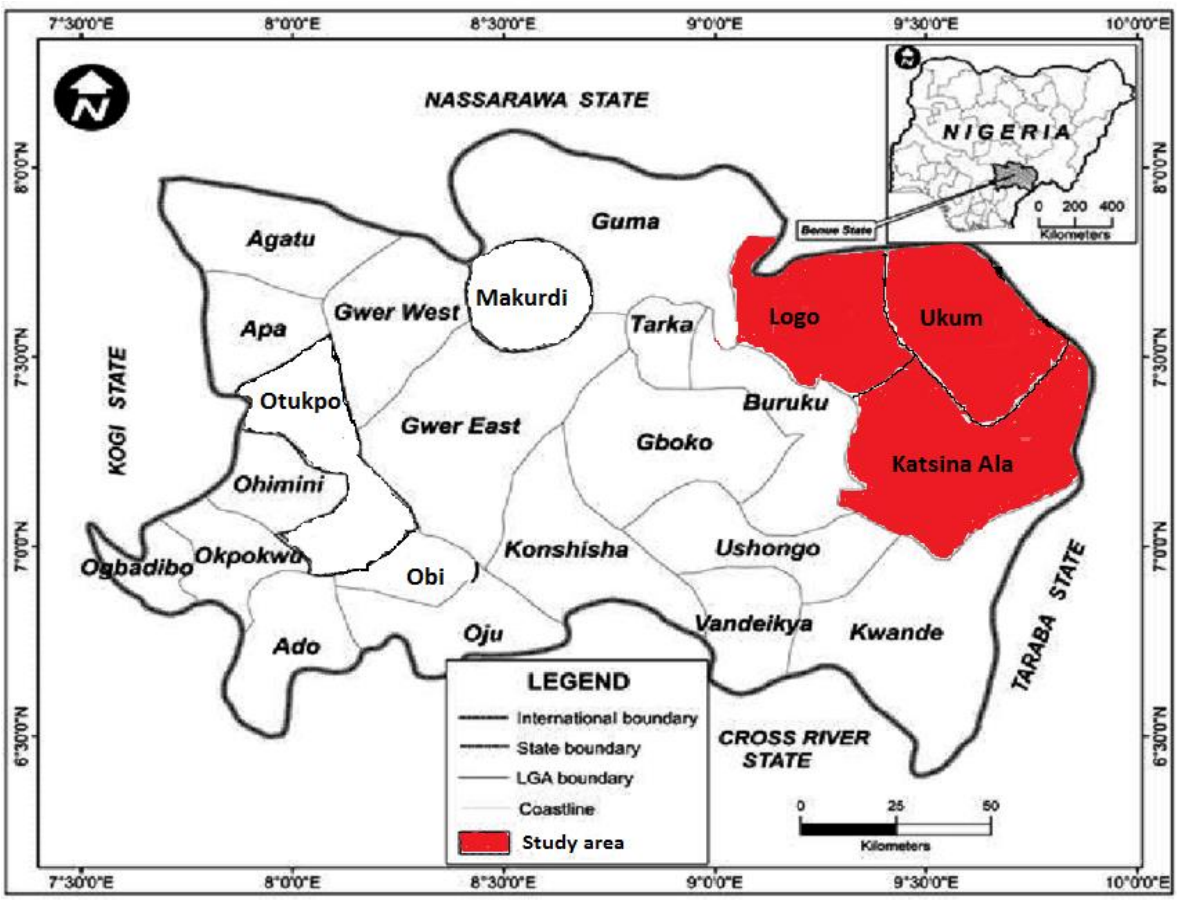

Figure 1: Map of Benue state showing the study area
Source: IamBenue (2018).

Data Collection and Analyses

The study area was stratified into Katsina Ala, Logo, and Ukum Local Government Areas (LGAs). A purposive sampling technique was employed to select one (1) major forest (community forest or forest reserve) each from Katsina Ala LGA (Ikyo Nyian forest), Logo LGA (Ukamberagya forest) and Ukum LGA (Gundu-Chaha forest reserve). Forest-dependent communities adjacent to the sampled forests were sampled based on their high tendency to depend on forests and their resources in the study area. Sample size of 385 respondents who depend on forests for their livelihoods were randomly sampled. Focus group discussions (FGD) were also adopted, guided by a check list of questions on the questionnaire. Administration of a structured questionnaire was conducted using the Cochran sampling method adopted by Kwaga *et al*. (2019). The formula is as follows:

$n_h = N_h \times \frac{n}{N}$ ……………………………………………………………………………Equation 1

Where: n_h = no. of questionnaire administered in each forest reserve; N_h = estimated population of the people in the LGA where the forest reserve is located; n = total no. of questionnaire administered; N = total no. of people in the study area.
Data was analyzed based on descriptive statistics (such as frequencies, percentages, tables, and pie charts) and the *Likert scale (*four scales). The *Likert scale* mean(s) for all indicators were categorized as follows: the mean(s) 1.00-1.49 = Strongly Disagree (SD), 1.50-2.49 = Disagree (DA), 2.50-3.49 = Agree (A) and 3.50-4.0 = Strongly Agree (SA). Spear man correlation was also used to test for significant relationship between respondents' perceptions on Forests ecosystems as banditry hideout and the ecological and socioeconomic implications on forest-dependent communities in Sankera axis of Benue State, Nigeria.

RESULTS AND DISCUSSION

Socio-economic characteristics of the respondents in north-east guinea savanna ecological zone of Sankera axis, Benue, Nigeria

The results of socio-economic characteristics in the north-east guinea savanna of Sankera axis, Benue state showed that3561.27%, 32.71% and 74.27% of the respondents35in Katsina Ala, Logo and Ukum LGAs respectively were males while3538.73%, 67.29% and 25.73% were female. According to the age category, 54.28% of the respondents were young adults between the ages of 10 to 30 (53.52% in Katsina Ala LGA, 56.08% in Logo LGA and 53.68% in Ukum LGA). Following this are individuals between the ages of 31 to 50 (31.69%) with Katsina Ala LGA (35.21%), Logo LGA (34.57%) and Ukum LGA (31.69%). Only 14.03% of them fall above 50 years with Katsina Ala, Logo and Ukum LGAs recording 11.27%, 9.35% and 20.59%, respectively (Table 1). According to the study's marital status results, 64.42% of the respondents were married, while 35.58% were single. In Katsina Ala LGA, 80.28% of the respondents were married, 58.88% in Logo, and 52.21% in Ukum LGA.
Majority of the respondents were observed to be married, male and young people between the ages of 10 to 30 years. This is a sign of a growing population that is in the prime of using, distributing, and consuming forest resources.35Clarke *et al*. (1996) affirmed that35forests provide a variety of goods and services that are crucial to the well-being of populations who depend on them, some of which serve as subsidies for agriculture (browsing and leaf mulch), while others meet critical requirements like food, shelter, and health.

The result (Table 1) also showed that, 49.35% of the respondents had secondary school education while 25.97% of them had primary school education. The respondents' occupational breakdown indicated that 54.28% of them were farmers, 21.56% were traders, and 20.00% were artisans/herbalists. There were just 4.16% civil servants. Despite the high educational of farming operations in the study area, the high level of education indicate that, respondents were knowledgeable about the social, ecological, and economic benefits of forests and forest products. Forty two point eighty five percent (42.85 %) of the respondents lived in households with more than 15 individuals, and 43.38% made between #100,000 and #200,000 annually (Table 1). The larger household sizes in the study area may be explained by socio-economic and socio-cultural factors like polygamy that encourage greater household consumption and extraction of forest resources.
This finding is comparable to the one made in a research by Kabubo-Mariara and Gachoki (2008), who reported that, families with large household size who resided close to forested areas explore more resources from the forests due to labour availability that can be spread across the forests. The larger household sizes could also be connected to the diversification of livelihood activities in the study area to include the use and marketing of forest products as well as farming. This supports the finding of Clarke *et al*. (1996), which noted that households in rural areas, particularly those living adjacent to forests depend on a variety of activities to meet their needs for a living. These activities include farming (crop and livestock production) as well as off-farm activities (urban remittances, craftwork and harvesting products from forests). The precise combination of these activities depends on a number of variables, including socio-economic considerations (population densities and demand for forest products).35
The average annual household income in the study area is below #200,000. This suggests that they are low-income, which accounts for their reliance on forest and forest resources. This result supports the claims made by Suleiman *et al*. (2017), Awoyemi (2011) and Vedeld *et al*. (2004) that low-income households heavily rely on forest resource extraction from nearby forestlands. Households with better income would opt to invest more in other sectors of the economy rather than relying on forest resources (Suleiman *et al*., 2017).

Table 1: Socio-economic characteristics of respondents

Variable	Frequency (Percentage, %)			
	Katsina Ala LGA	**Logo LGA**	**Ukum LGA**	**Total**
Gender				
Male	87 (61.27)	35 (32.71)	101 (74.27)	223 (57.92)
Female	55 (38.73)	72 (67.29)	35 (25.73)	162 (42.08)
Total	**142 (100)**	**107 (100)**	**136 (100)**	**385 (100)**
Age category				
10-30 years	76 (53.52)	60 (56.08)	73 (53.68)	209 (54.28)
31-50 years	50 (35.21)	37 (34.57)	35 (25.73)	122 (31.69)
51 years and above	16 (11.27)	10 (9.35)	28 (20.59)	54 (14.03)
Total	**142 (100)**	**107 (100)**	**136 (100)**	**385 (100)**
Marital Status				
Married	114 (80.28)	63 (58.88)	71 (52.21)	248 (64.42)

Variable	Frequency (Percentage, %)			
	Katsina Ala LGA	**Logo LGA**	**Ukum LGA**	**Total**
Single	28 (19.72)	44 (41.12)	65 (47.79)	137 (35.58)
Total	**142 (100)**	**107 (100)**	**136 (100)**	**385 (100)**
Educational Qualification				
Primary	29 (20.42)	30 (28.04)	41 (30.15)	100 (25.97)
Secondary	46 (32.39)	64 (59.81)	80 (58.82)	190 (49.35)
Tertiary	28 (19.72)	10 (9.35)	11 (8.09)	49 (12.73)
Non Formal Education	39 (27.47)	3 (2.80)	4 (2.94)	46 (11.95)
Total	**142 (100)**	**107 (100)**	**136 (100)**	**385 (100)**
Occupation				
Farming	63. (44.37)	58 (54.21)	88 (64.70)	209 (54.28)
Civil Servant	10 (7.04)	5 (4.67)	1 (0.74)	16 (4.16)
Artisan/Herbalist	48 (33.80)	12 (11.21)	17 (12.50)	77 (20.00)
Trading	21 (14.79)	32 (29.91)	30 (22.06)	83 (21.56)
Total	**142 (100)**	**107 (100)**	**136 (100)**	**385 (100)**
Household size				
Below 6	7 (4.93)	20 (18.70)	25 (18.38)	53 (13.51)
6-10	15 (10.56)	16 (14.95)	21 (15.44)	52 (13.51)
11-15	26 (18.31)	40 (37.38)	50 (36.77)	116 (30.13)
Above 15	94 (66.20)	31 (28.97)	40 (29.41)	165 (42.85)
Total	**142 (100)**	**107 (100)**	**136 (100)**	**385 (100)**
Income (₦) (Per Annum)				
Below 100,000	30 (21.13)	41 (38.32)	28 (20.59)	99 (25.71)
100,000 to 200,000	55 (38.73)	62 (57.94)	50 (36.76)	167 (43.38)
200,001 to 300,000	39 (27.47)	4 (3.74)	32 (23.53)	75 (19.48)
Above 300,000	18 (12.67)	0 (0.00)	26 (19.12)	44 (11.43)
Total	**142 (100)**	**107 (100)**	**136 (100)**	**385 (100)**

Nature and patterns of banditry attacks in north-east guinea savanna ecological zone (Sankera axis) of Benue State, Nigeria

The result on the nature and patterns of banditry attacks (Table 2) indicates that, majority (98.70%) of the responses implies that most of the bandits who attack forest dependent communities were young men who usually operate in gangs (groups) of 6 or more and use sophisticated weapons such as A.K 47 raffle to cause harm, suffering, and injuries to the poor forest dependent communities. This finding was in line with that of Shalangwa (2013), who reported that, bandits who attack the border communities of Adamawa state in north east Nigeria are purely males numbering from 10 and above.

Majority (64.49% and 66.18%) of the respondents in the study area (in Logo and Ukum LGAs, respectively) reported that, most bandits usually flee on motorcycles; while 76.76% of the respondents in Katsina Ala LGA, reported that, automobiles were the best form of transportation for bandits. The popularity of "bajaj" motorbikes in the study area could be due to the fact that these motorcycles move faster in the forest and bush paths. This agrees with Mudashir *et al*. (2021), they observed that bandits from Kuyambana forest in Kaduna and Kebbi states move to neighbouring villages on motorcycles with guns unchallenged. The vehicular escaping means of transportation preferred by the bandits in Katsina Ala LGA as opined by the respondents may be due to the thick vegetation and topography of the area. The Ikyo-Nyian forest's size and proximity, together with the presence of hills and mountains in Katsina Ala LGA, made it difficult for law enforcement officials to easily spot bandits.

This finding contradict Shalangwa's (2013), whose assertion showed that bandits usually escape on foots into the forests, hills and mountains of Adamawa state border communities of north-east Nigeria. Eighty seven point seventy nine percent (87.79%) of the respondents opined that the bandits typically escaped into the nearby forests after successive attacks on forest dependent communities. This implies that bandits have established a base of operations in the nearby forests of the study area thereby preventing forest dependent communities from accessing the forests. In keeping with this finding, Shalangwa (2013) reported the development of bandit hideouts in the forests of Adamawa and Borno states border communities.

Table 2: Nature and patterns of banditry attacks in the study area

Variable	Frequency (Percentage, %)			
	Katsina Ala LGA	**Logo LGA**	**Ukum LGA**	**Total**
Gender of the bandits that attack forest dependent communities				
Male	142 (100.00)	107 (100.00)	131 (96.33)	380 (98.70)
Female	0 (0.00)	0 (0.00)	0 (0.00)	57 (14.81)
Mixed gender	0 (0.00)	32 (0.00)	5 (3.67)	5 (1.30)
Total	**142 (100)**	**107 (100)**	**136 (100)**	**385 (100)**
Estimated number of bandits whenever they attack				
2-5	0 (0.00)	0 (0.00)	15 (11.03)	15 (3.90)
6-10	98 (69.01)	90 (84.11)	67 (49.26)	255 (66.23)

11 and above	44 (30.99)	17 (15.89)	54 (39.71)	115 (29.87)
Total	**142 (100)**	**107 (100)**	**136 (100)**	**385 (100)**
Types of weapons used by the bandits				
Sophiscated weapons	91 (64.08)	75 (70.09)	88 (64.71)	254 (65.97)
Small and light weapons	49 (34.51)	32 (29.91)	45 (33.09)	126 (32.73)
Non of the above	2 (1.41)	0 (0.00)	3 (2.20)	5 (1.30)
Total	**142 (100)**	**107 (100)**	**136 (100)**	**385 (100)**
Bandits escaping means after attack				
They escape by foot	0 (0.00)	18 (16.82)	0 (0.00)	18 (4.68)
They escape using motorcycles	33 (23.24)	69 (64.49)	90 (66.18)	192 (49.87)
They escape using vehicles	109 (76.76)	20 (18.69)	46 (33.82)	175 (45.45)
Total	**142 (100)**	**107 (100)**	**136 (100)**	**385 (100)**
Bandits hideout after attack				
They escape and hide in urban areas	0 (0.00)	4 (3.74)	9 (6.62)	13 (3.38)
They escape and hide in rural areas	31 (21.83)	3 (2.80)	0 (0.00)	34 (8.83)
They escape into the forests	111 (78.17)	100 (93.46)	127 (93.38)	338 (87.79)
Total	**142 (100)**	**107 (100)**	**136 (100)**	**385 (100)**

Tendency of respondents to depend on forest resources

Figure 2 depicts the tendency to depend on forest resources. The results revealed that majority (73.00%) of the respondents had a high tendency to rely on forest resources in the study area, but the existence of bandits in these forests defile their tendency. The high tendency to depend on forest resources may be explained by crucial functions that forests play in providing goods and services required for both human and animal well-being. According to Clarke *et al*. (1996), essential forest products include wood for tool handles and household utensils, poles and construction products, timber, foods, medicines, leaf litter, grazing, and browsing. Forest lands have a service role in controlling soil erosion, providing shade, modifying hydrological cycles and maintaining soil fertility. Religious and cultural customs which relate to designated woodland areas and certain tree species are vital to the spiritual well-being and effective functioning of rural communities (Clarke *et al*., 1996).

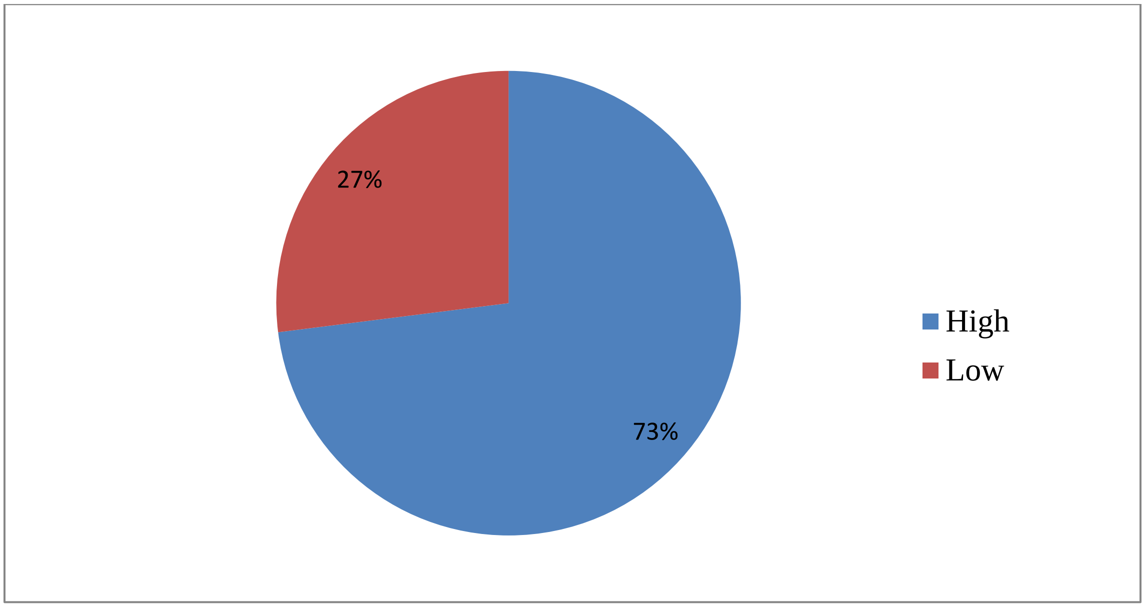

Figure 2: Respondents' forest dependent tendency in the study area

Consequences of banditry on forest ecosystems

The finding in Table 3 displays respondents' perceptions on how banditry affects the forest ecosystems in the study area. Based on the finding, the majority (55.84%) of the respondents believed that the majority of bandits in the study area significantly (p=4.56) use forest estates as a hideout for attack. All the respondents in the study area had the perception and agreed to the fact that bandits use forest estates as their hiding places in parts of Benue state. This implies that forests in the study area have turned into a haven for bandits. This result confirmed the statement made by El-Rufai (2022) that, bandits operate at the forest's fringes since the woodland serves as their primary hiding area. Rings of bandits have taken over chunks of hinterland communities in Benue State (Onwuzuruigbo, 2020). According to Mudashir *et al*. (2021), the nine forests include Sambisa, Alagarno, Kamuku, Kuduru, Kuyambana, linking almost the entire northern part of Nigeria and some neighbouring countries are being governed by bandits, thus worsening the insecurity challenges bedeviling the region. This development has affected the biodiversity of these forests, which in turn affects the extraction, distribution, and consumption of the forest resources. El-Rufai (2022) reaffirmed that the carpet-bombing of the forests usually leads to collateral damage to the forest.

Significant (p=3.84) proportion of the respondents (39.74% and 38.44% representing strongly agree and agree respectively) perceived that whenever bandits clash with security forces in the forest, their actions (such as airstrikes, forest fire and gunfire sounds) devastate the biodiversity of the area, causing forest degradation and wildlife migration. All of the respondents agreed that they loss their livelihoods due to banditry activities in the study area. The implication of this is the migration of wildlife species and displacement of human populations which affects the ecological, social and economic activities. The result of this finding indicates that banditry activities have significant implications for the respondents' socio-economic activities in the area.

Most of the respondents perceived that banditry activities destroy the available forest ecosystems in the area and disrupt social and economic activities (such as historical and religious festivals and educational activities, among others). Also, deliveries of basic amenities (such as instructional school materials, hospital equipment, water and electricity) and psychological trauma are some of the significant implications of banditry facing the study areas as perceived by the respondents.

Perception of ecological and socio-economic implications of banditry activities on forest- dependent communities in the study area

Table 4 shows the result of the respondents' perception of the ecological and socio-economic effects of bandits' activities on forest-dependent communities in the study area. Based on the result of this finding on the ecological and socio-economic effects implication, the majority of the respondents (44.16% for strongly agree and 48.83% for agree) significantly ($p = 3.82$) reported that the destruction of forests and forest products due to banditry activities in the area results in ecological implications such as soil erosion, drought, climate change, among others in the study area. Additionally, the respondents significantly ($p = 3.97$) perceived that banditry activities within the forest ecosystems mostly interfere with social activities (such as festivals, religious and educational activities) of the people that depend on forest.

Banditry-related economic disruption had a significant ($p = 3.37$) impact on forest-dependent communities in the study area. The banditry actions also significantly ($p = 3.74$) affect the supplies or deliveries of basic amenities (such as schools' or educational materials, medical equipment, electricity, and water, among other things). Also, the socio-economic implications of banditry activities in the study area were perceived to have psychological trauma on the surrounding communities who largely depend on forests and forest products for their livelihood in the study area (Table 4).

The result of the Spearman correlation test between respondents' perceptions on the effects of banditry hideouts in forest ecosystems and the ecological and socio-economic implications on forest-dependent communities in the study area is presented in Table 5. The test variables, spearman correlation scores, and p-values were displayed in the table. No significant (p 0.051) correlation was found between "forest ecosystems as banditry hideouts" and any of the ecological and socio-economic implications (Table 5). However, a negative correlation (-0.211) was recorded between "forest ecosystems as banditry hideouts" and psychological trauma experienced by forest dependents who are banditry victims and relatives of victims of banditry (Table 5).

The result on the correlation between forest ecosystems as banditry hideouts and different ecological and socio-economic effects revealed a non-significant positive correlation. There was a very high correlation (95%) between banditry hideouts in forest ecosystems and their effects on biotic and abiotic components of the forest. This indicates that the presence of banditry and high security activities in forest ecosystems influences the population status of biotic and abiotic components of the forest estates in the study area. Also, the presence of banditry and high security activities affects the utilization of wood and non-wood forest products (WNWFPs). Ecological disruption has various effects on forest ecosystems used by bandits as hideouts, including the extinction or threatened status of economically significant fauna species, among other NWFPs.

Effective prevention and control of banditry activities in the study area

Table 6 shows the respondents' perceptions on the effective prevention and control of banditry activities in the forest ecosystems in the study area. The majority of respondents (88.57%) believed that converting or clearing forest ecosystems (used by bandits as hideouts) to other uses would not be an effective means of preventing or controlling banditry activities in the study area. This implies that such a means of curtailing banditry activities in the area could have a great negative impact on their livelihood.

The respondents (51.95% and 29.09%) opined that the government should deploy more security personnel in the affected communities and provide enough equipment required for adequate crime control and prevention. The establishment of local security outfits (vigilante groups) and deployment of security personnel in the affected areas and the provision of equipment required to respond speedily to early warnings and distress calls to monitor forest ecosystems and their surroundings would be an effective control of such insecure activities in the area as significantly ($p = 4.16$) perceived by the respondents. The establishment of local security outfits (vigilante groups) to monitor forest ecosystems and their surroundings implies that authorities will never get it right in terms of securing the people unless the forests are ransacked, reclaimed, and properly guarded. The respondents (32.21%) significantly (p=3.12) perceived that the government should grant amnesty to the bandits and as well provide alternative livelihoods for them. Furthermore, the government and non-governmental organizations should provide basic infrastructure and amenities at the rural level in order to create employment opportunities, thereby discouraging any cooperation or collaboration between bandits and community members who could serve as informants to the banditry.

Table 3: Respondents' Perceptions on Effects of banditry on Forest Ecosystems in the Study Area

S/N	Consequences	SA		A		D		SD		No of Resp.	WS	WMS	Remark
		Freq (LS)	%	Freq (LS)	%	Freq (LS)	%	Freq (LS)	%				
i.	Most bandits use forests as their hideout	215 (1075)	55.84	170 (680)	44.16	0 (0)	0.00	0 (0)	0.00	385	1,755	4.56	**
ii.	Whenever bandits clash with security agencies in the forest, activities such as air bombardment, burning of forests and sounds from gun exchange destroy the living component of the forest including plants and animals	153 (750)	39.74	148 (592)	38.44	54 (108)	14.03	30 (30)	7.79	385	1,480	3.84	*
iii.	Banditry causes the migration of wild animals	140 (700)	36.36	177 (708)	45.97	42 (84)	10.91	26 (26)	6.75	385	1,518	3.94	*
iv.	Banditry affects the extraction, distribution, supply and consumption of forest resources such as timber, fruits, vegetable, honey, etc.	196 (980)	50.91	150 (600)	38.96	28 (56)	7.27	11 (11)	2.86	385	1,647	4.28	**
v.	Some forest-dependents whose houses or livelihood activities are located close to the forests abandoned their homes and livelihoods	181 (905)	47.01	204 (816)	52.99	0 (0)	0.00	0 (0)	0.00	385	1,721	4.47	**

Where: SA = Strongly Agree, A = Agree, D = Disagree, SD = Strongly Disagree, Freq = Frequency, LS = Likert scale, % = Percentage, WS = Weight score, WMS = Weight mean score, * = Significant effect, *= Highly significant effect.

Table 4: Perception on Socio-economic Effects of Banditry Activities on Forest-depended Communities in the Study Area

S/No	Implication	SA		A		D		SD		No of Resp.	WS	WMS	Remark
		Freq (LS)	%	Freq (LS)	%	Freq (LS)	%	Freq (LS)	%				
i.	Destruction of forests and displacement of forest-dependent communities resulting to famine, soil erosion, drought, climate change, etc.	170 (850)	44.16	188 (564)	48.83	27 (54)	7.01	0 (0)	0.00	385	1,468	3.82	*
ii.	Disruption of social activities e.g. festivals, religious and educational activities, etc.	186 (930)	48.31	199 (597)	51.69	0 (0)	0.00	0 (0)	0.00	385	1,527	3.97	*
iii.	Disruption of economic activities e. g. trade, transportation, tourism, etc.	109 (545)	28.31	216 (648)	56.10	46 (92)	11.95	14 (14)	3.64	385	1,299	3.37	*
iv.	Negative impact on supply/delivery of basic amenities like schools/instructional materials, hospitals/equipment, electricity, water, etc.	162 (810)	42.08	192 (576)	49.87	22 (44)	5.71	9 (9)	2.34	385	1,439	3.74	*
v.	Psychological trauma suffered by forest dependents who are victims of banditry and relatives of victims of banditry	98 (490)	25.46	64 (192)	16.62	137 (274)	35.58	86 (86)	22.34	385	1,042	2.71	*

Where: SA = Strongly Agree, A = Agree, D = Disagree, SD = Strongly Disagree, Freq = Frequency, LS = Likert scale, % = Percentage, WS = Weight score, WMS = Weight mean score, * = Significant effect.

Table 5: Relationship between respondents' perceptions on Forests ecosystems as banditry hideout and the ecological and socioeconomic implications on forest-dependent communities

Test Variables	Spearman value	*p*-value	Decision
Forests ecosystems as banditry hideout **vs.** Effects on biotic & abiotic components of forest	0.949	0.051	not sig.
Forests ecosystems as banditry hideout **vs.** Effects on fauna species	0.738	0.262	not sig.
Forests ecosystems as banditry hideout **vs.** Utilization of woods and non-wood forest products (WNWFPs)	0.949	0.051	not sig.
Forests ecosystems as banditry hideout **vs.** Communities livelihoods activities	0.778	0.222	not sig.
Forests ecosystems as banditry hideout **vs.** Destruction of forests and displacement	0.738	0.262	not sig.
Forests ecosystems as banditry hideout **vs.** Disruption of social & economic activities	0.738	0.262	not sig.
Forests ecosystems as banditry hideout **vs.** Effect on basic amenities	0.738	0.262	not sig.
Forests ecosystems as banditry hideout **vs.** Psychological trauma	-0.211	0.789	not sig.

Where: Not sig = Not significant at 0.05

This idea was backed up by 29.09% of the respondents. Only 15.84% disagreed and 24.94% strongly disagreed with the government's ability to provide infrastructure and amenity provision at the rural level due to the government's nonchalant attitude toward rural communities in Nigeria. Concerned stakeholders should, therefore, provide alternative livelihoods to the bandits through the provision of basic amenities that will create job opportunities.

Conclusion and Recommendations

Young and energetic male bandits use forests as their hideout in North east guinea savanna ecological zone of Sankera axis, Benue state, Nigeria. Their nefarious activities have continued to drive the general shift from forest conservation to forest degradation, resulting mainly from airstrikes, fire, and wildlife migration, all of which have adverse impact on how well the resources are utilized in the study area. Banditry activities have also posed a serious threat to the safety and security of forest-dependent communities. As a result, forest-dependent communities have been displaced, and their social, economic, and ecological activities have been disrupted. This finding suggests that clearing forest estates due to banditry activities, as commonly suggested by people, is not an effective method of prevention or control. Therefore, this study recommends strengthening both traditional and modern security systems to protect people’s lives and properties, including the forests.

Table 6: Effective Prevention and Control of Banditry Activities in the Study Area

S/No	Preventive/Control measures	SA Freq (LS)	SA %	A Freq (LS)	A %	D Freq (LS)	D %	SD Freq (LS)	SD %	No of Resp.	WS	WMS	Remark
i.	All the bandits hideout forest areas should be destroyed and converted to other uses	11 (55)	2.86	33 (132)	8.57	156 (312)	40.52	185 (185)	48.05	385	684	1.78	Ns
ii.	Establishment of local vigilante groups that will monitor forest ecosystems and forest dependent communities	164 (820)	42.60	175 (700)	45.45	36 (72)	9.35	10 (10)	2.60	385	1,602	4.16	**
iii.	Provision of security personnel and equipment required for adequate crime control and prevention	200 (1000)	51.95	185 (740)	48.05	0 (0)	0.00	0 (0)	0.00	385	1,740	4.52	**
iv.	Granting amnesty to bandits and provision of alternative livelihood to them	90 (450)	23.38	124 (496)	32.21	84 (168)	21.82	87 (87)	22.59	385	1,201	3.12	*
v.	Provision of basic infrastructure and amenities at the rural level with a view to creating employment opportunities	116 (580)	30.13	112 (448)	29.09	61 (122)	15.84	96 (96)	24.94	385	1,246	3.24	*

Where: SA = Strongly Agree, A = Agree, D = Disagree, SD = Strongly Disagree, Freq = Frequency, LS = Likert scale, % = Percentage, WS = Weight Score, WMS = Weight mean score, Ns = Not significant, ** = Highly significant effect, * = Significant effect.

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A REVIEW ON SUSTAINING ECOSYSTEM SERVICES IN EVOLVING URBAN LANDSCAPES IN NIGERIA: CURRENT KNOWLEDGE AND RESEARCH GAPS

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Abstract
The rapid increase in urbanization is one of the most significant socioeconomic developments taking place around the world. In developing countries, particularly Nigeria, urbanization is accelerating at an alarming rate. In terms of degree and distribution of urbanization, Nigeria is the most urbanized country. Urban ecosystems are becoming increasingly important as nodes of interaction between man and nature. As a result, sustainable management of urban ecosystems is a critical issue that must be investigated. The majority of the world's population spends their days in cities, and nearly 80% of Nigerians live in cities. The continued growth in the number and size of urban areas, as well as the increasing demand for resources and energy, pose significant challenges to ensuring human well-being in cities and preventing biodiversity loss. This article provides an overview of ecosystem service conservation research in Nigerian cities. Through the examination of selected articles from online databases. It seeks to close the knowledge gap between urbanization, demand generation, and the delivery of ecosystem services in urban areas. Street trees, lawns/parks, urban forests, cultivated land, swamps, lakes/seas, and streams have all been identified as urban ecosystems. Numerous ecosystem services are produced by these systems; Air filtration, microclimate regulation, noise reduction, storm water drainage, wastewater treatment, as well as leisure and cultural values, are local and direct services that are pertinent to Nigeria. It is concluded that local ecosystem services should be considered in land use planning since they have a significant impact on the quality of life in urban settings.

Keywords: Urbanization, Landscape, Ecosystem services, Sustainability, Population

Introduction

Cities play a pivotal role in the interaction between humans and the natural world because they are significant demand hubs for ecosystem services and they have profound environmental effects. Current predictions of metropolitan areas growing quickly bring both fundamental issues and opportunities for constructing cities that are more livable, healthier, and more resilient (e.g. adapting to the impacts of climate change).
According to Seto and Reenberg (2014), the world's population is predicted to dwell in cities and peri-urban areas by the year 2050, signaling the beginning of the urban age (UN World Population Prospects, 2012). Therefore, urban environments will soon become the norm for the vast majority of people on the planet. Nearly 80% of Europeans already reside in cities and large metropolitan areas, and there are no signs that this urban trend will change very soon (Haase, 2014). Protecting human well-being in cities and halting the escalating loss of land, ecosystems, resources, and biodiversity face significant challenges due to the continual expansion in the number and size of metropolitan areas as well as rising resource and energy needs (Haase, *et al.,* 2013). In a world that is becoming more and more dominated by humans, understanding how urban ecosystems function, how they develop, and what facilitates and inhibits their performance might help us understand ecosystem change in general (Elmqvist, *et al.,* 2013). There is no set pattern to urbanization because it is a complex social, economic, political, and technological process. Urban landscapes with patterns of densification, expansion/sprawl, and contraction are the primary manifestation of urbanization. New methodologies and approaches that take into consideration not just the complexity of urbanization dynamics but also the interactions between drivers, affects, and drivers are necessary to understand how these patterns form and their effects on the land and the environment. (Dagmar, *et al.*, 2014) Responses to these Dynamics The study topic on the ecological impact of urbanization is expanding, although it is still in its infancy and lacks a theory or framework in many ways (Cadenasso, *et al.*, 2008; Elmqvist , *et al.,* 2013).

Although they were frequently visible in the distant past, the hinterland links and feedbacks that fostered the rise of urban centers have become more and more lost in a globalized world (Elmqvist, *et al*., 2013). A current disregard for a socio-ecological perspective and a division between town and country can result in the emergence of significant feedback mechanisms, allowing them to remain undetected, mislead politicians, and take actions that have significant negative effects on the sustainability of the planet. Reintroducing a socio-ecological viewpoint on urban development and helping to redefine urban sustainability by making invisible feedback and connections visible are two goals of this special issue. Urban ecosystems have particular drivers and selection pressures because they are integral to societal function (Elmqvist, *et al*., 2013). A classic method of assessing urban complexity has been socio-technical, emphasizing how technological advancements drive change in cities and how cities are the living labs where technologies are hybridized and spread (Geels, 2011). The synergies, interactions, and trade-offs between society and ecosystems can be better understood using the socio-ecological systems approach to urban ecosystems. A socio-ecological co-production of ecosystem services (ES) and society, particularly in urban areas, could create new opportunities for resilience and quality of life (Go'mez-Baggethun *et al*., 2011).
In light of new and complex challenges like climate change (Bowler *et al.*, 2010; Ernstson *et al.*, 2010; Chelleri and Olazabal, 2012), migration (Seto *et al.*, 2011), relocation and global economic investment (Childers *et al.*, 2013), and urban rural telecommunications (Seto *et al.*, 2012), an urban socio-ecological approach will therefore become increasingly necessary to successfully improve human well-being in urban areas In the past, differences between the social scales of use, monitoring, and decision-making and the spatial and temporal scales of ecological processes and patterns have hindered not only our

understanding of ecological processes in urban landscapes but also the incorporation of urban ecological knowledge into urban planning (Kabisch and Hase, 2014).

Above all, the city can act as a testing ground for new ideas, providing a rich environment for cultural, social, geographical, temporal, institutional, and biological diversity (Knapp, *et al.*, 2008; Nevens, *et al.*, 2013). We must be concerned with issues of ecological functionality and ecological sustainability because this is where the majority of the population consumes the most (Grimm, *et al.*, 2008). Urban ecology as a sub-discipline of ecology didn't emerge until the 1970s in response to an awareness of human impact on the environment and the role of cities in this regard (Cadenasso, *et al.*, 2008; McPhearson *et al.*, 2013). While the term "urban ecology" has been used in schools of sociology and urban planning with varying meanings over the past century (Blanco, *et al.*, 2009), it has only been Urban ecology (Pickett *et al.*, 2004; Breuste *et al.*, 2013), which continues to try to combine both basic and practical research, is one legacy that has seen the scientific and planning professions come together. There is a need to better understand what can promote resilience and improve the quality of life in urban regions by bolstering and sustaining urban ecosystems, according to the conversation between science and policy. Urban ecology investigates the connections and linkages, whether good or negative, between the ecosystems and species that make up this complex matrix and the related human activities. Essentially, cities generate diverse landscapes with substantial temporal and spatial diversities. (Kabisch and Haase, 2014; Pickett *et al*., 2004).

The study of the context, cognition, demographics, and societal influences on which ES are regarded as crucial or significant by urban dwellers and planners is also gaining importance. We now comprehend that resilience and sustainability are influenced by cultural and biological differences (Andersson, 2006; TEEB, 2010). This poses the issue of how to create a solid analytical framework that guides planning and governance while taking into account social and environmental components and their dynamics. A rising body of empirical evidence demonstrates that urbanization has a significant impact on how we manage and utilize natural resources. It is yet unclear how these effects appear, particularly with regard to ecosystem services and biodiversity (Elmqvist, *et al.*, 2013; Haase, 2012) For instance, like in other regions of the world, most research in urban ecology and social ecology has been carried out by solitary research institutions. Many parts of functional city ecology are well understood, but future empirical research should take a more comprehensive and integrated approach in accordance with global trends (Dagmar, *et al.*, 2014).

Urban Ecosystem Services

Natural resources such as clean air, water, food, and materials are examples of ecosystem services (ES), which are provided by the environment and utilized by humans (Barbier, 2011). They have significant economic value and support social and cultural well-being (Fischer *et al.*, 2009). (Emerton and Bos, 2004; Turner, *et al.*, 2008). Provisioning, regulating, cultural, and supporting ecosystem services are the major categories into which they have been divided (MEA, 2005). Highlights of the overall findings and fresh perspectives on urban ES produced by research from the Urban Biodiversity and Ecosystem Services (URBES) project are listed below, along with significant accomplishments and unmet research needs (Schewenius, *et al.*, 2014): Covering land and land use - While outcome-based indicators are suitable for evaluating ES, they have limits for comparison study in metropolitan locations and may deter future empirical field-based research; Cross-border and multi-scale analyses are necessary to comprehend the linkages and inconsistencies between urban ES supply and demand; Urban ES are mediated by non-ecological factors, including the built environment, technology, social norms, and cultural settings in which people interact with their surroundings. Urban nature provides city dwellers with a chance to interact with nature; this question is particularly significant in urban regions because the high density of people and mediators necessitates a sophisticated investigation of the relationships between them. Through this connection to nature, cultural ES are generated that bring light on the many values and meanings that people derive from nature as well as facilitate, inform, and support discussions of ecological potentials and difficulties in cities. In order to effectively implement the urban ES concept in practice, disciplinary barriers between science, policy, and governance must be crossed, as well as gaps between science and planning frameworks and tools. The relationships between biodiversity and ES in urban areas are unclear, lacking evidence, and require new data and empirical research. ones that are already in existence: comparisons between cities are essential for this. Understanding the forces that shape ecosystem structure, function, and processes, and differentiating between dynamics that are specific to a certain location and those that apply to many metropolitan environments worldwide.

Urban Landscapes in Nigeria

The rapid rise in urbanization is one of the most important global trends. Urbanization is occurring at an alarming rate in emerging countries, where this is increasingly prevalent. Nigeria is no different. In terms of both population and distribution of urbanization, it is the most urbanized nation in all of Africa. Whether or not we have a vision to lead our transition to sustainability, on sizes ranging from local landscapes to the entire planet, will determine the future of humanity. This perspective is based on the science of sustainability, and landscapes and regions represent a major size domain (Wu, J. 2013). The ability of a landscape to continually deliver long-term ecosystem services that are unique to that landscape and necessary for preserving and enhancing human well-being is referred to as landscape sustainability. In essence, achieving well-being is a journey rather than a goal. The goal of landscape sustainability science is to comprehend and enhance the dynamic relationship between ecosystem services and human well-being in changing landscapes under uncertain conditions brought on by internal feedback and external disturbances. It is a place-based and use-inspired science. The importance of landscape interactions and hierarchical relationships with scales (or externalities) that are both finer and broader should not be overlooked, even while the science of landscape sustainability places an emphasis on place-based research at landscape and regional dimensions. Spatially explicit methods, in particular experimental strategies that take advantage of designed landscapes and multiscale simulation models that connect the dynamics of landscape services (ecosystem services provided by multiple landscape elements combined as properties emerging) and human well being, are crucial for advancing the science of landscape sustainability in Nigeria (Wu, J. 2013).

Housing and Urban Development

In Nigeria, colonialism came before the process of urban development. In the past, it has benefited from the country's constant socio-political and economic change, fast rural-urban migration, and natural population expansion through births. For instance, in 1921, over 20,000 people resided in urban areas across the nation's 18.63 million population (Oduwaye, 2016). Around 180 cities made up the nation's urban population in 1963, which accounted for 19.1% of all residents. In the middle of the 1970s, this percentage increased to about 35% of the population living in cities. The process of people moving from rural to urban areas is still going on. The World Bank estimates that the nation's population will reach 206.1 million by 2020. However, this has significant ramifications for the unfavorable environmental effects of cities' rapid physical growth in terms of land use development (Oduwaye, 2016).

Like other regions of the world, Nigeria has a long history of landscaping. The experience of Nigeria has demonstrated that it is a form of art that has a right to the cultural, social, and economic development of many regions of the nation. Unfortunately, it is one of the nation's last remaining arts. This may be because modern landscape planning began to emerge in Nigeria roughly 20 years ago. The concept has just lately gained traction thanks to the thoughtful design and implementation of public institutions, landscapes, a few wealthy individuals, and business interactions. The experience of Nigeria can be related to the common phenomena of landscape development, which doesn't happen in any company until a time of stable peace, prosperity, prosperity, and prosperity has been established. All of this gets individuals ready for the delicate yet fragile task of developing a landscape.

Although Nigeria needed to design its environment, the biggest challenge was the poor standard of living that resulted from the country's low income. This is made more challenging by the ongoing demographic shift toward large urban areas at the expense of rural populations, which has led to issues with natural landscape destruction, insufficient open spaces, ecology, environmental management, and a lack of adequate facilities, among other issues with landscape planning.

A lack of public awareness of the significance and applicability of landscape planning is the main barrier to its development in Nigeria. Therefore, highlighting the necessity for landscape planning in Nigeria today, when income is mostly subsistence-based paired with a low level of life, may cause further conflict, particularly with the impoverished majority. In contrast to solely aesthetic studies, the landscape does need to be improved functionally. To reduce the impact of environmental threats like pollution, radiation, erosion, and desertification, for instance, landscape planning is required, along with the necessity for balanced land use planning, among other things (Oduwaye, 2016).

In order to accomplish the aforementioned, Nigeria's previous and current administrations have significantly improved environmental quality by implementing programs like War Against Indiscipline (WAI), which has the dual goals of environmental restoration and waste management. Additionally, the government has started quick solutions to desertification, erosion, and floods. National, state, and local governments have all started National Tree Planting Days as well. Individuals and corporations are also mobilized by the government.

Over the past two decades, Nigeria's pace of urbanization has grown. . The legislative agenda has continued to prioritize urbanization over rural development, and there is a huge need for more urban infrastructure development. Because of the increase in construction density, urban ecosystems are at risk. Sometimes, trees are lost more quickly than they are planted again. Planning for urban development has been done with little to no regard for managing biodiversity and habitat, if at all. Urban design that prioritizes biodiversity can result in more chances for recreation and healthy living in urban settings, in addition to the advantages of saving species from extinction and preserving widespread species. Parks, gardens, and green belts are secondary concepts that aren't typically incorporated into housing and urban design.

Locally Generated Ecosystem Services

According to Costanza, *et al.*, (1997) "Ecosystem services" are "the benefits that human populations obtain, directly or indirectly, from ecosystem functioning" (1997). Even though some of these ecological services are not directly used by people, maintaining ecosystems requires them. Plant pollination and nitrogen cycling are two examples of these indirect benefits. Air filtering, climatic regulation at the city and street levels, recreational and cultural value, storm water drainage, waste water treatment, and noise reduction are additional locally generated services.

Remaining Challenges

According to Dagmar *et al.*, (2014), they examine how urban ecosystems work, how they deliver goods and services to city residents, how they change, and what promotes and inhibits their performance can help us understand socio-ecological dynamics and offer new suggestions for how to manage urban systems for resilience. There is still work to be done to demonstrate how the urban ecosystem services framework can offer transitional pathways and processes for creating plans and policies for urban resilience, governance frameworks that support poly-centrism and inclusiveness, and stewardship strategies to help meet demands and aspirations for sustainable urban growth, human health and well-being, ultimately paving the way for urban resilience. The issues that still need to be resolved include, but are not limited to: What new ideas and theoretical frameworks can help us better comprehend urban resilience from an ES perspective? What brand-new techniques and instruments are available for ES evaluation and bench-marking evaluation? What techniques can connect the local and global scales for ES evaluation, mapping, and modeling that are cross-scale and scale-sensitive? What may be learnt by using ES for planning and assessing resilience?

The research community needs to investigate these possibilities and any effects they might have on city governance at all levels, from municipal to international. It is believed that a socio-ecological strategy, which is likely to emerge under the initiative Emerging Future Earth, will put learning and scientific advancement at the center of urban sustainability and resilience on a world that is becoming more urbanized. Additionally, look at whether adaptive co-management might be a practical strategy for managing the ecosystem resilience of a bio-diverse urban landscape in Nigeria.

Conclusion

Given the high value of property in metropolitan areas, securing and enhancing the production of ecosystem services would probably need a combination of multiple land uses on the same parcel of land. There are several ways to boost vegetation, such as using trees in parking lots or small lawns as traffic dividers. Thinking flexibly is required. It makes sense to incorporate the consideration of biodiversity into the future design of housing and town planning, both as a fundamental tenet of the Federal Ministry of Housing and Urban Planning and of state agencies with analogous responsibilities.

Despite the fact that city inhabitants still rely on global ecosystem services for their existence, it is also obvious that urban ecosystem services improve the quality of life in cities. Locally offered services, such as air quality and noise levels, which cannot be enhanced utilizing remote ecosystems, increase the quality of life for city people. But it is important to keep in mind that just the impact of these issues is diminished, not the root of the issue that has to be fixed. Working on both ends is necessary. It is hoped that a greater understanding of ecosystem services will lead to more efficient city planning and construction. The contribution of urban ecosystems to urban life would then be completely understood, and their value would be estimated if the country were to be claimed for exploitation. Understanding the significance of ecosystem services may also allow for the maintenance or even expansion of mysterious urban areas. Metropolitan planners and political decision-makers need to understand and value the ecosystem services provided by urban areas and the ecosystems they support as cities are expected to expand rapidly over the coming decades. Finally, local ecosystem services must be considered when planning land use because they have a big impact on metropolitan areas' quality of life.

Recommendations

Urban regions have less greenery than rural areas, which contributes to the severity of the effects of climate change there. To lessen the effects of climate change, city inhabitants should be encouraged to cultivate flowers and trees. Rural areas should be given access to social institutions. As a result, fewer individuals move from rural to urban areas. If ecosystem services are to be preserved in the area, the government should also see to it that policies addressing environmental challenges in urban areas are adopted and appropriately enforced.

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DEVELOPMENT AND SUSTAINABLE FOREST MANAGEMENT IN NIGERIA: IMPLICATION OF COUNTRY'S INSECURITY

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Abstract
Forests represent important natural resources that help developing countries in the area of sustainable livelihood. However, mismanagement of the forestland in the course of urbanization, industrialization and illicit agricultural practices has led to forest degradation. Therefore, towards perpetuating the benefit of forest resources, several forest policies and Sustainable Forest Management (SFM) were employed. This paper reviews the trend of forestry development in Nigeria, its sustainable management and implications of insecurity on the forest estate. Forestry development has being in existence in Nigeria as far back as 1889 with emphasis on forest reservation and controlled timber exploitation. Politics, Poor forest management plan and enforcement of forestry legislation, unclear land tenure and property right and deforestation are some of the factors that influence sustainable forestry development. It is concluded that forestry development in Nigeria has never been undermined and several policies formulated as well as SFM have been helpful in the sustenance of Nigeria forests. Therefore, efforts of the stakeholders in forestry sectors and political leaders at all levels on the approach must not be relaxed. Every tier of government should work on training, education and empowerment of rural dwellers on alternative green entrepreneurs that will enhance sustainable livelihood and reduce pressure on the forest estates

Keywords: *Livelihood, Mismanagement, Urbanization, Degradation, Forest resources*

Introduction

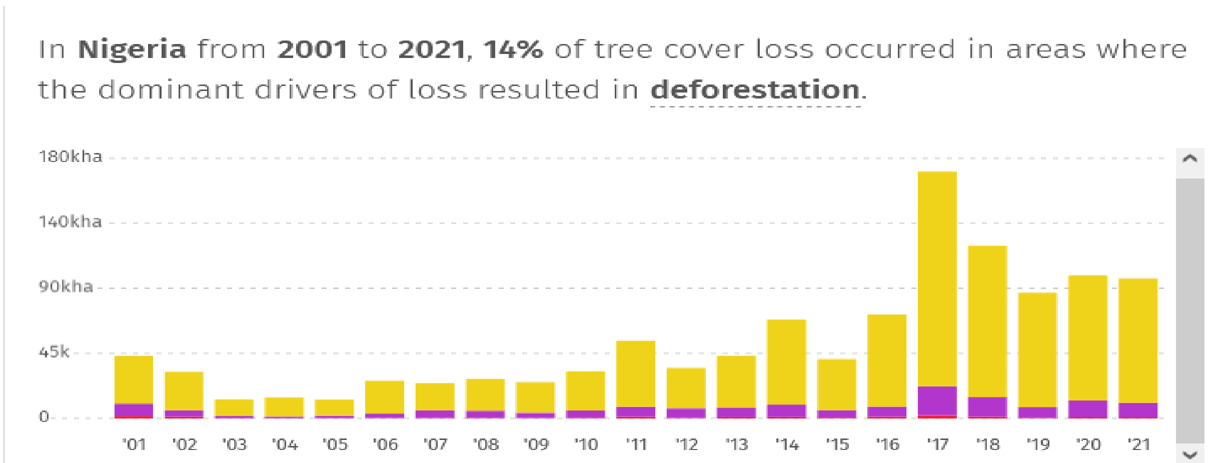
Forestry can be defined as the "scientific management of forests for the continuous production of goods and services". The lives of the largest percentage of the entire world populace depend on the forest. Trees are cultivated to meet some definite objectives. By and large, in planting the right tree the social and the economic benefit must be considered. Any error in this direction will lead to poor result in the future (Ojo *et al*., 2008).

Forests represent important natural resources that help developing countries improving their economic well-being. More than 1.6 billion people throughout the world depend on forests for some part of their livelihood (Rhett, 2020). Forests provide a wealth of important wood and non-timber forest products (such as edible nuts and fruits, medicinal plants, fibres, rattan, gum Arabic and tannins) that people in the developed and developing world rely on (Ojo *et al*., 2008). The value of wood and non-timber products provided by forests is immeasurable. In addition, forests provide environmental preservative services such as regulating water supplies and soil erosion control. These services have an enormous impact on worldwide agricultural productivity and human health. Forests play vital roles as major stores of greenhouse gases, such as carbon. This important function contributes to reducing global warming. Forests also provide important habitat for wildlife. Experts estimate that 70 percent of all land-based plants and animals live in forests (USAID, 2007).

Gestalt of Forestry Development in Nigeria

Forestry development came into existence in Nigeria since 1889 with emphasis on forest reservation and controlled timber harvesting (Geomatics, 1997). Before independence, available forest resources could adequately meet the needs of the country, both for the export market and for local needs. However, after independence, pressure was exerted on forest resources to generate revenues in order to support the young economy and respond to the needs of increasing populace. It has therefore become clear that available resources cannot be taken for granted without conscientious intervention. (Geomatics, 1997). Several programmes were therefore implemented at local and country levels such as Tropical shelter wood system (TSS), Enrichment planting schemes and agroforestry. Most of which were issue-specific without a holistic review of the forest sector. The problems plaguing the sector invariably persist in spite of huge financial commitment to these forest development programmes (Nwoboshi, 1986). In the 1960s and early 1970s, more than 60 percent of domestic export earnings came from forest products. During this period, timber supplies outweighed demand, but the country is currently unable to meet export demand for most tropical hardwood species from the natural forest (Geomatics, 1997). Mismanagement of forestland during logging and agricultural production activities has led to policy of the creation of forest reserves. But the policy that came about was not based on adequate knowledge of ecology, biology and silviculture of the natural forest ecosystem (Osemeobo, 1998). There was pervasive tendency to either over-value or under estimate the economic, social and ecological cost of forest utilization. In the 1980s, the demand for forest products, in particular wood, became insatiable because of the increasing pressure of the human population and economic growth. This led to unregulated forest exploitation, thus resulting in degradation of the forest resources in the country (Anadu and Green, 1990). From 2001 to 2021, Nigeria lost 1.14Mha of forest cover, which equates to an 11% decline in forest cover since 2000 and 587Mt of CO_2e emissions (GFW, 2021). The extent of this forest loss in Nigeria was ascribed to effects of land clearance for cropping by subsistence farmers in shifting cultivation. In fact, it accounted for about 80% of the deforestation (Enabor and Popoola, 1994). According to Nwoboshi (1986), it was estimated that 60 million hectares of Nigeria's total land area were forested in 1976, whereas in 1985 the figure fell to about 9.4 million hectares. In the year 2004 according to Food and Agriculture Organization, Nigeria had 15% forested land (FAO, 2004), it was evaluated at that time that about 360,000 km ^{2} (25.6%) of Nigeria land area was under forest cover (FAO, 2004).

In 1990's, the area of industrial forest plantations in Nigeria was about 160, 000 ha while the area of environmental plantations was 48,000 ha (Oyebo and Okiriguo, 1999). Rubber constitute about 50% of the plantation, *Gmelina arborea* - 30%, while *Pinus caribaea* account for about 1%. Other broad leaved tree species such as *Tectona grandis* and Eucalyptus species are moreover recovered within the plantation. However, improper forest management plan, nascent silvicultural practices, under-utilization of resources and high level of illicit logging within the forest plantation led to uncontrolled failures (FDF, 1998). According to Global Forest Watch (2021), 14% of tree cover loss between 2001 and 2021 occurred in area where the dominant drivers of lost resulted in deforestation (Fig. 1). In a bid to rescue the nation from this devastating state of Nigeria forest, the Federal Government of Nigeria (FGN) in 2019 seriously set out to embark on reforestation and afforestation programme so as to have 25% of total land area of the country forested. The programme is tagged National Afforestation Programme (NAP). The main aim of the NAP scheme was the ecological woodland restoration by the government and the development of forest resources with the help of the non-government sector, with a focus on increasing the livelihood of the forest-fringe community, including park rangers and those living in poverty. In achieving this, the FGN embarked on planting a minimum of 25 million trees where Forestry Research Institute of Nigeria (FRIN) raised 13 million seedlings; Great Green Wall raised about 7 million seedlings, and other sister agencies raised approved quantities based on their capabilities (Asinwa *et al*., 2020).



Source: Global Forest Watch, 2021
Figure 1: Tree cover loss between 2001 and 2021 in Nigeria

Factors affecting forestry development in Nigeria

There are several elements required for assurance of sustainable forestry development. They include legal and policy framework, sustained and optimal production of forest products. It requires protection of the environment, and well being of people to be put in place. Absence of any of these elements can result in negative influence on the availability and utilization of the forest resources (Eugene, 2004). Aftermath of the occurrence (courtesy anthropogenic activities) would be disruption of the forest ecosystem leads to the depletion of the forest resource (Campbell *et al.* 1996; Cleaver and Schreaber, 1990). Generally speaking, some factors that can influence sustainable forestry development include:

Politics

Political instability has made various programmes aimed at sustainable forestry such as Tropical Forestry Action Plan (TFAP) and National Forestry Action Programme (NFAP), to be short lived. Similarly, World Bank (1991) reported that instability in the political and economic policies, as well as lack of political will to implement the right energy policies were some of the reasons leading to low response by potential investors in sub-Saharan Africa.

Poor forest management plan and enforcement of forestry legislation.

Management plans play significant role on sustainable forest development from the time of land acquisition, preparation to harvesting period. Nigerian factors most in relation to corruption have made the forestry legislation so cumbersome. .

Deforestation

The drastic reduction in forest areas across the globe towards other uses such as agricultural croplands, urbanization and industrialization is being referred to deforestation. The menace greatly affects development of forestry. Other factors includes

- ✓ Inadequate land use planning
- ✓ Dearth of information about the forest resource base
- ✓ High fuel wood consumption and poverty
- ✓ Inefficient use of the forest resources
- ✓ Low degree private sector participation in forestry
- ✓ Denial of indigenous people's right
- ✓ Unequal distribution of benefits and costs for the use of the forest
- ✓ Inadequate protected area network

Sustainable Forest Management (SFM)

Sustainable Forest Management (SFM) is considered as one of the foremost critical commitments which the forestry segment can make to the feasible advancement and sustainable development targets of any country, especially those luxuriously blessed with forest resources

(FAO, 2007). The process of managing permanent forest reserves to realize one or more clearly indicated targets of administration with respect to the generation of a persistent stream of desired forest goods and services without undue diminishment in its inborn values and future efficiency and without undue undesirable impacts on the physical and social environment is called SFM

(ITTO, 2005). Towards optimum monitoring, evaluation and reporting of SFM, ITTO developed a set of key criteria and indicators (C&I) for the management of tropical forests. In a nut shell, the major objective of SFM is to ensure that derived forest production and products meet present-day needs without jeopardizing the future development. According to Jorge and Julio (2012), forest management includes the regulatory, legitimate, specialized, financial, social and natural angles of the preservation and utilization of forests. It suggests different degrees of human mediation, extending from activities pointed at conserving and protecting forest ecosystems and its capacities to favoring particular socially or financially profitable flora and fauna species for the improved production of goods and services (FAO, 2007).

Sustainable Forest Management Components

Considering different definitions of SFM, several fora of forestry in different parts of world (such as World Commission on Environment and Development, (1987); Federal Leadership In Environmental, Energy, and Economic Performance (Federal Register 2009); The Ministerial Conference on the Protection of Forests in Europe (2009)) have suggested the following key components of SFM. They include:

Extent of forest resources

This is all about having reasonable forest cover and stocking, including tree outside forests, to support the social, economic and environmental aspects of forestry. It encompasses ambitions to reduce deforestation and to restore and rehabilitate degraded forest landscapes.

Biological diversity

This is towards conservation, preservation and management of biodiversity of the ecosystems. Such conservation, includes protection of areas with degraded ecosystems, basically to ensure maintenance of biodiversity, and provides advantages of new forest products development.

Forest health and vitality

Management of forest is essential to reduce risks and influences of undesired disturbances such as wildfires, airborne pollution, storm felling, invasive species, pests, diseases and insects. The disturbances can impact social, economic as well as the environment in general..

Productive capacities of forest resources

This explains the desire to preserve the supply of essential forest products at present and at the same time guaranteeing the existence of these products for the use of incoming generations without compromising the management of future eras

Protective functions of forest resources

Here, the importance of forests on soil enrichment, watershed and environmental management is focused. This includes enhancement of drinkable water, reduction of flood risks, erosion control and drought management. It also contributes to ecosystem conservation efforts.

Socio-economic functions

This looks into the important functions of forest to host and protect sites and ecosystem that have high cultural, spiritual or recreational values, and thus include aspects of land tenure systems/ownership, indigenous knowledge and management of communal systems.

Criteria and indicators for SFM

Criteria and indicators are instruments utilized to characterize, evaluate and screen intermittent advance towards SFM administration in a given nation or a specified forest area, over a period of time. The ultimate aim of criteria and indicators is to enhance the improvement of all operations relating to management of forest at a particular period of time. Towards ensuring healthy and productive forest estates with reference to the social, economic, environmental, cultural and spiritual needs of the full range of stakeholder groups in countries concerned (ITTO, 2005).

The United Nations Conference on Environment and Development (UNCED) was held from June 3 through June 14, 1992, in Rio de Janeiro, Brazil. Among the agenda of the conference was the principles that guide SFM as a contribution towards sustainable development. Reconciliation among forest productive functions, protective roles, environmental and social roles was firmly discussed at UNCED. In this forum, not less than 27 guiding principles which target obligations of every country on environmental development was agreed. Following the conference about 160 countries are involved in development of C&I approach for SFM (ITTO, 2005).

Criteria and indicators can be used to encourage more holistic thinking when planning forest management activities, and to bring about greater rigor, openness, transparency and accountability in forest management planning. These C&I indicate the direction of change as regards to the forests and also suggest the ways to enhance the process to achieve the SFM. It would be supportive in adoption of better management practices so that the direction of change can be ascertained and timely actions to alleviate the foreseeable damages to forest resources can be put into consideration (ITTO, 2005).

Overview of Insecurity in Nigeria

Nigeria is passing through an unprecedented wave of different security crises ranging from banditry, insurgencies to kidnapping. This is prevalent in every geographical zone of the country.

The country has always faced different difficult challenges at different times. Just in the the country underwent a good a three-year Civil War with serious aftermath effects on certain parts of the nation. Lives of innocent citizens and properties that worth millions of naira were lost during this period of unprepared war. Invariably, throughout this period of civil war, indiscriminate killings were order of the day as a result of much insecurity (Oyewusi, 2022). Immediately after the war, armed robbery crept in as another form of insecurity. The robbery was so rampant at that time with great effects on every facet of life in the country. This led to fiery promulgation of decree by the ruling military government that armed robbers caught should be killed by firing squad. It was at that period that violent armed robbers like Ishola Oyenusi and his gang were executed at the bar beach. Ever since then, the nation has witnessed different groups of armed bandits terrorizing the entire landscape for instance, Lawrence Anini and Shina Rambo, and it has resulted in the formation of different squad of the police force saddled with the responsibility of keeping men of the underworld at bay (Oyewusi, 2022).

At moment, the reigning source of insecurity in the country is herdsmen and cattle rustlers. The herders carry sophisticated weapons, descend on innocent farmers and their families and take their lives. Several lives have been lost by this barbaric act of notorious herders. The heinous incidence has led to unguided rancor among Fulanis and Bororos who are generally believed to be major herders and most of their host communities. In addition to the hostility, larger percentages of the southern rural communities in Nigeria have rejected the plea by the Federal Government to allow herdsmen to settle with them (Oyewusi, 2022).

The religious extremists otherwise known as Boko Haram have constituted another insecurity factor that is militating against peace and tranquility of Nigeria. For over a decade now, these religious extremists have being ravaging every nook and corner of the Northern part of the country. In fact the devilish venom of these evil men is now being felt in the Southern part of the nation. (Oyewusi, 2022). In almost every day, thousands of people are being killed, many have been displaced and now live in Internally Displaced Persons camps spread across the whole Northern States. More to this is kidnapping for ransom which has become an intractable problem. Innocent school children especially in the North are being kidnapped on a daily basis and taken into the deep forest while their parents are thrown into great despair (Oyewusi, 2022). Outrightly, forests are the conspicuous hideouts of the perpetrators of these evils. The forest serves as base for rebels to launch attacks, hideouts for armed robbers who attacks travelers and traders; hideouts for thieves, kidnappers, ritual killers, criminals, and cattle rustlers; and camping sites for insurgents, as well as a base from which non-state armed actors organize guerrilla attacks against the state and/or its economic interests. The implication is that forest reserves have become ungoverned spaces that are mobilized by insurgents and criminal elements and redirected to anti-state activities (Suleiman, 2014).

Security threats posed by the Forests

7. Forests provide cover as forests consist of plant communities of plants especially trees growing close together which can be used by hideouts or for launching attacks in an ambush.
8. Being isolated areas where nobody lives, forests are used by those who oppose the government or societal values and carry out activities that are against the law such as theft, armed robbery, and attack on security personnel.
9. Forests can also be used as places for criminal activities such as base for drug abuse, ritual killings and hiding of weapons.

10. Forests are areas where there is least of presence of security personnel especially in developing countries and as such crimes can be committed and help cannot easily come to the victims (Suleiman, 2014)

Implications of Insecurity on SFM

The overall effect of insecurity on the sustainable forest management is forest degradation. In several occasions, insecurity has resulted in reducing the capacity of a forest to produce ecosystem services such as carbon storage and wood products as a result of anthropogenic activities such as building up of insurgent/bandit camps. Their activities constitute nuisance to the forest and its surrounding. This is evident from the findings of Suleiman (2014), who found that forests in the Northern part such as Sambisa Forest Reserve, Rumah/Kukar Jangarai Forest Reserve, kamuku Forest Reserve, kagoro Forest, kabakawa Forest Reserve, Idu and Gwagwa Forest Reserves, Falgore Forest and Balmo Forest were degraded either partially or wholly through deforestation.

Strategies towards sustainable forestry development

- The Federal, State and Local governments should work on training, education and empowerment of rural dwellers (most especially those living around the forest) on alternative green entrepreneurs such as establishment of wood lot, bee keeping, snail farming, mushroom production, rabbit farming and so on. This will enhance sustainable livelihood and reduce pressure on the forest
- Involvement of rural communities in the forest management must be highly encouraged.
- Development of new security strategies and encouragement/empowerment of local hunters to prevent infiltration of the forest.
- Every policy that enhances establishment and management of forest policies must be implemented accordingly without prejudice.
- In order to improve sustainable forest development, incessant field survey and dissemination of information should be encouraged

Conclusion

Forestry development in Nigeria has never been undermined from time immemorial. Significant efforts were always put in place basically to ensure continuous benefits from forest resources. Unfortunately, with upsurge in population coupled with incessant development (urbanization and industrialization) the developmental trend of forestry is dented. The impact of defective leadership and that of pronounced insecurity on country's forest estate cannot be overemphasized. Nevertheless, sustainable forest management is a veritable means which has being relatively keeping the sustenance of Nigeria forests. Therefore, efforts of the stakeholders on the approach must not be relaxed.

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IMPACT OF NATURE-BASED CONSERVATION MEASURES ON FLORA SITY AND PRODUCTIVITY IN TROPICAL RAINFOREST ECOSYSTEM OF NIGERIA

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Abstract
Nigeria is endowed with rich forest ecosystems, which have been subjected to severe threats. To prevent complete loss of the forests, several conservation measures were adopted such as Strict Nature Reserve (SNR) and Sacred Groves (SG). Currently, information on the impact forest conservation measures on biodiversity is scanty. We assessed tree species diversity of two primary forests (Omo-SNR and Akure-SNR), two SGs (Idanre Hills and Ogun-Onire) and two degraded forests (Eda and OA3 forest reserves) in rainforest ecosystem of south-western Nigeria. Data were collected from 48 (8 per site) 800m^2 temporary sample plots, systematically laid along two transects of 1000m per site. Tree species richness followed the order: Akure-SNR (63) > Ogun-Onire (62) > OA3 (56) > Omo-SNR (53) > Eda (45) > Idanre Hills (43). Shannon-Wiener diversity index was high in all sites, with OA3 forest having the highest value (3.68) and Idanre Hills SG having the lowest value (3.14). Species distributions among the sites were even (range: 0.83–0.93). Degraded forests had low mean dbh compared with primary forests and SGs. Degradation had a significant negative effect on forest productivity. This was evident from the lower basal area and volume production in degraded forests (7.09–15.40 m^{2}ha^{-1}; 58.00–138.53 m^{3}ha^{-1}) compared to primary forests (32.47–72.39 m^{2}ha^{-1}; 366.71–929.05 m^{3}ha^{-1}) and SGs (32.99–42.59 m^{2}ha^{-1}; 273.21–398.46 m^{2}ha^{-1}). The poor results from degraded forest could be attributed to degradation activities. These findings suggest that natural conservation measures can protect biodiversity in rainforest ecosystem. More efforts should be made to prevent further degradation and encroachment into primary forests and SGs.

Keywords: *Forest conservation, Flora diversity, Strict Nature Reserve, Sacred Grove, Degraded forest, Tropical rainforest*

Introduction

The threats posed by global climate change and biodiversity loss provide evidence that nature is under assault and in crisis. Scientists (e.g. Steffen et al. 2015) warn that the earth is approaching dangerous tipping points in our planetary system. What this means in practical terms is that many systemic changes may be difficult, costly, or impossible to reverse (Barber et al., 2020). The forest is top on the chart of ecosystems under severe threat. Over 40% of the world's land is now agricultural or urban land, with ecosystem processes deliberately redirected from natural to anthropogenic pathways (Barber et al., 2020). FAO (2015) opined that by 2010, about 37.7% and 31.6% of global forestland would have been converted to agricultural land and other land-use types, respectively while only 30.7% would be under forest cover.

For years, remorseless destruction of forests has been going on. Of all the factors associated with forest loss, deforestation, forest degradation and fragmentation are most notable (Onyekwelu, 2017). With a reported decrease in global forest area of 1.8 billion hectare within the past 5,000 years, FAO (2016) indicated that the current global forest area is only about 50% of what it was some 5,000 years ago. There are evidences that deforestation is not abating, forest decline will continue, though the rate of decline is decreasing, especially in developed countries. The 2015 global forest resources assessment indicated that global forest area declined by about 129 million ha (3.1%) between 1990 and 2015 (FAO, 2015). Forest fragmentation is reaching critical thresholds, with 70% of forests now less than 1 km from a forest edge (Haddad et al. 2015) and natural ecosystems fragmented into some 600,000 pieces (Ibisch et al. 2017). Currently, forest loss is most prevalent in the tropical regions of the world. Despite increased awareness of the key roles tropical forests play in solving the most urgent global environment and development challenges, the rate of tropical deforestation remains alarmingly high. Much of the forest loss is associated with population growth and demand of forestland for farming, grazing and other land-use forms, unsustainable levels of exploitation of forest resources, etc (Onyekwelu, 2017).

The need for action against the growing threat to forests is urgent. More than ever, there is need for nature to address the intertwined challenges of ecosystem destruction and biodiversity loss. For example, Onyekwelu (2017) postulated that if the estimated annual deforestation rate of 350,000– 400,000 ha in Nigeria is sustained, the country may become completely forestless within the next three decades. Nature-based solutions (NbS) is among the various approaches developed to address the menace of ecosystem destruction. IUCN defined nature-based solutions as "actions to protect, sustainably manage, and restore natural or modified ecosystems,that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". Thus, nature-based measures encompass a broad range of actions that protect, restore, or sustainably manage ecosystems (including natural, semi-natural, or created) to provide benefits (Cohen-Shacham et al., 2016). There are many many variants of NbS (e.g. ecosystem-based adaptation, natural infrastructure, forest and landscape restoration, natural climate solutions, etc (Cohen-Shacham et al., 2016). However, no matter the variant, the protection and strengthening of the ecological integrity of natural ecosystems must lie at the core of each. Barber et al. (2020) opined that although nature-based measures need to be applied across a diversity of ecosystems, the single most important intervention to deliver synergistic climate and biodiversity outcomes on land is the protection of primary forests. The closer ecosystems are kept to natural patterns of biodiversity distribution and abundance, the higher the stability and quality of the ecosystem services they provide (Barber et al., 2020). In this study, we examined the impact of nature-based conservation measures on flora diversity and productivity in tropical rainforest ecosystem of south-western Nigeria.

Methodology

This study was carried out in sacred groves, primary forests and degraded forests from the rainforest ecosystem within the south-western region of Nigeria (Figure 1). The ecological zones within the south-western region of Nigeria include: mangrove, tropical rainforest and derived savanna. Annual rainfall in this region could range from between 1400 mm to over 3000 mm while mean temperature varies between 21ºC and 34ºC. Rainy season occurs between the months of April and November while dry season lasts from December to March. Soils are predominantly ferruginous tropical, typical of the variety found in intensively weathered areas of basement complex formations in the rainforest ecosystem of south-western Nigeria (Onyekwelu *et al.* 2008).

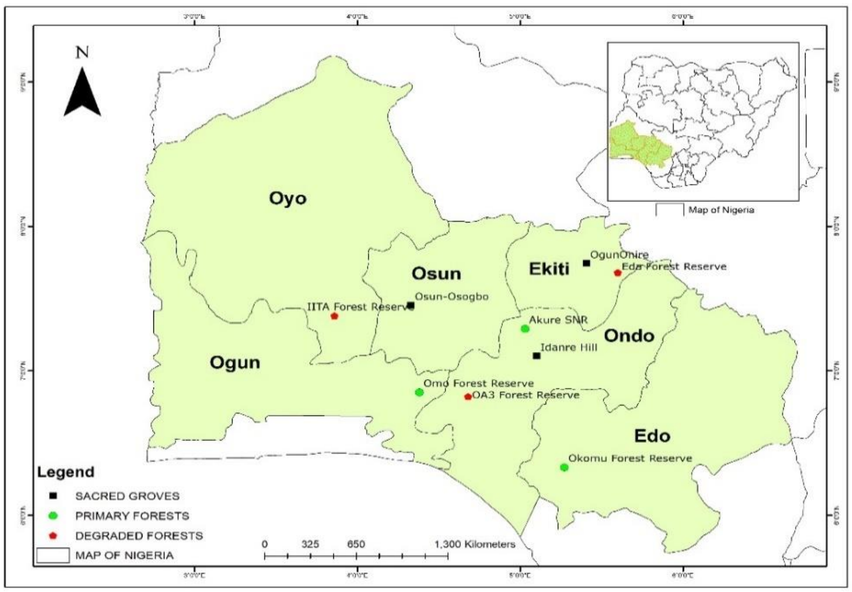

Figure 1: Map of south-western region of Nigeria showing the locations of the study sites

The three forest types involved in this study, which are under different management systems, are sacred groves (Idanre Hills and Ogun-Onire) primary forests (Akure and Omo Strict Nature Reserves (SNR)) and degraded forests (OA3 and Eda forest reserves). Akure-SNR is located in Akure forest reserve between latitude 7°16′ and 7°18′N and longitude 5°9′ and 5°11′E. It covers a land area of 69.93 km^2 and has been under strict conservation since 1936. Omo-SNR, located within Omo forest reserve, lies between latitude 6º 35' to 7º 05'N and longitude 4º 19' to 4º 40'E. It has been under strict conservation since 1949, it has a core and buffer zones of 460 and 14,200 ha, respectively (Onyekwelu *et al*. 2008). Idanre Hills sacred grove, located in Idanre, Ondo State Nigeria, has awesome natural landscapes and high plains with spectacular valleys interspersed with inselbergs of about 3,000 ft above sea level. It covers an area of 48 ha. Ogun-Onire sacred grove is located in Ire-Ekiti, in Ekiti State, Nigeria. It covers an area of 10 ha. Both sacred groves are protected using laws, taboos and strict religious restrictions. Eda forest reserve is located in Ekiti state, which lies on latitude 7º 23' and 7º 46' N and longitude 4º 45' to 5º 47' E. It occupies an area of about 200 km^2 on an elevation of 526 m above sea level. The OA3 forest is found within Oluwa forest reserve in Odigbo local government area of Ondo state. It lies within longitude 6° 55'N to 7°20'N and latitude 4°32'E to 3°45'E and covers a total area of 678.06 km^2.

Method of Data Collection

In this study, two primary forests (Omo-SNR and Akure-SNR), two sacred groves (Idanre Hill and Ogun-Onire) and two degraded forests (Eda and OA3 forest reserves) in tropical rainforest ecosystem of Nigeria were purposefully selected based on prominence/significance, accessibility and permission to conduct inventory. Two line transects of 1000 m each in length, separated by a distance of at least 1000 m were laid approximately at the middle of each site. Temporary sample plots of 40 m × 20 m were laid on alternate sides along each transect at every 250 m interval, giving a total of 4 plots per transect, 8 per site and 48 for this study. Within each sample plot, all trees with Dbh ≥ 10cm were identified and their diameter at breast height, diameters at the base, middle, top as well as total heights were measured. The scientific names of all trees and their authorities were confirmed using Trees of Nigeria (Keay, 1989).

Data computation and analyses

Basal Area Estimation

The basal area of all trees in each sample plot was calculated using equation 1:

$$BA = \frac{\pi D^2}{4} \text{...}(\text{eqn } 1)$$

Where BA = Basal Area (m^2), D = Diameter at Breast Height (cm) and π = Pie (3.142).

The total basal area for each sample plots was obtained as the sum of the basal areas of all trees in the plot. Basal area per hectare was obtained by first computing the mean plot basal area and then multiplying the mean plot basal area by 12.5 (i.e. number of 40 m x 20 m plots in an hectare)

Volume Estimation

Volume of individual trees was estimated using Newton's tree volume equation (eqn 2):

$$V = \pi h \frac{Db^2 + (Dm^2) + Dt^2}{24} \text{ .... (eqn 2)}$$

Where V is tree volume (m^3), Db, Dm and Dt are diameters (m) at the base, middle and top of each tree, and *h* is total tree height (m).

The total volume for each sample plots was obtained by summing the volumes of all trees in the plot. Volume per hectare was obtained by first computing the mean plot total volume and secondly by multiplying the mean plot total volume by 12.5, being the number of 40 m x 20 m plots in one hectare.

The following biodiversity indices were computed:

(i) Species diversity index was calculated using the Shannon-Wiener diversity index (eqn. 3):

$$H' = -\sum_{i=1}^{S} p_i \ln(p_i) \text{ .... (eqn. 3)}$$

Where: H' = Shannon-Wiener diversity index; P_i = proportion of S made up of the i^{th} species, ln = natural logarithm

(ii) Species evenness in each site was determined using Shannon's equitability (E_H)(eqn. 4):

$$E_H = \frac{H'}{H_{Max}} = \frac{\sum_{i=1}^{S} P_i \ln(P_i)}{\ln(S)} \text{ .... (eqn. 4)}$$

(iii) Margalef's index was calculated using the equation 5:

$$D = \frac{S-1}{\ln N} \text{ .... (eqn. 5)}$$

Where: S = number of species; N = number of individuals

(iv) Simpson's index

$$D = 1 - \sum \left(\frac{n_i}{N} \right)^2 \text{...}(6)$$

Where: n_i = number of individual of species I; N = total number of all tree species in the entire community

Results

The basal area production of the ten most dominant tree species in each of the study sites are presented in Table 1. With respect to basal area, no single tree species was found to be dominant across all the sites (Table 1). The most sites-wide basal area dominant tree species are: *Celtis zenkerii* (four sites); *Alstonia boonei, Cola gigantea, Sterculia rhinopetala* and *Cordia milenii* (three sites). Basal area production varied from site to site and from species to species within the same site. In Akure-SNR, *Entandrophragma cylindricum* had the highest basal area production (5.69 m^2) while *Cola gigantea* recorded the highest basal area production (4.41 m^2) in Omo-SNR. The tree species with the high basal area production in Ogun-Onire grove are *Celtis zenkerii* (5.46 m^2) and *Pterigota macrocarpa* (2.93 m^2). In Idanre Hill sacred groves, *Ceiba pentandra* (5.99 m^2) and *Alstonia boonei* (4.00m^2) had high basal area production. Basal area production of tree species in the degraded forests was relatively small compared to the values obtained for tree species in the primary forests and sacred groves. For example, *Celtis zenkerii* had the highest basal area production of 0.69 m^2 in OA3 forest, which is much lower than the 5.46 m^2 basal area production of the same species in Ogun-Onire grove (Table 1). *Spondias mombin* had basal area of 0.41 m^2 in Eda forest reserve.

Table 1: Basal Area (m^2) production of the ten most dominant tree species in the study sites

		Primary Forests		Sacred Groves		Degraded Forests	
S/N	Tree Species	Akure-SNR	Omo-SNR	Ogun-Onire	Idanre Hills	OA3 Forest	Eda Forest
1	*Ceiba pentandra*	-	-	-	5.99	-	-
2	*Entandrophragma cylindricum*	5.69	-	-	-	-	-
3	*Terminalia superba*	5.53	4.13	-	-	-	-
4	*Celtis zenkerii*	2.17	-	5.46		0.69	0.25
5	*Brachystegia nigerica*	4.97	-	-	-	-	0.20
6	*Triplochiton schleroxylon*	4.68		0.95	-	-	-
7	*Cola gigantean*	-	4.41	2.56	3.09	-	-
8	*Alstonia boonei*	-	0.63	-	4.00	0.36	-
9	*Entandrophragma angolense*	3.54	-	-	-	-	-
10	*Pterigota macrocarpa*	-	-	2.93	-	-	-
11	*Chrysophylum purpuchrum*	2.70	-	-	-	-	-
12	*Sterculia rhinopetala*	2.23	2.51	-	-	-	0.20
13	*Cassia siemen*	-	-	-	2.50	-	-
14	*Antiaris africana*	-	-	-	2.40	-	-
15	*Morus mesozygia*	-	-	2.23	-	-	-
16	*Mansonia altisima*	2.11	-	-	-	0.18	-
17	*Celtis mildbreadii*	2.05	1.47		-	-	-
18	*Blighia sapida*	-		1.88	-	-	-
19	*Baphia nitida*	-	1.29		-	-	-
20	*Anopysis kleniana*	-	-	1.14	-	-	-
21	*Trilepson madagascariensis*	-	-	1.18	-	-	0.33
22	*Ficus sycomorus*	-	-	1.18	-	-	-
23	*Funtumia elastica*	-	-	-	1.11	0.23	-
24	*Ricinodendrum heudelotii*	-	1.08	-	-	-	-
25	*Cordia plathutysa*	-	0.99	-	-	-	-
26	*Ficus mucuso*	-	-	-	0.90	-	-
27	*Cordia milenii*	-	-	0.89	-	0.22	0.16
28	*Milicia excels*	-	-	-	0.87	-	-
29	*Monodora myristica*	-	-	-	0.63	-	-
30	*Berlinia grandifolia*	-	-	-	0.61	-	-
31	*Pycnanthus angolensis*	-	0.59	-	-	-	-
32	*Microdesmis puberula*	-	0.47	-	-	-	-
33	*Spondias mombin*	-	-	-	-		0.41
34	*Draceana maginata*	-	-	-	-	0.35	
35	*Magariteria discoidea*	-	-	-	-	-	0.32
36	*Trichilia welwitschii*	-	-	-	-	-	0.28
37	*Macaranga barterii*	-	-	-	-	0.19	
38	*Cola acuminata*	-	-	-	-	-	0.18
39	*Entandrophragma utili*	-	-	-	-	-	0.17
40	*Trichilia monadelpha*	-	-	-	-	0.16	-

The volume production of the ten most dominant tree species in the study sites are presented in Table 2. With respect to volume production, *Entandrophragma cylindricum* had the highest volume production of 101.42 m^3 production in In Akure-SNR (range:

19.74 - 101.42 m^3) while *Terminalia superba* recorded the highest volume production of 53.31 m^3 in Omo-SNR (range: 8.47 - 53.31 m^3). *Ceiba pentandra* and *Celtis zenkerii* had the highest volume production of 62.99 m^3 and 47.33 m^3 at Idanre Hill (range: 4.36 - 62.99 m^3) and Ogun-Onire (range: 5.37 - 47.33 m^3) sacred groves, respectively, which were lower than those of the high volume producing tree species in primary forests (Table 2). Volume production of tree species in the three forest types followed similar trend with basal area production. Trees in the degraded forests exhibited lower volume production compared to those of trees in the primary forests and sacred groves. For example, while the highest tree volume production in primary forest and sacred grove were 101.42 m^3 and 62.99 m^3, respectively, the highest volume production of trees in the degraded forest was only 5.92 m^3 (Table 2). *Ricinodendrum heudelotii* had the highest volume production of 5.92m^2 in OA3 forest while *Magariteria discoidea* produced the highest volme of 0.27m^3 in Eda forest reserve.

Table 2: Volume (m^3) production of the ten most dominant tree species in the study sites

		Primary forests		Sacred groves		Degraded forests	
S/N	Tree Species	Akure-SNR	Omo-SNR	Ogun-Onire	Idanre Hills	OA3 Forest	Eda Forest
1	*Entandrophragma cylindricum*	101.42	-	-	-	-	-
2	*Triplochiton schleroxylon*	79.57	-	7.47	-	-	-
3	*Brachystegia nigerica*	74.17	-	-	-	-	1.56
4	*Terminalia superba*	72.37	53.31	-	-	-	-
5	*Ceiba pentandra*	-	-	-	62.99	-	-
6	*Cola gigantean*	-	52.89	22.97	24.36	-	-
7	*Celtis zenkerii*	25.69	-	47.33	-	5.26	1.63
8	*Alstonia boonei*	-	8.47	-	38.96	2.52	1.37
9	*Sterculia rhinopetala*	23.37	31.63	-	-	-	1.98
10	*Cassia siemen*	-	-	-	30.57	-	-
11	*Entandrophragma angolensis*	30.32	-	-	-	-	-
12	*Morus mesozygia*	-	-	27.65	-	-	-
13	*Pterigota macrocarpa*	-	-	27.47	-	-	-
14	*Mansonia altisima*	25.60	-	-	-	1.23	
15	*Chrysophylum purpuchrum*	23.93	-	-	-	-	-
16	*Cordia plathutysa*	-	23.11	-	-	-	-
17	*Antiaris africana*	-	-	-	21.52	-	-
18	*Celtis mildbreadii*	19.74	15.05	-	-	1.07	-
19	*Milicia excelsa*	-	-	-	13.05	-	-
20	*Blighia sapida*	-	-	11.47	-	-	-
21	*Ricinodendrum heudelotii*	-	11.15		-	5.92	-
22	*Cordia milenii*	-	10.39	5.37	-	2.98	-
23	*Ficus sycomorus*	-	-	9.73	-	-	-
24	*Funtumia elastica*	-	-	-	9.47	1.40	-
25	*Pycnanthus angolensis*	-	9.25	-	-	-	-
26	*Baphia nitida*	-	8.64	-	-	-	-
27	*Ficus mucuso*	-	-	-	7.77	-	-
28	*Trilepson madagascariensis*	-	-	7.46	-	-	2.71
29	*Anopysis kleniana*	-	-	7.28	-	-	-
30	*Magariteria discoidea*	-	-	-	-	-	5.65
31	*Albizia zygia*	-	-	-	4.46	-	-
32	*Berlinia grandifolia*	-	-	-	4.36	-	-
33	*Monodora myristica*	-	-	-	-	-	-
34	*Spondias mombin*	-	-	-	-	-	2.83
35	*Musanga cecropioides*	-	-	-	-	2.59	-
36	*Draceana maginata*	-	-	-	-	2.13	-
37	*Trichilia welwitschii*	-	-	-	-	-	1.86
38	*Cola acuminate*	-	-	-	-	-	1.36
39	*Entandrophragma utili*	-	-	-	-	-	1.30
40	*Sterculia tricagantha*	-	-	-	-	1.27	-

Tree dbh distribution in the primary forests, degraded forests and sacred groves followed the inverse-J pattern typical of natural tropical rainforest ecosystem (Figure 2a-c). Majority of the trees in the six sites fell within 10–20 cm dbh class, followed by 20–30 cm class. Only few trees in the primary forest and sacred grove sites had dbh above 100 cm (Figure 2a & b), which is contrary to the degraded forest sites where the largest trees fell within the dbh class of 40–50 cm (Figure 2c). The highest stand density across the six sites was recorded in the lowest dbh class of 10–20 cm, making this class the highest contributor of stand density to total density for each site. Stand density consistently decreased with increase in dbh (Figure 2a-c).

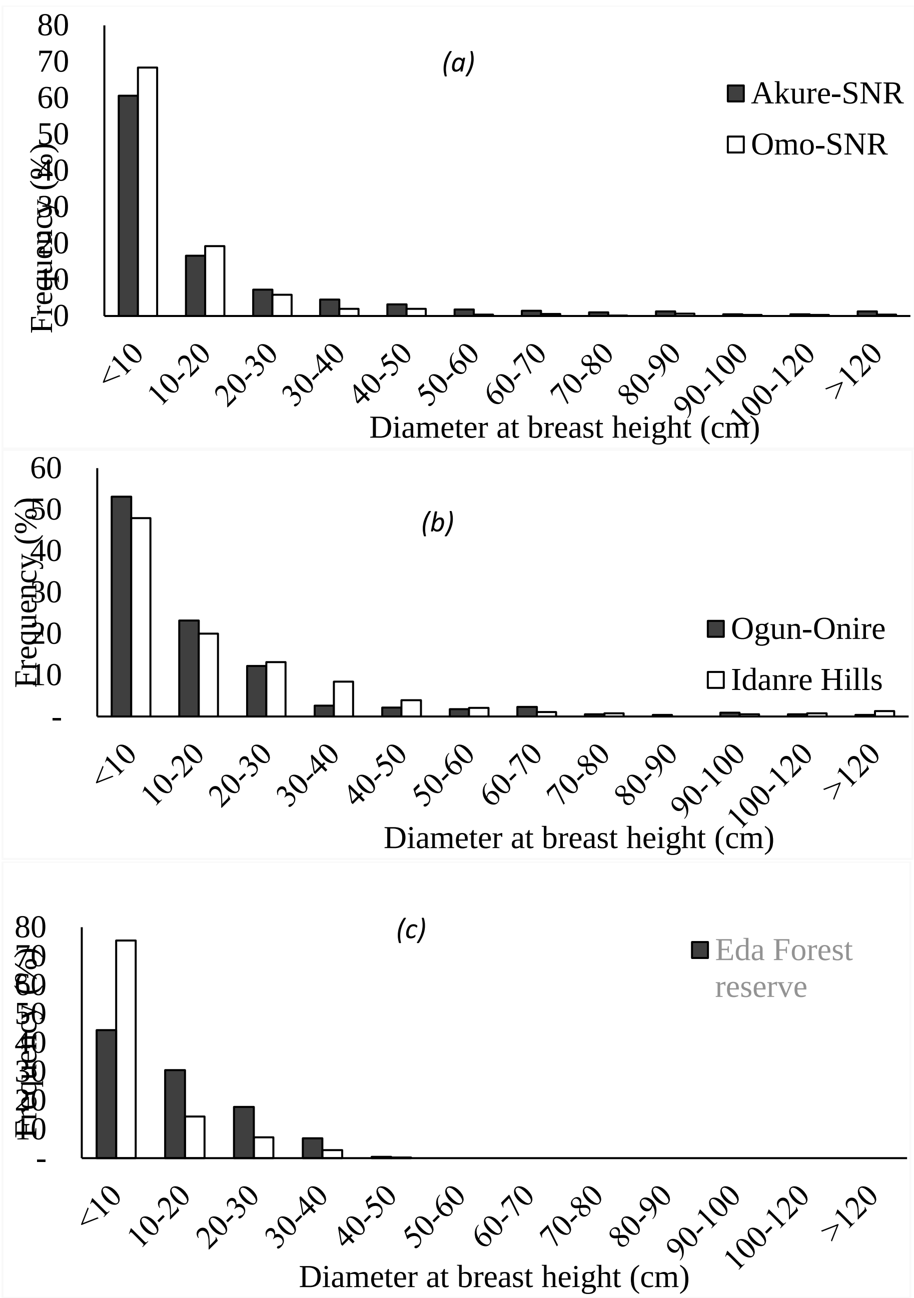

Figure 2: Tree diameter distribution in (a) primary forest, (b) sacred grove and (c) degraded forest sites in south-western Nigeria

The summaries of biodiversity indices and tree growth variables in the study sites are presented on Table 3. Family richness varied from 15 to 25 with Omo SNR having the highest and Eda forest reserve having the lowest. Tree species richness followed the order:

Akure-SNR (63) > Ogun-Onire sacred grove (62) > OA3 forest reserve (56) > Omo-SNR (53) > Eda forest reserve (45) > Idanre Hill sacred grove (43). There were significant differences in species diversity index, with OA3 forest reserve having the highest Shannon-Wiener diversity index (3.68) and Idanre Hills sacred grove having the lowest value (3.25). Species distributions among the sites were even (range: 0.85 to 0.93). Degraded forests had lower mean dbh (20.7cm to 23.9cm) compared with primary forests (26.1cm to 35.6cm) and sacred groves (24.4cm to 31.9cm). Trees in degraded forests (range: 10.22 m - 10.36 m) were generally shorter than those in primary forests (range: 14.15 m - 17.41 m) and sacred groves (range: 13.50 m - 13.73 m) as revealed by their mean heights. Also, basal area and volume per hectare were much higher in the primary forests and sacred groves compared to degraded forests (Table 3). There were more individual trees per hectare in primary forest sites (range: 372 - 381) and sacred grove sites (309 - 413) than in the degraded forest sites (177 - 234).

Table 3: Summary of biodiversity indices and tree growth variables in the study sites

Biodiversity indices	Primary Forest		Sacred groves		Degraded Forest	
	Akure SNR	Omo SNR	Idanre Hills	Ogun-Onire	Eda forest	OA3 forest
Number of Families	24	25	19	24	15	24
Number of Species	63	53	43	62	45	56
Number of Trees Ha^{-1}	381	372	309	413	177	234
Shannon-Wiener Diversity Index	3.57	3.43	3.25	3.50	3.53	3.68
Species Evenness	0.86	0.86	0.86	0.85	0.93	0.91
Simpson Concentration (λ)	0.95	0.95	0.94	0.95	0.96	0.97
Species Richness (Margalef Index)	11.28	9.50	7.94	10.13	9.31	10.98
Mean Dbh (cm)	35.61	26.10	31.92	28.04	21.09	20.69
Dominant Dbh (cm)	251.5	168.5	185.00	131.50	42.30	57.50
Mean height (m)	17.41	14.15	13.50	13.73	10.68	10.22
Dominant height (m)	54.60	28.80	24.80	23.2	11.20	15.5
Basal Area (m^2ha^{-1})	72.39	36.63	42.59	41.11	7.09	9.38
Volume (m^3ha^{-1})	929.05	427.08	398.46	337.39	58.00	64.78

Discussion

Globally, tropical forests directly affect the livelihoods of over 1.35 billion people (FAO, 2014), store about 247 Gigatons of carbon (Saatchi *et al.,* 2011) and harbor over half of the world's terrestrial biodiversity (Onyekwelu *et al*., 2018; Gibson *et al*., 2011). In many countries, intact tropical forests have disappeared completely (Potapov *et al.*, 2017) while many are under different stages of degradation. In Nigeria, tropical rainforest is fast disappearing as a result of steady increase in anthropogenic activities that degrade the forest, coupled with the increase in the demand for forest lands and products. To guarantee a stable environment and ensure sustainable ecosystem services provision from Nigerian tropical rainforest to the people, conservation of the ecosystem is necessary.

Biodiversity indices are usually generated to bring the floristic diversity and abundance in different habitats to similar scale for comparison, which is important in studying the effectiveness of conservation measures (Onyekwelu, 2021). Species diversity and richness are among the important indices used to characterize biodiversity conservation status of forest ecosystems. Shannon-Wiener diversity index (H') is widely used to investigate community diversity indices because it takes both richness and evenness into account and because species abundances are standardised to proportions (Kent and Coker, 1992). Studies have shown that the number of tree species in tropical rainforests is far higher than in any other forest ecosystem, except in a situation where deforestation and forest encroachment have eaten deep into tropical forests. For example, between 100 and 300 tree species per hectare are found in rainforests (especially in south America and southeast Asia (Richards, 1996)), a value that is much higher than that the number of species found in temperate forests (Onyekwelu *et al*., 2008). Nwoboshi (1982) opined that the number of trees per hectare could be as high as 400 in very rich rainforests. The low number of tree species (i.e. 43 - 63) reported for the three forest types in this study compared to the general range for tropical rainforests (100 - 400), may be an indication that Nigerian tropical rainforest ecosystems are species-poor, which is collaborated by past studies that which reported a range of 32 to 79 species (Lowe, 1997; Adekunle, 2006; Adekunle and Olagoke, 2008; Onyekwelu *el al.,* 2008; Onyekwelu and Olusola, 2014; Onyekwelu *et al*. (2021). The high Shannon-Wiener diversity index for the primary forests and sacred groves in this study (3.25 - 3.57), which is consistent with reports for similar sites in Nigeria (Adekunle and Olagoke, 2008; Onyekwelu *et al*., 2008; Onyekwelu and Olusola, 2014), is attributed to their mature and fairly undisturbed forest canopy, which supports rich and diverse plant and animal species. The diversity index for the sacred groves (3.25 - 3.63) is similar to the values (2.86–3.96) reported for sacred groves in India and Nigeria (Rao *et al*., 2011; Onyekwelu and Olusola, 2014) but higher than the range of 1.2 – 1.4 reported by Mgumia and Oba (2003) for sacred groves in Tanzania.

The primary forests in this study (Akure-SNR and Omo-SNR) have been under strict conservation since 1936 and 1949 (Isichei, 1995; Onyekwelu *et al*., 2008). There is no recorded evidence of timber exploitation in both forests within living memory. Similarly, the two sacred groves in this study have been under strict conservation since they were constituted. Tree felling, farming and other forest degradation activities are forbidden in the sacred groves. The primary forests and sacred groves are not under any form of conventional management method, they are managed by nature. The degraded forests in this study (OA3 and Eda forest reserves) have experienced repeated exploitation and degradation activities in recent times to the extent that they have been classified as highly degraded forests.

The primary forests and sacred groves in this study are considered nature-based conservation measures because of their protection and ecological integrity and because they are kept closer to natural patterns of biodiversity distribution and abundance (Barber *et al*., 2020). The better growth parameters of the primary forests in this study compared to the degraded forests, coupled with their good biodiversity indices, could be attributed to the effectiveness of nature-based conservation strategy. The concept of sacred grove is also an effective nature-based conservation strategy due to their comparably higher tree growth parameters and slightly better biodiversity indices than the degraded forests. The poor growth parameters of the degraded forests is expected, given their long history of degradation and almost uncontrolled nature of logging as well as high volume of timber removed from them. Degradation had negative effect on productivity in the degraded forests as evidenced by the much lower basal area and volume production in degraded forests (7.09–9.38 m^2ha^{-1}; 58.00–64.78 m^3ha^{-1}) compared to primary forests (36.63–72.39 m^2ha^{-1}; 427.08–929.05 m^3ha^{-1}) and sacred groves (41.11–42.59 m^2ha^{-1}; 337.39–398.46 m^3ha^{-1}). Another evidence of the effect of degradation is the absence of large trees in the degraded forests as revealed by results on Table 3 and Figure 2).

Conclusion

This study reveals the positive impact of nature-based conservation strategies on flora diversity and productivity. We discovered that the growth parameters and tree species diversity indices were higher in the primary forests and sacred groves than in the degraded forests. These findings suggest that nature-based conservation measures can protect flora diversity in the rainforest ecosystem. Therefore, more effort towards preventing further forest degradation and encroachment into primary forests and sacred groves is recommended.

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NEED FOR SUSTAINABLE LANDSCAPE OF PORT HARCOURT METROPOLIS

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Abstract
Over the years it has been proven that a good and proper landscaping will assist in creating a comfortable and conducive environment for housing development. Important information to decision makers regarding sustainable land management, space and time of climate variables, land surface pollution and land use changes for Port Harcourt metropolis are limited. This work highlighted the importance of landscaping as a vital key to urban development and how it can improve the outlook of Port Harcourt metropolis and meeting the desires of those living and intending to move to into the state. Landscape practices and business engagement have great potentials to uplift a city's status to either that of developed, under-developed or developing. Among the accruing benefits, are the value added to style of living, improved health status by way of alleviation of stress and development of a buoyant economy through financial in flow from provision of job opportunities and payment to garden owners for relaxation services rendered. This paper reviewed and made case for house owners and property developers to consider landscaping as an integral part of their buildings and elucidated the importance of landscaping in relation to environmental remediation.

Keywords: landscape, value-added, land use, house

Introduction

The standard of the urban area and the quality of life in Port Harcourt metropolis sometimes does not grow with the ever growing process of the economic development of the city while some cities grow base on increase in population as a result of more people leaving the rural area to the urban city for greener pastures. For us to have a sustainable and living environment we must focus on providing a good and quality housing. Densely populated areas are changing, and more complicated landscapes in which green or open spaces are considered to be of incalculable value for the well-being of people and wildlife are being developed (Pickett *et al.,* 2011) . Throughout history, societies have struggled with environmental constraints. The sharp increase in human population triggered by the industrial revolution also increased the scale of human impact on Earth and created a negative by-product: large-scale landscape degradation, caused by an economy that does not properly restock its key assets: the ecosystem functions it depends upon (Barmelgy, 2013). The need for landscaping of Port Harcourt metropolis cannot be overemphasized as an appealing landscape contributes to people's health (Abraham *et al.,* 2010). Studies have proved that the environment surrounding a person is of great importance to his or her stress level and health (Millennium Ecosystem Assessment,2005).Various human activities produce pressures that alter the environment, leading to negative impacts on the human health and the environmental eco-system (Barmelgy, 2013). Studies confirmed that inhabitants could benefit from nature, greening and landscape through direct contact with such an environment. Barmelgy, (2013) observed that greenery has the potential of inducing an active living and increasing public health. This finding is in line with Roger Ulrich's Psycho-Evolutionary Theory and Stephen and Rachel Kaplan's Attention Restoration Theory who argued that contact with nature aids recovery from all forms of stress, not just attention fatigue. Characteristics of the environment provide an early-warning signal for safety and survival that triggers positive emotional reactions. Key elements are a level ground surface, considerable spatial openness, the presence of a pattern or structure, curving sightlines and the presence of water (Health Council of The Netherlands, 2004). The Kaplan's consider natural settings which are aesthetically pleasing and are restorative environments which hold one's attention effortlessly (Health Council of The Netherlands, 2004). As noted by Barmelgy, (2013) landscape can be seen as the mitigation process in which health and well-being can be achieved through the sustainability process. Landscaping with ornamental trees with attractive geometric forms provides emotional soothing and healing to man is categorized in secondary consumptive value of the forests.

Among many factors, landscaping; an aspect of city development and environmental beautification has gradually gained acceptance and transformed into a culture, although through uncoordinated awareness efforts which with the immense contribution is gradually influencing the national economy at an increasing steady rate. It is not uncommon to see structures either private or public, of different magnitudes developing not without the inclusion of aesthetic plants for purposes of beautification and value addition to such properties. Cities are dynamic organisms. There is not a single 'historic' city in the world that has retained its 'original' character: the concept is a moving target, destined to change with society itself. To preserve the urban historic landscape, strategic and dynamic alliances need to be built between various actors in the urban scene, foremost between public authorities that manage the city, developers, and entrepreneurs that operate in the city (UNESCO, 2013).

Landscapes and features are important because they contribute significantly to our well-being and quality of life. They provide the broader context within which we live our lives. Living within aesthetically pleasing and culturally meaningful landscapes enhances our sense of wellbeing. Visiting largely undeveloped landscapes enables people to re-connect with nature, to refresh their minds and bodies and to gain a greater appreciation of natural heritage. Accessible natural landscapes within close proximity of urban areas, plays an important role in increasing the quality of life within those cities. Iconic features if present, also contribute to the visual identities of the cities and settled areas (Millennium Ecosystem Assessment. 2005).

One of the prevailing environmental pollution in the city of Port Harcourt is the high presence of Black Carbon particles commonly known as "soot". Residents of the city started experiencing particle (soot) pollution since the last quarter of 2016 (Yakubu, 2018; Chris, 2018). The state recorded a high reading of 270 micrograms per cubic meter for air pollution in the city from a 2016 sampling. According to the U.S. Environmental Protection Agency's (EPA) Air Quality Index (AQI), a reading of 0 - 50 is good, readings between 200 - 300 which Port Harcourt falls under is considered unhealthy for everyone and E.P.A advises residents of such areas to avoid heavy and prolonged exertion, and move activities indoors, (US EPA, 2014) for a 15-month period ending in June (2018). Air quality was in the unhealthy range on 240 days, with 85 days ranking very unhealthy, and 13 days as hazardous. (Cunningham, 2018). The City has also experienced increased rate of flooding, which is partly as a result of improper drainage system, ineffective town planning and landscaping and a weak waste management system. Governmental policies advocating the planting one tree per person has aided as catalyst in the observed transformations. Soot (particulates) are not only detrimental to humans in Port Harcourt and its environs but alters the photoperiods of trees and other woody species and interferes with natural biogeochemical cycles which results in early or late fruiting season of tree-fruit-bearers. Soot pollution in Port Harcourt interferes and disrupts photosynthesis and respirations of the leaves and vegetation

Important ornamental plant production and commercial centres are located in the cosmopolitan city of Lagos in South West Nigeria, alongside other cities in the humid rain forest which include Calabar in South-East and Port-Harcourt in South-South, while other centres characterized by the drier savannah vegetation include Abuja Federal Capital Territory (FCT) and Jos Plateau both located in the Middle Belt zone (Olubode *et al.,* 2015). The cultural diversity and creativity are considered as key assets for human, social and economic development accompanied by the integration of environmental, social and cultural concerns which are woven into the planning, design and implementation of urban development contributing to very positive and encouraging results (UNESCO, 2013).

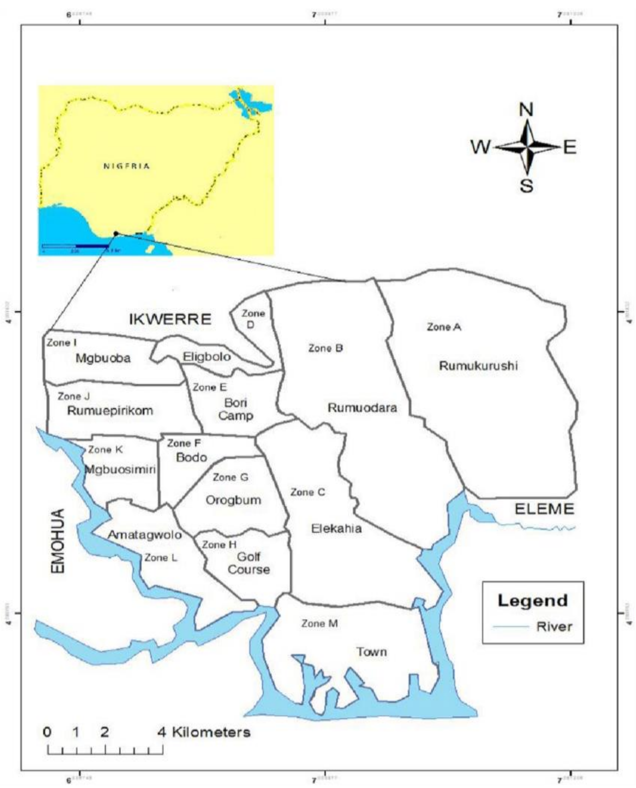

Figure 1: Port Harcourt Metropolis Map
Source: Ministry of Environment, Rivers State (2022)

Description of Port Harcourt

Port Harcourt is the capital and largest city in Rivers State, Nigeria. It is the fifth most populous city in Nigeria after Lagos, Kano, Ibadan and Kaduna. It lies along the Bonny River and is located in the Niger Delta. As of 2016, the Port Harcourt urban area has an estimated population of 1,865,000 inhabitants, up from 1,382,592 as of 2006. (Arizona *et al.*, 2011; Demographia, 2016). The population of the metropolitan area of Port Harcourt is almost twice its urban area population estimate of 3,171,076 (United Nations, 2021). In 1950, the population of Port Harcourt was 59,752. Port Harcourt has grown by 150,844 since 2015, which represents a 4.99% annual change.

Landscaping otherwise described as landscape planning has been described as a process concerned with activities geared towards the articulation of existing open spaces for the purpose of enhancing the quality of the environment (Essaghah, 1997). This includes the process of rehabilitation of open spaces as well as the coordination of the existing relationship between them. This is usually carried out in the cities with the main aim of protecting property values to revive civic pride, promote circulation and increase environmental wellbeing, in some cases to create leisure areas.

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Plates 1 and 2: Use of Hard and Soft scape in construction of a walkway.
Source: Field Work, 2022

Elements of Landscape Design

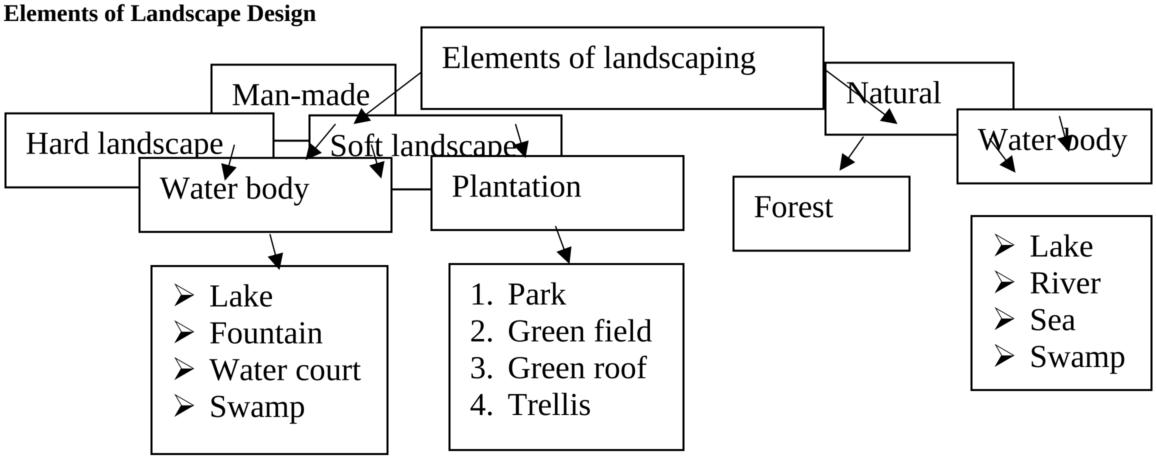

Figure 2: Landscape Design Elements
Source: Ale *et al.*, 2019

Reasons for Landscaping Adoption in Port Harcourt Metropolis

Landscaping is when trees and other plants are brought in to create an area of beauty, whether it's in a quiet neighborhood or a bustling city thus increasing the scenic value of trees and plants. Today, population estimate of 3,171,076 of Port Harcourt (United Nations, 2021) put ecological pressure on landscaped plants including trees as infrastructural development of the State Government and individuals which either alter the scenic architecture of Port Harcourt or remove avenue-planted-trees. In Port Harcourt one an find impressive landscaping projects in the form of rooftop gardens, urban pocket parks, and backyard oases. However, urban landscapes can significantly and positively impact the environment. Planting trees in cities helps reduce the levels of fossil fuels, distribute energy, and improve air and rain quality as well as surface temperature and also reduce the motility of polluted air particularly soot thereby converting soot into droplets through oxygenation. These benefits prove just how important it is to take the small step of developing urban landscapes to counteract the disastrous consequences of climate change on our planet. This simple step will promote a huge positive step for our planet's future.

Landscaping Preserves the Environment

Sprawling cities hurt the environment. We know the negative consequences of deforestation and shrinking green spaces. Landscaping provides an opportunity to preserve and protect the environment. Planting native flora, avoiding chemicals, and addressing environmental problems keep green spaces healthy and thriving. It also reduces chemical usage, Minimizes environmental impacts on land, water, habitat, and wildlife by reducing forest fires, soil erosion/runoff and pollution, Noise pollution is an often overlooked problem. Excessive or unwanted sound has negative physical and psychological effects. Noise can come from many sources, especially roads and highways. Trees can play an important role in deadening unwanted noise. Sound waves are absorbed by a tree's leaves, branches, and twigs. Studies suggest that belts of trees 100' wide and 45' long can cut highway noise to half (A Handbook of Landscape, 2013).

Landscaping Helps Manage Soil Pollution

Factory pollution is one of the most serious types of pollution. The areas around factories are poisoned by toxic waste, chemical spills, and emissions. Simply getting rid of all the factories isn't feasible at this point. Landscaping can help mitigate some of the issues when Plants purify the soil contaminated by factories. Certain plants like alfalfa and sunflower are so good at this; they are also called "super-plants." The official term however is "phytoremediation."

Landscaping Helps Clean the Air

Plants clean the air as well as the soil. Trees are especially effective at this purification. The world's forests absorb around one third of global emissions each year. Tree leaves (and the leaves of all plants) absorb pollutants like smoke, ozone, and nitrogen oxides, filtering them from the air. Some of these particulates are inhalable and can pass into the lungs and bloodstream, causing a variety of health problems. Port Harcourt metropolis can be purified through urban landscaping..

Particles of air pollutants are absorbed by leaf surfaces or they may be deposited on the leaves as they fall on the soil, they are absorbed. Mbah (2001) indicated that quantified pollution remediation by plants and showed that 85% of lead from vehicles can be removed by a shelter belt of trees. Landscaping plants mask fumes and disagreeable odour by replacing them with more pleasing scents or absorbing them. Air flow modification caused by these plants affects transport and diffusion of water pollutants and energy. Trees particularly and other plants through their growth processes act as a sink for atmospheric carbon dioxide, the predominant greenhouse gas. Mbah (2001), assert increased trees in the landscape will potentially slow the accumulation of atmospheric CO_2. In addition, the production of CO_2 by fossil powered generating plants will be reduced and energy conserved. Some plants such as *Eucalyptus saligna*, *Brunfelsia hopeana*, *Nerium oleander* etc. produce sweet scent capable of neutralizing the polluted air thereby making the air fresh for human consumption.

Landscaping Helps with Water Management

Water may be a sustainable resource, but it is not limitless. It needs to be managed carefully. Landscaping can help by prioritizing water drainage solutions; landscapers protect natural waterways, create rain gardens, and rejuvenate wetlands. Wetland-friendly landscaping is important because wetlands are endangered. These areas encourage biodiversity, purify storm water, and control floods. Humidity is a measure of the amount of water vapor in the air. As long as heat present, the heat energy will be absorbed by moisture and released to the air in exchange for the use of heat energy. Plants in general increase the humidity of the site. They can therefore increase the thermal comfort during hot, dry seasons, although the plants have to be watered regularly. The plants take water from the soil, and when this water evaporates from the leaves it increases the relative humidity while lowering the air temperature. Pools and ponds behave in a similar manner. Water evaporating from the surface increases relative humidity while reducing air temperature (Adedeji *et al.,* 2011).

Landscaping Creates a Cooling Effect

Cities can get very hot, creating what is known as "heat islands". This is when the temperature in the city is much warmer than in nearby rural areas. The presence of concrete, cars, and other human activities are responsible and to stay cool, people run their air conditioners more. Trees are nature's air conditioners. They reduce the temperature in a heat island. On a hot day, a backyard with trees will be 6-degrees cooler than a yard without trees. The surrounding temperature goes down, meaning that people will use their air conditioners less, significantly reducing emissions.

Plate Trees, shrubs planted to beautify and provide shade.
Source: Field work, 2022

Landscaping Stops Erosion

Erosion is a serious issue, it leads to increased pollution and sedimentation in rivers and streams. Waterways get clogged, which kills fish and other species. Erosion also destroys fertile land and leads to more flooding. Landscaping, especially grass and shrubs, hold the soil together with their roots. Trees and shrubs could serve as shield to cover the bare soil while holding the soil together and their roots serving as barriers against run-offs. The characteristic features of plants in land reclamation and erosion control is that their strong spreading roots help to hold the soil particles together (Adams, *et al.*, 2002). Most of the incidences of soil erosion in urban centres can be minimized if appropriate and well planned tree planting is combined with other developmental activities. Trees such as *Terminalia catappa* has strong spreading roots that can hold the soil together. Planting of drought resistant trees such as *Azadirachta indica* and *Acacia spp* in the Northern part of the country could be effectively used to checkmate the deleterious effects of wind storm common in Kano, Borno and Sokoto States. Adams *et al.*, (2002), found that the wind breaking effect of trees has caused the reduction of wind speed by as much as 30%-50%.Trees and shrubs should be systematically arranged in the direction of the prevailing wind in order to form strong obstruction and resistance against the speed of turbulent windstorm and consequently check its devastating effects.

Landscaping Plays a Big Role in Sustainability

Sustainability is so crucial that the United Nations has a blueprint of 17 Sustainable Development Goals. They address things like climate change and environmental degradation. Good landscapers prioritize the health of the environment. They are at the forefront of techniques and innovations dealing with energy efficiency, clean water, clean air, and more.

Landscaping Improves People's Mental and Physical Health

Studies consistently show that being in nature is good for a person's mental health. It can improve their memory, reduce stress, and boost feeling of happiness. Nature is so powerful that something as small as one tree or a single houseplant can improve mental health. Plants such as *Araucaria* spp, *Grevillea robusta* and *Agava sisalana* (A Handbook of Landscape, 2013) are very useful for this purpose. Having access to quality urban green spaces and spending time outside exercising, playing, socializing, enjoying nature, relaxing is healthy for the body and mind. Green spaces encourage and increase physical activity, leading to numerous health benefits relevant to cardiovascular disease, diabetes, hypercholesterolemia, osteoporosis, mood disorders, psychological issues and overall health. Researches have confirmed that urban landscapes enhance the health and quality of life of city dwellers. One of the first studies on plants and psychology confirmed that hospital patients recover more quickly when they have a view of nature. Some newer hospitals around the country are incorporating this into their design and landscaping, as are some Japanese hospitals with “ecology gardens”. Restorative gardens are used in many hospices for treating patients. A more recent study showed that office workers with a view of nature are more productive, report fewer illnesses, and have higher job satisfaction. Interior plants also can be beneficial to workers, increasing productivity and reducing stress. Studies in public housing neighborhoods show that having trees can lower levels of fear, reduce violent and aggressive behavior, and encourage better neighbor interactions. Weeding for one hour is equivalent to walking or cycling at a moderate pace, burning 300 calories. Pushing a mower for an hour is the same as playing tennis, burning 500 calories. One study specifically on women showed that those between the age of 50years and above who gardened at least once weekly had higher bone density than those who did common exercises such as aerobics, walking, or jogging. The Sloan Kettering Institute in New York found that if women spend time in a garden they recover more quickly from breast cancer.

Landscaping Adds Value to an Area

Landscaping is not only good for the environment and peoples’ mental health but adds value to an area. It is no secret that when someone intends selling their homes, their landscaping affects the asking price. Urban landscapes create dynamic and inviting public spaces that attract people and encourage them to engage in meaningful social interaction. Good landscaping also encourages surrounding houses and areas to step up their game. Plants provide a variety of aesthetic values and accentuate the architectural design of buildings. Avenue plants such as *Thuja plicata, Lagaestromia indica, Caryota mitis, Juniperus chinensis, Hura crepitans* on our roads and pedestrian walkways create a safer restful and scenic view and provide shade to the pedestrians and other road users. Trees in a single or double row have strong visual impact. This arrangement is suitable for the urban or built environment (Adams *et al.*, 2002; Orewere *et al.*, 2019). On Rivers State Universty Campus trees such *as Terminalia mantaly, Casuarina equisifolia, Polyathia longifera,* royal palm and others are planted along avenues, roads and pathways, though most of these trees are old, partly rotten and wolfed which requires replacing.

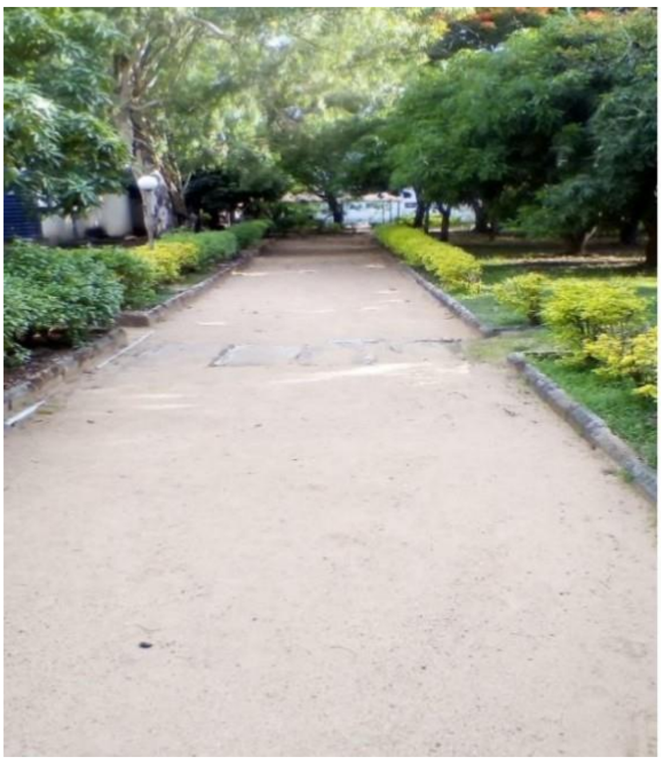

Plate Landscaping with different plant and tree species of Rivers State University, Port Harcourt, Rivers State
Source: Field work, 2022

Well-Maintained Landscaping Protects Homes and Buildings

The presence of plants (trees) is worthwhile, but there is a balance required. If left to her own devices, Mother Nature will take over. For homeowners, this can be a serious problem. The roots of trees and plants can damage the foundation of a house and get into the plumbing. Overgrowth from branches can also cause issues, though these are usually easier to spot quickly. For nature and humans to live in harmony, healthy maintenance is necessary.

Modification of Temperature

Landscape planting especially trees and shrubs modify solar radiation, for example through provision of shade. The amount of radiant energy absorbed, stored or radiated by buildings and concrete surfacing in the living environment is significantly reduced by shading. Evapotranspiration in planted landscapes helps reduce sensible heat which warms air and the result is reduced temperature. It is estimated that tree planting around houses reduces energy for cooling by 10 to 50% and in temperate climate where heating may be needed, it is reduced by 4 to 22% (NNA/ISSA, 1991; Mbah, 2001).

Improves Water Quality

Plants help anchor soil and reduce storm water runoff, saving the high costs of drainage ditches, storm sewers, and other "engineered solutions" to storm water management. A Street lined with 32' tall trees can reduce runoff by almost 327 gallons, allowing cities to install smaller and less expensive water management systems. Reducing runoff also decreases topsoil erosion and the amount of silt and other pollutants washed into streams, rivers and lakes (A Handbook of Landscape, 2013).

Fences/Boundary Demarcation

Plant species such as *Duranta rupens*, *Dodonea viscosa*, *Hibiscus spp*., *Thevetia peruviana*, *Rosa sinensi* are used in constructing fences in our surroundings. While popular woody species such as *Lonchocarpus cyanescens*, *P. santalinoides*, *Millefia thonningii*, *Jatropha* spp., *Dracaena mann Thevetia peruviana*, *Moringa oleifera*, *Calotropis procera*, serve for boundary demarcation in both urban and rural landscapes in Nigeria. They demarcate boundaries between church lands, school lands and farm lands (Omokhua *et al.*, 2002). While Trees species such as *Terminialia mantalis Caesalpinia pulcherrima, Tectona grandis, Terminalia catappa* are often used as windbreaks to shelter sensitive crops (A Handbook of Landscape, 2013). Fences around private buildings provide, restrict movement of domestic animals and eliminate trespasss. They are also used in primary, secondary and tertiary institutions in game courts.

Conclusion

This paper has stressed the need for landscaping of Port Harcourt with trees and woody species due to its benefits to the city dwellers and its environs to combat and cleans the soot-pollution. The government should take the issue of landscaping seriously both in terms of design and during building construction in Port Harcourt metropolis. It also give a details importance of landscape design in respect to having a sustainable environment and as we look forward to having a better, finer, healthier and cleaner Port Harcourt city.

Improving the quality of life, human well-being and biodiversity are currently important policy drivers in metropolitan areas and megacities through urban green space. Green spaces are one of the most important wildlife habitats in the urban area. Herbaceous vegetation is an increasingly essential element of the urban landscape. Currently, public and professional urban designers increasingly accept naturalistic planting design, semi-natural grassland and meadow in the urban landscape. Both native and exotic species have an essential role in naturalistic planting design. Understanding the process of climate change adaptation is necessary to designing plant communities for use in public landscapes.

Recommendation

Based on these reviews, the following are recommended:

- ➢ Landscape design should be part of buildings and any building that does not have a proper landscape design should not be approved.
- ➢ Urban planners should always visit the site during construction to ensure buildings are constructed according to design.
- ➢ There is the need to inculcate more studies on the importance of landscaping, landscape planning and other environmental issues into the primary, secondary and tertiary curriculum.
- ➢ Professionals in landscape planning and other related disciplines (Horticulturists, landscape planners) should be employed in the Planning and Horticulture unit to handle issues of landscape design and planning in development of housing estates in the city.
- ➢ There should be need for adequate funding of landscape projects as well as sensitization to residents on the importance of an aesthetic environment as well as compel residents to show more concern and respect for the environment.
- ➢ There should be continuous and a well-structured maintenance schedule of landscape elements of the housing estates to sustain the beautification of the environment.
- ➢ Establish new forest zones and Carry out community orientation, workshops and enlightenment campaigns on climate change and reduction of carbon footprint

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THE PROMINENCE OF TRADITIONAL AND RELIGIOUS BELIEFS AND PRACTICES IN BIODIVERSITY CONSERVATION

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Abstract

Regarding the conservation of biodiversity in underdeveloped-nations, it is impossible to overstate the importance of cultural and religious beliefs and practices. For decades in Africa, traditional and religious forests have played significant roles in sustaining biodiversity and variety of ecosystem functions. However, a number of reasons, such as urbanization, population growth, and shifts in land use patterns, are presently endangering these forested areas; as a result, there is rise in demand for agricultural land that is much more fruitful for forests production. Majority of the population is now adopting widespread Christianity or Islam as a religion, which could encourage the deterioration of some indigenous traditional and religious beliefs, practices, and values and, consequently, have an impact on ancient times of religious beliefs and biodiversity preservation. Traditional and religious practices have greatly contributed to the conservation of biodiversity in a number of ways, including: preserving some plant and animal species that are listed by the IUCN as vulnerable or near threatened; conserving soil and water in forest estates, thereby preventing soil erosion. Additionally, these sacred forests provide a source of water, medicinal-herbs, and income for daily living. In addition to providing significant ecological, environmental, and social services to their host communities, these sacred forests preserve the local biodiversity. They also improve local hydrological dynamics, mitigating climate change, among other functions. Therefore, in order to raise the level of conservation in these forest areas for climate change mitigation, this study suggests that traditional and religious actors be valued and supported.

Keywords: *Beliefs, Biodiversity, Fauna, Forest, Preservation, Sacred.*

Introduction

Despite commitments from world leaders to substantially slow this rate of biodiversity loss, the rate of habitat loss at the global level has not declined in recent decades (Butchart *et al.,* 2010). Due to a rising emphasis on economic development and growth, the country today faces serious environmental issues such as land degradation, coastal erosion, water pollution, deforestation, and desertification (Jiboye *et al*., 2019). Therefore, it is essential to understand and sustain any societal customs or other procedures that might help to preserve or conserve the environment in African countries.

If not all, then the majority of religions and belief systems have a deep connection (direct or otherwise) with nature. These spiritual ties are attested to by the books of the main religions, including the Bible (Christianity), the Qur'an (Islam), and traditions, as well as their practices and rites. The most striking example of the spiritual link may be seen in the landscapes of religious communities all over the world, where there are sacred trees, groves, and woods. In Nigeria, there are many communities and people who are connected to the forest or wildlife on a spiritual, religious, or cultural level. Traditional wisdom and religious doctrine are essential for the conservation of natural resources (forests, water, and agro-ecosystems). Indigenous knowledge plays a significant role in sustainable natural resource management, traditional culture, and livelihoods. It is typically intertwined with local religious beliefs, rituals, folklore, and land use practices (Parrotta *et al*., 2007; Liu, 2007; Yuan *et al*., 2012).

Prominence of Traditional and Religious Beliefs and Practices on the Conservation of Biodiversity

Most people consider traditional and religious woodlands to be sacred. Native forest habitats or vegetation that has special spiritual importance to humanity are traditionally safeguarded by traditional councils, priests, and/or local communities using a variety of cultural beliefs and customs. These regions serve as typical illustrations of in-situ biodiversity conservation systems (Onyekwelu and Olusola, 2014; Ray *et al.,* 2014; Daniel *et al*., 2015; Ray *et al*., 2015; Daye and Healey, 2015).

Traditional and religious forests have made a significant contribution to the preservation of wildlife and forest resources; this adage is generally acknowledged. As a result, cultural and religious beliefs and practices frequently make a big difference in the preservation of forests, potentially acting as a crucial instrument for environmental protection. For instance, tree-ordination ceremonies in Thailand have been used as a sociopolitical tool to influence the government to slow down environmental devastation (Tannenbaum, 2000). By forbidding a specific conduct, other standards, which could be classified as social taboos, may safeguard the environment. All sacred forest ecosystems (holy groves) share a connection to gods and goddesses (Chandrakanth *et al.,* 2004), which frequently leads to local communities protecting these areas on moral or religious grounds (Onyekwelu and Olusola, 2014). Results from multiple linear regressions, according to Adeyanju (2020), revealed that the respondents who were working and had a monthly income were more likely to concur that religious and cultural advantages are what drive biodiversity protection in sacred groves. Adeyanju report contrasted with a mindset that said more prosperous and financially secure people tend to become less eager to participate actively in religious institutions and more wary of superstitious beliefs (Norris and Inglehart, 2011).

Belief and Practices towards Forest and Products Conservation

Some plant species are held in high esteem, t hey might not always be destroyed, eaten, or touched. The Akan people of Ghana are one group who practise this, and one instance of this is the "tradition of the totem plant," in which several clans have wild plant species as their totems, from the raffia palm Raffia hookeri to the leopard Panthera leo (Ntiamoa-Baidu, 2002).Traditionally, such species are mostly protected by members of the clan. Use of leaves from the Newbouldia laevis tree, also known locally as the "Akoko," is a typical Yoruba rite in south-west Nigeria for the crowning of traditional leaders and the awarding of chieftaincy titles (Babalola, 2011). Such trees, among others, are highly safeguarded and kept from going extinct as a result of this significant use, supporting the essential contribution holy groves provide to biodiversity preservation (Babalola, 2011). Local authorities in the Benin Republic prevented the disrespect of sacred trees by strictly enforcing cultural taboos and restrictions among the native and immigrant populations in the riparian settlements (Ceperley *et al.,* 2010).

It is also common in many rural African communities to find small patches of forest set aside as sacred and accorded strict protection under customary laws (Figure 1). Others instances of these religious forest areas include: Obibagwa, Ohuma, Oyinyi-Oyeche, and Ebonda Ipenu-Igede forest in Benue state (Nigeria); Akai Mbiam, Akai AnwaIbok, Akai Uya all in Akwa Ibom state (Nigeria) (Daniel *et al.,* 2016); Umuojima-Efere Umuogwo, Mgbedeala in Abia State (Nigeria) (Chima and Nuga, 2011); Idanre Hills at Oke-Idanre, Ondo State (Nigeria) (Adeyanju *et al.,* 2022); Igbo-Ile sacred grove at Ibere Ogo Oluwa Oyo State (Oyelowo *et al*., 2014), and Igbo-Oba at Oba Ile Olorunda in Osun State (Oyelowo *et al.,* 2014).

Number of studies have shown that even in heavily humanised landscapes, traditional and religious forest areas are significant refuges for biodiversity and fauna, including edible plants, medicinal plants, and vegetables that contribute to household income (Udoakpan et al., 2013; Ray et al., 2014; Balachandran et al., 2015; Daye and Healey, 2015). There are many different reasons for this status, including forests that serve as royal burial grounds, forests along the banks of significant rivers that provide water to a village community, forests with historical significance in a particular people group's culture, or patches of forest that are home to totem species (Soutter, 2003).

Figure 1: Sacred Tree (*Ficus polita*) around a Posurban Shrine in South Ghana
Source: (Britt and Tinde, 2011).

Table 1: Most Sacred Tree Species in Ghana

S/N	Family	Species name
1	Bignoniaceae	*Newbouldia laevis*
2	Santalaceae	*Okoubaka aubrevillei*
3	Fabaceae	*Dalbergia sp.*
4	Fabaceae	*Daniellia ogea*
5	Leguminoseae	*Distemonanthus benthamianus*
6	Lamiaceae	*Ocimum americanum*
7	Euphorbiaceae	*Croton gratissimus*
8	Cucurbitaceae	*Momordica charantia*
9	Asteraceae	*Ageratum conyzoides*
10	Malvaceae	*Ceiba pentandra*
11	Fabaceae	*Dalbergia sp.*
12	Santalaceae	*Okoubaka aubrevillei*
13	Fabaceae	*Daniellia ogea*
14	Leguminoseae	*Distemonanthus benthamianus*
15	Malvaceae	*Ceiba pentandra*
16	Fabaceae	*Dalbergia saxatilis*
17	Moraceae	*Milicia excelsa*
18	Combretaceae	*Combretum comosum*
19	Passifloraceae	*Adenia dinklagei*
20	Fabaceae	*Baphia nitida*

Source: (Britt and Tinde, 2011).

At Akai Ekpe, (Forest of the Masquerade), is a traditional and religious forest area at Amammong-Okobo in Akwa Ibom state, which is the exclusive meeting place for members of the Ekpe cult; all uninitiated, including visitors, are not allowed access (Daniel *et al.*, 2016). Other strict traditional and religious forests in the area include - Iso Idim Ekpo and Owuk Ntuk-enyen, among others (Table 2).

Table 2: Sacred Forests that Studies are not allowed by the Communities due its sanctity/sacredness

Traditional/religious forests	Category of uses	Explanation
Iso Idim Ekpo	Water source	The grove provides water for the community all year round.
Owuk Ntuk-enyen	Children burial Ground	Used primarily for burying Children who die below the age of 7years, often believed to belong to 'transitory' group.
Akai Ekpe	Meeting/worship/ Sacrifice	An abode for 'Ekpo' diety where the Ekpe cult members meet and where 'Ekpe host' are consulted to avenge rivals or assist in war.

Source: Daniel *et al. (*2016).

Belief and Practices towards Fauna Species Conservation

In most rural places, where choices about the exploitation of regional natural resources are greatly influenced by traditional authorities, traditional knowledge is still highly prevalent. In some instances, it is common practice to regulate the exploitation of species that have a connection to the community on a material or spiritual level (Etiendem *et al*., 2011). Forests that are traditionally used for religious purposes serve as an example of African heritage that protects both the physical and non - physical values of the populace. Relationships between nature and communities are primarily shaped by cultural values and social conceptions of nature and the environment. While culture may favor biodiversity protection in the short term, if the authorities ignore the significance of simultaneously encouraging active local community engagement in protected areas, such an approach may fail to sustain biodiversity in the long run (Adeyemi and Ayinloye, 2020).

The protection of faunal species has benefited enormously from traditional and religious practices in a variety of ways. The significance of the sacred grove (Osun-osogbo, Nigeria) to sustainable biodiversity management in Nigeria was revealed by Adeyemi and Ayinloye in 2020. According to their findings, there are serious penalties for violators of the laws against poaching, tree cutting, farming, fishing, chemical water pollution, and the construction of unauthorised constructions (Table 3). "Regardless of gender or color, anyone who breaks the ancient rules faces death, the goddess' wrath or inundation, imbecility or insanity, and unproductiveness; however, consequences based on conventional laws are less severe and do not prevent future offenders from committing the crime" (Adeyemi and Ayinloye, 2020).

A finding about the conservation of Cross River Gorillas (totem gorilla) was published in 2011 by Etiendem *et al.* According to their survey, the majority of their respondents (56 percent) were aware that gorilla hunting and eating were banned in their tribe

(Bechati, Fossimondi, Besali, Cameroon). Traditional councils are the major means by which the taboos are enforced. Defaulters are either penalized by arbitrary spiritual sanctions, such as sickness and/or death, or by other sanctions imposed by the head or elite members of the traditional council. People who shoot gorillas or chimpanzees in Cameroon may be punished by being barred from participating in community activities, banished from the area, made to perform certain rites, or compelled to pay a fine. For instance, the IUCN has classed Cross River gorillas as severely endangered since 2007, and their remaining habitats are dispersed widely (Etiendem *et al.*, 2011).

Conservationists have emphasized that the participation of nearby local communities will ultimately determine whether populations outside of protected areas (like the Bechati-Fossimondi-Besali population) survive (Oates et al. 2007). Traditional knowledge of wildlife is essential in such places where the conservation of endangered animals urgently requires the support of local communities, and until these belief systems completely disappear, incorporating them into conservation strategies is vital to the ongoing survival of the species they protect.

According to Daniel *et al.* (2016), there are groves for certain purposes, some of which have few trees, such as the "Iso Idim Ekpo" (Akwa ibom-Nigeria), which translates to "the head from whence Ekpo's stream runs." As long as the ancient cultural ceremonies are carried out and the related divine commandments are obeyed by the people, it is apparent that these sacred activities have promoted biodiversity and wildlife conservation and will do so in the future.

Depending on the community, a given fauna species may have a different religious meaning. For instance, the Luhya of Kenya's Busia District practise religion in which particular animals are frequently used in purification rites or to bind people to oaths (Gumo, 1993). Some people, like the Luo, believe snakes to be sacred, especially pythons, which are protected species. The "Omweri," which was situated in Nyakach, Nyanza, Kenya, is a recent illustration. Many cultures link snakes to the afterlife or other human spirits; as a result, when these snakes visit people's homes, they are fed and watered.

Table 3: Taboos associated with Sacred Grove in Nigeria

Offences	Punishment	
Hunting/Killing of animals	Death	Payment of fine or one-month jail term
Felling of trees	Wrath of the Osun goddess/ Flood	Payment of fine or one-month jail term
Farming	Unproductiveness	Payment of fine or Jailed for one month
Fishing	Insanity	Payment of fine or one-month jail term
Water pollution	Wrath of the Osun goddess	Payment of fine or one-month jail term
Building of unauthorized structures	Wrath of the Osun goddess	Payment of fine or one-month jail term

Adeyemi and Ayinloye (2020)

Due to the high rate of tree felling and poaching of fauna species around some traditional and religious belief areas, there is a high decline in biodiversity in both the outer and buffer zones of such areas. As obtained from our findings in Osun Osogbo sacred grove, the core zone of the grove contributed greatly to the conservation of some fauna species in the area (Table 4), which indicated a higher density of fauna than the outer and buffer zones. The area also plays a role in conserving some plant and fauna species that are tagged as vulnerable or near threatened by IUCN lists (Table 5). The values obtained indicate high values, which confirm that the study area (Core zone) is of rich tree and fauna species diversity. Due to high anthropogenic activity and encroachment, the buffer zone and outer zone of the grove had a low diversity index, species richness, and evenness for trees and fauna species.

Table 4: Fauna Population Estimate and Density in the Study Area

Locations	Population Estimate	Density(Pop/ha)
Core	0.39	0.06
Buffer	0.26	0.005
Outer	0.21	0.003

Source: Kuje and Ugbe (2022).

Table 5: Some Vulnerable Plant and Fauna Species Conserved by Religious Practices in Osun Osogbo Sacred Grove, Nigeria

Scientific name	Families	IUNC status	Type
Soricidae spp	Mammalia	Vulnerable	Fauna
Phataginus tricuspis	Mammalia	Vulnerable	Fauna
Cercopithecus erythrogaster	Mammalia	Vulnerable	Fauna
Lannea welwitschii	Anacardiaceae	Near threatened	Plant
Milicia excels	Moraceae	Near threatened	Plant

Scientific name	Families	IUNC status	Type
Afzelia Africana	Fabaceae	Vulnerable	Plant
Nesogordonia papaverifera	Malvaceae	Vulnerable	Plant
Terminalia ivorensis	Combretaceae	Vulnerable	Plant

Source: Kuje and Ugbe (2022)

According to Kandari et al. (2014), certain parts of India's fauna have traditional beliefs related to them. Panthera tigris is reportedly employed in both ceremonies and medicine, according to their study (Table 6). In Hindu mythology, the gods and the demons (Asura) churned the ocean during Sagar Manthan (Milk Sea Churning) in search of the nectar known as "Amrit," which gave them immortality. The "navratnas" (nine jewels) emerged from the churning. White elephants (Elephas maximus indicus), trees (Karpavruksha), and Kamadhenu are a few of these beauties (holy cow). Bos taurus has a unique position in Hindu mythology. Since ancient times, Hinduism has placed a strong emphasis on respecting animals. Lord Shiva's "vehicle" or "vahana" is the Bull. Peacocks (Pavo cristatus) are connected to the goddess Saraswati in Hindu mythology (goddess of education and knowledge). Thus, the feathers stand for traits like generosity, tolerance, and luck. In mythology, some snakes are regarded as "protectors," while others are seen as "harmful/destructive." A snake served as jewellery on Lord Shiva. Lord Vishnu rests atop Adiseshu, a snake with a thousand heads, in the milky sea (King Cobra).

According to the epic Ramayana, Ravana and the vulture King Jatayau (Gyps indicus) engaged in a bloody struggle while attempting to kidnap Sita and bring her to his country of Lanka. The bird's attempt to save Sita from Ravana resulted in fatal injuries (Kandari et al., 2014). In India, squirrels are revered and should not be harmed since they are connected to Lord Rama. Lord Rama and the Vanara Sena built the Adi Sethu (bridge) at Rameshwaram, and a small squirrel (Ratufa indica) also made a small contribution. The Indian squirrel has had white stripes on its back ever since Lord Ramas touched its back in appreciation for the critters' devotion, and this is thought to be the mark of Lord Ramas' fingers. Varaha, a pig (Sus scrofa Linnaeus), was Lord Vishnu's third avatar. Varaha is frequently shown as having a human body and a wild boar head. The Hindu goddess Durga known as Varahi appears as a wild boar (Kandari et al., 2014).

Table 6 List of some common Fauna and their associated beliefs

Scientific name	Local name	Beliefs/uses
Panthera tigris	Tiger	Used in rituals and medicine.
Elephas maximus Indicus	Elephant	Sacred/sacrifice/ritual
Bos Taurus	Bull	Means of transportation during sacrifice
Antilope cervicapra	Black buck	It is also known as Krishna Mruga in Kannada.
Macaca mulatta	Monkey	Monkey is known to be associated in the army of Hindu god Hanuman hence considered sacred.
Felis catus	Cat	Cats are associated with fertility and the goddess of birth, Shakti.
Pavo cristatus	Peacock	Sacred
Naja naja	Snake	The snake is commonly called ('Nag' in Hindi language) is worshipped by people across the country.
Gyps indicus	Indian vulture	Sacred
Ratufa indica	Squirrel	Sacred
Sus scrofa Linnaeus	Wild Boar	Sacred

Source: Kandari et al. (2014).

Most cases of poaching of fauna species have significantly decreased in communities with stringent traditional and religious views and practises, largely as a result of these traditional values and practises. It has been suggested elsewhere that the existence of taboos against the species' exploitation is a successful local conservation approach (Banjo et al. 2006, Saj et al. 2006). The loss of respect for the ideas and customs that gave rise to the taboo, however, is imminent if they are not renewed. It is not impossible for a fading traditional or religious belief and/or practise system to be revived. For instance, in most developing countries, it is possible to reinstate traditional or religious practises or beliefs that support the protection and conservation of forests and forest resources if modern approaches are combined with traditional or religious councils as a tool for sustainable management.

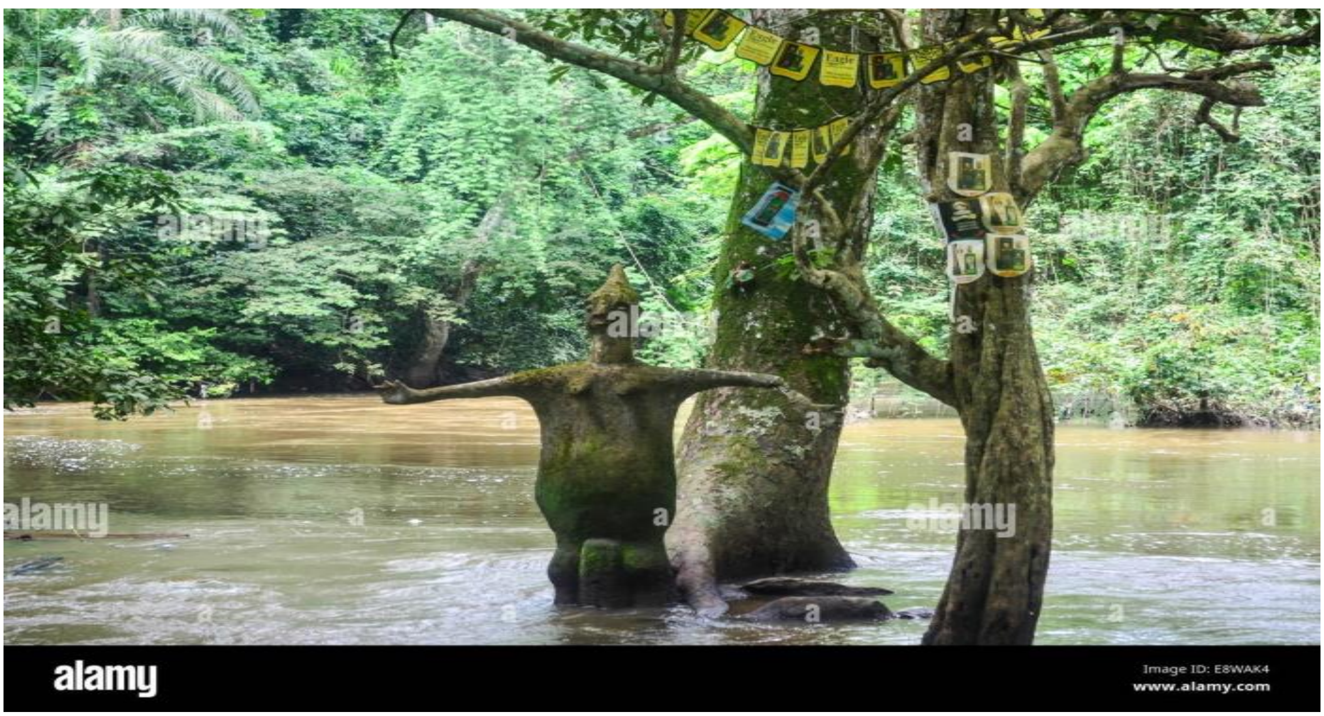
Belief and Practices towards Ecological Conservation

Religious beliefs and practices contribute greatly to ecological conservation, through sacred groves management. Sacred groves offer a range of ecological benefits, including erosion prevention, windbreaks, soil conservation, hydrological cycle management, watershed protection, water filtration, and upkeep (Ormsby, 2012a; Udeagha et al., 2013; Oyelowo et al., 2014). Sacred groves *among other totem improve soil stability of a region and act as soil binders. In sacred areas, tree plants such as vetiver grass (*Vetiveria zizanioides*) and Eucalyptus spp. are maintained to bind the soil, thereby preventing soil erosion (Kandari* et al., *2014). The North Pare natives of Tanzania acknowledged the ecological services that the sacred groves of Mpungi and Mshitu provided for the conservation of soil and water (Sheridan, 2009). Most communities and areas that settled on the banks of rivers around sacred or traditional areas are not only considered sacred but are also a source of water use for house chores. Small natural water bodies are maintained, near sacred and/or traditional areas to take care of drinking water problems during drought. Villagers are now improving the surrounding areas of water bodies with concrete structures to conserve natural flowing water bodies and maintain them in a hygienic condition.*

Traditional and religious forests vary widely in their size and functions; some of them are small fragments of forest (less than 1 hectare), while others are more extensive, spanning well above 100 hectares (Udoakpan *et al.*, 2013; Bhagwat *et al.,* 2014; Daniel *et al.,* 2015). Despite the size limitations and functions, these forests conserve local biodiversity and offer important ecological, environmental and social services to their host communities and also enhance local hydrological dynamics (Chandran *et al*., 2010; Hu *et al*., 2011; Udeagha *et al.,* 2013; Daye and Healey, 2015; Balachandran *et al.,* 2015; Ray *et al*., 2015).

There are many different traditional and religious rivers and bodies of water located in different locations. For instance (Figure 2): The Osun Sacred Grove On the outskirts of the city of Osogbo, is one of the last remnants of primary high forest in southern Nigeria. Regarded as the abode of the goddess of fertility, Osun, one of the pantheon of Yoruba gods, the landscape of the grove and its meandering river (Borokini 2016) is dotted with sanctuaries and shrines, sculptures and art works in honour of Osun and other deities. Erin Ayonigba River in Erinjiyan Ekiti, Ekiti West Local Government Area of Ekiti State, is a river with strange kind of fish. The river is said to heal various ailments.Other international sacred streams or rivers include (Arthur Griffin/Encyclopædia Britannica, Inc., 2020):

The Urubamba River flows through the Andes of southern Peru. The Jordan River, which connects the Dead Sea with the Mediterranean, passes through Israel, Jordan, Lebanon, and Syria. It's sacred in both Judaism and Christianity for different reasons. Whanganui River New Zealand's Whanganui River has long been sacred to the local Māori, who view it as a living, breathing ancestor, and last year it became the first river in the world to be granted the same legal rights as a human being *(*Arthur Griffin/Encyclopædia Britannica, Inc. 2020).



a. Osun Sacred Grove Nigeria

b. Otamiri River (Sacred) in Imo, Nigeria
Source: (Encyclopedia, 2022-https://en.wikipedia.org/wiki/Otamiri_River; accessed 6/8/2022)

(c). Erin Ayonigba River in Ekiti Nigeria.
Source: Priscilla Ediare (2020).

Economic Benefits of Biodiversity Conservation by Traditional and Religious Beliefs and Practices

A sacred grove's level of care and protection is typically determined by the value given to it (Aniah and Yelfaanibe, 2016). The celebration of traditional festivals and the worship of gods, whether privately or publicly, are common practises in numerous sacred groves in south-west Nigeria. For instance, one of the major events observed on the hills in Idanre is the Orosun festival (Adebayo, 2016). The grove is home to the annual Osun Osogbo festival, which draws thousands of guests, tourists, and pilgrims each year

(Probst, 2013). In Southern Nigeria, sacred trees are used as gathering spots by distinctive groups of people to make significant decisions (Daniel *et al*., 2016).

Regular visits to the groves by domestic and foreign tourists directly support host communities, although the scale varies from grove to grove (Ormsby, 2012b; Udeagha et al., 2013; Oyelowo et al., 2014; Adigun et al., 2016). Hotels, restaurants, tour guides, transportation services, and other service providers are examples of local businesses found in sacred sites. They make a good living, as do outside businesses that are only open for the festivals. With the support of the governmental and non - governmental organizations, this worldwide festival has grown to be a multi-million dollar event (Onyekwelu and Olusola, 2014). A crucial justification for preserving the groves is the fact that they have boosted the reputation and popularity of the various villages that surround the sacred trees where they are located.

Communities in Ghanaian, Nigerian, among other countries are motivated to safeguard and sustain sacred groves by economic incentives brought on by jobs, tourism, and revenue generating (Ormsby, 2012b; Onyekwelu and Olusola, 2014). Ecotourism development was suggested as a substitute strategy to encourage local residents in Zanzibar, Tanzania, to preserve the last few sections of sacred forests (Madeweya *et al*., 2004). Ecotourism revenue lessens the impact of local economic challenges, which in turn deters the destruction of sacred forests (Nyamweru and Kimaru, 2008). Successful ecotourism implementation in Kenya's sacred Kaya woodland was founded on a strong institutional structure, backing from outside organisations, and full local community participation (Nyamweru and Kimaru, 2008). Even though tourism benefits the economy, if it is not properly controlled, mass tourist could endanger sacred trees. Increased pressure from visitor numbers could have detrimental effects on the environment, problems with solid waste management, and loss of cultural integrity (Adeyanju, 2020).

Conclusion

Most local people are now embracing widespread Christianity or Islam as an alternative religious belief with little or no interest in forest conservation through religious practices, while gradually abandoning traditional and cultural beliefs and practices. Traditional and religious practises have greatly contributed to the conservation of plant and fauna species in a number of ways, including: preserving some plant and fauna species that are listed by the IUCN as vulnerable or near threatened; conserving soil and water in forest estates, thereby preventing soil erosion; conservation of water catchment areas which serve as sources of drinking water and other sources of medicinal herbs; and revenue for daily living. In addition to providing significant ecological, environmental, and social services to their host communities, these traditional and religious forests preserve the local biodiversity. Traditional beliefs and practises help to improve local hydrological dynamics, mitigating climate change among other functions. Therefore, in order to raise the level of conservation in these forest areas for climate change mitigation, this study recommends that Christianity and/or Islam can conserve forest estates by carrying out some key holy practises in the forest estate as practised by traditional priests. Also, traditional and religious actors should be valued and supported in order to increase the level of traditional and religious biodiversity conservation. Most lost taboo systems can be brought back through the influence of local conservation organizations, such as Christians, Islam, and traditional councils or religious authorities.

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PHYSICO-CHEMICAL PROPERTIES OF SOILS UNDER TREES SPECIES FARMLANDS AT GAFAN, BUNKURE L. G. A., KANO STATE, NIGERIA

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Abstract
Due to increase in population and farming activities most farmers remove trees from their farm lands for more farming spaces instead of maintaining them for improving fertility of the soils leading to soil degradation. Trees specie investigated were Azadirachta indica, Mangifera indica, Adansonia digitata, Parkia biglobosa, Eucalyptus camaldulensis, Moringa oleifera, Diospyros mesiliformis and Vitellaria paradoxa. Three line transects of 300m were laid at 100m interval on farmlands. Soil samples under the tree species and 50 m away from the trees canopies (open land) were collected at 0-30cm depth at tree cardinal points using soil auger and analyzed. Textural classes of the soils were found to be loamy sand under Azadirachta indica, Diospyros mesiliformis, Vitellaria paradoxa, Tamaridus indica, Mangifera indica, Adansonia digitata and sandy loam under Eucalyptus camaldulesis and Moringa oleifera. The pH values of the samples were 7.78 and 5.38 under Eucalyptus camaldulensis, and Diospyros mesiliformis, respectively. Organic carbon ranges from (0.20%) under open land to (1.14%) under Diospyros mesiliformis. Total nitrogen (%) was lower at open land (0.05) and higher under Eucalyptus camaldulensis (0.40). However, soils under Eucalyptus camaldulensis had the highest content of Calcium (4.31cmol/kg), Phosphorus (15.21cmol/kg) and CEC (6.35cmol/kg) compare to the soils under other plant species. Farmers in the area of study should be advised to plant and conserve trees especially Eucalyptus camaldulensis due to its highest value of CEC which is the most significant factor in improving fertility status of farmland soils.

Key words: *Tree diversity, Soil, Physico-chemical property, Farmland trees.*

Introduction

Trees have always existed on lands whether cultivated or not. In early days farmers in tropics use existing trees or plants trees for some purposes like shade fire wood and fruits. Over the years they come to realize that trees have certain desirable role that they play on the soils which they uses to cultivate agricultural crops, this was simply by noticing better performance of crops grown under trees than those grown beyond the canopies of trees. Soil is a vital resource for human survival; it is a mixture of organic and inorganic materials on the immediate surface of the earth that serves as a natural medium for the growth of plants. The organic component of soil is made up of micro-organisms (dead and alive), and plants in varying stages of decay called humus. It improves soil structures and allows soil to store moisture, providing energy for soil microorganisms to make soil tillable for farming and provides nutrition for plants. The nutrients required by plant in relatively large quantity are nitrogen (N), phosphorous (P) and potassium (K) commonly referred to as N P K, Efretuei (2016). It has been observed that as the fertility of soil declines, soil structure weakens and the soil becomes susceptible to erosion (Adetunji, 2004). Soil biodiversity and its physical properties that control water movement and retention in the soil are largely affected due to animal activities (Young, 1999). The important of tree based land use systems in restoring soil fertility and improving the economy of farmers having small land holdings has been realized during the last two decades (Long, 1999). Trees help to maintain soil organic matter and improve physical properties and supply nutrient in farmland. Thus, integration of trees into farming system could go a long way to help in crop growth and enhancing the recycling of materials to provide a more complete ground cover which help to protect the soil from erosion and moderate extreme temperature (Adedire, 2004).

The problem under the study area is that most of the farmers remove trees from their farm land for more farming space, charcoal production and to reduce shading effect on crops instead of maintaining them for improving fertility of soils. Thus, this research can be fundamental to providing crucial information on soil protection and fertility improvements by trees, there by subsequently enhance farmers to protect and plant trees on their farm land, as in a greater part of Africa and indeed Nigeria, trees are a common feature in many farms particularly in subsistence agriculture. Therefore, this study was designed to investigate physico-chemical properties of soils under some selected tree species on farmlands in Gafan village, Bunkure local government, Kano state.

Materials and methods

Study Area.

Bunkure local government is located between Latitude 110 34` 02"N to 110 46′ 05"N of the Equator and Longitude 80 26′ 36"E to 80 46′ 43"E of the prime meridian (Figure 2). The research was conducted at Gafan Village in Bunkure local government area of Kano state and is located between latitude 110 40'09"N of equator and Longitude 80 27'8"E.

Sample Collections

Eighteen (50m x 50m) plots were used for this study. Three lines transects of 300 m long were laid at 100 m intervals. On each transect, six plots of size 50 m × 50 m (0.25 ha) were alternately laid at 50m intervals including an open land 50 m x 50 m away from the trees canopies. Eight (8) tree species were found in the farmland which were as follows; *Azadirachta indica, Eucalyptus camaldulensis, Adansonia digitata, Moringa oleifera, Mangifera indica, Tamarindus indica, Diospyros mesiliforms and Vitellaria paradoxa.* Soil samples were collected from under the identified trees species on the farmlands at depth of 0 - 30cm at four cardinal points, using soil auger**.** The samples were air-dried, sieved with a 2 mm sieve, and put in plastic bags and properly tagged according to Marditech (2011), which later were taken to Soil Science Laboratory of Bayero, University Kano for physico-chemical analysis.

Soil analysis

The samples collected were analyzed for physico-chemical properties. The particle size was determined by Bouyocous hydrometer method (Bouyocous, 1951) and the textural class by soil texture triangle (USDA, 1960), soil pH by the used of pH meter as described by Blackman (1965); organic carbon content was determined by dichromate wet oxidation method as described by Wolf (1982); N content by Micro-Kjedhal method as described by Bremmer (1965); available phosphorus (P) was extracted using the Bray 1 method (Bray and Kurtz, 1945); exchangeable bases (Ca, Mg, K and Na) using 1M ammonium acetate solution (Anderson and Ingram, 1993) and CEC was estimated by summation of exchangeable bases.

Data Analysis

The data collected on the physico-chemical properties of the different soil samples were subjected to analysis of variance using "F" TEST as described by Snedecor and Cochran (1967) where significance was showed by "F" test. Genstat (17^{th} Edition) was used for ANOVA and significant different means were separated using Duncan`s multiples range test.

Results

Diversity and Frequencies of Tree Species Found on the Study Area

Tree species found on the farmlands of the study were presented on Table 1. The result indicated that *Azadirachta indica* had the highest frequency of 15 stands, followed by *Adansonia digitata* with total frequency of 12 stands then *Moringa oleifera* 8 stands, *Eucalyptus camaldulensis* 6 stands, *Vitellaria paradoxa* 5 stands and *Mangifera indica* 5 stands, while trees specie with lowest stands were obtained to be *Tamarindus indica* 4 stands and *Diospyros mesiliformis* 2 stands.

Table 1: Tree species in the study area

SN	TREES SPECIES	LOCAL NAMES	FREQUENCIES
1	*Eucalyptus camaldulensis*	Turare	6
2	*Azadirachta indica*	Darbejiya	15
3	*Diospyros mesiliformis*	Kanya	2
4	*Vitellaria paradoxa*	Kadanya	5
5	*Moringa oleifera*	Zogale	8
6	*Tamarindus indica*	Tsamiya	4
7	*Mangifera indica*	Mangwaro	5
8	*Adansonia digitata*	Kuka	12

Physical Properties and Particles Size of Soils of the Study Area

Table 2, shows the Result of physical properties and particles size of the soil samples. The result indicated that sand particles ranged between (76.00 - 86.00%). Soils under *Vitellaria paradoxa, Tamarindus indica and Adansonia digitata* recorded the highest sand particles size (86.00 - 84.00) and there textural class was loamy sand, while soils under *Mangifera indica, Diospyros mesiliformis* and *Azadirachta indica* sand particles size was between (80.00 - 82.00). The result also indicated that sand particle size of the soil samples obtained under *Moringa oleifera and Eucalyptus camaldulensis* was between (78.00 and 76.00%) which was obtained to be the lowest particle size of sand and its textural class was sandy loam. This indicated there was a difference between the soils under the different trees species. The sand fraction in the soil falls in to the categories of sand textural class (Brady, 1999). Percentage silt ranges from (15.00 -17.00%). The highest value of silt was observed with soil samples under *Diospyros mesiliformis* (17%) followed by *Eucalyptus camaldulensis* (15.00%), *Tamarindus indica* (13.00%), *Mangifera indica* (11.00%), *Azadirachta indica* (11.00%), and *Adansoia digitata* (9.00%), while The lowest value of silt particles size was obtained with soil samples around *Vitellaria paradoxa and Moringa oleifera* (5%) each. This shows that there was a difference in silt level between the tree species which indicates low silt level in the soil samples. Percentage of clay particles size was presented in (Table 2). It shows that clay particles size ranged from (12 - 2%). The higher value of clay was observed with soil samples under *Moringa oleifera* (12%) followed by *Vitellaria paradoxa, Azadirachta indica,* open land of 50 m away from trees canopies and *Eucalyptus camaldulanesis* (10%), each, *Mangifera indica* and *Adansonia digitata* (8%) each, respectively, while the lowest value of clay particles size were recorded with soil samples under *Tamarindus indica (*4) and *Diospyros mesiliformis* (2). There was difference in pH between the soils under the tree species. Result of the analysis revealed that the pH of the soils was found to be higher under *Eucalyptus camaldulensis* (7.78) followed by *Diospyros mesiliformis* (7.16), open land (6.54), *Adansoia digitata* (6.05), *Azadirachta indica* (6.01), *Moringa oleifera* (5.97) *Mangifera indica* (5.94), *Vitellaria paradoxa* (5.59), and was lower under *Tamarindus indica* (5.38).

Table 2: Physical Properties of the Soil Sample under Different Tree Species at Gafan Village

	PHYSICAL PROPERTIES				
TREE SPP	Sand (%)	Silt(%)	Clay (%)	Textural class	pH (H_2O)
Ec	76	15	10	Sandy loamy	7.78
Ai	80	11	10	Loamy sand	6.01
Dm	82	17	2	Loamy sand	7.16
Vp	86	5	10	Loamy sand	5.59
Mo	78	5	12	Sandy loam	5.97
Ti	84	13	4	Loamy sand	5.38
Mi	82	11	8	Loamy sand	5.94
Ad	84	9	8	Loamy sand	6.05
OL	80	12	10	Loamy sand	6.54

Trees specie Ec= *Eucalyptus camaldulensis,* Ai= *Azadirachta indica, Mo= Moringa oleifera,* Dm= *Diospyros mesiliformis,* Mi= *Mangifera indica, Vi= Vitellaria paradoxa,* Ti= *Tamarindus indica,* Ad= *Adansonia digitata,* OL= Open Land

Chemical Properties of the Soil Samples

Table 3 presents the chemical properties of soil under different trees species in the area of study. The result obtained from the soil samples analysis indicated that soil around *Eucalyptus camaldulensis* and *Moringa oleifera* were statistically at par in CEC content but significantly higher than the soils around the remaining tree species which were obtained to be statistically the same but in turn higher than the open land soil. The result also showed that Calcium (Ca) content of the soils around *Eucalyptus camaldulensis* and *Diospyros mesiliformis* statistically at par were significantly higher in Ca than soils around *Moringa oleifera* which was also significantly higher than soils around the remaining tree species including soil of open land statistically at par also. Soils under *Tamarindus indica* and *Mangifera indica* had the same amount of Potassium (K) concentration but significantly than soils around *Eucalyptus camaldulensis*, *Vitellaria paradoxa* and *Azadirachta indica* which were statistically similar also but significantly higher in K than *Adansonia digitata* that was obtained to be higher than the soils around *Diospyros mesiliformis* and *Moringa oleifera* statistically the same but in turn significantly higher than soil of open land. Magnesium (Mg) content, result obtained shows that soil of open land was significantly higher in Mg than *Eucalyptus camaldulensis* and *Mangifera indica* which were statistically similar but significantly higher in Mg than *Adansonia digitata* and *Vitellaria paradoxa* also statistically at par but higher than soils around *Azadirachta indica* and *Tamarindus indica* which were also the same but significantly higher than soils around *Moringa oleifera* which was in turn significantly higher than soil around *Diospyros mesiliformis.* Nitrogen (N) content, the result showed that there was no significant difference among the different soils around the trees specie of the study area but higher N was obtained with soil around *Eucalyptus camaldulensis* while lower was recorded with soil of open land. Sodium (Na) content, result recorded revealed that Na content of the soils around *Vitellaria paradoxa* was significantly higher than that of soils around *Diospyros mesiliformis, Eucalyptus camaldulensis, Adansonia digitata, Mangifera indica, Moringa oleifera* and *Azadirachta indica* statistically the same but significantly higher than soils around *Tamarindus indica* and open land. Organic Carbon (O.G) content the result obtained showed that O.G content of the soils indicated that soil around *Diospyros mesiliformis* was significantly higher in O.G than soil around *Eucalyptus camaldulensis* and *Mangifera indica* statistically at par but significantly higher than soils around *Moringa oleifera, Vitellaria paradoxa, Adansonia digitata, Azadirachta indica* and *Tamarindus indica* all statistically at par with one another but significantly higher than the soil of the open land that recorded the lowest O.G content. Phosphorus (P) content, the result indicated that soil around *Eucalyptus camaldulensis* was significantly higher in P than soils around *Mangifera indica* and *Azadirachta indica* which were statistically similar but significantly higher in P than soil around *Vitellaria paradoxa* and *Adansonia digitata* that was obtained to be at par but in turn significantly higher than the soils around *Diospyros mesiliformis, Tamarindus indica* and open land soil statistically the same. Trees specie percentage (TSP), result obtained indicated that there was no significant difference among the trees specie.

Table 3: Chemical properties of soil under different trees species at Gafan, Bunkure L. G. A

				CHEMICAL PROPERTIES					
TREE SPECIES	TSP	CEC (cmo/kg)	Ca (mg/100g)	K(mg/100g)	Mg (mg/100g)	N (mg/100g)	Na (mg/100g)	O.G (%)	P (mg/100g)
Ec	2.67	6.35a	4.31a	0.28b	1.35b	0.40	0.23b	0.21d	15.21a
Mo	2.67	5.07ab	2.94b	0.19d	0.74d	0.10	0.24b	0.46c	10.42d
Vp	2.00	4.32b	2.68c	0.24b	0.96c	0.14	0.46a	0.57c	11.76c
Ad	4.33	4.62b	2.44c	0.21c	0.99c	0.17	0.23b	0.56c	11.33c
Dm	1.33	4.56b	4.10a	0.19d	0.48e	0.24	0.20b	1.14a	8.89e
Mi	2.00	4.40b	1.96c	0.44a	1.19b	0.21	0.25b	0.86b	13.03b
Ai	5.00	4.27b	2.17c	0.30b	0.76d	0.14	0.26b	0.55c	11.39b
Ti	4.00	3.89b	1.80c	0.52a	0.87cd	0.07	0.01c	0.45c	9.66e
OL	0.00	1.45c	2.17c	0.18e	1.67a	0.05	0.11c	0.20d	9.27e
SE+	1.395	0.476	0.405	0.011	0.046	0.103	0.037	0.069	0.285
P-value	0.570	<.001	0.002	<.001	<.001	0.468	<.001	<.001	<.001

Note; Means followed by the same letter(s) are not significantly different at 5% level of significance using Duncan`s Multiples Range test.
Trees specie Ec= *Eucalyptus camaldulensis,* Ai= *Azadirachta indica, Mo= Moringa oleifera,* Dm= *Diospyros mesiliformis,* Mi= *Mangifera indica, Vi= Vitellaria paradoxa,* Ti= *Tamarindus indica,* Ad= *Adansonia digitata,* OL= Open Land
O.G= Organic carbon, TSP= Trees species percentage, CEC= Cation Exchange Charge

Discussion

Particles Size Analysis

The result indicated that sand quantity was between (80-76%). The sand, silt and clay fractions in the soil therefore, fall in to the categories of sand textural class (Brady, 1999 and U.S.D.A, 1960).

The result of the study showed that organic carbon levels ranges 0.20 to 1.14. The highest value was observed with soil under *Diospyros mesiliformis* (1.14%) while the lowest value of organic carbon was obtained with soil of open land (0.20%). These pointed out that there was significance difference among the tree species in organic carbon. The result also revealed very low organic carbon content of the soils (Chude *et al*, 2012). Total nitrogen the result shows N content ranges between (0.05 to 0.40%). However, the result indicated that total nitrogen was found to be higher under *Eucalyptus camaldulensis* the lowest was observed around open land. However, the result indicated that there was no significance difference among the soils around trees specie in Nitrogen levels; it also revealed very low N content of the soils of the study area (Chude *et al.*, 2012). Though findings of Radwanski and Wickens (1981) reported there was higher level of total nitrogen under trees than away from its canopy. The low Nitrogen probably could be due to the maturity of the trees and land uses. Result of available phosphorus shows that there was significance difference in the available P between the trees specie values ranged from (8.89 - 15.21mg/kg), indicating moderate level of available P in the soils (Chude *et al.*, 2012). *Eucalyptus camaldulensis* has highest value of the amount of (15.21cmol/kg). However, *Diospyros mesiliformis* was found to be the lowest in P level 8.89 cmol/kg.

The result of exchangeable bases (Ca, M, K, and Na) shows that there was significance difference between the soil under the tree species in available calcium which ranged from (1.80 - 4.31 cmol/kg) with a mean of (0.405cmol/kg). Chude *et al.* (2012) reported that tropical soils with calcium level as low as 0.2cmol/kg is good for agricultural crops. The higher calcium level was recorded around *Eucalyptus camaldulensis* (4.31cmol/kg) the lowest value was recorded around *Tamarindus indica* (1.80cmol/kg). Magnesium level in the soils ranges from (0.48 - 1.67cmol/kg). Chimdi *et al*. (2012) reported that magnesium level of 0.5cmol/kg is considered deficient treasured in the tropics. Magnesium values obtained in this study was higher under *Eucalyptus camaldulesis* (1.35cmol/kg), while the lowest value of magnesium was obtained from soil under *Diospyros mesiliformis* (0.48cmol/kg). Potassium level in the soil ranged from (0.18 - 0.44cmol/kg). The value obtained in this study pointed out that there was significance difference in potassium level between the soils under the trees specie were by high K level was observed around *Mangifera*. indica with (0.44cmol/kg) while the lowest value was under open land (0.18cmol/kg). Sodium level in the soil ranged from (0.46 - 0.01cmol/kg) with a mean value of indicating a significant difference among the soils under the trees specie in sodium level. Chimdi *et al*. (2012) reported that soil with exchangeable sodium level > 1cmol/kg are considered as potentially Sodic. Sodium value obtained in this study was high around *Vitellaria paradoxa* (0.46cmol/kg) while the lowest was observed under *Tamarindus indica* (0.01cmol/kg).

The result of C.E.C was range (1.45 - 6.35cmol/kg) indicating a moderate C.E.C in the soil. The highest value of C.E.C was recorded with soil under *Eucalyptus camaldulensis* (6.35cmol/kg) while the lowest value was around open land (1.45). These show that there was significant difference in C.E.C level among the trees specie. This could be due to variation in tree maturity and litter fall contributed by the trees. The result of C.E.C the result confirmed the finding of Radwanski and Wickens (1981) that C.E.C value are found to be high or low depending on type of tree species and land uses.

Conclusion and recommendations

The study has shown that there were few trees species in the area. The dominant tree species was *Azadirachta indica*. Result from soil analysis showed poor soil in terms of organic carbon and total nitrogen, which are mainly the most important nutrients for plant growth and development and this could be attributed to continuous cropping taking place in the area. This may further worsen the problem of biodiversity loss in the area. Based on the findings of this research it could be recommended that Farmers in Gafan village can be advised to plant more trees especially *Eucalyptus camaldulensis* in their farmlands because it has the highest values in CEC and organic carbon for soil fertility enhancement of their farm land. It is also recommended that indiscriminate felling of trees for whatever purpose should be minimized because the litter from these trees is important in ameliorating the soil and protection of farmland.

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INCREASING HOUSE-HOLD DEMAND FOR WOOD FUEL: A GREAT THREAT TO SUSTAINABLE FORESTRY DEVELOPMENT IN NIGERIA

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Abstract
Over exploitation of forest-based products had been a serious issue and a great threat to forestry development in Nigeria. Among these forest products are the fuel woods. This comes as a result of deforestation without reforestation. Domestic cooking energy needs account for the high energy consumption in household and due to the increasing population of Nigeria, the available fossil fuels which serve as sources of cooking energy for most urban and rural dwellers have become inadequate, unaffordable and most times unavailable for the population. Fuel wood such as firewood and charcoal which is being used by 90% of rural households now becomes the highly demanded cooking fuel for households despite the health risks or environmental challenges that emanates from its use. This paper, therefore, evaluates the increasing rate of household demand both in rural and urban areas for wood fuel which is a great threat to forestry development in Nigeria. It specifically describes firewood and charcoal as the common types of wood fuels; kerosene and cooking gas as the most use fossil fuels in Nigeria. It also establishes that the increase in the price of fossil fuel leads to increase in the demand for wood fuels in Nigeria. The recent hike in wood fuel demand brought about by the high cost of fossil fuels such as kerosene and Liquefied Petroleum Gas (LPG) has led to the felling down of trees illegally by people especially those involved in firewood and charcoal productions. The paper therefore recommended that there should be increase the subsidy on fossil fuels, development of alternative cooking fuel (such as and use of agricultural and industrial wastes, forest plantations solely for the purpose of energy production should be established to prevent deforestation of forest reserves.

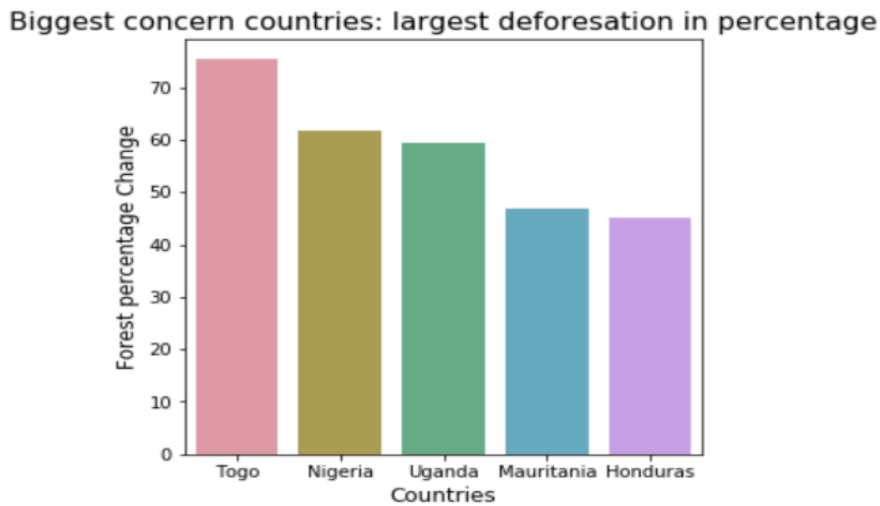
Keywords: *fuel wood, wood fuel, fossil fuel, sustainable forestry development*

Introduction

Forest is defined as a large area of land where trees and under bushes are densely dominated. It is also a large tract of land where trees and other plants are found closely growing together and forests in its natural state remain in a relatively fixed condition over a long period of time. (Lodla, 2007; Oludotun, 2011). Forest is termed as “primary” when there are no visible traces of human activities and “secondary”, when it is completely and powerfully altered by humans. Forests are called the” lungs of the earth” and it works against climate change. Nigeria's forests provide significant economic, social and ecological benefits for the people. Ecological benefits of forests include climate amelioration, carbon dynamics, biodiversity conservation, reduction in global warming, maintenance of water shed, Soil stability, erosion and desertification control, wildlife conservation and aesthetic value (FRIN, 2015). The forests have traditionally yielded a great variety of useful products or resources which are useful asset to Nigeria as well as her citizens. This is because the welfare of many Nigerians is directly or indirectly linked with the forest and its resources. (Adedayo, 2018). Over 1.6 billion people all over the world depend on forests for their livelihoods (Vedeld*et al*. 2007), and the role of forest resources on the livelihood of rural dwellers has received an increased attention during the last decade (Angelsen*et al*. 2014). Forest resources can be classified as timber and non-timber forest products (NTFPs) which include food, fodder, medicine, housing materials and fuel among others. (Smith *et al.*, 2017). Besides providing access to basic materials, forests serve as subsistence income or an “economic buffer in hard times” thereby contributing to total household and cash incomes, (Kar and Jacobson 2012).

Nigeria population is among the highest in Africa countries. The population is estimated at 218 million people spread across 923,768km^2 areas (Wikipedia, 2018). The rise in population rate of the country shows that large amount of energy will be required for meeting the energy needs at both the urban and rural areas in the country. The country is blessed with energy resources that are sustainable. The nation is also rich in conventional energy resources, these energy includes oil, natural gas, lignite, and coal. Furthermore, renewable energy sources such as wood, solar, hydropower and wind could also be found in Nigeria (Okafor and Uzuegbu, 2010). Today, consumption of energy across the globe shows that Nigeria and many indeed African nations have the lowest rates of consumption. Nevertheless, inadequate supply of energy is one of the problems facing Nigeria as a nation. This is associated with increasing energy demand, a typical nature of developing economy. There are different sources of cooking energy used in Nigeria such as; liquefied petroleum gas (LPG), kerosene, compressed natural gas and electricity. These energy sources are expensive compared to traditional fuels such as biomass and wood fuel which are available at little or no cost. In Nigeria the average daily income of more than 60% of people is less than $1 per day (Bello and Roslan, 2010) biomass and wood fuels stands as the preferred source of household cooking energy in Nigeria.

Nigeria is one of the fifteen (15) largest exporters of crude petroleum in the world, yet, a larger percentage of the country's population live in poverty. This poverty goes beyond low income, savings and growth rate but covers high inequality in terms of assets and income, basic infrastructural facilities and capabilities. Poverty is caused by low level of education, poor governance, high level of unemployment, widespread corruption amongst others.(UNDP, 2010; World Bank, 2012). A connection exists between poverty and energy which can be explained in terms of quantity and quantity of energy used.
Forestry in developing countries with Nigeria as an example has faced and currently facing several challenges such as poor funding of the forestry sub sector, inadequate information on the impact of climate change on forest and the mitigation procedures, mismanagement of forest as revealed in the high rate of deforestation through uncontrolled tree felling for domestic and commercial purposes, overexploitation of the forest resources among others (Ayeni, 2013).The fact that most trees can be used as fuel wood and charcoal production increases deforestation activities which pose great threats to sustainable forest management. Deforestation rate in Nigeria was estimated at 10 million hectares per year between the period of 2015 and 2020 compared to the yearly estimate of 16 million hectares 1990s. There is tremoudious decrease primary forest of over 80 million hectares worldwide since 1990. (FAO, 2020). Togo, Nigeria, Uganda and Mauritania are the four countries from Sub-Sahara Africa having the highest decrease in the forest cover. Among the four countries, Nigeria appears both on the list of decrease in forest area in sq. km and percent decrease. Therefore to tackle this global problem, strict actions should be taken by Nigeria.



Tyagi, (2020) Source: FAO, 2020

Sustainable Forest Management is the way through which forests are continually managed in order to achieve the stated goals and objectives of forest development without reduction of its inherent values and future productivity and without undesirable effects on the physical and social environment. It therefore follows that SFM will enhance the status of the forest to meet the forest resources needs of the people- especially the food needs of the people. (FAO, 2017). According to Lipper (2000), forests offer many benefits in terms of food production, income and protection of watershed. Therefore, deforestation and forest degradation impair the capacity of the forests to contribute to food security. This paper therefore examined energy uses among household and the hike in price of cooking energy such as kerosene and Liquefied Petroleum Gas (LPG) with implication on sustainable forest management due to the increasing demand for fossil fuel as alternative cooking energy sources.

Cooking energy
Energy is the ability or capacity to do a work. Cooking activities account for the high energy consumption in household which is a potential source of indoor air pollutants and global warming (Borisade *et al*, 2020). About 80% of the country's households depend on forest for the bulk of their domestic energy. Rural communities adjacent to forest plantations harvest wood for cooking (FRIN, 2015). Cooking energy sources can either be through wood or fossil fuels.

Table 1: Fuels and their common household uses

S/N	FUELS	HOUSEHOLD USES
➢	Firewood, animal dungs, Biomass	Cooking, water heating
➢	Charcoal	Cooking, water heating
➢	Candles	Lighting
➢	Kerosene	Lighting (wicks and hurricane lamps), cooking
➢	Biogas	Cooking
➢	Liquefied Petroleum Gas (LPG)	Cooking, lighting (less often)
➢	Diesel	Lighting lamps, electricity (diesel generators)
➢	Gasoline	Transport and electricity
➢	Distinct heating	Space heating
➢	Natural Gas	Cooking and space heating

Source: Borisade et *al.* (2020)

➢ **WOOD FUEL**

Wood energy is the energy generated from wood and wood- derived materials through combustion processes and used for energy purposes such as cooking, heating or electricity generation (WHO, 2014). Wood used as energy may come from the natural forests, trees found outside the forest, forest plantations, residues from wood harvesting and post processing wastes from wood processing industries. Wood fuels can come in three forms namely; solid wood fuels e.g. fuel wood (which is also known as firewood), charcoal, and wood pellets (e.g. chips, pellets, briquettes which are gotten from wood residues), unprocessed woody biomass (e.g. sawdust, wood shavings; gotten from the branches or other parts of a tree during wood processing. The liquid wood fuel comprises of the bio-oil, bio- ethanol/ methanol, black liquor and the wood gas is an example of the gaseous wood fuel. (FAO, 2008). Liquid and gaseous fuels derived from woody biomass are yet to be generated commercially for industrial purposes. Solid wood fuel in the form of wood pellets and wood chips, on the other hand, are used at a large scale for power generation and district heating in many industrialized countries, mainly in Europe. (FAO, 2017). The traditional household wood fuel consumption decreases as their income increases because there will be a shift to use of other fuels and electricity likewise the national consumption of wood fuel increases with increase in population growth rate. (FAO, 2008).This review will be focusing on Firewood and Charcoal as the two major wood fuels that are used in Nigeria.

Fuel Wood (Firewood)

Household utilization of firewood has been estimated to about 1.55 billion cubic meters. This estimate is based on the use of fuel wood by about 3 billion people as their primary source of energy globally. In developing countries about 2 billion rural dwellers rely solely on firewood for heating and cooking. (Borisade et *al.* 2020) Fuel wood accounts to about 80% of household energy requirements in rural areas and thus accounts for close to 10% of net national energy consumption. However, at a national scale, an estimate of about 11 million tonnes of fuel wood is consumed in Nigeria per annum (FRIN, 2015). Carbon monoxide, sulphur and nitrogen oxides which are dangerous pollutants released to the atmosphere when fuel wood is being used are as a result of the incomplete combustion of firewood. In many households, poor ventilation worsens the effects of these pollutants, and women and children are often exposed to them at significant levels for 3 to 7 hours each day (Bruce *et al.,* 2000).

Charcoal

Charcoal is another significant type of wood fuels. One of the reasons why wood is converted into charcoal is to reduce its weight with respect to its energy content and to increase its economic transportation distance. Charcoal has a heating value twice as much as fuel woodon an equal weight basis.FAO, 2019 noted that of all the woods used as fuels worldwide, about 17 percent is converted to charcoal. Charcoal production is expected to increase continually in the coming decades because it generates income for more than 40 million peopleeven though the sector is informal.

Charcoal consumption is often linked to lack of modern alternatives but all over the world, electrified regions are still using charcoal as an energy source. In Brazil, the world's largest producer and consumer of charcoal, for example, more than 90% of the population has access to electricity,yet residential consumption has persisted at 9.7% of the country's total charcoal production. (Chidumayo and Gumbo, 2013). Despite Mainland China's access to widespread electricity, it also features in the world's top 10 charcoal producers (FAO, 2019). Germany, which has diverse financial assets of modernenergy resources, is still the world's biggest importer of charcoal (FAO, 2019).The global charcoal importsand exports are estimated at US$1.16 B. From 1993–2017, the world's top 10 charcoal-producingcountries generated an average of 24.5 Mt of charcoal annually, of which more than 50%were produced by Brazil, Nigeria, and Ethiopia . With the exception of Nigeria and Mainland China, top charcoal producers are not necessarily the leading exporters of charcoal. (Macromarket; FAO, 2019).

Advantages of wood fuel

i. Fuel wood is the most locally available fuel.
ii. Fuel wood is the most affordable fuel for cooking and heating especially among the low income households.

iii. Sustainable Development Goals could be enhanced by wood fuel energy
iv. The wood energy sector contributes to SDG8 (economic growth and employment); the modernization of the wood energy value chain would have considerable economic impacts and create many jobs, especially in rural areas. FAO has estimated that 195 million people in Africa are employed in the wood energy sector on a full-time or part-time basis – the equivalent of 45 million full-time jobs
v. Wood energy can play an important role in combating climate change.

Disadvantages of woodfuel

11. Unsustainable and illegal production leads to deforestation, forest degradation and in some areas, wood fuel scarcity.
12. Another problem associated with the traditional wood fuel sector is indoor air pollution due to the use of inefficient woodstoves, wet firewood or charcoals.
13. Health problems arises from inhaling smokes from burning, charcoal particles etc
14. Fuel wood collection can impose a disproportionate work burden on women and children.

- **FOSSIL FUEL**

These are non renewable energy resources gotten from the altered remains of living organisms buried by sediments and exposed to elevated pressures and temperatures for millions of years. These resources are classified into three namely; petroleum (or crude oil), natural gas and coal. They are widely though not uniformly distributed in the earth (Gerali, 2020).

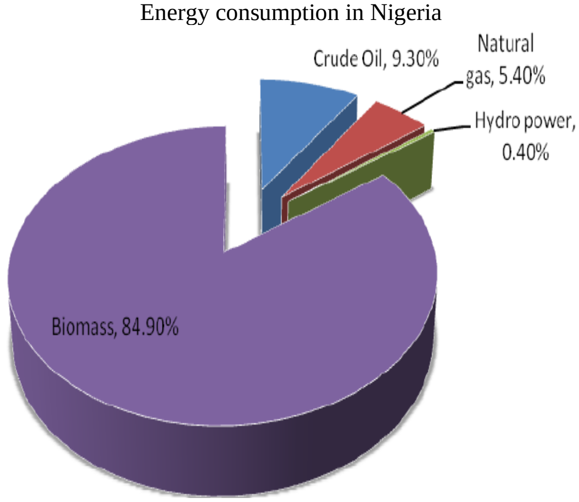
Kerosene

Kerosene, also known as paraffin is a transparent liquid fuel produced from coal (coal oil), with a mixture of hydrocarbon chains 6 to 16 carbons in length. (U.S. Environmental Protection Agency; EPA, 2016). Globally, an estimated 500 million households still rely on kerosene or other liquid fuels for lighting, corresponding to 7.6 billion liters that is consumed annually (Mills, 2005). Some notable international agencies have in the past treated kerosene as a “clean fuel” (ESMAP 2003) while some researchers treated it as a “polluting fuel”which was grouped with other known sources of air pollution e.g. coal and biomass. (Wichmann et al, 2006). The use of kerosene for cooking has greatly increased in many developing countries especially in urban areas where electricity and Compressed Natural Gas (CNG) are unreliable and expensive and Biomass is not readily available.

Liquefied Petroleum Gas (LPG)

Cooking fuels, most especially the liquefied petroleum Gas (LPG) and natural gas are the cooking fuels of choice in most countries (Parikh, 2010). LPG and natural gas provides higher energy efficiency than traditional fuels; and it is cleaner and more ozone-layer friendly. The causes of low consumption of LPG in Nigeria found in the literature include household income, infrastructural challenges, subsidy on kerosene, the perceived higher cost of LPG, and safety issues that have led to various government interventions through policies and plans (Ige, 2009).

Energy consumption in Nigeria



Source: IEA, 2017.

Shifts in household’s choice of cooking energy

The fundamental energy needs of most household are for cooking and lighting. Energy consumption patterns in the world today shows that Nigeria and indeed African countries have the lowest rates of consumption. Nigeria is suffering from an inadequate supply of usable energy due to the rapidly increasing demand, increase in population rate among others which is typical of a developing economy. The rural dwellers depend to a large extent on the traditional sources of energy for their domestic energy requirements while the majority of the urban dwellers depend on traditional energy sources and fossil fuels. (Iro and Danlami, 2022). The Nigerian energy sector is not well developed and one of the most inefficient sectors because people do not have access to reliable and affordable energy despite the enormous energy sources available. Therefore, the unavailability and unaffordability of these cooking energy sources pose a serious threat to forestry development in Nigeria.

The “energy ladder” is a simple model used to describe the hierarchy of household energy options characterized by attributes such as cost, cleanliness, energy efficiency and convenience. It also means that with increasing income, people move up the energy ladder from firewood to charcoal or kerosene and then to LPG/ natural gas, or electricity. Household tend to move from cheapest to least convenient fuel (biomass) to more convenient and normally more expensive ones (charcoal, kerosene) and eventually to the most convenient and usually most expensive type of energy (LPG, natural gas, electricity). (Masera et al., 2000, Arnold *et al.*, 2006). The use of multiple fuels or use of combination of fuels is known as “fuel stacking”. Households partly switched from one type of fuel to the other or use of multiple fuels. Fuel stacking occurs due to three major factors namely; high cost of modern energy sources; cultural preferences(which includes familiarity with existing fuels) and to avoid total dependence on one fuel evident from price, demand and supply vulnerability. (Heltberg, 2005; Masera *et al*., 2000).The literatures on fuel choice had shown that many factors other than income could influence the household fuel adoption decision. The main among these are the household size, gender composition, location, cooking habitat, gender of the household head, age, education, availability of fuel alternatives and accessibility including cooking utensils as well as the degree of the development of fuel markets and wage labour market (Moses, 2006). They may choose a combination of high-cost and low-cost fuels, depending on their budgets, preferences and needs (World Bank, 2003). Ease of access and consistent availability of fuels are important factors that determine the extent and or permanence of fuel switching in any household (Démurger and Fournier, 2010).

The energy ladder hypothesis is one of the most common conceptualizations of energy use dynamics among households. It has also been revealed through literatures that household energy demand and choice has shownthat households in transition (that is, those between low income and high income) consume transition fuels such as charcoal and kerosene. While low income households use biomass fuels, higher income households consume energy that is cleaner and more expensive such as liquefied petroleum gas and electricity. (Heltberg, 2005).

The recent hike in prices of commodities in developing countries most especially Nigeria has led the low and transition income earners to be living below the standard. This low living standard induces greater dependence on firewood and other biomass fuels owing to a combination of income and substitution effects (Baland *et al*., 2007). The use of wood fuels such as charcoal and fuel wood is now found in urban centers too as there has been a shift in the use of kerosene and Compressed Natural Gas. The shift is against Bhattarai, 1998, who asserted that even if the population in urban centers will be growing rapidly in the coming years, the demand for charcoal and other biomass fuels is not likely to increase accordingly due to peoples’ changing preferences. In Nigeria presently, the shift in the type of cooking energy used due to the increase in price of fossil fuels has also led to an increase in the demand and price of wood fuels and this has led to illegal deforestation of forests which is a serious threat to sustainable forestry in Nigeria.

Implication of increasing household demand for fuel wood on sustainable forest management in Nigeria

The cost of cooking gas and kerosene is fast rising. This has gone beyond the reach of common man despite the Federal Government declaration on making the products available for household usage and a decade of cooking gas with Central Bank of Nigeria (CBN) setting up a ₦250 billion fund to expand the usage of the product across the country. Due to high increase in the price of cooking gas, most household who had said goodbye to firewood and charcoal usage have embraced it again. This has a great implication on forest management. This means that the demand for firewood and charcoal which has been on the increase before will continue to be increased, more trees will be felled and resulted to high rate of deforestation (Odunwole *et al*., 2017). More than 90 million of Nigerians live below one dollar per day this reflect high incidence of poverty. Therefore, the upward shift in the price of cooking gas and kerosene has made the products to become luxury in the midst of unemployment, high inflation rate and the un addressed effect of COVID-19 pandemic. This implied that if the trend in the price of cooking gas and kerosene is not checked and the demand for wood fuel continue to increase reduction in forest cover will continue and its adverse effect on environment is imminent (FRIN, 2015).

Conclusion and recommendations

It has been established that household demand for fuel wood is on the increase. The recent hike in wood fuel demand brought about by the high cost of fossil fuels such as kerosene and Compressed Natural Gas (CNG). This has a great implication on forest development as this would continue to result to the felling down of trees, hence, high rate of deforestation. This study therefore recommends that there should be development of alternative cooking fuel such as the use of agricultural and industrial wastes; forest plantations should be established solely for the purpose of energy production; supportive laws, regulations, policies (those governing wood fuel production, trade and consumption) and information should be disseminated to forest owners, entrepreneurs and actors involved in forest and forestry development.

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MITIGATING THE EFFECTS OF GOLD MINING ON FOREST–BASED RAL LIVELIHOODS IN BIRNIN-GWARI LOCAL GOVERNMENT AREA, KADUNA STATE, NIGERIA

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Abstract
*This study was carried out to evaluate the mitigations of mining effects on forest–based rural livelihoods in Birnin-Gwari Local Government Area, Kaduna State***,** *Nigeria***.** *Five (5) districts of mining activities were selected within the Government Area. Primary data were generated using questionnaires for this. A total of One hundred and twenty (120) questionnaires were distributed. Results revealed that adults from above 46 years of age were mostly (29.9%) affected by mining in the area. Also, (32.65%) of the affected people had secondary education and were majorly (62.50%) farmers. The negative effects of mining activities on the forest based livelihood activities of the respondents includes: (17.7%) reducing soil fertility> (16.4%) soil erosion effects > (15.3%) loss of Wild animals> (9.1%) scarce forage > (8.0%) loss of NTFPs and reduction in agricultural land. The mitigation measures identified includes: reclamation through state tree planting programme, waste management, water treatment and were achieved via different methods. It was concluded that the mining and exploration of gold poses great dangers to mining workers and neighborhood communities especially whose livelihood activities are forest based. We recommend that emphasis be shifted towards effective utilization of the mined resources in order to minimize the rate of mining induced de-vegetation and deforestation.*

Keywords: *Mining, Mitigations, Forest- based -livelihoods and Community dwellers.*

Introduction

Nigeria is endowed with abundant mineral resources, crude oil, gold, diamond, salt, iron ore, natural gas, phosphate, coal and nickel among others. In Kaduna State, major gold fields are located in several communities including: Birnin-Gwari ,Jama'a, Igabi, Kajuru, Kachia, Ikara, Makarfi, Giwa, Sanga and Kagarko (Kaduna State Water Board, 2004). Mineral exploration and exploitation in Birnin-Gwari began in the 1980s, though evidence suggested that local people used traditional methods of mineral mining before the colonial administration.

Mining has a number of activities, each of which has potentially-adverse impacts on the natural environment, society and cultural heritage, the health and safety of mine workers, and communities based in close proximity to operations (Akabzaa, 2000). The alteration to local ecology, especially soil and vegetation constitute costly disruptions on rural communities' livelihoods that depend largely on the land. Therefore, this research seeks to investigate the mitigations of mining activities on forest rural-based livelihoods in Birnin-Gwari Local Government Area, Kaduna State.

Materials and method

Study Area

Birnin-Gwari Local Government Area lies in the Western part of Kaduna State and forms a significant part of the state borders with Zamfara and Kastina States. It lies within the Northern Guinea Savanna. The rainfall ranging between1000mm-1300mm per annum, the 'sub humid' zone receives an annual rainfall of 600mm-1000mm per annum (KSWB Birnin-Gwari office, 2004). The major occupation in this LGA is farming and livestock production (animal rearing). The coordinate of the study area is described in the table below.

Table1: Mining Community Latitude Longitude

Community	Latitude	Longitude
Old Birnini Gwari	$10^{0}39^{I}$N	6^{0} 56^{I}E
Bugai	10^{0} 45^{I}N	6^{0} 30^{I}E
Damari	$10^{0}33^{I}$N	6^{0} 52^{I}E
Kungi	10^{0} 36^{I}N	6^{0} 44^{I}E
Dagara	10^{0} 31^{I}N	6^{0} 35^{I}E

Field Survey, 2019

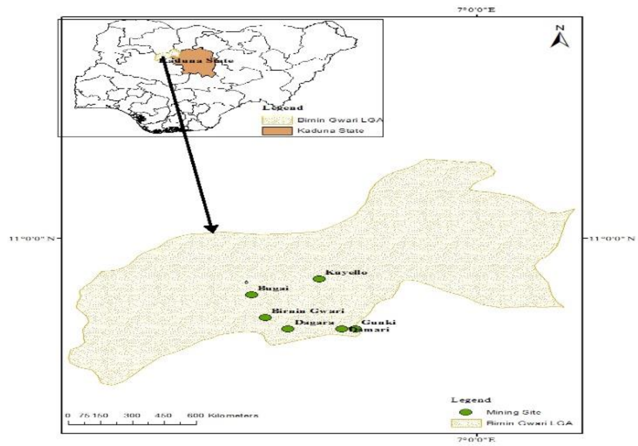

Fig 1: *Map of the Birnin Gwari Local Government showing the study Area*

Method of Data Collection

Primary and secondary data were used for this study. The primary data were generated through the use of structured questionnaires. Information on land reclamation and mitigation strategies employed in the Study Area was sourced through questionnaires as evidence of reclamation and the extent of corrective measures towards recovering the mined area.

Sampling Techniques

The six disstricts of gold mining activities in Birnin-Gwari Local Government Area include: Old Birnin-Gwari, Damari, Bugai, Dagara, Kungi and Kuyello. However, Kuyello could not be accessed due to communal crises and insecurity. A total of one hundred (100) questionnaires were used for data collection such that twenty (20) questionnaires each were randomly distributed in each of the five (5) selected districts, and ninety-eight (98) questionnaires were retrieved for statistical analysis.

Data Analysis

Descriptive statistics including graph, frequency table and percentage were used for the data analysis.

Results

Table 2: Demographic Characteristics of the Respondents

S/N	Variance	Frequency	Percentage
1	**Age**		
	16 – 20	7	7.07
	21 – 25	10	10.10
	26 – 30	13	13.13
	31 – 35	20	20.20
	36 – 40	10	10.10
	41 – 45	10	10.10
	46 & above	29	29.29
2	**Education**		
	Non-formal	19	19.39
	Primary	29	29.29
	Secondary	32	32.65
	Tertiary	17	17.35
	Adult education	1	1.02
3	**Sex**		
	Male	88	88.89
	Female	11	11.11
4	**Occupation**		
	Forestry	18	18.75
	Farming	60	62.50
	Civil service	8	8.33
	NTFPS Collection	1	1.04
	Timber Contraction	1	1.04
	Minning	5	5.21
	Others	3	3.13
	TOTAL	**98**	**100.00**

SOURCE: Field Survey, 2019

Table3: Identify Gold Mining Mitigations and Reclamation Strategies in the Study Area

S/N	Mitigation Effect	Mitigation Criteria / indices	(Freq.) Bugai	Kuyello	Damari	O/Birnin-Gwari	Total	Percentage (%)
1	**Reclamation**	Re – establishment of vegetation	2	3	3	5	13	18.06
		Refilling of opened pits	4	3	4	6	17	23.61
		Slope and topography modification	3	6	4	5	18	25.00
		Organic soil amendment	4	5	3	5	17	23.61
		Cultivation of tolerant species (Rehabilitation)	2	7	1	2	7	9.72
		Total					**72**	**100**
2	**Waste Management**	Alternative use of dug out soil from gold mining for other purpose	6	4	4	6	20	32.26
		Land use classification (Local)		1	2	2	5	8.06
		Digging of water – way (erosion ways)	3	1	4	6	14	22.58
		Barigation and Isolation of stream use for gold washing	4	2	-	6	12	19.35
		Alternative use of dugout soil for road construction	2	5	1	3	11	17.74
		Total					**62**	**100**
3	**Water Treatment**	Addition neutralizing agent to mine polluted well	3	2	2	4	11	25.00
		Legislation against consumption of gold polluted water	2	4	3	6	15	34.09
		Isolation and barigation of mining polluted stream	-	1	-	2	3	6.82
		Organic treatment of polluted water (Using plant product)	4	2	4	5	15	34.09
		Total					**44**	**100**
4	**shutting by laws and local pressure**	Shut – down of mining operation monitoring	4	2	6	3	15	32.61
		Establishment of post -closure supervision	5	4	-	6	15	32.61
		Seizing of license from gold mining	7	2	-	7	16	34.78
	TOTAL						**46**	**100**

SOURCE: Field Survey, 2019

Table 4: NEGATIVE EFFECTS OF GOLD MINNING ON RURAL BASED FOREST DEPENDANT LIVELIHOOD ACTIVITIES

	LFS		**LWA**		**ERSN**		**SOF**		**RFW**		**LNTFPS**		**LAT**		**EMV HT**		**Poor Fruit**		**LTPDTS**		**AOA**		**Total**
LOCATION	F	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**Percentage (%)**
BUGGAI	5	20.8	8	20.8	5	20.8	3	12.5	1	4.2	1	4.2	1	4.2									100
OLD B/GWARI	9	14.1	6	14.1	8	12.5	7	10.9	4	6.3	5	7.8	5	7.8	4	6.3	4	6.3	7	10.9	5	7.8	100
DAGARA	3	11.5	4	15.4	7	26.9	1	3.8	2	7.7	2	7.7	2	7.7	1	3.9	1	3.9	2	7.7	1	3.9	100
BAMARI	5	20.0	5	20.0	3	12.0	2	8.0	2	8.0	3	12.0	3	12.0	0		1	4.0	1	4.0			100
KUNGI	8	21.6	4	10.8	6	16.2	3	8.1	4	10.8	3	8.1	3	8.1	2	5.4	1	2.7	1	8.1			100
TOTAL	30		27		29		16		13		14		14		7		7		13		6		100
PERCENTAGE	17.1		15.3		16.4		9.1		7.4		8.0		8.0		4.0		4.0		7.4		3.4		100

KEY:

- LFS = Loss of Fertile Soil RFW= Reduced Fuel Wood
- LNTFPS = Loss of Non Timber Forest Products SOF = Scarcity of Forest
- LWA = Loss of Wild animals ED = Excessive Dryness
- ERSN = Erosion
- LAL = Loss of Agricultural Land PF = Poor Fruiting
- LTPATS = Loss of Timber products AOA = Lost of Agricultural Land

Discussions

Characteristics of the Respondents

Results of the socio-economic characteristics of the respondents are represented in table 2. Respondents within the age of 46 and above were the highest (29.9%) among the age categories in the study area. This is followed by those between the ages of 31 and 35 representing 20.20% of the population. Respondents of the ages 21 -25, 36 - 40 and 41- 45 each represented 10.10% of the population. It could be deduced from this study that the majority of the respondents are between the age of 46 and above. This age group of respondents are those whose daily activities are directly associated with the studied environment; farming, mining, fishing, hunting and marketing activities. Moreover, these categories of people are full of responsibilities of caring for their families. Hence, they are the group whose sources of livelihood were mostly affected positively or otherwise by mining activities. Regarding the educational distribution of the respondent, a good number of the respondents had secondary education (32.65%). about (29.59%) of the respondents had primary education, 17.35% of the respondents had tertiary education. This indicates that the majority of the people living around and or whose work (involved) directly or indirectly with mining operations are literate, Although, this does not mean that majority of the respondents are educated or literate enough to know the implication of mining on their environment whether socially, culturally and ecologically. Hence, their consciousness of its financial benefits makes the respondents concentrate on this activity; this is why they damage the environment the more in sourcing for money in order to maintain their socio- economic and financial wellbeing even at the expense of ecosystem.

Result shows that majority of the respondents are male and this represent 88.89%. This is an indication of the tedious nature of the job, it is the reverse of the popular saying "what a man can do a woman can do better" as only few women with petty trading, farming etc were identified. Though, this does not mean that mining doesn't contribute to the socio-economic wellbeing of female respondents in terms of income generation. Occupationally, the majority of the people living in and around the mining site are farmers, this represent 62.50% of the population. Many of these people, especially the able men among them also partake in other activities either as job men in mining, and those who intermittently engage in mining to support their major source of livelihood, this because the communities are dominated by low income earning peasant farmers whose major livelihood activities are being affected. About 18.75% of them were miners, dealing with mineral extractions (majorly gold), while 5.21% of them were foresters. Others were civil servant, NTFPs collectors, and timber contractors represent 5.21% and 1.04% of the surveyed population.

Negative impacts of Gold mining activities on Rural Based Livelihoods Activities

The negative impacts of gold mining in the various districts selected for this study were similar, ranges from; loss of wild animals, loss of soil fertility, erosion, scarcity of forage, reduction of fuel wood, loss of other Non Timber Forest Products, loss of Agricultural land, environmental heat, and mining induced bad weather. Though, the extent to which the respondents reacted to the experience of these effects were differs from district to the other. See table 3 above.

The gross analysis of the negative impact of gold mining on the livelihood activities of the respondents is expressed in percentages in table 4 above. In the overall, majority of the respondents (17.7%) identified the major impact of mining as reducing soil fertility> (16.4%) soil erosion effects > (15.3%) Loss of Wild animals> (9.1%) scarce forage > (8.0%) loss of NTFPs> and reduction in land size for farming activities > (7.4%) stated loss of timber and reduction in the availability of fuel wood , (4.0%) environmental heat, the remaining (4.0%) relates the effects of gold mining to bad weather (8.0%). Loss of soil fertility was the greatest, this could be traced to combined effects of deforestation, de-vegetation and the excavation of soil surface, which later resulted in erosion which not only led to the washing away of topsoil but also exposure of heavy metals. These exposed heavy metals are washed (and or) blown down the streams leading to pollution of water bodies which has detrimental effects on aquatic and terrestrial lives dependent on the streams. This concurs with World Bank, (1995) which stated that the principal environmental hazards caused by small-scale mining activities are mercury pollution from gold processing and land scarcity. Cobbina *et al*., (2012) also reported that generally, occupant children and adults are at risk of exposure to mercury in shallow dug-wells and dugouts in the Nangodi area which is very destructive to human life. Essumang *et al*. (2007) , Obiri *et al*. (2010) Paruchuri *et al*. ((2010) reported that in recent times, there have been cases of waterlogged pits, soil erosion, pollution of fresh vegetables and food items, rivers and other source of drinking water for communities in mining area. **Identified Mitigation Strategies in the Study Area.**

Four (4) major mitigation strategies were identified in the study areas. These major identified strategies include: i) Reclamation, ii) Waste Management, iii) Water Treatment, iv) Closure by Laws and Local Pressure. These mitigation strategies were achieved through different methods in the five districts.

Reclamation strategies: This was achieved through several methods, the methods include; refilling of open casts or pits, topography modification, organic soil amendment, and re-vegetation. Above eighteen percent (18.06%) of respondents identified re-vegetation as their way of reclaiming the old mined area, 23 .61% of them recognized refilling of open pits as the reclamation strategy used for mitigating the effects of gold mining on humans and her environment, 25.00% used slope and topography modification. Organic mineralization or amendment of the polluted soil was reported by 23.61% of them, while above nine percent (9.72%) of them reclaimed mined site through the cultivation of tolerant species such as: *Khaya senegalensis, Azadirachta indica, Mangifera indica, Eucalyptus camaldulensis* etc

Waste Management: There were several methods of waste management techniques employed in the area. Some of these include the alternative use of dugout soil for other purposes (32.26%). For instance, in road construction, block molding as revealed by them, 8.06% of the respondents identified that the area where gold was dominated have been purely designated for mining purposes while agriculture and residential area were classified out of the mining surrounding. Over (22.58%) of the respondents identified digging of waterways and the channelization of the mined – site run-off to designated dam and isolated river normally used for gold washing in order to protect other adjacent water body and farmland from pollution. Above nineteen percent (19.35%) of them states the isolation of rivers where mined gold is normally washed as a way to mitigate the negative effect of mining in the study area.

Water Treatment: Based on the investigation, results show that (25.00 %) of the respondent identified the addition of neutralizing agent to mine polluted wells, 34.09 % attested to the use of legislation to guide against the consumption of gold mining polluted well and another 34.09 % percent usually applied organic method of water treatment on their source of useable or drinkable water due to the hazardous effect of mining on the community dwellers.
Also, shutting down by laws and local pressure was adopted in the study area. More than thirty-two percent of the respondents identified the use of local laws to shut down mining operations. Fifteen percent (15.00%) of them identified establishment of -post-closure supervisory teams, 34.78 % of them recognized the forceful termination) of mining license by the Government due to the activities of the pressure groups within the mining communities as measures towards mitigating the effects of gold mining.

Conclusion
From the results of this study, it could be concluded that the mining and exploration of gold pose great dangers with potential health risks to mining workers and neighbourhood communities, especially those whose livelihood activities are forest based such as; fuel wood collection, sources of herbs, fruits and seed gathering, harvesting of timber and other wood types, collection of non-timber forest products etc. Also, Government, individuals and mining companies displayed various mitigations and correctional efforts towards minimizing the effects of mining. Despite these efforts, the effects of miming on forest-based livelihood activities in the study area are still enormous.

Recommendation
Emphasis should shift towards effective utilization of the mine resources to minimize waste. This could be achieved by enhancing the local miners to have sophisticated sorting equipment, and also educating the miners on how to convert the enormous wastes to by-products. The miners should be sensitized to cover the open pit after mining to reduce mining-induced danger to vegetation, inhabitants and the neighbourhood of the mining location. Safe disposal of unavoidable waste in a stable and aesthetically acceptable structure must be enforced through legislation.

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DIMORPHIC TRAITS OF FEMALE *GARCINIA KOLA* (HECKEL) TREE: CASE STUDY IN THE RAINFOREST-MANGROVE AREA OF ONNE RIVER STATE

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Abstract
Sexual dimorphism and reproductive allocation studies often require the knowledge of the dimorphic traits required to *differentiate the sexes especially at seedling stage. A study was therefore designed to investigate the dimorphic traits of female Garcinia kola in the rainforest-mangrove area of Onne, Rivers state. Three (3) female trees that have been observed to flower regularly for three years were randomly selected for the study: a total of 100 inflorescence was randomly collected from the crown of each tree and 500 flowers randomly assessed within the period of four (4) flowering seasons: floral sex assessment was done visually and with a hand magnifying lens. Three (3) flowering twigs were randomly collected from the crown of each tree and twenty-seven (27) reproductive and vegetative traits assessed per tree. Traits were subjected to principal component analysis (PCA) to understand the combination of traits most relevant for sexual differentiation of the female tree. Five (5) principal components with eigen Value greater than 1 were extracted. Component one explained 39% of the variation, component two 29%, component three 11%, component four 9%, and component five 4%; communality for almost all the factors was close to 1 indicating high level of relationship between factors. Each of the components provides an insight into the combination of traits that that are important to the estimation of floral dry weight, vegetative dry weight, reproductive allocation and sexual differentiation of the tree.*

Keywords: *components, sexual, traits, vegetative, reproductive.*

Introduction

Investigating correlations among dimorphic floral traits may provide insights into how selection shapes patterns of dimorphism in dioecious and monoecious populations (Yakimowski *et al.* 2010). Patterns of dimorphic behaviour in plants are important to the understanding of reproductive behavioural and evolutionary studies but equally needed for early differentiation of seedling gender in the nursery particularly in dioecious species. Dimorphic traits that are identifiable or pronounced at early stage are required to separate the sexes at an early stage.

Sexual dimorphism studies related to plant sex mediated response to resources such as light and nutrients or growth rate and dry weight can be of great help in finding the combination of dimorphic traits needed to early plant gender differentiation in the nursery. For example, Tonnabel *et al.* (2019) investigating sex-specific selection on plant architecture through 'budget' and 'direct' effects in experimental populations of a wind-pollinated herb *Mercurialis annua* documented some correlations of dimorphic traits such as high-density planting favouring male sex selection while low density favoured female sex selection. The particular response of different species to sex selection at low and high-density planting nevertheless needs to be investigated as plants respond differently to different environmental niches (Delph, 1996). This divergent dimorphic behaviour of different sexes has been reported by some authors; males trees sometimes are smaller in size in (Delph, 1999), show lesser natural defence (Avila-Sakar and Romanow 2012), and express lower rates of gas exchange and lower water-use efficiency (Dawson and Geber 1999) in comparison to females while sometimes male and female trees different in longevity (Delph, 1999).

Morphological differences between male and female trees could arise due to the variations in the physiological requirements for the fulfilment of the particular sex function (Downhower 1976; Freeman et al. 1976; Harris and Pannell 2008). For example, female trees in preparation for their reproductive function of fruit and seed production may acquire vegetative traits that enable the deployment of carbon and water (Obeso 2002; Burd 1994; Dawson and Geber 1999). Sexual dimorphism could also arise due to the variation in the type of resources required for the different sex functions which in turn results in the acquisition of morphological traits that enhance the harvesting of the resources (Conn and Blum 1981; Zimmerman and Lechowicz 1982; Lovett-Doust *et al.* 1987; Dorken and Barrett 2004; Herlihy and Delph 2009; Harris and Pannell 2008; Teitel *et al*. 2016; Tonnabel *et al*. 2017). There is also the element of sexual dimorphism arising due to sexual or fecundity selection or even heredity (Delph and Ashman 2006; Delph *et al.* 2011; Moore and Pannell 2011). There is therefore the need to investigate the combination of traits that can help to separate the sexes at the early nursery stage especially for dioecious and subdioecious species. A study was therefore designed to investigate the dimorphic traits of female *G. kola*.

Materials and methods

Study area

The study was conducted at the Swamp Forest Research station, of the Forestry Research Institute of Nigeria. The area is located on Latitude 4°42´ - 10°32´N and Long. 7°10´ - 32°46´E, with 2400 mm mean annual rainfall, relative humidity 78% in February (dry season) and 89% in July (rainy season), mean annual temperature 27°C in February and 25°C in July, soils are ultisols derived of coastal sediments, highly acidic (pH 4.4), with low fertility, and classified as siliceous, isohyperthermic, typic paleudult, usually deep, chemically poor, well drained with good physical properties. The vegetation is a rainforest-mangrove transition forest zone.

In this preliminary study three (3) female trees that have been observed to flower regularly for three years were randomly selected for the study: a total of 100 inflorescence was randomly collected from the crown of each tree and 500 flowers randomly assessed within the period of four (4) flowering seasons: floral sex assessment was done visually and with a hand magnifying lens.

Three (3) flowering twigs were randomly collected from the crown of each tree and the following twenty seven (27) reproductive and vegetative traits assessed per tree: number of twig per branch (counted), twig length (cm), number of leaf per twig (counted), inflorescence length (cm), inflorescence width (cm), number of flower bud per inflorescence (counted), leaf length (cm), leaf width (cm), petiole length (mm), petiole width (mm), number of inflorescence per twig (counted), total number of branches per tree (counted), branch diameter (mm), pedicel length (mm), pedicel width (mm), sepal length (mm), sepal width (mm), petal length (mm), petal width (mm), stigma length (mm), stigma width (mm), style length (mm), style width (mm), ovary length (mm), reproductive allocation (%), floral dry weight (g), and vegetative dry weight (g): measuring instruments used were veneer calliper and ruler graduated in millimetre and centimetre respectively. Twig was separated into floral parts (flowers, and inflorescences) and vegetative parts (leaves and stem) and air-dried at ambient temperature until constant weigh was achieved. Data was analysed with the aid of principal component analysis (PCA). Reproductive allocation (RA) was calculated viz (Shivannah and Tandon 2014):

$$RA = \frac{Floral\ dry\ weight}{Vegetative\ dry\ weight} \times 100 - 1$$

Results and discussions

Using Kaiser rule (Johnson and Wichern, 1982) five (5) principal components with eigenValue greater than 1 (fig. 1) were extracted. Component one explained 39% of the variation, component two 29%, component three 11%, component four 9%, and component five 4%; communality for almost all the factors was close to 1 indicating high level of relationship between factors (table 1). Each of the components provides an insight into the combination of factors that that are important to the estimation of floral dry weight, vegetative dry weight, reproductive allocation and sexual dimorphic characters of the tree.

Component one showed a significant high loading of reproductive allocation, vegetative dry weight, and floral dry weight along-side factors such ovary length, style length and width, stigma length and width, petal length and width, sepal length and width, pedicel width, number of twigs per branch, petiole width, number of inflorescences per twig and branch diameter: Component two shows a significant high loading of reproductive allocation along-side factors such as ovary and style length, petal length and width, sepal length and width, pedicel length and width, number of twigs per branch, number of inflorescences per twig, twig length, number of leaves per twig and inflorescence width: Component three showed significant high loading of branch diameter and total number of branches along-side factors such as petiole length, inflorescence width, twig length and number of leaves per twig: Component four showed significant high loading of petiole length and width along-side factors such as number of flower bud per twig, inflorescence length and width, and number of leaves per twig; while, component five showed high significant loading of branch diameter along-side factors such as leaf length, width, and inflorescence width (Table 1). While components one and two explained more of the combination of factors important to reproductive allocation estimation, components three, four and five relates more to sexual dimorphic characters of the tree.

Sexual dimorphism is a factor frequently associated with dioecious and subdioecious species (Delph *et al*., 1996; Eckhart, 1999). In studying sexual dimorphism authors often use different floral and vegetative traits or factors. For example, Yakimowski *et al.* (2010) investigating floral dimorphism in plant populations with combined versus separate sexes measured factors such as total number of flowers per inflorescence, daily display size (number of flowers in anthesis), perianth diameter, and leaf mid-vein length of the subtending leaf to the inflorescence. Asouad *et al.* (1977) studied the reproductive capacities in the sexual forms of the gynodioecious species *Thymus vulgaris* using factors such as number of inflorescences per plant, length of styles, corolla size and total number of pollen grain found on the stigma. Understanding the combination of vegetative and floral traits that best differentiate the sexes in dimorphic populations is therefore a central issue in any study of sexual dimorphism (Delph 1996). This is because in plants sexual dimorphic features may not readily be identifiable (Harris and Pannell 2008; Renner 2014). Hence, plant reproductive biologists have been working to trace patterns of sexual differentiation in dimorphic populations. Sexual dimorphism has been traced to traits and behaviours such as flower size, time and duration of flowering, physiology, allocation of resources to vegetative, fruit, seed, pollen production, size of ovary and floral production etc (Bawa and Webb, 1983; Agrawal *et al*., 1999; Mazer *et al*., 1999; Venable and Lloyd, 2004; Vilas and Pannell 2011).

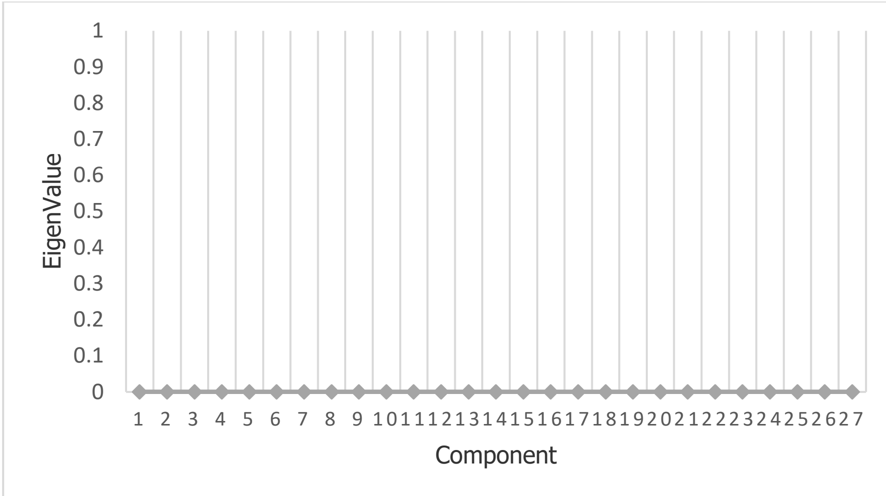

Figure 1. Components and eigen values

Table 1. Principal components extracted and percent variation explained, communality, and specific factor of variation.

Traits/ %	**PC**1 39%	**PC** 29%	**PC**3 11%	**PC4** 9%	**PC**5 4%	**Comm**	**Specific**
Twig Length	-0.184	**0.434**	**0.803**	-0.099	0.083	0.883	0.117
Leaf per Twig	-0.149	**0.395**	**0.572**	**-0.491**	0.147	0.769	0.231
Inflorescence length	-0.259	0.039	-0.284	**-0.893**	0.220	0.996	0.004
Inflorescence width	0.043	**0.337**	**-0.685**	**-0.508**	**0.310**	0.938	0.062
No of flower bud	0.284	0.016	0.102	**-0.854**	-0.036	0.822	0.178
Leaf Length	0.204	-0.447	-0.208	-0.006	**-0.829**	0.972	0.028
Leaf Width	0.291	-0.190	0.098	0.190	**-0.885**	0.949	0.051
Petiole Length	-0.027	-0.285	**0.739**	**0.317**	0.025	0.729	0.271
Petiole Width	**0.445**	0.245	-0.201	**0.665**	-0.038	0.741	0.259
Inflorescence per twig	**0.612**	**-0.754**	-0.037	0.040	-0.201	0.986	0.014
Twig per branch	**0.590**	**0.682**	0.066	-0.215	0.140	0.883	0.117
Number of branches	-0.096	-0.088	**0.824**	-0.145	0.040	0.719	0.281
Branch diameter	**0.480**	0.147	**-0.555**	0.148	**-0.541**	0.875	0.125
Vegetative dry weight	**-0.954**	0.183	0.075	-0.026	0.203	0.991	0.009
Floral dry weight	**-0.963**	-0.163	0.145	-0.069	0.116	0.993	0.007
Reproductive allocation	**0.535**	**-0.742**	-0.006	0.029	-0.202	0.879	0.121
Pedicel length	-0.177	**-0.972**	0.046	0.001	-0.104	0.989	0.011
Pedicel width	**0.356**	**0.925**	-0.062	0.009	0.069	0.991	0.009
Sepal length	**0.356**	**0.925**	-0.062	0.009	0.069	0.991	0.009
Sepal width	**0.867**	**0.479**	-0.098	0.040	-0.073	0.998	0.002
Petal length	**0.356**	**0.925**	-0.062	0.009	0.069	0.991	0.009
Petal width	**-0.612**	**0.754**	0.037	-0.040	0.201	0.986	0.014
Stigma length	**-0.969**	-0.171	0.099	-0.048	0.132	0.997	0.003
Stigma width	**-0.969**	-0.173	0.099	-0.048	0.132	0.997	0.003
Style width	**-0.969**	-0.172	0.099	-0.048	0.132	0.997	0.003
Style length	**0.356**	**0.925**	-0.062	0.009	0.069	0.991	0.009
Ovary length	**-0.831**	**-0.543**	0.096	-0.037	0.059	0.998	0.002

* Factor loading≥0.3=significant; Trait=vegetative and reproductive traits; %= percentage proportion of variation explained per component; PC=principal component; Comm=communality of variation of traits; Specific=variation unique to a trait.

Conclusion

Five (5) principal components with eigenValue greater than 1 were extracted. Component one explained 39% of the variation, component two 29%, component three 11%, component four 9%, and component five 4%; communality for almost all the factors was close to 1 indicating high level of relationship between factors. Each of the components provides an insight into the combination of traits that that are important to the estimation of floral dry weight, vegetative dry weight, reproductive allocation and sexual differentiation of the female *G. kola* tree.

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SOAKING AND STORAGE DURATION EFFECT ON GERMINATION AND GROWTH OF WILD SOURSOP (*Annona senegalensis* Pers): PROSPECT FOR CONSERVATION

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Abstract
Rapid genetic erosion of wild species from deforestation coupled with the immerse benefits of wild species calls for urgent massive conservation efforts. This study was therefore carried out to assess the effect of soaking and storage duration on the germination and growth of wild soursop with the aim of conserving it. The two factors nursery experiment comprised of storage time (0, 2, 4, and 6 weeks) and soaking time (0.8, 16 and 24 hours) arranged in completely randomized design in five replications. Data collected on germination: number of leaves, plant height, collar diameter and biomass, were subjected to descriptive as well as analysis of variance using SAS and significant means were separated using Fishers least significant difference at 5% level of probability. Results showed that seed stored at 0 weeks soaked for 8 hours had the highest germination percentage of 92% while the least was observed in 6 weeks with 0 hours soaking. The result also showed that soaking duration had significant effect P≤0.05 on number of leaves, plant height and biomass. The effect of storage was also significant on number of leaves and biomass. The interaction between soaking and storage duration had significant effect P≤0.05 on collar diameter and biomass. The study demonstrated that soaking seeds of wild soursop enhances germination resulting in uniform seedlings growth as well as improved growth parameter of this wild species.
The study recommends that seeds collected for conservation purposes, should not be stored for more than two weeks at room temperature.

***Key words**: wild soursop, germination, storage, soaking, growth*

Introduction

Annona senegalensis, a wild fruit tree commonly known as wild soursop or wild custard apple belonging to the family Annonaceae has immerse benefits to man, animal and industries (NRC, 2008). The fleshy pulp is eaten by man and the leaves are used as fodder for livestock. The leaves are also used for treating pneumonia and as a tonic to promote general well being. The bark is used as an insecticide and also used for treating guinea worms and other worms, diarrhoea, gastroenteritis, snakebite, toothache and respiratory infections. The gum from the bark is used in sealing cuts and wounds (Orwa *et al*., 2009). The roots are used for stomachache and venereal diseases (Orwa *et al*., 2009).With these enormous benefits of this wild species to man and livestock, it is expedient to conserve and improve upon the traits to meet the demand of man and other users.

The use of wild plants or crop wild relatives in breeding cannot be overemphasized. They are useful genetic resources used in breeding improved varieties that are high yielding, nutritious, pest and disease resistant, stress tolerant and resilient. These benefits derived from wild species may be hampered by their inadequate representation in gene banks and the loss of wild varieties to deforestation, unsustainable harvesting and usage, climate change and other impacts (Castañeda-Álvarez *et al*. 2016). There is therefore the need to prevent the loss of these useful genetic resources and to maximize their availability. This demand an urgent attention in ensuring their appropriate conservation and sustainable use.

The immense benefits of this wild species and the threat posed by mass genetic erosion calls for massive germplasm collection and conservation efforts. Through germplasm collection, the genetic diversity essential to any tree improvement programme could be safe guarded, (Asaah *et al.*, 2006). Seed storage which is an *ex situ* germplasms conservation is an essential step for the long-term conservation of plant genetic resources. Seed storage is employed in maintaining seed viability for longer period and this is very crucial in preserving the genetic integrity in stored seeds (Pradhan and Badola, 2012). Seed storage mostly in genebanks is the most practical *ex situ* conservation technique for many plant species (Maxted *et al.*, 2013)

Seed is the reproductive unit which also houses the genetic material of any plant. Viable seeds are essential for continuity of any species. Seed storage plays an important role in making large volume of viable seeds available for use (Merritt and Dixon, 2011). Different types of seed respond different to storage duration. Orthodox seeds could store successfully for long durations at low temperature and low moisture content (Fennessy, 2002) while recalcitrant seeds do not store because as the storage period increases, moisture content further reduces and respiration rate declines (Warren and Adams, 2001).

Seed germination is an important aspect of plant conservation. The key to success in seed propagation is proper timing and high germination percentage. Plants that possess hard coat poses serious problem to seed germination by hindering water permeability and germination thereby resulting in seeds taking too long to germinate or have random germination when no pre-germination treatment is applied (Azad *et al*. 2010). Pre-germination treatment technique such as soaking enhances germination in hard coated seed. Seed soaking before sowing is employed to shorten the lag phase in germination thereby resulting in faster seedling establishment (Azad *et al*. 2010).

Since storage is an important factor in preserving viable seeds from time of collection until they are required for sowing (Ojo, 2008), it is thus important to identify how long seed stored will maintain viability. The study also aimed at identifying the most effective soaking period for germination, growth and development of wild soursop. This will add to the information necessary for the conservation and utilization of this wild species as the use of crop wild relatives is expected to increase with better information about the species (Castañeda-Álvarez *et al*. 2016). This study was, therefore conducted to determine the effect of storage and soaking duration on the seed germination and seedling growth of wild soursop for conservation purpose.

Materials and methods

Matured fruits of *A. senegalensis* were sourced and allowed to ferment for easy extraction of seeds. Seeds were extracted from the softened fruit manually with the use of hands. The extracted seeds were tested for their viability by the floatation method. Only the unfloated seeds were considered viable and suitable for the experiment. The floated seeds are mainly the immature seeds and were therefore discarded. The seeds were stored at room temperature in the laboratory for further usage.

Experimental site

The experiments were carried out at the Physiology Nursery of Forestry Research Institute of Nigeria (FRIN) Headquarters, Jericho, Ibadan. FRIN is located on the longitude 07023'18"N to 07023'43"N and latitude 03051'20"E to 03051'43"E. The climate of the study area is the West African monsoon with dry and wet seasons. The dry season is usually from November through March and is characterized by dry cold wind of harmattan. The wet season usually starts from April to October with occasional strong winds and thunderstorms. Mean annual rainfall is about 1548.9 mm, falling within approximately 90 days. The mean maximum temperature is 31.90C, minimum 24.20C while the mean daily relative humidity is about 71.9% (FRIN, 2015).

Experimental procedure

A total of 800 seeds was used for the entire experiment which was divided according to the treatment combinations below: the treatment comprised of two factors at four levels each. Factor one is storage time (0, 2, 4 and 6 weeks) while factor 2 is soaking time (0.8, 16 and 24 hours). These were combined in the following ways:

Table 1: Treatment combination for the experiment

Treatment combination s	**Storage time (weeks)**	**Soaking time (hours)**
Ti	0	0
T2	0	8
T3	0	16
T4	0	24
T5	2	0
T6	2	8
T7	2	16
T8	2	24
T9	4	0
T10	4	8
T11	4	16
T12	4	24
T13	6	0
T14	6	8
T15	6	16
T16	6	24

Each of the ~~treatments~~ treatments combinations comprised of 10 seeds replicated five times making a total of 50 seeds for each of the treatment combination.

The seeds were broadcasted on a germination sieve filled with top soil. These are arranged in a completely randomized design in a nursery shed. Watering was done daily.

After germination, the seedlings were potted in a 6"X 8" polythene pots and nursed for 6 weeks. At 6 weeks, 80 uniformly growing seedlings were selected from all the treatment combinations for assessments. The assessment was done at two weeks interval for six months.

Data collection and analysis

Data was collected on the following germination parameters

- Number of seeds germinated: the number of seeds that germinated was counted on a daily basis from the onset of seed germination until no further germination occurred. *Annona senegalensis* exhibit epigeal form of germination, germination was therefore said to occur when the plumule rises above the soil.
- Germination percentage (GP): It is computed as follows:

  $$GP = \frac{\text{Number od seed germinated}}{Total\ number\ of\ seed\ sown}\ X\ 100$$
- Number of leaves : Physical counting of the leaves
- Collar diameter (mm): By the use of digital vernier caliper placed at the marked collar
- Plant height: By the use of meter rule. This was placed at the base of the plant and stretched to the tip of the plant. The distance between the base to the tip of the plant is the plant height
- Biomass: this was destructively measured at the beginning and end of the experiment. The seedlings were dipped into a bowl of water to loosen the soil off the root. The young plants are then dried in an oven until a constant weight is obtained. This serves as dried biomass weight.

The collected data was subjected to analysis of variance (ANOVA) using SAS (2000) and means that are significant were separated using Fishers least significant difference at 5% level of probability. Results are presented in graph and tables.

Results

The results revealed that higher percentage of 50% and above were recorded for the seeds stored from 0 to 2 weeks irrespective of the soaking duration while seeds stored for 6 weeks irrespective of the soaking duration recorded very low germination percentage of less than 20%. However, the result further revealed that seeds sown immediately after extraction with 8 hours soaking had the overall highest germination of 92%. This was closely followed by freshly extracted seeds sown after zero hours of soaking and seeds stored for one week and eight hours of soaking. They both produced the same germination percentage of 88%. The least of all was recorded in seeds sown after 6 weeks storage without soaking.

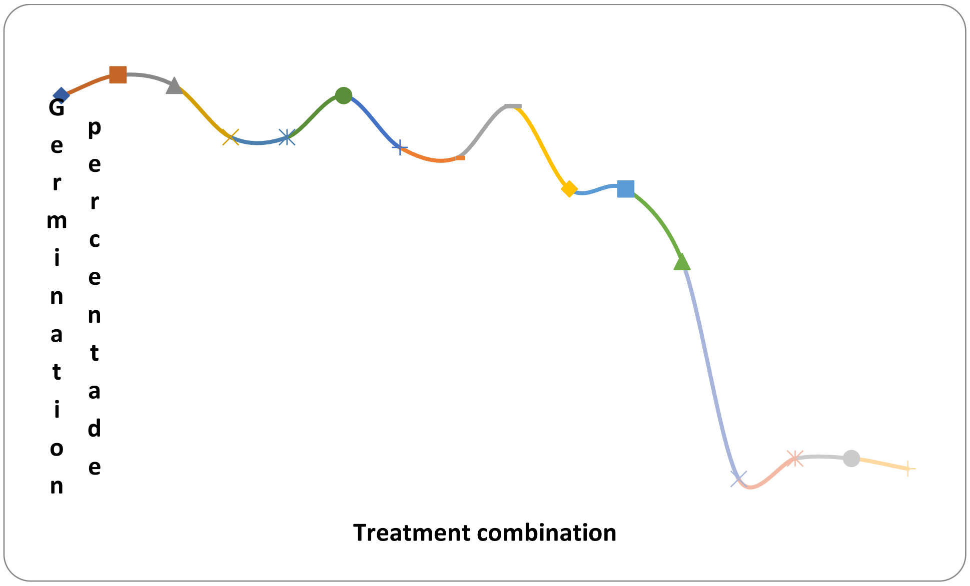

Figure 1: Germination percentage (%) of wild soursop as affected by soaking and storage duration

The mean square analysis for the effect of soaking and storage duration on the growth traits of wild soursop showed that soaking duration had significant effect P≤0.05 on number of leaves, plant height and biomass (Table 2). The effect of storage was also significant on number of leaves as well as on biomass. The two way interaction between soaking and storage duration had significant effect P≤0.05 on collar diameter and biomass.

Table 2: Mean square effect of storage and soaking duration on the growth traits of *A. senegalensis*

Sources of variation	DF	NOL	Height	CD	Biomass
Soaking	3	125.381*	132.482*	16.179*	14.508*
Storage	3	215.547*	70.48ns	1.200ns	24.584*
soaking*storage	9	69.825ns	51.501ns	4.381*	32.028*
Error	64	41.706	31.949	1.436	1.84
total	79				

*significant ($p<0.05$), ns- not significant ($p>0.05$)

Seeds soaked for 16 hours produced the highest number of leaves followed by seeds soaked for 24 hours (Table 3). The least number of leaves was observed in seedlings produced from seeds soaked for 8 hours though not significantly different from each other (Table 2).
Seeds soaked for 24 hours produced the tallest plant of 17.375cm followed by seeds soaked for 16 hours and the shortest plant was produced from seeds soaked for 8 hours.
The seedlings produced from seeds soaked for 24 hours performed better than all the other soaking durations in terms of collar diameter as it recorded a mean collar diameter of 4.432mm and the least was observed among the seedlings produced from 0 hours soaking with a mean collar diameter of 2.478mm.
The effect of soaking duration on biomass was significant effect. The highest biomass of 6.741g was observed in 16 hours soaking, next to this is 8 hours and 24 hours soaking which produced the same effect.

Table 3: Effect of soaking time on growth traits of wild soursop

soaking time (hours)	NOL	Height (cm)	CD (mm)	Biomass (g)
0	13.69a	12.32c	2.478c	4.934b
8	13.3a	11.73c	2.623bc	6.558ab
16	18.65a	14.715b	2.902b	6.741a
24	14.05a	17.375a	4.432a	6.592ab
Sig	0.037	0.100	0.00	0.00

The storage duration had significant effect $p\leq0.05$ on number of leaves and biomass (Table 2). The mean effect revealed that 0 weeks storage had the highest number of leaves of 18.94 followed by 2 week storage which produced number of leaves of 15.90 (Table 4). The least number of leaves was observed in 6 weeks storage.
The highest biomass of 7.362g was produced from 0 weeks storage followed by 2 week storage and the least biomass of 5.131g was observed among seedlings raised from seeds stored for 6 weeks.

Table 4: Effect of storage time on the growth traits of wild sour sop

Storage duration (weeks)	Number of leaves	Height (cm)	Collar diameter (mm)	Biomass (g)
0	18.94a	16.085a	3.428a	7.362a
2	15.90b	12.37a	3.099a	6.937b
4	13.60c	15.17a	3.075a	5.393c
6	11.25d	12.51a	2.832a	5.131c
Sig	0.003	0.096	0.479	0.000

Table 5: Interactive effect of soaking and storage duration on the growth traits of wild soursop

The two way interaction between soaking and storage duration on wild soursop had no significant effect on number of leaves produced. Nonetheless, the highest number of leaves of 23.00 was observed among the seedlings raised from seeds soaked for 16 hours after 0 week of storage, next to this were seeds soaked for 24 hours at 0 weeks storage with a biomass of 21.76g. Higher biomass of 19.40 was recorded for 8 hours soaking and 0 weeks storage as well as 20.00g for 24 hours at 2 weeks of storage. The least of all was observed among seedlings raised from seeds stored for 6 weeks at 0 hour soaking.

Soaking duration (hours)	**Storage (weeks)**	**Number of leaves**	**Height (cm)**	**Collar diameter (mm)**	**Biomass (g)**
0	0	14.60a	13.12a	2.596c	9.85a
0	2	11.20a	13.54a	2.138d	7.028b
0	4	10.60a	17.72a	2.152d	3.484e
0	6	7.80a	14.48a	4.722ab	6.600c
8	0	19.40a	11.44a	2.93c	4.634d
8	2	10.20a	9.60a	3.38b	2.988e
8	4	8.60a	14.20a	2.49c	5.284cd
8	6	15.00a	11.68a	1.692e	6.830c
16	0	23.00a	17.24a	2.674c	9.186a
16	2	20.00a	11.98a	2.144d	9.652a
16	4	15.80a	14.10a	2.702c	5.408cd
16	6	15.80a	5.96a	2.394cd	1.986f
24	0	21.76a	22.54a	3.128b	5.78cd
24	2	20.00a	14.38a	4.736ab	8.08b
24	4	10.00a	14.66a	4.958a	7.398b
24	6	13.00a	17.92a	4.906a	5.108d
Sig		0.114	.131	.004	0.000

Discussion

Rapid genetic erosion of wild species from unsustainable tropical deforestation coupled with the immerse benefits of wild species calls for urgent massive conservation efforts. Seed storage is a critical step in conservation as this will greatly influence the lifespan of seeds because seeds need to be stored from time of collection until they are required for sowing (Ojo (2008). Hard-coated tree species poses serious problem in germination which hinders these species for conservation, therefore finding alternative to this problem is necessary.

Higher percentage of 80% and above recorded for seeds stored for 0 weeks irrespective of the soaking duration and subsequent decline to about 50% after 4 weeks of storage and to less than 20% seed germination for seeds stored for 6 weeks is an indication that the seed loses viability as storage time increases. This finding agrees with the findings of Kandari (2008) who observed a steady decrease in viability of tropical tree species when stored beyond 2weeks.

On the soaking effect, seed soaking enhances germination of wild soursop. This is in line with the thought of Copeland (1976) who observed that most seeds when swollen in water and sown germinate faster than unsoaked seeds. This also is in line with many authors who reported that soaking seeds before sowing increase seed germination (Alamgir and Hossain, 2005, Azad *et al.*, 2010, Olatunji *et al*., 2013 and Billah *et al.*, 2015; Odoi *et al.*, 2019)

The result also showed that soaking duration had significant effect $P \leq 0.05$ on number of leaves, plant height and biomass (Table 2). Seeds soaked for 16 hours produced the highest number of leaves followed by seeds soaked for 24 hours. Seeds soaked for 24 hours produced the tallest plant of 17.375cm followed by seeds soaked for 16 hours. The highest biomass of 6.741g was observed in 16 hours soaking. The high performance in 16 and 24 hour soaking treatment suggest the seed of *A. senegalensis* require an optimal level of moisture through soaking to activate the embryo to commence the process of cell division, differentiation and multiplication to grow into a seedling. This according to Sabongari and Aliero, 2004 is due to hydrolysis of complex into simple sugars that are readily utilized in the synthesis of auxins and proteins. The auxins produced help to soften cell walls to facilitate growth and the proteins readily utilized in the production of new tissues (Sabongari and Aliero, 2004).

The storage duration had significant effect $p \leq 0.05$ on number of leaves and biomass (Table 2). The seed stored for 0 weeks had the highest number of leaves of 18.94 followed by 2 weeks storage which produced 15.90. The highest biomass of 7.362g was produced from 0 weeks storage followed by 2 week storage. The least of these two were produced by the 6 weeks storage. This is a pointer that as seed loses moisture during storage, even though germination eventually takes place, the vigour of the seedling produced will be adversely affected and these seedlings may not be able to survived further thus hampering the conservation of the species. This result is also a clear indication that sowing seeds immediately after collection not only produced the highest germination percentage but also enhanced the growth of this wild species . Thus, suggesting the inadequacy of ambient temperature in storing seeds.

Conclusions and recommendations

The study demonstrated that soaking seeds of wild soursop enhances germination resulting in high germination percentage as well as uniform seedlings growth. Soaking of seed also improved the collar diameter, height and biomass accumulation of this wild species.

The result of this study also demonstrated seed storage duration affect seeds germination as sowing immediately without storing the seeds of wild soursop also resulted in the production of seedlings with good vigour in terms of number of leaves and biomass accumulation.

It concludes convincingly that there is prospect for the conservation of this wild species by giving due consideration to the storage as well as soaking time because storage duration affects the seed germination percentage in wild soursop which declines with increasing storage duration irrespective of soaking duration as well as affected the vigour of seedling produced.

The study recommended that for producing seedlings with good vigour for conservation of this wild species, seeds collected should not be stored for more than 2 weeks at room temperature for best result. Research on storage conditions necessary for long time storage for the conservation of this species is advocated.

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SUB-THEME 2

FORESTRY-BASED SOLUTIONS TO THE CHALLENGES OF CLIMATE CHANGE, INSECURITY AND HEALTH HAZARDS

FORESTRY-BASED SOLUTIONS TO THE CHALLENGES OF CLIMATE INSECURITY AND HEALTH HAZARDS

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INTRODUCTION

To address the topic, questions may help. What becomes of forestry in Nigeria especially now that forests are becoming "official" enemies of state? Are forests responsible for banditry in Nigeria? What is forestry? What happened to the scope of forestry in the past one hundred years? Has Nigeria's forestry changed significantly from the colonial format she had at independence? What has become of the various formulas in forestry management? Who are the managers of forestry in Nigeria, the forestry professional or the political officer holder? What are forest resources? Are forest soil microbes and macrobes as important as the "mined" timbers? What are the glorified products from the forests in the past one hundred years? What is the meaning of "minor forest products" and the later transmuted terminology "non-wood forest products"?

What is climate change? Can the forests survive? What is the scope of forestry? Are we aware that forest soils and microorganisms are crucial to the health of world's climate? Are we aware that soil microbes alone account for a large chunk of sequestered carbon? Are we aware that the oceans and the water bodies also sequester large quantities of carbon?

What happens to the climate when western nations begin mining on the Moon and perhaps Mars? What are the effects of deep-sea mining that has become a craze in the western world? What are the effects of military laser weaponry that is becoming a global threat on climate? What about classified information concerning the effects of nuclear tests on climate? Can forests help mitigate the current level of electromagnetic radiation in the environment? What will be the level of radon gas on soil surface and the environment generally, when forests are gone? Is there any consciousness about the possible level of radon gas emitted currently because of the removal of forest vegetation, indiscriminate mining, and house constructions especially in the mushrooming housing estates in the country? How many know that an increase in the level of radon gas in the environment will led to an increase in lung cancer? When the myriads of soil microbes are destroyed resulting from deforestation, what happens to human biome? Will geopathic stress increase when forests are gone? Does it ever occur to anyone that "estates" in Nigeria do not promote good health because of the concretes, buried microbes, and lack of forest plots?

Is there any relationship between forest destruction and the rising frightening level of deadly diseases such as cancer, diabetes, hypertension in Nigeria? Are the forests not helpful in minimizing road rage, domestic violence, and suicide? Can forest resources help to curtail the rising levels of hunger and "hidden hunger" (Type B malnutrition)?

What happened to indigenous knowledge especially about forest management? Is the assemblage of indigenous knowledge not important now than ever before? Can forestry begin to include indigenous knowledge studies in her curricular?

What are the prospects of forests in the next one hundred years? Is there a political will to plan for the next one hundred years? Are there forestry professionals who are dreaming of forests in the next one hundred years in Nigeria?

Are forestry professionals trained (formal and self-trained) enough to cope with the emerging scenarios in the world?

Are there forestry professionals who will champion neuroplasticity in foresters and stakeholders in forestry? Can FRIN and other stakeholders in forestry advance a policy on Healing Forests in Nigeria? When shall a school, faculty, department of herbal and natural medicine be established or taught in institutions of forestry in Nigeria?

What happens to the forests in case of nuclear attacks? Are there plants in the forests that can ameliorate or withstand nuclear radiation? Can there be a "doomsday forest reserve and vault" in Nigeria? Can FRIN, Universities with forestry faculties or departments and other stakeholders have lands where forest plants, insects and other creatures can be cultivated?

Is it not possible to extend the scope of forestry to plant and animal populations in oceans and other water bodies?

What have forestry professionals learnt in the past two decades about modern methods of forest management? Are the syllabi of forestry schools and institutions in Nigeria relevant in addressing current situations in the country and in the world? Can postgraduate studies in forestry include such fields of study as forest archeology, biophysics, human brain studies, e-electricity studies and innovation, graphene, and space science? Can forestry incorporate the study of Periodic Table as an economic tool for development? Can Nigeria's forestry learn from Japan, China, India and other nations that have developed trade in insects, scorpions, earthworms and others for medicine and medicine?

Is it not time to address the legendary corruption and indiscipline among forestry officials who are conduit pipes in siphoning resources from the forests and forest revenue? Have forestry officials not lived riotously and gluttonously to the detriment of their primary constituency, which is the forest?

Forestry as advocated in this paper can address the persistent and long-term development challenges in Nigeria. The challenges are those described by Anigbogu and Adelaja (2015) as challenges mitigating the emergence of Africa. The challenges include among others, undiversified production structure, weak governance, low human capital, and climate change.
This paper presentation will therefore focus more on the problem of undiversified production structure in forestry by giving examples of products and services that can be derived from forest resources.
A. Nuclear Tests: The Great Albatross Hanging on Global and Extra Terrestrial Climates
In the New Mexico desert just three weeks before the atomic bombings of Hiroshima and Nagasaki, in 1945, the United States conducted the world's first nuclear test explosion, code-named "Trinity". Its giant fireball turned the sands into glass, illuminated the surrounding mountains, and sent a mushroom cloud of radioactive debris 12 kilometres into the sky (The International Campaign to Abolish Nuclear Weapons (ICAN), 2017).
Since the first nuclear test explosion on July 16, 1945, at least eight nations have detonated 2,056 nuclear test explosions in many sites in the world (Arms Control Association, 2020). Around one-quarter of these tests were in the atmosphere – causing long-term harm to human health and the environment. The nuclear explosions have resulted in epidemics of cancers and other chronic illnesses. Large swathes of land remain radioactive and unsafe for habitation; even decades after test sites were closed. More than 60 sites around the world bear the scars of these tests. Even those that have been closed for decades and partially cleaned up remain uninhabitable. The sheer scale of the devastation is staggering. The 528 atmospheric tests alone had a destructive force equal to 29,000 Hiroshima bombs. They dispersed radioactive particles far and wide, poisoning the soil, air, and water (The International Campaign to Abolish Nuclear Weapons (ICAN), 2017). Many underground nuclear blasts have also vented radioactive material into the atmosphere and left radioactive contamination in the soil (Arms Control Association, 2020).
Figure 1 shows the nuclear testing numbers between 1945 and 2017.

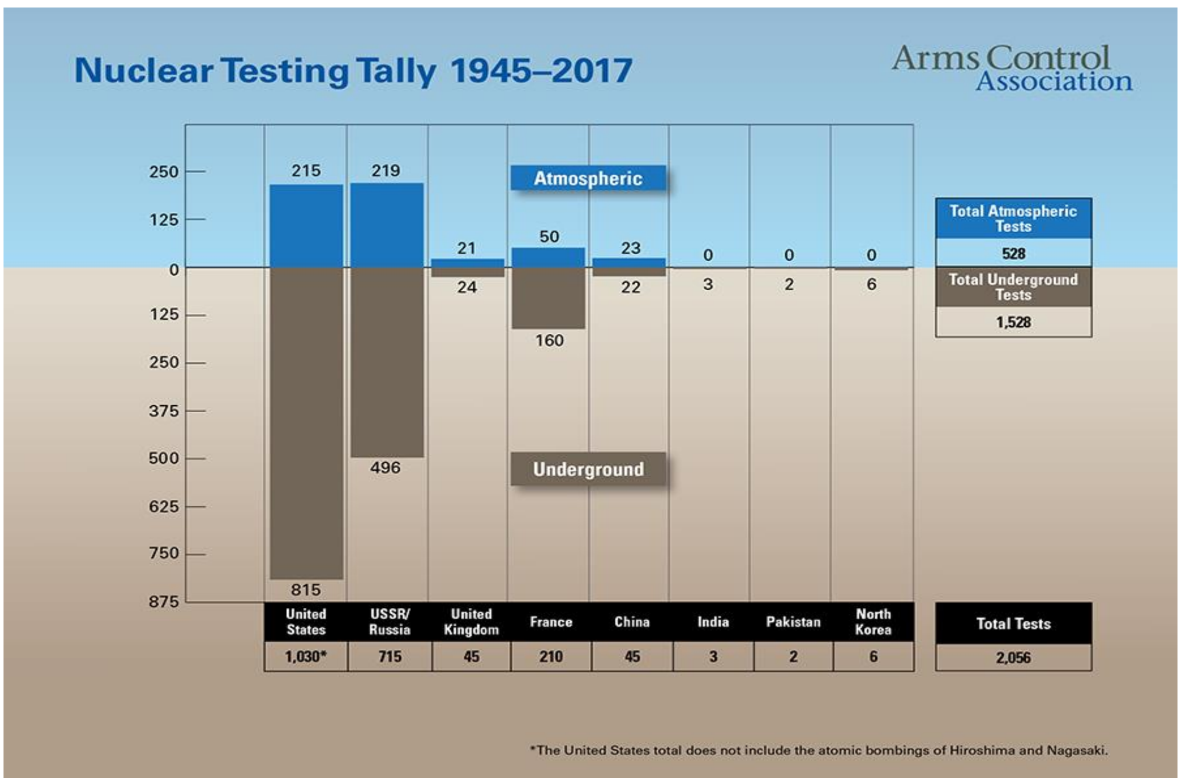

Figure 1. Nuclear Testing Tally 145-2017

Figure 2 shows the number of underground and atmospheric nuclear testing between 1945 and 2017. The number of underground testing is about three times that of the atmospheric. These have grave implications for soil, water and food contamination. Food produced from such areas are shipped for sale in many other parts of the world.

The effects of nuclear explosions on the environment are classified information. That is, the population is not to know the adverse effects on the environment.

The implications of the nuclear testing for people's lives and the Earth's fragile ecosystems will be felt for generations to come (The International Campaign to Abolish Nuclear Weapons (ICAN), 2017).

Type of Test	United States	USSR/ Russia	United Kingdom	France	China	India	Pakistan	North Korea	Total
Atmospheric	*215*	*219*	*21*	*50*	*23*	*0*	*0*	*0*	***528***
Underground	815	496	24	160	22	3	2	6	**1,528**
Total	**1,030**[1] *(Note: does not include atomic bombings of Hiroshima and Nagasaki.)*	**715**	**45**	**210**	**45**	**3**	**2**	**6**	**2,056**

Figure 2. The number of underground and atmospheric nuclear testing between 1945 and 2017 Source: Arms Control Association, 2020

The following remedies can be helpful against radiation. Plastic pollution and herbicides. Radiation is not limited to nuclear tests alone but also includes sources such as hospital diagnostic equipment, detection equipment in the airports and offices, telecommunication masts, home electrical appliances and the ubiquitous handsets.

1. Anti-radiation tea:

Blend Atlantic kelp, Atlantic dulse, dandelion leaf (*Taraxacum officinale* (L.) Weber ex F.H. Wigg.), and nettle leaf (Stinging nettle *Urtica dioica* L.) in equal parts. Blend all together, make a tea from a tablespoon of the mixture per cup of hot water.

Sea kelp is seaweed or algae. The kelp scientific name is Laminariales. Some species of kelp form large forests beneath the shallow waters of the ocean. These areas are sometimes referred to as the rain forests of the ocean because of the great biological diversity within their midst.

Kelp is also an important resource for humans and is harvested for food, medicinal purposes and its uses in various products (Bethney Foster, 2019).

2. Anti-Plastic Tea:

Rid the body of plastic and plastic by-products, blend equal parts fenugreek (*Trigonella foenum-graecum* L), mullein leaf (*Verbascum Thapsus* Linnaeus), olive leaf (*Olea europaea* L.), and lemon balm (*Melissa officinalis* L.). Steep one tablespoon of the mixture per cup of hot water for tea.

3. Anti-Pesticide/Anti-Herbicide/Anti-Fungicide Tea:

To remove pesticides, herbicides, and fungicides deeply stored in the body, blend equal parts of burdock root, (*Arctium lappa* L.) red clover (*Trifolium pretense* L.), lemon verbena, and ginger. Steep one tablespoon of the mixture in a cup of hot water to make tea.

Source: 1, 2, 3: (Anthony Williams, 2015).

Sea kelp is seaweed or algae. The kelp scientific name is Laminariales. Some species of kelp form large forests beneath the shallow waters of the ocean. These areas are sometimes referred to as the rain forests of the ocean because of the great biological diversity within their midst.

Kelp is also an important resource for humans and is harvested for food, medicinal purposes and its uses in various products (Bethney Foster, 2019).

The following anti-radiation remedies are from Oluwalana, S. A. and Oluwalana, E.O.A. (2010).

1. Flax seed (*Linum usitatissimum* Linn.) water: Shower for 10 minutes, then cleanse the entire body with a flax water decoction (3 tablespoons of flax seeds to 2 cups of water, boil for 10 minutes) and then wrap the body into a linen cloth soaked in flax water. Do this 2-3 times per day as a measure against radiation.

From Reinhard Schiller, Author of Hiddergard Medicine Practice.

2. Nascent Iodine: Supplement with nascent iodine to help counteract the effects of radioactive Iodine. Nascent iodine is one of the single most bio-available forms of iodine, and may be effective in aiding individuals exposed to radiation by lowering accumulated and stored radioactive toxins in the thyroid gland.
3. Potassium Ororate: In addition to exposure to radioactive iodine, the body may also be exposed to a radioactive isotope of caesium known as Cesium-137.Supplementing with potassium ororate can prevent the accumulation and retention of Cesium-137.
4. Calcium and Magnesium: Taking calcium or magnesium can decontaminate Strontium 90, a form of nuclear waste. Calcium supplementation can lower Strontium absorption by the body by up to 90 percent.
5. Organic Germanium-132: Taking 100 mg of organic germanium-132 per day is recommended in case of exposure to radiation.
6. Zeolites: Zeolite clay can be taken internally for detoxing radiation.
7. Kaolin, Red Clay, Bentonite, Fuller's Earth, Montmorillonite, French Green Clay: Any of these clays can bond to nuclear waste from the body. These clays possess the ability to rid radiation, toxic metals and chemical residues from the human body. They can be used in bath, or, can be ingested.

8. Cold-pressed organic vegetable oils: Drinking about 100 cl of cold-pressed organic oil is recommended in cases of exposure to radiation. Cold-pressed organic oils such as sesame oil, extra virgin olive oil and coconut oil are known to be able to pull radiation out from the human body. The lipids in the oils bind the toxins, and they also offer a protective layer on cellular membranes.
9. Organic Brewers Yeast: As a prevention against radiation exposure, 5 mg. to 15 mg. for children, and 25 mg. to 50 mg. for adults of organic brewers yeast are recommended. Double these amounts in cases of direct exposure to to radiation.
10. Bee pollen: Taking 2 tablespoons bee pollen may lower the negative side effects of radiation exposure, particularly that of radium, x-rays and cobalt-60 radiotherapy.
11. Beets (*Beta vulgaris* Linn.): Eating a diet heavy in beet pulp can effectively reduce the effects of radio active cesium-137.
12. Glutamine: Take 5,000 to 15,000 mg of the amino acid glutamine a day as one of the best remedies for shielding the intestine from the damage of chemotherapy and radiation.
13. *Umeboshi* tea (consisting of umeboshi, a Japanese word for salt plum paste, the root of kudzu plant and, ginger): Put ½ teaspoon of kudzu powder in a bowl and combine with enough cold water to make a paste. Mash the paste, then pour 1 cup of hot water over it to dissolve it. Then, add ½ teaspoon of umeboshi and ½ teaspoon of grated or powdered ginger, pour the water into a small pot, and simmer on low heat for 30 minutes. Strain the mixture before drinking, taking a cup twice a day, including one cup before breakfast. It helps to settle the stomach of the cancer patient when the tea is taken first thing in the morning. Umeboshi tea is one of the best remedies for nausea and vomiting caused by conventional cancer treatments.
14. Astragalus/Huang Qi (=yellow energy): Astragalus/Huang Qi (*Astralagus membranaceus* (Fisch.) Bunge/*Astralagus mongholicus* Bunge), a Chinese herb: is one of the best long-term immune tonics. For adults, take 20 to 30 drops of the tincture of Astralagus three times a day. In capsule form, dose is 1,000 mg capsule, three times a day. Astralagus helps to protect patients from the side effects of chemotherapy. Astralagus taken inconjunction with *Ligustrum lucidum* (glossy privet) may increase survival rates in patients being treated conventionally for breast cancer.
15. Supplement programme: Hair loss is often results from chemotherapy and radiation treatments for cancer. To help reduce hair loss and speed up its healthy regrowth, take the following supplement programme: Take:
3 mg biotin twice a day throughout the chemo or radiation treatment, and for two weeks after. After the two weeks, cut back to 3 mg once a day;
a multivitamin-and-mineral capsule every day;
400 IU of vitamin E succinate three times a day;
500 mg quercetin three times a day with meals;
500 mg hesperidin three times a day with meals;
500 mg curcumin three times a day. Dissolve the contents of one capsule in one tablespoon of extra virgin olive oil;
100 mg of decaffeinated green tea extract with each meal.
16. Supplement programme: Depressed production of blood-forming cells (bone marrow depression) is a major consequence of chemotherapy. The body's hemopoietic system (comprising of the bone marrow, instestinal wall (Peyer's patches), lymph nodes, spleen, and a few other tissues) produce immune cells. When these cell types are depressed, especially with chemo drugs, there can be increased risk of infections, increased spead of the cancer, abnormal bleeding, and severe state of blood insufficiency (anaemia).
To help protect the haematopoietic system, take the following supplement programme: Take:
500 mg of the flavonoid curcumin three times a day. Dissolve the contents of one capsule in one tablespoon of extra virgin olive oil. Curcumin derived from turmeric (*Curcuma longa* Linn.) not only protects the bone marrow cells, but also capable of stimulating the regeneration of the bone marrow cells;
800 mcg of folate every day. Folate is needed tin haematopoietic cell reproduction;
1,000 mcg of sublingual methylcobalamin three times a day. Sublingual means that it should be dissolved under the tongue. A day after the chemo or radiation treatments are finished, reduce the dosage to one tablet twice a day;
50 mg of pyridoxal-5-phosphate (the form of vitamin B_6 used by the blood cells) every day;
a multivitamin-and-mineral capsule every day between meals, but in case it causes stomach upset or nausea, take with meals;
500 mg vitamin C (buffered as magnesium ascorbate) three times a day between meals;
400 IU vitamin E succinate three time s a day; 500 mg of the vitamin niacinamide twice a day.
17. Pine Bark Extract: Cancer patients undergoing chemotherapy or radiation treatment should take 50 mg Pine bark extract (Pycnogenol) three times a day to reduce the effects of the chemo or radiation treatments such as nausea, vomiting, diarrhea, weight loss, ulceration and soreness of the mouth, water retention, and weakness.
Pine bark extract is a natural extract from the bark of the maritime pine tree (*Pinus pinaster* Aiton.), a European coastal pine that grows along the coast of southwest France.
Pine bark extract is sold as Pcynogenol (pronounced as *pik-NOJ-en-all*).
CAUTION: Avoid use if on blood-thinning medication, as Pycnogenol is a blood thinner. Also, avoid if on medication for diabetes as pycnogenol lowers blood-sugar levels. Avoid Pycnogenol if pregnant, or nursing baby.
18. Sacred clay (Pyrophyllite): Due to its exceptionally small particle size, high silica and high electrolyte content, sacred clay is highly recommended during times of radiation emergency. Eat and take sacred clay to pull out all forms of radiation faster and effectively.

19. Sacred clay (Pyrophyllite), Himalayan salt, Humic/Fulvic Earth, Ocean Magnesium: Combine sacred clay (pyrophyllite), Himalayan salt, humic/fulvic earth, and ocean magnesium and use in bath to drastically reduce the effect of radiation and expel radiation from the body.

B. Suggested Areas of Utilization in Forest Resources Management:

1. Soil Microbes: The Unsung Heroes of the Environment:

Soils bustle with life (Soil Association), and are essential to life. Soils are one of the main global reservoirs of biodiversity. They host more than 25 percent of the world's biological diversity (New FAO). The species range from beetles and springtails to worms, spiders, nematodes, and billions of other microorganisms too small to be seen by the naked eye, but vitally important to soil health and the planet. Up to 10 billion microorganisms can be found in just a quarter of a teaspoon of soil (Soil Association). In addition, more than 40 percent of living organisms in terrestrial ecosystems are associated with soils during their life cycle (New FAO report).

Soil microbes and animals, from tiny soil bacteria to earthworms, are unsung heroes in the environment, providing hundreds of billions of dollars in ecosystem services. These organisms are critical to maintaining the global biosphere and human existence (Virginia Tech. 2019).

Soil microorganisms have a significant potential to mitigate climate change. They play a key role in carbon sequestration and reducing greenhouse gas emission. They play a crucial role in boosting food production, enhancing nutritious diets, preserving human health, remediating pollution and combating climate change, but their contribution remains largely underestimated. Their protection is of the utmost importance to ensure the future of agri-food systems and the provision of key ecosystem services (New FAO report).

Soil microbes include nematodes, tarnigrades, bacteria, protozoa, and fungi. Soil-inhabiting nematodes are one of the most abundant creatures on Earth, as just one gram of soil may contain more than a million nematodes. Water bears, or tardigrades, are famous for being one of the most resistant animals on Earth. Incredibly, they can go up to 30 years without food or water, can survive at temperatures from freezing to above boiling, and can even withstand the vacuum of space (Soil Association).

Tardigrades, scientifically called Tarnigrada, are 0.5 mm microscopic eight-legged omnivorous animals. They have also been observed in all kinds of environments, from the deep sea to sand dunes. Around 1,300 species of tardigrades are found worldwide. They belong to an elite category of animals known as extremophiles, or critters that can survive environments that most others cannot. For instance, tardigrades can go up to 30 years without food or water. They can also live at temperatures as cold as absolute zero or above boiling, at pressures six times that of the ocean’s deepest trenches, and in vacuum of space.

Their resiliency is in part due to a unique protein in their bodies called Dsup – short for “damage suppressor” – that protects their DNA from being harmed by things such as ionizing radiation, which is present in soil, water, and vegetation.

Tarnigrades also use another amazing survival trick called cryptobiosis. Cryptobiosis is a state of inactivity triggered by a dry environment. The micro-animals squeeze all the water out of their bodies, retract their heads and limbs, roll up into a little ball, and become dormant. When conditions improve, they unfurl themselves and go about their business. Tarnigrades were first described in 1773 by German pastor J.A.E. Goeze, who called them *kleiner Wasserbär*, or “little water bear." (National Geographic).

Bacteria are crucial to living, healthy soil and a balanced ecosystem. Most bacteria are decomposers, converting the energy stored in organic matter into nutrients that feed and enrich other organisms deep in the soil. Others are nitrogen-fixing bacteria, converting nitrogen into a useful form for plants, helping them to grow and thrive and playing an important role in the nitrogen cycle.

Springtails (eat fungi, bacteria, algae and decaying organic matter, recycling the nutrients back into the soil. They benefit most plants by spreading beneficial fungi onto plant roots, helping them thrive). Protozoa are aquatic single-celled animals that live in the water-filled pores, and the film of water that surrounds soil particles. Living in the top fifteen centimeters of soil, they consume bacteria, releasing excess nitrogen in a form available to the plant roots that surround them.

Soil fungi, hidden underground, can spread for kilometres, creating a huge network that's vital for soils, and helps plants and trees to communicate - it’s sometimes known as the ‘wood wide web’.

Most fungi live as an underground network of branching, fusing cells called mycelium. If teased apart and laid it end to end, the mycelium found in a teaspoon of healthy soil could stretch anywhere from 100 metres to 10 km.

Fungi are ‘decomposers’. They get their nutrition by breaking down decaying organic matter like dead plants, trees and animals. This process releases nutrients into the soil, which then become available for plants and trees to absorb. In doing so, they enable the ‘circle of life,’ cycling nutrients throughout our ecosystem. Fungi have been shown to be amazing cleaners of soils, filtering out everything from heavy metals to pesticides, and even radioactive waste. Fungi also capture carbon. There is more carbon in soils than there is in all the world’s plants, forests and the atmosphere combined. The role fungi play in the ecosystem is invaluable (Soil Association).

Soil microbes are not just carbon processors, the vast microbial communities underfoot affect air quality and global temperatures, they can also affect the taste and quality of the food grown (Elizabeth Svoboda, 2015). Soil microorganisms have been sequestering carbon for hundreds of millions of years through the mycorrizal filaments, which are coated in a sticky protein called "glomalin." As much as 30 to 40 percent of the glomalin molecule is carbon. Glomalin may account for as much as one-third of the world's soil carbon -- and the soil contains more carbon than all plants and the atmosphere combined (Mike Amaranthus and Bruce Allen, 2013).

There's more carbon in our soils than there is in all the world's plants, forests and the atmosphere combined. Studies show that healthy soils on organic farms are able to store ('sequester') up to 25% more carbon in the long term (Frederick Kirschenmann, 2021).

Soil biodiversity supports human health, both directly and indirectly. Several soil bacteria and fungi are traditionally used in the production of soy sauce, cheese, wine, and other fermented food and beverages. Soil microorganisms can also help prevent chronic inflammatory diseases, including allergy, asthma, autoimmune diseases, inflammatory bowel disease, and depression. Since the early 1900s, many drugs and vaccines have been derived from soil organisms, from well-known antibiotics such as penicillin to bleomycin used to treat cancer and amphotericin for fungal infections. In a context of increasing diseases caused by resistant microorganisms, soil biodiversity has enormous potential to provide new drugs to combat them (New FAO report). The single greatest leverage point for a sustainable and healthy future for the seven billion people on the planet is thus arguably immediately underfoot: the living soil, where food is grown. Overall soil ecology still holds many mysteries. What Leonardo Da Vinci said five hundred years ago is probably still true today: "We know more about the movement of celestial bodies than about the soil underfoot."

Much is heard about many endangered animals in the Amazon and now all around the world. So also about the chainsaw-wielding workers cutting trees in the rainforest. However, relatively little is heard about the destruction of the habitat of kingdoms of life beyond plant and animal -- that of bacteria and fungi. Some microbiologists are warning that man must stop the destruction of the human microbiome, and that important species of microorganisms may have already gone extinct, some which might possibly play a key role in human health.

The Earth Microbiome Project is dedicated to analyzing and mapping microbial communities in soils and waters across the globe (Mike Amaranthus and Bruce Allen, 2013).

2. Forest Archeology

Forest archeology may help to trace human history in the forests. As stated by Skibo (2020), one might never know that human history here goes back thousands of years, but forests can help tell the story through archeology. Cultural sites discovered through archeological activities can become places of research, and cultural protection.

The job of Forest Archaeologists, according to Skibo (2020), is to make sure that forest operation activities avoid disturbing or destroying cultural resources.

In Honduras, a lost city was discovered in the Honduran rain forest (Preston, 2015).

Forest archeology is a vital field of study in forestry, at least to expand the scope of forest resources management and protection.

3. Treasure hunting

Treasure hunting is an activity that can enhance forest management. There are specialized instruments that detect underground water bodies even up and more than 200 meters deep, in addition to mineral deposits such as gold, diamond, and many others. Forest plant and animal species as bio indicators of the water bodies and mineral deposits can then be mapped out. Underground caves, burial grounds, buried treasures are discovered in underground treasure hunting. Treasure hunting and forest archeology can be of help in discovering the history of a forest and human occupation even for the past thousands of years.

4. Entomotherapy Entomophagy, Insect Farming, and other Arthropods

a. Entomotherapy,

Insects have a long and rich history in traditional medicine across the globe (Shriram H Bairagi, 2019). The use of insects as medicine and is an important alternative to modern therapy in many parts of the world including India, Mexico, Korea, China, Spain, Brazil, Argentina, Ecuador and various African countries (Lauren Seabrooks and Longqin Hu, 2017).

Weaver ants (*Oecophylla smaragdina*) have been used in the treatment of severe cough, cold and flu in Myanmar, Africa, Australia and India. In Thai culture, they are used for detoxification of blood, arresting hemorrhage during miscarriages, restoration of uterus and removal of any aftermath from the uterine canal after childbirth, stimulating pulse and heartbeat, and dizziness (Lauren Seabrooks and Longqin Hu, 2017).

The medicinal uses of insects and other arthropods plays an important role to treat various maladies and injuries and has a long tradition can be effective and provide results. Insect as a natural product having potential source as a medicine that is useful in curing as well as giving protection from some major diseases such as bacterial infections, HIV and cancer (Shriram H Bairagi, 2019).

Insects constitute an almost inexhaustible resource for pharmacological research due to the defensive chemicals they have developed over millennia of co-evolution with plants and predators (Eraldo Medeiros Costa-Neto, 2005). If given the proper attention, insect-derived substances hold great promise for the future of natural product drug discovery (Shriram H Bairagi, 2019).

Smt. Maneka Sanjay Gandhi (2019) gave the following summary of some lesser-known insects, which are used in human medicine:

i. The University of Miami is researching the use of the venom of the South American Devil Tree Ant in rheumatoid arthritis.

Many native healers use ants. Black Mountain Ant extracts dilate blood vessels that supply the penis. The venom of the Red Harvester Ant was used to cure rheumatism, arthritis and poliomyelitis. The South American tree ant, Pseudomyrmex sp., commonly called as the Samsum Ant's venom can reduce inflammation, inhibit tumour growth and treat liver ailments.

Even 3,000 years ago the mandibles of soldier ants were used as stitches. The ant was agitated, and when it opened its jaws , it was placed around the wound to be stitched and the mouth allowed to close. The ant's body was then pinched away, leaving the head holding the wound together.

ii. Several African cultures use poultices made from ground grasshoppers as pain relievers for migraines. Neurologists hypothesize that grasshopper toxins stimulate the human central nervous system, and dilate blood vessels, increasing circulation. Powdered, sun-dried, grasshopper is turned into a tea for the treatment of asthma and hepatitis.

iii. Across Southeast Asia, healers have capitalized on blister beetles' healing powers since ancient times. Also known as "Spanish Fly," the beetles represent humankind's first remedy for erectile dysfunction. Blister beetle secretions reduce burning pain sensations commonly associated with urinary tract infections, insect bites, kidney problems, and burns.

Blister beetles secrete cantharidin, which is effective in treating severe viral infections, because it prevents viral cell reproduction, and may be useful in treatment of cancerous tumours resistant to radiation and chemotherapy.

iv. Emerging science suggests that silkworm extracts may have benefits, as dietary supplements, for patients with heart disease and circulatory disorders. Preliminary studies indicate they reduce serum cholesterol, and dissolve vascular plaque. Boiled silkworm pupae have been used by Chinese medicine to treat apoplexy, bronchitis, convulsions and frequent urination. A bacteria that lives in the digestive system of silkworms contains a substance known as serrapeptase. This substance appears to offer pain relief for people with back injuries. There are studies underway to see if they can also help with sports injuries.

v. Traditional Asian practitioners use centipedes to treat tetanus, seizures, and convulsions. Centipedes are dried, ground into a paste, and applied topically to sores and carbuncles.

vi. Ayurveda uses termites, and their mounds, for ulcers, rheumatic diseases, anaemia, and pain. In Africa Termites are used in asthma, bronchitis, influenza, whooping cough.

vii. Spider silk is an ideal material to use in skin grafts, or ligament implants, because it is one of the strongest known natural fibres, and triggers little immune response. Spider silk may also be used to make fine sutures for stitching nerves, or eyes, to heal with little scarring.

viii. The Jatropha Leaf Miner, a moth who feeds on the Jatropha plant, is an example of an insect considered a pest who has medicinal value. The larvae of the insect are harvested, boiled, and mashed into a paste which is administered topically and is said to induce lactation, reduce fever, and soothe gastrointestinal tracts.

Jatropha Leaf Miner, *Stomphastis thraustica* (Meyrick, 1908) is a moth of the family Gracillariidae. It is known in Democratic Republic of Congo, Congo, Central African Republic, Ghana, and Nigeria. In addition, from Namibia, Zimbabwe, South Africa, Madagascar, Indonesia, India, and recently recorded in China.

ix. In southwestern Nigeria, an infected foot is treated by smearing and rubbing mashed mole crickets on it.

Gryllotalpa africana (Palisot de Beauvois, 1805), also known as the African mole cricket.

x. Locusts are eaten in post childbirth anaemia, lung diseases, asthma and chronic cough.

xi. The May Beetle is used as a remedy for anaemia and rheumatism. The Peanut Beetle for asthma, arthritis, tuberculosis and the Palm Beetle for earache.

May beetle of the Order Coleoptera, Family Scarabaeidae and Genus *Phyllophaga* (Harris, 1827).

xii. Cicadas are crushed and applied to treat migraine headaches and ear infection.

The cicadas are a superfamily, *Cicadoidea* (Latreille, 1802), of insects in the order Hemiptera (true bugs).

xiii. The Red Velvet Mite is eaten in urogenital disorders, and paralysis.

Red velvet mites, true velvet mites, or rain bugs, are small arachnids (eight-legged arthropods) found in plant litter and are known for their bright red color. They belong to the family *Trombidiidae* Leach, 1815.

xiv. A mass of boiled Mealybugs was ingested to alleviate the affects of poisonous mushrooms and other fungi, or diarrhoea, and to clean the teeth and in the treatment of caries.

xv. In the heads of cockroaches are chemical compounds that can kill Escherichia coli (E. Coli) and Methicillin-resistant Staphylococcus aureus (MRSA), two harmful bacteria that are resistant to most drugs. It was discovered that tissues, taken from the brains and nervous system of the insects, killed off over 90% of MRSA infections and E. coli.

xvi. At the Institute for Biomedical Research, Barcelona, scientists have carried out successful *in vitro* tests, using wasp venom, to kill cancer cells. Wasp venom contains Polybia MPI (from venom of the wasp Polybiapaulista), which shows anti tumour activity and kills only cancer cells, leaving the healthy cells around it.

xvii. Studies on caterpillar venom show that cecropins, which are a group of peptides isolated from the caterpillar blood of the Giant Silk Moth Hyalophoracecropia, have anti-microbial activity, and have been used as a potent anti-cancer agent against a variety of tumour cell lines. Cecropins are active against several mammalian lymphomas and leukaemia, and may offer novel strategies for the treatment of bladder cancer.

xviii. In 1993, Margatoxin was synthesized from the venom of the Central American bark scorpion. Patented by Merck, it has the potential to prevent bypass graft failure. Scorpion venom extract has been shown to be able to detect and spotlight cancer cells, under a special light used during surgery.

b. Entomophagy

Entomophagy, the scientific term for eating insects as a form of sustenance, is prevalent in over 3,000 ethnic groups across the world, which totals around 25 percent of the global population. Crickets, ants, beetle pupae and such have been regarded as nutritious, sustainable sources of protein before mankind discovered farming, and continue to be viable, if not more so, today (Beatrice Bowers. 2020.).

The world population is grows by 80 million a year and is expected to reach 9 billion by 2050. This means that there will be 2 billion more people in the world, which the current food production system may not be able to produce enough protein to feed. Eating insects may offer the way out (Sens Foods, 2017)**.**

There is a growing global demand for healthy insect products as shown in Figure 3. The factors responsible for the growing demand include the rising cost of animal meat. The current worldwide annual meat consumption of 280 million tonnes is to double by the year 2050 (Iwuoha, 2015a). Meat production already takes up a lot of agricultural land and is responsible for a huge amount of greenhouse gas emissions. The world clearly needs other alternative sources of animal protein, because meat production takes up a lot of land and water resources, and is clearly not sustainable in the long run. As shown in Figure 3, the market value of edible insects worldwide grew from US$503 million in 2019 to a projected over US$1 billion in 2023.

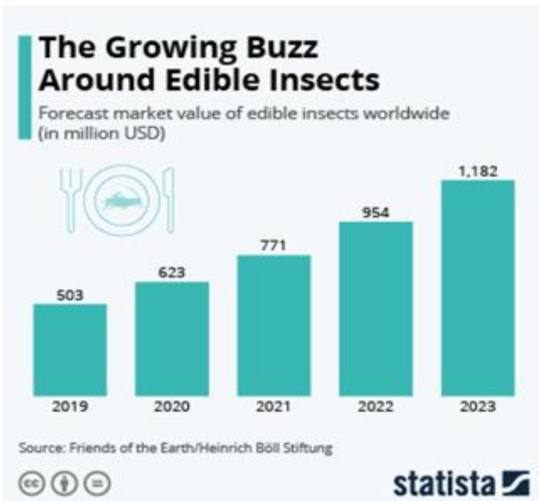

Figure 3: Market Value of Edible Insects Worldwide (in USD)

Despite the over 1,500 different edible insect species in Africa, Africa is not exploiting the world market for edible insects as shown in Figure 4. All other regions of the world apart from Africa and the Middle East are taking advantage of the economic boom of insect trade.

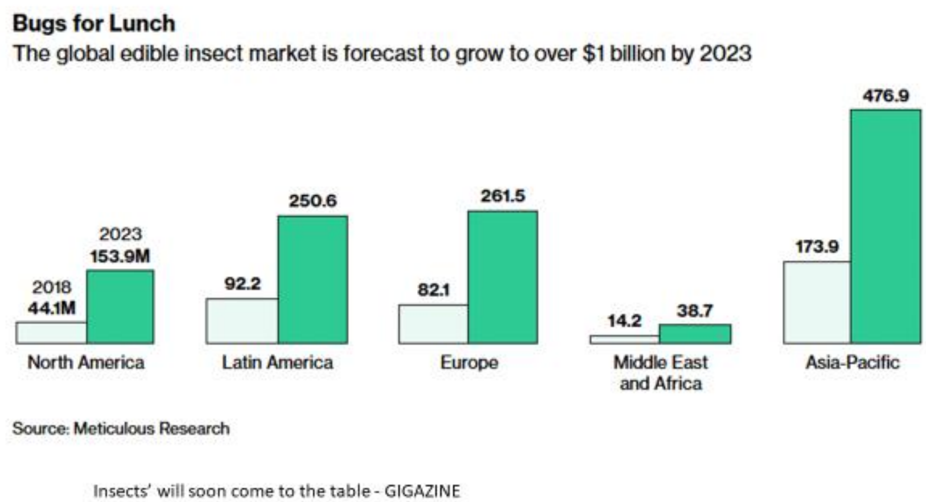

Figure 4: The Global Edible Insect Market Forecast by Regions (in USD)

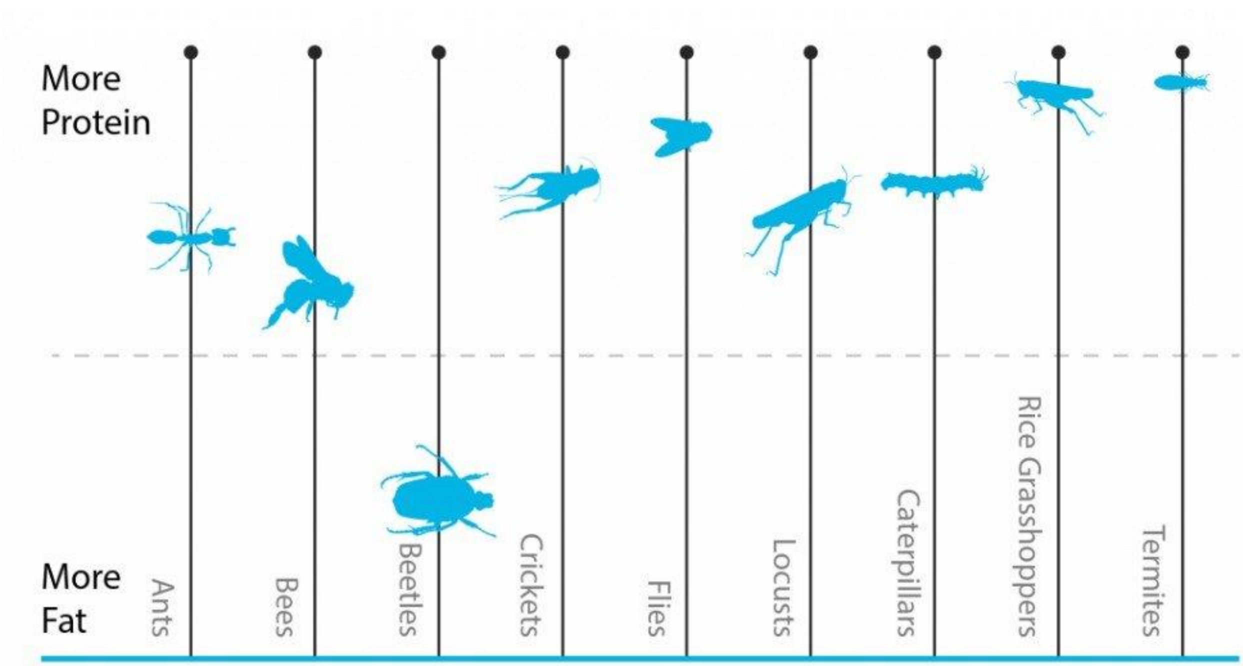

Figure 5: Insects as Healthy Protein Alternatives

Source: Broad nutritional scale of major insects. (Photo credit: precisionnutrition.com). Iwuoha (2015a)
Figures 5 shows that insects are good sources of protein.

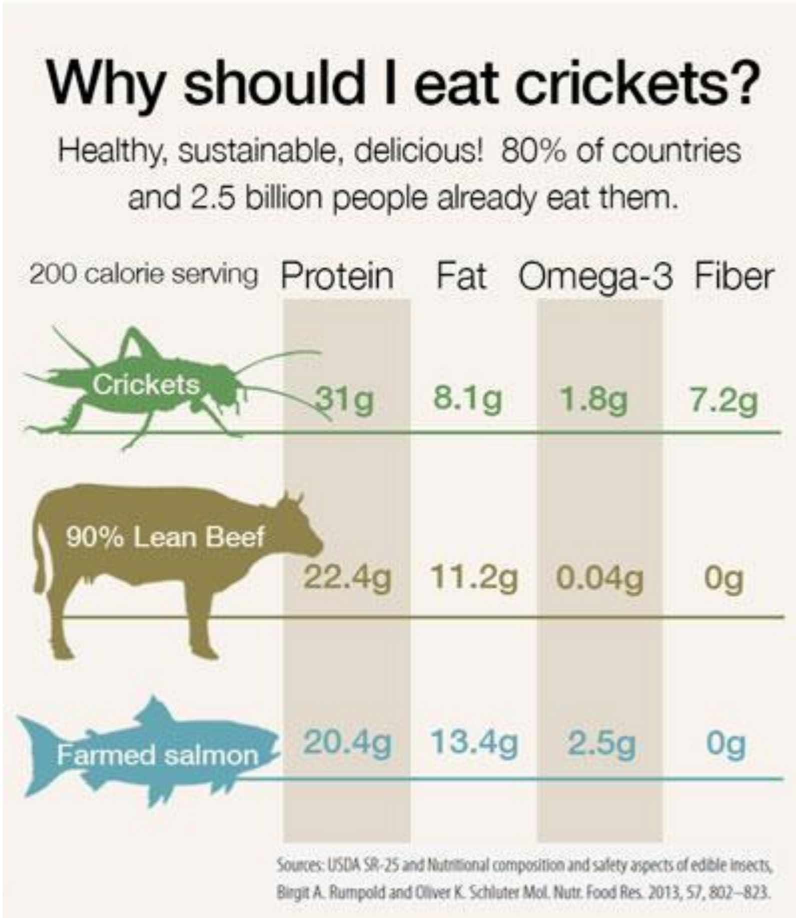

Figure 6. An infographic by Edible Insects (Photo credit: Edible Insects) (Beatrice Bowers. 2020).

Crickets for example have more protein than beef and salmon fish (Figure 6). It has less fat than beef and salmon. Crickets are good sources of omega-3. Fiber, which is totally lacking in beef and salmon, is present in crickets.

Crickets, for example, not only do they have a higher protein count than the same amount of ground beef per kilogram, but they also require fewer resources to farm, and therefore they less taxing on our environment to produce. In a period tormented by global warming, eco-consciousness is the norm, and entomophagy seems like the fairytale solution.

c. Insect farming:

AgriProtein, a South African young business, is breeding billions of flies on a farm to mate, lay eggs and produce maggots. AgriProtein's facility in Cape Town (South Africa) is the world's largest fly farm and houses roughly 8.5 billion flies that produce more than 20,000 kilograms of maggots every day. AgriProtein wants to shake up the international animal feed business by producing a cheaper and more valuable product that will help farmers around to world to make extra profits by reducing some of their feed costs (Iwuoha, 2015b).

A fly lays up to 400 eggs daily. The eggs, gathered from the cages, are hatched in a separate place. The maggots increase in size nearly 5,000 times in the span of just a few weeks. As they grow, they feed on the organic waste and convert it into protein. According to Iwuoha (2015b), the fast growth and efficient conversion of waste to protein is the biggest miracle in the entire process. The maggots recycle smelly organic waste, such as blood and animal manure, into odourless humus. The humus can be used as fertilizer to replenish farmlands. After feeding on and digesting waste for a couple of weeks, the maggots reach the optimum size for harvest after which they are separated from the residue.

After harvesting, the maggots are washed, dried, and crushed for oil extraction. The oil is very rich in fatty acids. The solid residue is milled into a flaked product that is packaged and sold to animal feed mills.

Bill Broadbent (2014) gave a graphical presentation of the protein content differences in protein and calorie, methane generation, feed, and water needs between crickets, chickens and cattle as presented in Figure 6 below.

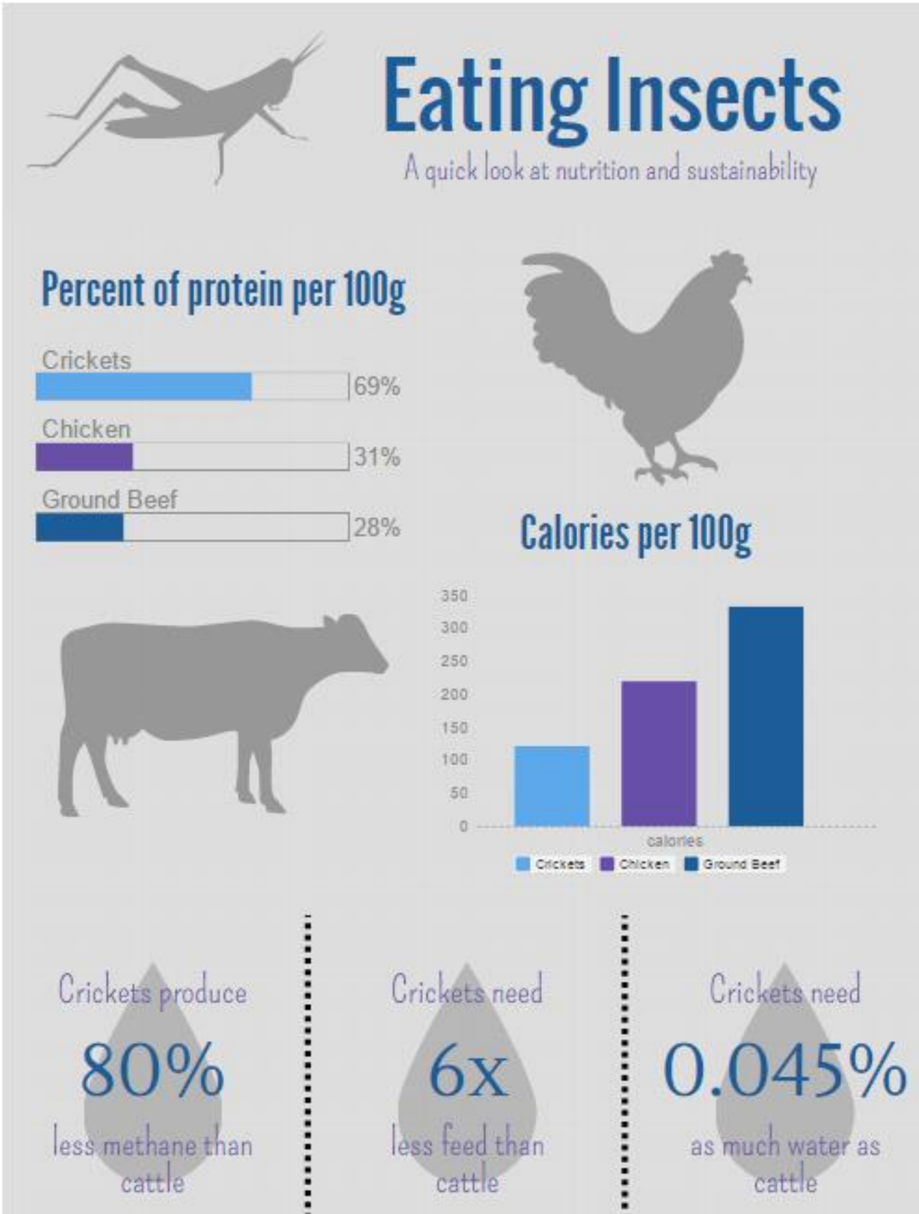

Figure 7: Eating Insects. Source: Bill Broadbent (2014).

Figure 7 shows that cricket farming can help cut greenhouse gases as crickets produce 80% less methane than cattle, need six times less feed than cattle, and need 0.045% as much water as cattle.

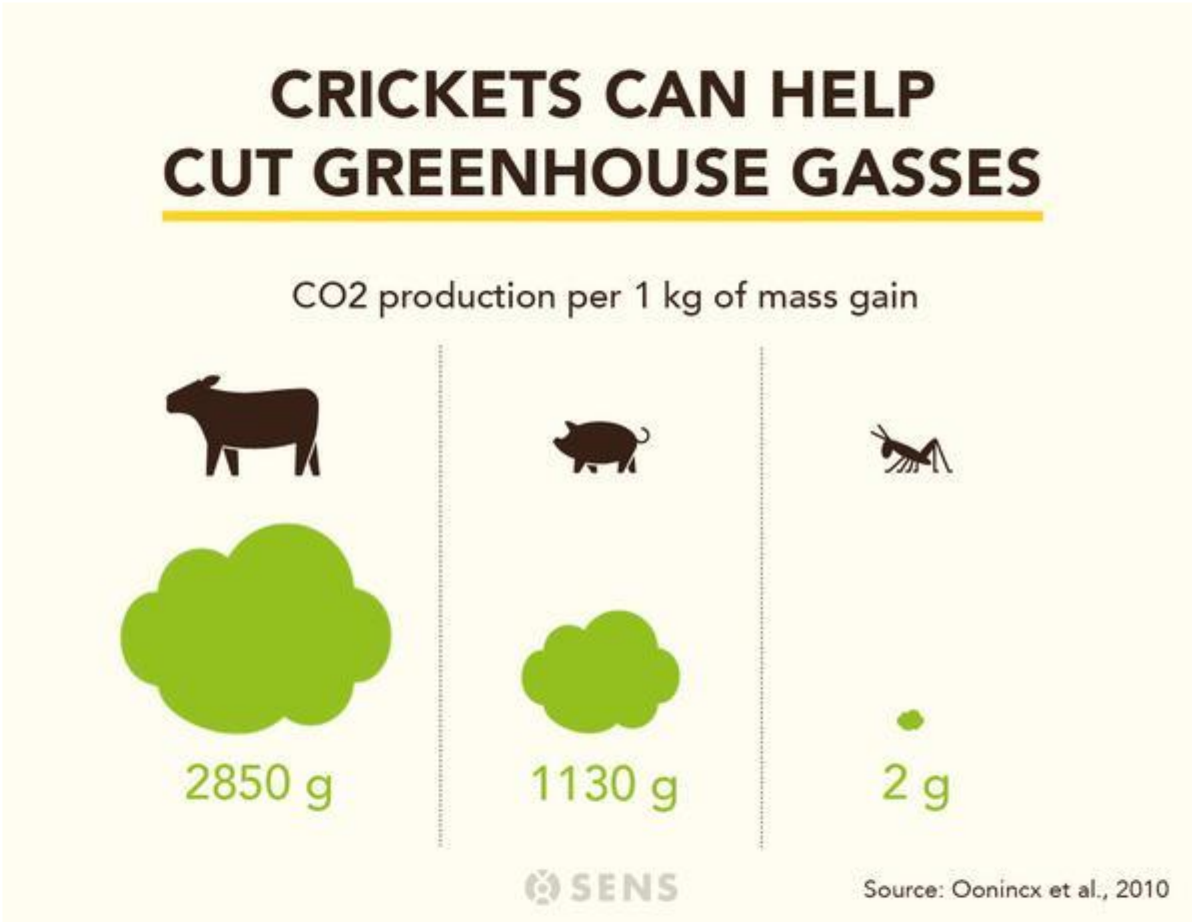

Figure 8. Cricket faming for the reduction of greenhouse gases. From Sens Foods (2017).

Figure 8 shows that for every one kilogram mass gain, about 3000 g of carbon dioxide are produced in cattle, 1130 g in piggery, and only 2 g in crickets.

Crickets, for example, not only do they have a higher protein count than the same amount of ground beef per kilogram, but they also require fewer resources to farm (Figure 7), and therefore they are less taxing on the environment to produce. In a period tormented by global warming, eco-consciousness is the norm, and entomophagy seems like a solution.

Crickets as beer. A Tokyo-based startup known as Join Earth launched a cricket-based craft brew in February, 2020, made in collaboration with Tono Brewing. It is the world's, first foray into drinkable bug juice. Grass-fed crickets are roasted and brewed with malt to create a dark ale that tastes like roasted caramel.

Gin from ants: The Cambridge Distillery worked with Rene Redzepi's Nordic Food Lab in 2014 to produce the Anty Gin (Figure 9), which contains the distillate of red wood ants, as well as nettle and wild wood avens to accent the traditional gin botanicals used (Beatrice Bowers. 2020).

Figure 9. Anty Gin. (Photo credit: The Cambridge Distillery)

Anty Gin bagged the top prize at the World Beverage Innovation Awards in 2015.
d. Other Arthropods
i. Scorpions:
Daniel A. Medina (2014) wrote that scorpions were in high demand for researchers from the US and EU for the venom they possess, and used as an ingredient to develop compounds for ant-cancer medicines. In China, they are eaten as a street-food snack
The demand has created a lucrative industry in Pakistan. A black scorpion weighing 60 grams can bring in $50,000 or more. Daniel A. Medina (2014) quoting a report in 2007 in The Wall Street Journal, 3.785 liters (one gallon) of scorpion venom sold for about US$ 39 million. In addition, at Los Angeles International Airport, California, described by authorities as a hub of exotic animal trafficking, scorpion smugglers were detained.
In some cultures of the world, scorpions are used as food as shown in Figure 10.

In China, scorpions are a tasty delicacy – Punch Newspapers

Figure 10: Scorpions prepared as a tasty delicacy in China
ii. Crabs:
Medicinal Bandage from crabs:

Figure 11. Seafood shells, such as from crab claws (here), contain a valuable material called chitin. Researchers have turned chitin into a new type of medical dressing that can boost wound healing (Silke Schmidt, 2021).
According to Silke Schmidt (2021), a new medical dressing helps skin wounds heal faster. Its innovative ingredient is the structural material in the skeletons, scales and shells of marine animals and insects.
Called chitin (KY-tin), a polymer, is second only to plant cellulose as nature's most abundant material. As a natural waste produced by seafood-processors, chitin costs little.

5. Fish Collagen:
There are benefits associated with all animal collagen sources, but fish collagen peptides have the best absorption and bioavailability due to their smaller particle sizes compared to other animal collagens, making them antioxidant powerhouses. Fish collagen is absorbed up to 1.5 times more efficiently into the body and has superior bioavailability over bovine or porcine collagens. Because its high bioavailability, fish collagen is absorbed more efficiently and enters the bloodstream more quickly, it is a best collagen source for medicinal purposes (Axe, 2021).

The scales, skin, bones and fins of fresh or saltwater fish are used for making fish collagen supplements. The scales, skin, bones and fins are usually considered waste products during fish processing, using them to create other products helps reduce environmental pollution.

According to Axe (2021), the health benefits of fish collagen include:
i. Anti-aging ii. Bone healing and regeneration iii. Wound healing
iv. Good protein source. Fish collagen is over 97 percent protein with no fat, sugars or carbohydrates, making it one of the absolute best protein foods. It also has a very distinctive amino acid profile. v. Antibacterial abilities
6. Nixtamalization: Enhancing the nutritional quality and economic value of maize:
About 1,500 B.C., cooks in coastal Guatemala figured out that cooking dried corn in alkali water removed thekernels' skins and produced a softer dough than unprocessed ground corn.
This process, called nixtamalization, increases the bioavailability of both protein and niacin, and radically reduces the toxins often found in moldy corn. The resulting dough, called masa, is the basis for corn tortillas, chips, tamales and other specialty corn foods. Whole corn that has been nixtamalized is called hominy or posole, while the ground form is called masa (The Mother Earth News Editors).
7. Gold and other minerals from an unusual Source – Human Feces
The headings for written articles on human feces are revealing. Stinking Rich? Human Waste Contains Gold, Research Finds (Charles D. Winters. 2015), Your poop could be a literal goldmine of precious metals (Rachael Feltman, 2015), You can earn $13,000 a year selling your poop (Rachael Feltman, 2015), Scientists claim gold in human excrement is worth millions (Celicia Jamasmie, 2015), and, Mining for Metals in the Waste We Create (John R. Wilsdon, 2022). Others are, Americans poop up to $4.2B in precious metals every year (Yaron Steinbuch, 2015), Sewage sludge could contain millions of dollars' worth of gold (Warren Cornwall, 2015), Turning manure into gold: The excrement economy (Melissa Pandika, 2015), and, 10 Exceptional Ways to Put Human Waste to Use in an Environmentally-Friendly Way (Conserve-Energy-Future).
All the nine pointed to the latest in human resources, gold and other minerals from human feces. Beyond the minerals, Conserve-Energy-Future listed possible uses of human feces.
According to Charles D. Winter (2015), researchers have detected trace amounts of gold, silver and other precious metals in human waste and are exploring how to make their extraction commercially feasible — a move that may stymie the dispersal of metals in the environment and lessen our dependence on mining. Rachael Feltman (2015a) wrote that a recent study estimated that a city of 1 million people in the USA might produce US$13 million worth of biosolid metals a year.
When biosolids are separated from effluent and dried, they become sludge. In some countries, the sewer sludge is gathered and sifted to extract precious metals. This can be especially profitable in third world nations. In Japan, the sludge, or what remains after the sewage is treated, is collected. In Suwa in Nagano Prefecture, a treatment plant near a large number of precision equipment manufacturers reportedly collected nearly 2 kilograms of gold in every metric ton of ash left from burning sludge, making it more gold-rich than the ore in many mines. The Japanese prefecture (similar to a U.S. county) has been mining its sewage treatment plant for the last 10 years. In 2008, it recovered $168,000 worth of gold. The recovery value is based on fluctuating gold prices (John R. Wilsdon, 2022).

Of particular interest is the report by Rachael Feltman (2015b). She wrote "…Yes**,** your feces are perhaps your greatest untapped monetary resource. Thanks to a nonprofit organization called OpenBiome, you can cash in to the tune of $13,000 a year -- and save lives while you're at it.
Since 2013, OpenBiome has been processing and shipping loads of it all over the country. The frozen stool is administered to patients who are very sick with infections of a bacterium called *C. difficile*. The bacterium can cause extreme gastrointestinal distress, leaving some sufferers housebound. Antibiotics often help, but sometimes the bacterium rears back as soon as treatment stops. That leads to a miserable, continuous course of antibiotics. By introducing healthy fecal matter into the gut of a patient (by way of endoscopy, nasal tubes, or swallowed capsules) doctors can abolish *C. difficile* for good.
…Finding a donor is tough business, and some patients grow so desperate that they treat themselves with fecal matter from friends and family. That's what happened to a friend of OpenBiome's founders, inspiring them to open up the first nationwide bank. So far they've shipped about 2,000 treatments to 185 hospitals around the country."
Melissa Pandika, (2015) also reported on the same fecal transplant.
Of particular interest is the submission by Conserve-Energy-Future tagged "10 Exceptional Ways to Put Human Waste to Use in an Environmentally-Friendly Way."
i. Production of biogas ii. Fertilizer iii. Fecal Transplant
iv. Hydrogen Fuel. Hydrogen fuel can be obtained from human waste through the same process as one of passing a current through water. It proves to be more efficient with less energy required in the process. Water is distilled from human waste solids then the waste is left in air-sealed tanks for microbial action to take place. This results in the formation of methane and carbon dioxide.
Methane formed in this process is cheaper as compared to relying on natural gas. Methane and carbon go through a tri-generation process that produces hydrogen fuel, heat, and electricity. With the abundance of human waste, a consistent supply of hydrogen

fuel can be achieved. Hydrogen fuel can be utilized in the running of rockets and the production of electricity by combining hydrogen and oxygen atoms.
v. Brick-making. Who knew that human waste could be used in the making of bricks? Incinerated sewage sludge ash is combined with vegetable oil in the making of bricks. These bricks are carbon-negative as the oil used is derived from plants, which have sucked carbon dioxide from the atmosphere.
In addition, in the utilization of such bricks in construction, the environment is protected considering that traditional bricks are made using processes that emit carbon dioxide. Human waste that traditionally would be sent to a landfill is utilized to build structures of many kinds without a scent and it is pocket-friendly.
The bricks are lighter and stronger which means wide usage of such bricks would revolutionize the construction industry not mentioning improvements could be made to them to make them better over time. Making these bricks could serve as a source of revenue for many.
vi. Fuel. In developing countries, the majority of households cook using biomass. Charcoal and fuelwood being the major sources of energy lead to the degradation of forests. A great solution is the use of human poop heated in the sun as fuel. This alternative fuel burns for two times longer compared to charcoal and releases lesser carbon monoxide.
Packaged as briquettes, one ton of these briquettes saves around 88 trees and proves to be a cheaper source of energy.
The process of making this fuel begins with the treatment of fecal waste by heating it in a waiting container so as to remove any harmful pathogens. The fecal waste is heated by the Sun to temperatures of around 60^{o} C for three hours.
Further improvements in technology would help mean that the lowest possible temperature and time can be used to sanitize waste. Upon cooling, hard and solid briquettes are formed as a result of the high fiber content present in feces.
vii. Source of Metals
viii. Janicki Omni Processor. The Janicki Omni Processor combines solid fuel combustion, steam power generation, and water treatment in the recycling of human waste to produce energy and clean drinking water. Therefore, the process can be used to sustain millions in the world who lack access to clean water. The process begins with human waste fed into a dryer to remove moisture thereby reducing it to dry fly ash.
The heat generated in this process is used to heat water in boiler pipes to form steam, which runs a generator to produce electricity. This electricity is enough to power the whole processor and surplus can be sold.
The steam that leaves the dryer goes through a series of filters before condensation and distillation to produce clean water. The Omni Processor doesn’t let out the foul smell and meets current emission standards.

ix. Cosmic Radiation Shield. Life in Mars is expected to pose a great risk to the health of those who will visit it since there is exposure to radiation from cosmic rays. The extent of the effects posed to human beings on exposure to galactic cosmic rays is not clearly known but it is known to increase the risk of cancer.

To protect humans, human waste together with water and food can be put in bags. These are used as a shield against radiation by lining the bags on the space shuttle used in interplanetary travels. Initially from the earth, the bags will be filled with drinking water. On reaching Mars, when the water is depleted, they will be replaced by bags with human waste.

x. Source of water. Due to the potential of producing water that is not potable from human waste, electrolysis of this water can be used to produce oxygen and hydrogen. This method of producing oxygen is used as a backup oxygen system for astronauts on long missions. Arguably, this method of extracting non-drinkable water can be utilized further to come up with water that is safe to drink by treating it.

Human waste in the production of renewable energy is a milestone. Through recycling of poop that would have ended up in a landfill and polluted the environment, benefits such as biogas, fertilizer, fecal transplant, hydrogen fuel, building bricks, metals, and drinking water can be obtained.

By all the uses, human waste proves to be cheap and an environmentally friendly alternative. Human waste has great potential to change the world.

8. Indigenous Knowledge:

I. Plants and animals in warfare:

a. Goat droppings and salt, combined and used as bullets.

In China, goat droppings are used as a drink as shown below.

TRENDING!! Goat Feces Now In High Demand In China Because Of It's Richness In Protein It's served in most cases with a combination of fruit juice, soya milk and other such extracts. – newsdesk, December 4, 2021

b. "Crab eye"seeds (Abrus precatorius subsp. africanus) used as bullets. The seeds are very toxic if ingested. In Queensland, Australia, the toxicity category is 1 (One).

Children's Health Queensland - Crab's eye (Abrus precatorius subsp. africanus)
Toxicity Category: 1

Warning**:** Seek urgent medical attention for any ingestion.

c. Army ants and Maize grain
Army ants (known as soldier ants in Nigeria) and a grain of maize seed are used in warfare especially in dislocating enemies out of a location.

Army Ants – Pinterest

d. *Sida acuta*: The dry leaves on the stems are harvested, wrapped, smoked or sniffed as tobacco against accidents, and gunshot attacks.

f. Black ant -“ikandu” in Yoruba, and palm kernel oil, used to secure property from being stolen by people from outside the home but not from thieves from within.

g. Black ant -“ikandu” in Yoruba, and bitter kola are used in war fronts against being hit by bullets.

II. Fire outbreak prevention:

a. *Securidaca longipedunculata* Fresen. (Igi Ìpẹta in Yoruba): To use this plant, the centre of a house wooden roof is located, and a piece of *Securidaca* wood is nailed to the located position of the roof; this serves as a thunder catcher and lightning arrestor.

Securidaca longipedunculata Fresen.- Alchetron

III. Storm prevention:

a. Onion peels and the peels of native banana ("ogede ominni" in Yoruba), dig a hole in the ground, put the onion peels first and on top, put the banana peels, cover with soil. There will be no storm in such a place.

b. Stubborn grass (*Eleusine indica*): The grass is uprooted and is placed on a forked tree stem with a piece of stone or rock placed on it to prevent storm on a farm.

IV. Anti-army ants (soldier ants) preparation: White bowl, white quartz stone and water: To effect the moving out of army ants from properties they have invaded, put water and a piece of white quartz stone in a white bowl. The bowl(s) are placed at the entrance(s) of the property, the army ants will move out of the property.

V. Infertility:

a. *Waltheria indica* (Padimo in Yoruba): Uproot whole plant, cut into roots, leaves and stems. In a pot, first put the roots, then the leaves, and the aerial parts. Next put ashes wrapped in banana leaves on top of the aerial parts. Add water, boil, and drink for infertility.

Waltheria indica – Photoimages.siu.edu

VI. Low or No sperm count:

Fresh maize grains (*Zea mays* Linn.), Monkey cola (*Cola millenii*/*Cola laurifolia* (obì ẹdun in Yoruba), table salt; grind all together, dry, and take with maize pap every night.

VII. Diseases:

a. Asthma: *Thaumatococcus danielli* (Benn.) Benth. and, Megaphrynium macrostachyum (K.Schum.) Milne-Redh:

The roots of *Thaumatococcus danielli (*Ewéran in Yoruba), and *Megaphrynium macrostachyum* (Gbòdògì in Yoruba) are dried, pyrolysed, powdered; the powder is mixed with honey and licked for asthma.

b. Bile duct obstruction/Oliguria: *Hoslunda opposita* Vahl: Boil the dried ground leaves in water, cool and strain. Drink three times daily for bile obstruction and oliguria.

African Plants - A Photo Guide – *Hoslunda opposita* Vahl

c. Hypertension: For, hypertension, pyrolyse the whole fruit of *Blighia sapida,* orally take the powder with warm water daily.

Fruits fro A-Z – WordPress.com Ackee/akee apple/Blighia sapida

9. Plants used in the management of brain disorders:

i. *Achyranthes aspera* Prickly chaff flower When inhaled the powder of the seeds, it gives relief from stiffness and headache of migraine.

ii. *Albizzia lebbek* (i) Its seeds and black pepper powder when applied near eyes, cures unconsciousness. (ii) Its seed powder is one of the constituents for treating psychosis, insanity, anxiety, hysteria.

iii. *Allium cepa* Onion Tea from its seeds is beneficial in sleeplessness.

iv. *Brassica nigra* Black mustard (i) Its seeds and pigeon's droppings after grinding, are applied on forehead. It helps relieve migraine. (ii) Its fresh oil when massaged, reduces fatigue and laziness.
v. *Citrus aurantifolia* Lemon (i) Seeds and juice are beneficial in insanity related disorder. (ii) Lemon juice is given to the patient of anxiety to regularize the heart beat.
vi. *Cynodon dactylon* Dobb grass, Carpet grass Extract of whole plant helps cure madness and epilepsy.
vii. *Daucus carota* Carrot Leaves are extracted with warm "ghee" and drops given in nose and ears to cure migraine through sneezing.
viii. *Eclipta alba* After mixing black pepper powder in its juice, it is applied on forehead for relief in migraine.
ix. *Lawsonia inermis* Henna Seeds in honey or decoction of flowers are given to cure giddiness.
x. *Moringa oleifera* Moringa (i) After grinding the bark, the liquid is squeezed and put into the nostrils or given orally as drink to cure meningitis. (ii) Decoction of its roots is given for epilepsy and hysteria in women.
xi. *Mucuna pruriens* Velvet bean In Ayurveda, it has been described for use in several illnesses and overall body strength. Scientifically it has also been found to be effective in Parkinson's disease.

xii. *Psidium guajava* Guava (i) Decoction of leaves is given to cure mental and physical deformities. (ii) Tincture of leaves is massaged on the backbone of children for convulsions.

xiii. *Punica granatum* Pomegranate (i) Leaves after boiling with water and concentrating, the extract is given in warm milk to cure fatigue, tiredness and insomnia. (ii) Leaves and rose flowers are cooked in water and concentrated. It is given in ghee to cure madness.

xiv. *Sesbania grandiflora* Sesbane (i) Sesbane leaves and black pepper are ground in cow urine and made to inhale. It brings immediate relief from epilepsy. (ii) Few drops of leaf or flower extract are put in the opposite nostril of migraine pain giving immediate relief.

xv. *Sida cordifolia* Country mallow (i) Its powder after cooking in milk, is given to the patient or massaged, giving relief in facial paralysis. (ii) To control the excessive anxiety, the plant and "apamarg" (Achyranthes aspera) are boiled in milk until concentration and given.
xvi. *Syzygium aromaticum* Cloves are ground in water and the paste is applied on the earlobes to cure migraine. Except genetically rooted brain disorders, the Ayurvedic plants have potential to cure most of the mental diseases (Balkrishna, and Misra, 2017).
10. Plant oils: Health Benefits of Navel Oiling:
Navel oiling or navel therapy is an age-old practice of massaging the belly button with essential oils to achieve astounding health benefits, thereby helping to treat various ailments in the body. Once a gateway to the life-sustaining umbilical cord, the belly button serves as a centre of balance in adulthood, where a lot of energy is stored (Nikita Bhardwaj, 2021). Scientific studies recommend a delay of cord clamping to one to three minutes post birth, citing benefits to the infants. Interestingly, after a person's death, the belly button stays warm up to three hours. Being rich in stem cells, several studies also support the storing of the umbilical cord blood. These cells can morph into other cells and can help deal with ailments (Resha Patel).

The belly button is more than just a little dot on the navel (News18). The belly button is connected to every organ of the body through multiple veins, so massaging oil can help to nourish the nerve endings and help the body stay healthy (Nikita Bhardwaj, 2021).

According to Resha Patel, the belly button is not so little. Resha Patel lists the following about belly button:

i. The belly button has the thinnest layer of muscle between the inner vagus nerve and the skin compared to other areas. By activating it, one directly stimulates the vagus nerve, affecting the brain.

ii. There are 72,000 veins in the navel, making the belly button a focal point. All these nerves get stimulated when the belly button is cared for and nourished.

iii. In Ayurveda, *nabhi* (navel or umbilical cord) is considered as an anatomical landmark to identify the position of various organs.

iv. The displacement of the umbilicus or *nabhi chyuti* leads to various diseases. Many conditions get cured just by correcting this.

v. The nabhi is '*agni sthana*' or 'seat of agni.' This is where *samana vayu* (the prana or life force energy that supports digestion, formation, and elimination of urine) and *pachaka pitta* (digestive fire) resides. Massaging or stimulating the *nabhi* will aid these functions.

vi. A scientific study of 60 participants found 2,368 different types of germs nestling in the belly button. Similar to every human being's fingerprints being unique, the belly button bacteria are also one-of-a-kind, many of which are a sign of good health.

vii. The center of the belly button is at the center of the solar plexus. This region assumes unique physical and spiritual significance. The solar plexus is also called the Manipura chakra, which when balanced, promotes clarity of mind, confidence, strength, and compassion. Physiologically, the solar plexus is connected to the central nervous system, optic nerves, and stomach.

Oiling the belly button is an Ayurvedic practice. In Ayurveda, belly button oiling is known as Nabhi Chikitsa. Nabhi means the belly button in Sanskrit. Ayurvedic experts practised this method to get optimum relief from various ailments. They believe the belly button is a secret spot on the body that can effectively cure daily health problems. The belly button is the source of energy connected to other parts of the body; to the mouth, the skin and even to health concerns like menstrual cramps. Once inserted into the belly button, oil is easily absorbed and effortlessly distributed throughout the body, and studies have shown systemic bioavailability of medications via navel administration (Healthy Huemans, 2021).

As an ancient practice, Navel therapy is about filling the belly button (on an empty stomach) with lukewarm oil for detoxifying, nurturing, and treating ailments in the body. Since the belly button presents an abundance of blood vessels and pathways to the body's extremities, the absorption of oils through the navel pathways is very strong. Hence, it has unbelievable health and beauty benefits. However, remember to keep the belly button clean all the time, as it is a very sensitive organ of the body and has tendency for the buildup of bacteria and fungi (Dallas Yoga Fest, 2019).

'The Gut' (Intestines), situated right behind the belly button is home to millions of neurons – all of which are connected to the brain. Hence the connection between 'gut feelings' and many emotions. The intestines hold 60% blood of in the body, produce 90 per cent of serotonin and 50 per cent of dopamine. Serotonin and Dopamine are known as the 'happy' hormones due to the roles they play in regulating mood and emotion (Dallas Yoga Fest, 2019).

From dryness of the eyes, poor vision, chapped lips, weight loss, fertility, infections, glowing youthful skin, healthy hair, joint pain, and more, oiling the belly button can provide a ton of health benefits (Healthy Huemans, 2021).

Just by tending to this little one, you could (Resha Patel):

- feel instantly calmer
- switch on the glow lights in your skin
- coax your hair to grow longer and thicker
- improve your moods (clue: feel happier)
- stimulate your brain to function better
- increase your digestive ability
- be kinder to your knees

According to (Dallas Yoga Fest, 2019), try Navel Therapy if you are looking to….

- Improve mood, energy cure depression
- Relieve chronic pain
- Want to sleep better
- Achieve hormonal balance
- Increase blood circulation
- Want to cool off the head and heat up the belly
- Improve gut health and enhance your digestive function
- Promotes inner peace and empathy

- Sharpens eyesight

Navel Therapy (Nabhi Chikitsa) (Dallas Yoga Fest, 2019).

i. Enhances digestive ability

Massaging the belly button with a few drops of mustard oil can help to relieve irritable bowel syndrome, aid gut health, and reduce other digestive issues like an upset stomach, bloating, or constipation.

Daily application of mustard oil around the edges of your belly in circular motion helps to release gastric and bile juice from the spleen in the liver, which improves digestion. To get relief from nausea and gut pain, apply peppermint or ginger oil on the belly button (Nikita Bhardwaj, 2021).

ii. Stomach Pain

Belly button oiling can alleviate stomach pain by releasing the pressure off the belly area. It can cure symptoms like indigestion, food poisoning, nausea, gastritis, bloating, and diarrhea. **Recommended oil: Peppermint Essential oil diluted with Olive Oil (**Healthy Huemans, (2021)**.**

iii. Calms the mind

Rhythmically stimulating the belly button with circular motion can help to de-stress and relax. Lavender oil, popularly used in aromatherapy for de-stressing, can be used to massage the belly button for improved mental well-being (Nikita Bhardwaj, 2021).

iv. Stimulates natural glow to the skin

For a smooth, clear, and glowing complexion, massage the belly button with olive oil every day. Enriched with natural fatty acids and antioxidants, olive oil can help to reduce inflammation, prevent skin problems, cure skin infections and moisturize the skin from head to toe, including lips and heels (Nikita Bhardwaj, 2021).

Applying almond oil on the naval ensures optimum absorption of the nutrients and subsequently, it helps in improving the texture of skin and imparting glow to skin. **Recommended oil:** Almond **(**Healthy Huemans, (2021)**.**

v. Clear Skin

Applying oil on belly button helps treat acne quickly. Apply oil to the belly button is often considered more potent a remedy than topical application. **Recommended oil:** Neem (Healthy Huemans, (2021).

vi. Stimulates hair growth

Connected to 72,000 veins inside the body, the belly button helps the body to absorb minerals that are responsible for healthy hair growth and volume. Providing nourishment to the veins responsible for graying of hair can help to prevent premature graying, making the hair strong from the roots.

Rich in vitamins, minerals, vitamin C, B, E, copper, and zinc, coconut oil is the best choice to prevent hair loss and improve hair quality. One can also use olive oil or jojoba oil on the belly button to prevent excessive dry scalp and hair (Nikita Bhardwaj, 2021).

Belly button oiling can help speed up hair growth. **Recommended oil: Castor** (Healthy Huemans, (2021).

vii. Improves reproductive health/Fertility

Ayurvedic experts recommend massaging the belly button with essential oils can improve reproductive health in both males and females. Putting a few drops of neem oil, rosehip oil, coconut oil, or lemon essential oil to the belly every day can help to increase sperm count, relieve menstrual cramps, boost fertility, and prevent reproductive disorders (Nikita Bhardwaj, 2021).

The belly button is connected to fertility. Adding oils to this spot can influence fertility, whether in a man or woman. The remedy works by promoting relaxation of the uterine and abdominal muscles, protecting the sperm inside the tube for fertilization, enhancing the sperm motility and count, and treating menstrual issues like irregular periods. **Recommended oil: Coconut (**(Healthy Huemans, 2021).

viii. Relieves joint pain

Inflammation in muscles or excessive wear and tear could result in joint pain. Using castor oil, rosemary oil, for navel therapy can help to reduce pain, strengthen joints, and improve flexibility. Navel therapy is a natural alternative for people in their early stages of arthritis or with weak bone density **(**Nikita Bhardwaj, 2021**).**

ix. Improves dry eyes syndrome

Pollution, too much reading, watching the screen, smoking, aging, or any other medical condition could result in dry eyes that might hinder vision and result in a burning sensation in the eyes. Massaging the belly button with coconut can help to nourish the dry veins, which in turn improves blood circulation and improves eye health (Nikita Bhardwaj, 2021).

x. Anti-Aging

Belly button oiling benefits include reducing the signs of aging. Applying oil to belly button reduces the appearance of wrinkles and under eye circles. **Recommended oil: Castor (Healthy Huemans).**

xi. Menstrual Cramps

Belly button oiling benefits include relieving menstrual cramps and pain. By relaxing the abdominal muscles and soothing the discomfort caused by uterine contraction. The pain is relieved due to the antioxidant properties of oil. **Recommended oil: Ginger Essential oil diluted with Olive Oil (Healthy Huemans, 2021).**

xii. Infection

The belly button is a very sensitive organ of the body and connects to other parts of the body system. Belly button oiling can help cure bacteria and fungi. The best oils for this purpose is tea tree oil, coconut oil, and eucalyptus oil. These oils have antibacterial and antiviral properties that effectively kill the bacteria. **Recommended oil: Coconut and Tea Tree (Healthy Huemnas, 2021).**

xiii. Nail Health
Belly button oiling can help with nail health by removing any fungus. **Recommended oil: Castor (Healthy Huemans, 2021).**
xiv. Lightens lip shade
Coconut oil applied to the belly button every night before bedtime lightens and protects lips from chapping.
xv. Blood cleansing
Belly button oiling helps in cleaning blood and getting rid of pollutants and blemishes in the body. Therapeutic oils such as neem oil, rosehip oil, coconut oil, and lemon essential oil can help (News18, 2021).
xvi. Balanced Chakra
According to Ayurveda, the Navel Chakra is a major source of energy and imagination. It is home to one's biggest dreams, fantasies, and goals. You should keep your navel balanced if you want to connect with your creativity.

Recommended oil: Grapeseed (Healthy Hueman, 2021).
xvii. Helps to remove dirt. Cleaning the belly button removes bacteria and filth that has accumulated and keeps the stomach and navel regions clear of any potential ailments.
xviii. Good for eyes. Oiling the belly button with any suitable oil mixed with mustard oil will improve eye health in people suffering from poor vision. In addition, it is suitable to reduce the appearance of puffy eyes and dark circles in people who constantly strain their eyes on the screens.
The procedure for belly button oiling takes only few minutes. Warm oil is poured over the belly button, and the belly button is massaged in a circular motion for 5-10 minutes. For the best outcome, this should be done every day before going to bed or after bath. In addition, oiling at night can make one feel more relaxed upon wake up in the morning (News18, 2021; Healthy Huemans, 2021). The belly button should be regularly cleansed; and not too much pressure should be applied on the navel.
Rub a few drops of oil inside and around the belly button every night. Regular practice of this will give stunning results, and with absolutely no side effects. There are certain oils that can be used for specific conditions (Resha Patel).

Table 1: Oils and their specific uses in Belly Button Oiling

Coconut Oil	• Keeps internal organs strong and prevents bloating • Helps in treating cough, cold and flu. • Provides relief from stomach cramps pain during menstrual cycles • Provisions for better eyesight • Reduces belly fat
Almond Oil	• Softens the skin, makes it supple and glowing as Almonds are rich source of Vitamin E and proteins • Fades dark circles and wrinkles • Heals dry and cracked lips
Neem Oil	• Cures acne, dark spots and other skin infections, due to medicinal properties of Neem • Cures itching and rashes on the skin • Cures intestinal worms thus improves conditions of loss of appetite • Reduces hair fall conditions
Castor Oil	• Reduces intestinal swelling • Relieves stomach pain and helps to expel trapped gas • Works on Hair growth • Reduces knee pain • Relieves Arthritis, back pain and muscle aches
Mustard Oil	• Eliminates dryness of skin and moistens lips especially during the winter season • Cures throat infections, nose congestion, ear and leg pains • Improves memory, reduces feeling of tiredness and signs of depression • Stimulates the intestine and activates the excretory system thus improving the digestion process
Olive Oil	• Stabilizes hormonal imbalance in women and consequently increase fertility • Relieves vitiated Pitta conditions for example, high blood pressure
Clarified Butter/Indian Desi Ghee	• Keeps lips and skin optimally moisturized and improves fairness • Improves blood flow of the nervous system and increase immunity • Prevents hair fall and keeps them silky and shining • Relieves knee and joint pains • Cures constipation and improves digestive system

Source: Adapted from Dallas Yoga Fest, 2019. Want To Know The Simple Secret Key To Daily Good Health?
10. Charcoal Medicine:

Charcoal is an incredible substance renowned in history for its healing powers and has been commonly used by man and beast alike for possibly thousands of years. Charcoal is a lifesaver and it is one of the most powerful antidotes known to man (Not the Norm Ltd, 2015).

Animals knew the medicinal properties of charcoal before man and many species of wild beast are known to eat charcoal resulting from bonfires or lightning strikes (Engel, Cindy, 2003). Many scientific studies confirm these observations (Not the Norm Ltd, 2015).

Since ancient times, animals and humans have relied on charcoal to counteract the ill-effects of harmful materials that have been ingested, intentionally or otherwise. This is especially valid for wild animals and ancient peoples who had to depend upon limited food resources. The diet of charcoal-eating animals includes a variety of plants that contain a high amount of phenolic and other harmful compounds that interfere with their digestion. Studies have confirmed that ingested charcoal render these toxins harmless once inside their guts (Not the Norm Ltd, 2015).

It is natural, safe, non-toxic and relieves several ailments including drug overdose (Engel, Cindy, 2003), poisoning, stomach disorders (Lucas, G. H. W., and V. E. Henderson, 1933) and high blood cholesterol (Neuvonen, P. J., et al. 1989). One study carried out using rat models even suggests the ability of charcoal to increase the lifespan of mammals by 43% (Frolkis, V. V., et al., 1989). According to ANI (2009), a study found that charcoal could prove useful in dealing with the high rate of heart disease in patients with advanced kidney disease.

It has been observed in the past that patients with advanced kidney disease have high rates of atherosclerosis or "hardening of the arteries" and death from heart disease.

Studies have shown that AST-120, the form of oral activated charcoal a product called AST-120 previously used by doctors in emergency treatment for certain types of poisoning, can be helpful in treating kidney disease as well. This is especially important because there is no effective treatment to reduce the high rate of cardiovascular mortality in patients with end-stage renal disease (ANI (2009).

In the great book titled “Charcoal, God’s Humble Doctor,” the author, John Densely gave an in-depth into some uses of charcoal as follows:

i. Charcoal is used for cooking.

ii. It is used in the International Space Station (ISS) to purify water and air so that the two can be used repeatedly. One liter of water can cost upwards of US$10,000 to take to the ISS, so it is important to be able to clean it and use it again repeatedly.

iii. Charcoal is used to purify the air in nuclear submarines that travel for months under the water in the deepest oceans.

iv. Charcoal is used in the most modern hospitals in the world to treat different health problems.

Charcoal is used in kidney and liver dialysis machines to purify the blood when the kidneys or liver are sick and not functioning properly.

v. Charcoal works to prevent cerebral malaria.

vi. Charcoal is used in very expensive wound dressings to stop the spread of infections when antibiotics fail.

vii. Charcoal neutralizes ingested poisons. When people take drugs and become sick, charcoal is used to reverse the drug poisoning.

viii. A tablespoon of very fine charcoal powder mixed with olive oil is swallowed to cure indigestion.

ix. Charcoal crumbs given to chickens help the chickens to lay more eggs and bigger eggs.

x. Charcoal crumbs given to cows help in the cure of mastitis and in addition help the cows to produce more milk.

xi. Charcoal crumbs spread in animal pens help adsorb bad odours, thereby having less flies and with less flies, less infections.

xii. There are hundreds of different charcoal products. These include, charcoal soaps, charcoal creams and salves for skin problems, charcoal fabric, charcoal cosmetics, charcoal powders and toothpaste.

xiii. Charcoal is used in different foods for colourings.

xiv. Charcoal fibres are used in combat uniforms to neutralize poisonous gases including radioactive chemicals and athletic gear to promote circulation.

xv. Charcoal fibres are used in athletic gear to promote circulation.

xvi. Charcoal is used in hundreds of applications to purify contaminated water.

xvii. Charcoal in agriculture. Adding charcoal to the soil has be shown to increase some crop production up to 400%.

xviii. Charcoal in agriculture. Sprinkling charcoal in banana plantation has shown to help stop the dreaded BXM or BBW wilt.

xix. Charcoal in agriculture. Where the soil has been poisoned by repeated use of pesticides, herbicides, and fertilizers, charcoal helps to restore the soil by neutralizing the buildup of the poisons in the soil.

11. Healing Forest:

Healing forest is a concept that I have actively promoted over the years to enhance the health and welfare of our citizens. It has immense benefits for urban dwellers exposed to stress and the attendant consequences. I acknowledge the Ogun State Traditional Medicine Board who immediately accepted my suggestion to have it in the State.

Evans (2018) has noted that "Nature deficit disorder" is a modern affliction. This manifests increasingly in people living in cities, working in high-rise office buildings, and becoming addicted to their innumerable electronic devices.

University of Minnesota (2016) noted that research revealed that environments could increase or reduce stress, which in turn impact human bodies. The stress of an unpleasant environment can cause one to feel anxious, sad, or helpless. This in turn elevates blood pressure, heart rate, and muscle tension and suppresses immune system. A pleasing environment reverses that. The University further stated that what people are seeing, hearing, experiencing at any moment is changing not only their mood, but also how the nervous, endocrine, and immune systems are working. In addition, that "Nature deprivation," a lack of time in the natural world, largely due to hours spent in front of TV or computer screens, has been associated, unsurprisingly, with depression.

Exposure to natural world reduces mental fatigue provoked by the city environment and increases concentration and the ability to perform tasks. Having a walk in nature may clear the head of bad feelings. Natural spaces have also an effect on behaviour: promotes self-discipline, self-esteem, self-reliance, self-concept, and self-perception and reduces aggressive behaviours. Plants in a work office or a classroom decreases coughing, headaches, dry skin and fatigue. They also reduce the occurrence and frequency of time off through illnesses (Camps, 2016).

Being in nature, or even viewing scenes of nature, reduces anger, fear, and stress and increases pleasant feelings. Exposure to nature not only makes one feel better emotionally, it contributes to physical wellbeing, reducing blood pressure, heart rate, muscle tension, and the production of stress hormones. It may even reduce mortality.

Research done in hospitals, offices, and schools has found that even a simple plant in a room can have a significant impact on stress and anxiety (University of Minnesota, 2016).

A Japanese organization, Japanese Society of Forest Medicine promotes research on the therapeutic effects of forests on human health and educates people on the practice of forest. It has found that spending time in a forest can reduce stress, anxiety, depression, and anger; strengthen the immune system; improve cardiovascular and metabolic health; and boost overall well-being.

*Japan, in 1982 launched a national program to encourage forest bathing, and in 2004, a formal study of the link between forests and human health began in Iiyama, Japan—a place particularly known for its lush, green forests. Now, each year upwards of 2.5 million people walk those forest trails as a way to ease stress and enhance health. The art of "forest bathing"—*shinrin-yoku *involves slowly walking through a forest (Evans, 2018).*

Camps (2016) listed the following as benefits of connecting children with nature:

- Foster their intellectual, cognitive, emotional, social, spiritual and physical development.
- Supports creativity and problem solving.
- Display decision-making skills.
- Increases their ability to focus and enhances cognitive abilities.
- Improves academic performance (social studies, science, language arts and maths).
- Reduces symptoms of Attention Deficit Disorder (ADD) and Attention Deficit Hyperactivity Disorder (ADHD).
- Increases physical activity, aware of nutrition, politeness and creativity.
- Increases calmness and reduces disruptive behaviour.
- Reduces myopia.
- Improves social relations, self-control and self-discipline.
- Reduces stress.
- Promotes wellness of future adults.
- Promotes support and concern to conservation initiatives in adulthood.

Recommendations:

1. A broader perception about forests, their products, services, and uses needs to be taken beyond being regarded only as wood production lots.
2. Forest soils, and all soils, are a life production machine that can enhance national economy, and the health of the people. We need not wait until we start importing soil organisms from other nations before we know that we have destroyed and forfeited our own natural resources. Soils need protection for the sake of human survival.

Foresters and soil scientists should be seen as important doctors of nature and should therefore be rightly accorded the prime place of importance.

3. Forestry is the science and management of life of all components of the ecosystem including that of man. A revolutionary insight into forestry is advocated in this submission. The current focus and overemphasis on teaching forestry for the production of wood is myopic. In any case, deforestation has shown that the timber is no longer freely available.
4. Revolutionary research areas highlighted in this paper can help enhance the scope and acceptance of forests and forest practitioners by the general populace and the ruling class.

5. The establishment of healing forests will contribute significantly to the health of Nigerians especially the overstressed individuals in the cities.
6. Insect and all other arthropods should be documented. In addition, they should studied for their medicinal values and ecological services. Insect farming practice is recommended.
7. Man is a central point in forestry. Therefore his products such as the feces and urine, if properly used can contribute to the enhancement of the environment.
8. On belly button oiling, tropical oil seeds in Nigeria can be studied for their use in belly button applications.
9. Forestry organizations especially the Forest Products Society should begin the use of YouTube channels, television programmes for nature, nature photography such as underwater photography, Time lapse photography are avenues for the development of radical forestry in the 21st Century.
10. Leadership studies should be included in forestry programmes. It is clear that Nigeria needs a new crop of leaders from every sphere including forestry. Political leadership has become an albatross on forestry development.
11. Forestry institutions in Nigeria should become the best especially in Africa in order for forestry to be regarded and respected. This can be through innovative programmes. Forestry can be oriented to become the “economic basket” of the nation through innovative research, programmes and products. This association can set up a body to study and compile research studies that can be further developed for innovations.
First class laboratories are “sine qua non” (indispensable) for forestry development. So also is the acquisition of technological instruments such as drones, geo-hunters, telescopes, DNA testers, food sniffers, black light, essential oil extractors, refractometers, banana fiber extractors, cow dung dewatering machine, among many others.

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CONTRIBUTION OF MOLECULAR MARKERS TO FOOD SECURITY: INTROGRESSION AND PYRAMIDING

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Abstract
The development of sustainable tolerant/resistant lines with high precision in shortest possible time for agricultural sustainability has been accelerated by gene pyramids through Marker-Assisted Selection (MAS) and other procedures. Gene pyramiding involves the stacking of multiple genes that simultaneously exhibit more than one gene in a given species to develop a sustainable expression of resistance, thereby improving plant breeding efficiency leading to genetic resistance and the accurate development of broad spectrum resistance. Conventional crop-breeding technology alone cannot be adequate in modern day agriculture for the sustainable achievement of the growing population food demand. A number of environmental challenges, including drought, severe temperatures, excessive salt, parasite and insect pest infestation, etc, threaten sustainable agricultural output. In many nations, these difficult environmental circumstances can have negative consequences for future farming production. Therefore, advancement in molecular genetics to the selection of new plant species is promising instruments.

Keywords: *Gene pyramiding, Marker-Assisted Selection (MAS), broad spectrum resistance, food security, new plant species*

Introduction

In the world of increasing food demand scientists are trying to improve and produce more crop in an unfavorable environmental conditions by selecting for desired traits in most crop plants. However, biotic and abiotic stresses remain the greatest constraint to crop production which accounts to an annual yield loss globally (Suresh and Malathi, 2013). Biotic factors such as bacteria, viruses, fungi, nematodes, insect pests and weeds are considered to be that factors limiting crop production (Vincelli, 2016). A recent assessment documents how these stress factors collectively affect all of the components of food security from overall production to physical availability, distribution, economic access, stability of production, quality and nutritive value (Savary *et al*., 2017). For years, the damage caused by these stress factors is being controlled by the use of chemicals. But nowadays, interest in the use of chemicals against biotic stress is decreasing as a result of its various limitations such as there is need for more than one chemical application, an investment that is not affordable by most small-scale farmers (Brading *et al*., 2002). Aside this, application of chemicals may have adverse effects on human health and the environment, including beneficial organisms (Miedaner, *et al*., 2013). On the other hand, the use of resistant cultivars is currently seen as the best strategy, durable, economical, and environmentally friendly means of control (Ragimekula. *et al*., 2013, Klarquist, *et al*., 2016, Hansona, *et al*., 2016).

As regards to the above, molecular breeding efforts can be adopted to incorporate resistant gene into crop plants but care must be taken in doing so as most of the plants would eventually lead to resistance breakdown within a short period (Kottapalli. 2010). Hence, a phenomenon called gene pyramiding can be adopted to target cultivars that can withstand multiple stresses by assemblage of series of genes from different parents into a single genotype (Jain and Bar, 2010, Suresh and Malathi, 2013). This procedure is usually an end product of a genotype with all the target genes present (Guoyou and Kevin, 2008). The technique is very helpful for developing crops that confer broad spectrum resistance against different races of combination of these stress factors (Joshi and Nayak 2010).

This breeding approach involving a series of phenotyping and genotyping by screening of a large population to obtain desired variability and a high frequency of favorable genes (Kumar *et al*. 2014). But there is also a conventional breeding approach involving sequential selection of large segregating populations for biotic and abiotic stresses across generations which helps breeders to develop breeding lines that combines tolerance of both stresses. As a result, a superior line is promoted for release in terms of acceptable plant type, grain yield, quality attributes, and steady performance under various environmental situations (Kumar *et al*. 2014; Sandhu and Kumar 2017). Selection typically involves evaluating a breeding population for one or more traits in field or glasshouse trials. The goal of plant breeding is to develop more desirable combinations of genes in new varieties. (Collard and Mackill 2007).

Therefore, this review focuses on gene pyramiding approaches that have proven to be effective in modern agriculture for boosting crop tolerance to biotic and abiotic challenges and ensuring long-term crop improvement.

Conventional method

Traditional breeding for several years has been used to identify and incorporate multiple resistant genes into cultivars of interest to develop durable resistance to biotic and abiotic stresses (Ragimekula. *et al*., 2013). And this can be confirmed mostly by phenotyping at an individual level where the target genes are present. The breeder's art of recognizing desirable traits which is by physical identification should be good and, pollinating them to produce the next generation is very important. But, conventional phenotype screening approach to gene pyramiding is usually very difficult and sometimes not possible, because of the effects of epistasis of genes of disease resistance, dominance and also due to limitations associated to screening against the two diseases through the year (Sundaram et al., 2014).

However, conventional method of crop improvement has been criticized for being slow, inflexible, labor-intensive and expensive (Wieczorek, 2003; Choudhary *et al*., 2008). With conventional breeding approach, breeder's capability to track the presence or absence of the target genes is very slow and limited. This limits the number of genes to be stacked into elite cultivars at many times (Malav, 2016). Therefore, an intervention that can reduce the cost and time is necessary to be developed so as to release new cultivars with durable resistance

Molecular markers

Recently, Molecular Marker, a biotechnological tool is a widely used tool crop improvement for efficient and rapid accumulation of desirable genes from various sources into a single background to produce broad spectrum/durable resistance (Malav, 2016, Ragimekula. *et al*., Suresh and Malathi, 2013). This has made it easier to identify, map and efficiently pyramid desirable genes/QTLs into crop plants (SH 2003). Hence, identification of genes/QTLs with closely linked DNA-markers is useful for successful transfer of the gene/QTLs into improved cultivars via Marker-Assisted Selection MAS (Campbell *et al*., 2003).

Most of the time in plant breeding program, the primary goal is to find the favorable genes for a desirable traits (Yan and Rajcan 2002, Dehghani *et al*., 2008). Usually, selections of parents used in crosses are from advanced and developed lines. While after crossing the new cultivars should possess superior combinations of characters and parents should serve as excellent donors of one or more traits being targeted by the breeding program (Yan and FrégeauReid 2008). Hence, identifying and utilizing genotype that possesses these targeted characters is of most importance in producing a population for developing a new variety (Samonte *et al*., 2013). However, to target, identify and utilize this approach, Marker Assisted Selection (MAS) needs to be adopted. This approach is applied extensively in numerous ways in agriculture in breeding a new cultivar (Mackill, 2007).

Marker assisted selection

Marker Assisted Selection is used in the pyramiding process for selecting the progenies that possess the desired traits and taking them to the next cross. In such way, the time for selection in the field can be decreased and the efficiency can be enhanced; ultimately creating a broad-spectrum pyramid genotype (Manoj Sapkota 2018). Most times it is difficult to select the multiple traits based only on the plant phenotype since they might be expressed due to epistasis. MAS are often used for selecting the resistance against the stress factor by the application of genetic markers to identify and select the specific genes of interest governing the resistance (Shi, *et al*., 2008). We should not forget also that the desired gene should also be effective and must provide the desired trait and should not have any negative effects on other desired traits.

The target genotypes can be more effectively selected which may enable certain traits to be 'fast-tracked', resulting in faster line development and variety release. Markers are also used as a replacement for phenotyping, which allows selection in off-season nurseries making it more cost-effective to grow more generations per year (Ribaut& Hoisington 1998). Another advantage of MAS is that it can reduce the number of lines that need to be examined. Since many lines can be discarded after MAS early in a breeding scheme, this permits more efficient use of glasshouse and/or field space which is often limited because only important breeding material is maintained.

Furthermore, aids to selection can be carried out at the seedling stage. This may be useful for many traits, but especially for traits that are expressed at later developmental stages. Therefore, undesirable plant genotypes can be quickly eliminated. This may have tremendous benefits in plant breeding because typical plant production practices involve sowing pre-germinated seeds and transplanting seedlings as the case may arise, making it easy to transplant only selected seedlings to the main field. There are several instances when phenotypic screening can be strategically combined with MAS. In the first instance, 'combined MAS' (Moreau et al., 2004) may have advantages over phenotypic screening or MAS alone in order to maximize genetic gain (Lande & Thompson 1990). When there are still unidentified QTLs influencing a characteristic or when a large number of QTLs need to be altered, this strategy could be adopted. This strategy is more efficient than phenotypic screening alone, according to simulation studies, especially when large population sizes are used and trait heritability is low (Hospital et al., 1997). Bohn et al., (2001) investigated into the possibility of using MAS to improve insect resistance in tropical maize and discovered that it was less effective than traditional phenotypic selection. When MAS and phenotypic screening were combined, however, relative efficiency increased slightly. For an example in wheat, MAS combined with phenotypic screening was more effective than phenotypic screening alone for a major QTL on chromosome 3BS for Fusarium head blight resistance (Zhou et al., 2003b). The advantages of MAS over conventional breeding must be fully explored for MAS to attain its full potential for crop improvement.

Pyramiding of multiple traits

With the development of gene identification technologies, gene pyramiding technique targeted for introgression has been successfully demonstrated and typically used in improving biotic and abiotic factors. This strategy has been used as an advanced approach incorporating durable and multiple pathogens for resistance in many crops. (Joshi and Nayak 2010). The most common use of this technique is to integrate one or several highly inherited features into an adapted or elite variety. These different resistance genes often confer resistance to different isolates, races or biotypes. In most cases, for instance, the elite variety used for crossing possesses a large number of desired traits but only has a few features while the other parent, known as the donor parent, has one or more genes that control an important feature that is not present in the elite variety (Hansan et al., 2016).

In addition, since the advent of molecular markers, marker assisted selection has been successfully used in gene pyramiding program in targeting, transferring and pyramiding resistance loci to create more durability and broad-spectrum resistance in various crops (Joshi and Nayak 2010). The use of these molecular markers, permits completes gene identification of the progeny at each generation, thereby increasing the speed of pyramiding process. Thus, this technique permits resistance genes to be accumulated into a single genotype, thereby making use of major genes, different or the same alleles of one gene (Tan et al., 2010). However, gene pyramiding scheme can be distinguished into two parts. The first part is known as a pedigree, and it aims to combine all target genes into a single genotype known as the root genotype, while the second part is known as the fixation step, and it aims to fix the target genes into a homozygous state, i.e. to derive the ideal genotype from a single genotype.

Marker-assisted gene pyraniding in developing crop varieties

Gene stacking, also known as pyramiding, is a useful technique for transferring multiple desired genes or QTLs from different parents into a single genotype in the shortest time possible (two to three generations), as opposed to conventional breeding, which takes at least six generations to recover 99.2 percent of the recurrent parent genome [Suresh et al., 2013, Hasan et al., 2015]. Plant scientists have successfully utilized this technique to pyramid resistant genes or QTLs into crops to increase its durability through the help of closely associated markers against biotic stresses.

For instance, a study carried out by Kumar et al. 2019 used marker-assisted backcrossing and phenotypic selection to pyramid three tomato leaf curl virus resistance genes (Ty-1, Ty-2, and Ty-3), two late blight resistance genes (Ph-2 and Ph-3), and one root knot nematodes resistance gene (Mi1.2) from distinct donor parents. From the study, it was deduced that the introgression of the various genes remarkably enhanced resistance against leaf curl, late blight and root knot nematodes diseases. However, it was concluded that these enhanced lines of resistant multiple diseases can play a significant role in future. Moreover, another study was investigated by pyramiding more than one resistance genes in sweet Charleston pepper line Y-CAR. Molecular markers and biological assay was used to carry out this study. The study successfully transferred resistance genes to these viruses on molecular markers and biological tests to the superior sweet Charleston pepper line Y-CAR. A new line has therefore been developed that is resistant to PVY, TSWV and PMMoV. The results also show that a pyramid strategy for the reproduction of multiple resistance viruses is applicable in pepper.

Furthermore, marker assisted gene pyramiding was successfully carried out to incorporate Phg-2 R of the angular leaf spot resistance gene and two CBB main quantitative feature loci (RQTLs) into the background of the susceptible and most common bean cultivar REDWOLAITA, or RW in Ethiopia. It was deduced that the lines developed were highly resistant to the CBB and ALS strains under screening conditions (Rezene *et al.,* 2019). In a high yielding Malaysian Putra 1 with a genetic background of 3 blasting resistance genes (piz, Pi2 and Pi9) two dominant (Xa4 and Xa21) and two recessive (xa5 and Xa13) Xoo resistance genes were introgressed. The discovery from this investigation through Marker-assisted background selection revealed a high percentage of about 95.9% recurrent parent genome recovery. The incorporation in the newly developed lines of four bacterial leaf blight and three blast-resistant genes (Xa4 + xa5 + xa13 + Xa21; Pi9 + Pi2 + Piz) would provide for wide spectrum and lasting resistance to two important diseases investigated. It is worth noting that blast is caused by *Magnaporthe oryzae* and bacterial leaf blight is caused by *Xanthomonas oryzae* pv *oryzae* (*Xoo*) are major diseases responsible for significant yield loss in rice production across all rice growing regions (Chukwu *et al.,* 2020).

The technique of Marker-Assisted Selection (MAS) was used to develop ten new lines with blast, bacterial blight (BB) and BPH resistance genes. A higher line was obtained with blast resistor genes, BB and BPH. In general, information about the development of the restorers is useful for rice resistance breeding through the pyramiding various resistance genes (Zhi-juan *et al*., 2016). Arunakumari *et al*., 2016 was able to pyramid bacterial leaf blight (BB) resistance genes and blast resistance gene into an Indian rice variety MTU1010 through Marker-Assisted Selection and it was observed that the improved lines were highly resistant to the disease. Yanchang and Zhongchao 2013 also recorded a success in pyramiding multiple traits of semi-dwarf gene, submergence tolerance gene, blast resistance gene and bacterial blight resistance genes in rice by Marker-Assisted Selection and the improved line was able to carry the designated multiple traits.

Challenges

In some circumstances, there is inadequate linkage between the marker and the gene, resulting in recombination between the marker and the gene/QTL (Sharp et al., 2001). In that wise marker validation is essential to determine a marker's ability to predict phenotype, and this highlights the benefits of employing flanking markers. Furthermore, breeding material has a restricted number of markers and polymorphism of markers. Ideally, markers would be able to detect traits in a wide spectrum of breeding stock. In other words, markers should be able to distinguish between varieties that display the feature and those that do not. Even in some crops with a greater number of accessible markers, there may be certain chromosome regions harboring an important gene or QTL for which polymorphic markers are difficult to discover. Meanwhile, another problem with pyramiding is the influence of genetic background. It has been discovered that QTLs found in one mapping population may not be effective in other populations (Liao *et al.,* 2001). For instance, Steele et al. (2006) discovered in rice that just one of four root-length QTLs was effective when backcrossed into a new variety of rice. In certain circumstances, this is owing to the small effect of an allele transferred into elite varieties (Charcosset & Moreau 2004).

Parents representing the extreme ends of the trait phenotype are often selected for QTL mapping experiments. This increases the likelihood of discovering these QTLs because QTL mapping is based on statistically distinct group of markers. However, the fundamental disadvantage of this method is that one (or both) parents may have QTL alleles that are similar, if not identical, to the elite germplasm employed in breeding programs (Holland 2001).

Moreover, high Marker-Assisted Selection costs are another problem. The cost of using MAS can vary significantly compared to conventional phenotypes, although this is covered by only a relatively small number of studies. The cost-benefit ratio of MAS has been shown to depend on various factors such as the inheritance of the trait, method of phenotypic assessment, the cost of field and glasshouse experiments as well as the cost of labor (Dreher *et al.,* (2003) and Morris *et al,*. (2003). It should also be noted that large initial investments in capital are needed in equipment purchases and that regular maintenance costs are incurred. The costs of MAS could also be affected by intellectual property rights, such as patent granting costs (Brennan *et al*., 2005). One approach to this challenge is to contract out the Marker-Assisted Selection program to sophisticated laboratories that can help in saving cost by the use of high-performance equipment. Generally speaking, the cost of MAS remains a major barrier to its use. It should be noted, depending on the number of samples or the number of marker assays, that MAS cost estimates may change. Dreher *et al*., (2003) study indicated that cost may decrease as the number of samples and/or marker tests increases because many components of MAS are economical in scale and lack divisibility. A current trend is the establishment of marker genotyping firms, which will make it possible to outsourced marker genotyping. In the event that genotyping outsource costs are cheaper and logistical problems are not created or minimized, the breeding programs can offer more MAS opportunities.

Finally, the knowledge gap between plant breeders, molecular biologists, and other disciplines. In recent decades, rapid developments have been observed with DNA marker technology, QTL theory and statistical methodology for the QTL analysis. These concepts used by molecular biologists are not clearly understood by plant breeders and other plant research scientists (Collard *et al*., 2005). Moreover, wide ranges of highly specialized equipment are based on advanced molecular-genotyping techniques. Similarly, molecular biologists may not understand fundamental concepts in plant breeding. This reduces the integration level between conventional and molecular breeding and eventually influences the evolution of new breeding lines.

Conclusion

The breeding of plants has made significant progress in improving crops and it is crucial that this continues. In other words, MAS could be very helpful in reaching this objective, although to date there has been a minimal impact on varietal development. To achieve the MAS potential, greater integration with breeding programs, and the development of current barriers and solutions are imperative. The use of the benefits of MAS in relation to conventional breeding could have a significant effect on crop improvement.

The high cost of MAS will remain a major obstacle for adoption in near future in the developing countries, as a result s budgets may need to be adjusted. Nonetheless new technology for markers would significantly reduce the cost of MAS. When validating the efficiency of the new methods and easily getting equipment, this should allow MAS be more wide-scaled for crop breeding programs.

Future prospects

In this coordinated effort to increase food production, plant breeding will continue to play a crucial role. In the light of current yield trends, projected population growth and environmental pressures, yield stability and sustainability characteristics should be a key focus of efforts in plant breeding. These include resistance to durable diseases, abiotic stress tolerance, and efficiency in nutrient and water use (Mackill *et al*., 1999; Slafer *et al*., 2005; Trethowan *et al*., 2005). Moreover, cultivation of varieties in marginal areas, especially in developing countries, need to be developed (Naylor *et al*., 2004).

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AWARENESS AND PERCEPTION OF CLIMATE CHANGE AMONG MEDICAL STUDENTS IN THE UNIVERSITY COLLEGE HOSPITAL, IBADAN

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Abstract
The importance of being educated on climate change over a period of time usually comes with long lasting impact on the individual in the choice of food to eat, what car to use and how to reduce carbon emission for a cleaner environment. However, there is a low level of perception of the meaning, causes and effects of climate change especially among students.This study was carried out in the University of Ibadan Campus using medical students as respondents to gather data. The students were selected from medicine and surgery, Dentistry, Physiology, Nursing, Human Nutrition and Physiotherapy using multistage random sampling. Three hundred copies of questionnaire were administered to the respondents asides focus group discussion and analysed using descriptive statistics to present results in frequency and percentages on tables. The result showed the level of awareness among students, the sources of information and impacts of climate change. The students in Medicine department take courses on climate change (33.7%) more than their counterparts in the college and submitted that climate change help to provide information (85.2%) in certain aspects of their course just like those in Human nutrition (88.2%) agreed. However, Physiotherapy students agreed more on climate change being a source of employment (85.7%) than other usefulness. All the students from each department proved that the internet was the best source of information on climate change. The consequential effect of climate change as identified by the students also gave an indication on their perception of climate change. In order to be able to achieve adequate preventive, adaptive and mitigative measures on climate change as there is need for better education of these students through inclusion of climate change topics in their curriculum as climate change affects everyone irrespective of discipline, culture or clime.

***Keywords**: Climate change, Education, impacts and awareness*

Introduction

Climate refers to the average weather conditions of a particular place studied over a period of time. The changes in rainfall pattern, wind speed and direction, light intensity all have direct impact on the growth and abundance of plant species and subsequently affect the animal population that rely on them for survival. Historically, agriculture develops over time in a given region based on "normal" or average climate conditions. The frequency of occurrence of extreme climate conditions dictates the response of agriculture to climate variability/change (Raymond, 2008).

All over Nigeria, millions of people are already experiencing changing seasonal patterns of rainfall and increased heat (Falaki *et al*., 2013). This has led to severe changes in rainfall patterns and amount causing drought in the northern part and flooding in the southern parts of the country as well as an influx of pests and diseases. Climate also determines to a large extent availability of water, which impacts health and ultimately the level of poverty amongst Nigerians (Falaki *et al*., 2013). The changes in weather conditions, vegetation pattern, animal populations and ecological balance among others have been the bane of intellectual discuss among conservationists, ecologists, academia, policy makers and other stakeholders for about two decades ago. However, the few individuals that think they are not directly affected are just being illusioned about the importance of these changes. Hence, the need to study the perception of climate changes among medical students in the University of Ibadan campus.

Boko *et al.* (2007) and Falaki *et al*. (2013) both submitted that the government and researchers focused on the social, environmental and financial implications as well as adaptive measures to climate change when majority of the populace still lacked perception of it. Meanwhile, public perception of an issue (climate change) is very important to the success or failure of any measures (economic, political or social) to be adopted in controlling or adapting to such. Zube *et al.* (1982) once posited that the response of a man to issues pertaining to his environment can be broadly categorised as cognitive (related to knowledge and understanding), affective (related to feelings, attitudes, and emotions), behavioural (related to changes in behaviour of the viewer), and physiological (biological or physical effects on the observer's body). Perception determines the social mental picture of climate change. Therefore, demographic information of students from the four faculties that made up medical and health sciences were examined to determine perception among respondents used for this study.

Perception of climate change is a precursor for mitigating and adaptive measures of climate change. Climate change has hitherto been associated more with agricultural sciences, environmental studies and some science courses; when in actual fact every individual is under the influence of climate change but some lack perception. This is why the medical students were targeted for this study as they spend most of their time at the University College Hospital.

Methodology

Study Area

This study was carried out in the University College Hospital (UCH) with medical students being the respondents. UCH is located within Ibadan North Local Government which is the Southwest part of Agodi government reserved area (GRA) towards

Mokola, Ibadan. Ibadan is located approximately on longitude $3^0 54'$ of Greenwich Meridian and latitude $7^0 26'$ North of the equator. It has a total land area of 130km^2 and 750m above sea level.

Sampling Techniques

A multistage random sampling procedure was used to collect primary data from 300 respondents from the College of Medicine, University of Ibadan, using structured questionnaires. Each department from the four faculties of Basic Medical Sciences, Clinical Sciences, Public Health and Dentistry was ably represented at all levels. Based on the students' population, random selection was done on a 10% and 20% for lower and higher populations respectively.

Sources of data

Reconnaissance survey of the students and Departments in the College was carried out to determine students' population before the questionnaires were administered. The data was obtained through questionnaires and personal interview of the students.

Data Analysis

The data obtained from the questionnaire was based on the departments available in the College of Medicine before being analysed by SPSS using descriptive statistics. The results of analysis are presented as frequency and percentages in tables

Results and discussion

Demographic Characteristics of Respondents

The total number of respondents was 300 (Table 1) of which 53.7% were males and 46.3% females. The Department of nursing had the least number of students with no male respondents while Biochemistry, Dentistry, Physiotherapy and medicine and surgery had 55%, 59%, 100% and 59% males respectively. This implies that there are more male students in medical related courses than females except for nursing which seems to be a female dominated department.

The age of respondents sampled for this study ranged from 16 to 30 years with the highest frequency (46.3%) being 21 to 25 years old students and the oldest set of respondents were 27.0% of the sampled population.

Table 1: Demographic Characteristics of Respondents

Socio-characteristics	Range	Frequency
Gender	Male	161 (53.7%)
	Female	139 (46.3%)
Age	16-20	81 (27.0%)
	21-25	172 (57.3%)
	26-30	47 (15.7%)

Courses on Climate Change as Perquisite in the College

Teaching about climate change can be a daunting challenge, but it is a critical field for students to learn about, as it affects many parts of society. Table 2 showed that most of the respondents in the department of medicine and surgery (34%) as well as a few in nursing (3%) were of the opinion that they had no environmental based course in their curriculum while in Physiotherapy, Dental Surgery, Physiology, Human Nutrition, Biochemistry and Nursing; 4.7%, 4.7%, 4.3%, 4.3%, 4.3% and 1.3% respondents respectively agreed that they had taken climate change as an environmental-based course at one point or the other in their curriculum. The result obtained for this study is contrary to the report of Ayanlade and Jegede (2016) that about 70.7% of university graduates received brief lectures in some special elective courses during their university education, while only 4.1% were taught to more than three semesters/terms in some special elective courses.

The importance of being educated on climate change over a period of time as a course usually comes with long lasting impact on the individual as submitted by Cordero *et al*., (2020) through decisions made after graduation on what car to buy, food choices and reduction in carbon emissions. As medical students who would be saddled with meeting people on a daily basis; an educational background in climate change can help them to make informed decisions on diseases diagnosed from environmental causes, nutrient deficiencies as well as counselling patients to live healthily.

Table 2: Courses on Climate Change as Perquisite in the College

Department	Yes Freq (%)	No Freq (%)	Total Freq (%)
Medicine & Surgery	80 (26.7)	102 (34)	182 (60.7)
Physiotherapy	14 (4.7)	9 (3)	23 (7.7)
Dental Surgery	14 (4.7)	11 (3.7)	25 (8.3)
Physiology	13 (4.3)	6 (2.0)	19 (6.3)
Human Nutrition	13 (4.3)	4 (1.3)	17 (5.7)
Biochemistry	13 (4.3)	8 (2.7)	21 (7.0)
Nursing	4 (1.3)	9 (3.0)	13 (4.3)

Total	151 (50.3%)	149 (49.7%)	300(100%)

Relevance of Climate Change Courses to Students

Table 3 showed that 85.2% of the respondents in the department of medicine and surgery believed that climate change will be needed to meet their own information needs, while another 79.1% of this same set of respondents opined that the study of climate change gave them a better understanding of the world. For the Physiotherapy respondents, 78.6% agreed that climate change has provided them with useful information relating to their course of study; 64.3% considered it as an opportunity for getting jobs after school and 85.7% reported that climate change has given them a better understanding of the world surrounding them. Though, 68.2% and 68.2% in Dental surgery, 83.3% and 57.9% in Physiology, 88.2% and 82.4% in Human nutrition, 85% and 70% in Biochemistry and 80.8% and 73.1% in Nursing respectively all agreed that the knowledge of climate change has provided them with some needed information in their field as well as better understanding of the world in general. However, 59.1% in Dental surgery, 52.9% in Human nutrition, and 50% in Biochemistry students respectively were of the opinion that the knowledge of climate change will increase their prospects for getting jobs. Moreover, 58.8% of the respondents sampled in Human nutrition submitted that climate change is a key factor influencing people's lifestyles.

The results presented above showed the level of awareness and depth of knowledge of the respondents on climate change. For the few that agreed that climate change provided much needed information, it could be an eye opener to the influx of certain diseases related to nutrient deficiencies as well as excessive heat and dust particles. According to Okali (2008) in Ayanlade and Jegede (2016), climate change contributes to the global burden of disease and premature deaths through human exposure to changing weather patterns and indirectly through changes in water, air, and food quality, not forgetting the changes in ecosystems, agriculture, industry, and settlements and economy.

Table 4: Relevance of Climate Change Courses to Students

Department	Information needs		Lifestyle		Job placement		World view	
	Yes (%)	No (%)	Yes (%)	No(%)	Yes(%)	No(%)	Yes(%)	No(%)
Medicine	155 (85.2)	27 (14.8)	70 (38.5)	112 (61.5)	63 (34.6)	119 (65.4)	144(79.1)	38(20.9)
Physiotherapy	11(78.6)	3(21.4)	6(42.9)	8(57.1)	9(64.3)	5(35.7)	21(85.7)	2(14.3)
Dental Surgery	15(68.2)	7(31.8)	7(31.8)	15(68.2)	13(59.1)	9(40.9)	15(68.2)	7(31.8)
Physiology	18(83.3)	3(16.7)	5(26.3)	14(73.7)	9(47.4)	10(52.6)	11(57.9)	8(42.1)
Human nutrition	18(88.2)	2(11.8)	10(58.8)	7(41.2)	9(52.9)	8(47.1)	14(82.4)	3(17.6)
Biochemistry	17(85)	3(15)	6(30)	14(70)	10(50)	10(50)	14(70)	6(30)
Nursing	26(80.8)	5(19.2)	11(42.3)	15(57.7)	9(34.6)	17(65.4)	19(73.1)	7(26.9)
Total	249(83.3%)	50(16.7%)	115(38.3%)	185(61.7%)	122(40.7%)	178(59.3%)	229(76.3)	71(23.7)

Perception of Students on Impact of Climate Change

The perception of climate change among the medical students sampled is given in Table 4. Of the respondents, 42.0% perceived climate change as just the atmospheric condition of a place; another 17.7% could only see climate change literarily as a change in climate. 5.3% of these respondents argued that climate change meant the weather conditions experienced as well as significant changes observed in weather conditions in a particular place at a certain time. Meanwhile, 11.0% of the total respondents as well as another 5.7% perceived climate change as global warming, ozone depletion and a deviation from the normal climatic changes respectively. The results above is in line with the findings of Oruonye (2011) where 18.2% of the students of Jalingo Tertiary institutions interviewed had never heard of climate change and 89% of those who had heard (81.8%) do not know what climate change was all about, its causes, effects, and possible adaptive or mitigative measures.

Sources of Information on Climate Change

It is obvious that the students sampled possess literary understanding of climate change and lack adequate knowledge of the depth, causal factors and consequences of climate change that the world is battling with. This may be due to their curriculum being different from those of their counterparts in agriculture and environment-based disciplines. This observation supports the findings of Akrofi *et al* (2012) that students' involvement in climate change-related workshops and campaigns significantly influenced their knowledge levels. Moreover, climate change affects all living beings under the sun regardless of career paths. The lack of proper understanding of the issue being discussed is contrary to the findings of Ayanlade and Jegede (2016), Ojomo *et al.*, (2015) and Agboola and Emmanuel (2016) in which student respondents clearly identified the impact of climate change on agriculture, fishery as well as labelling it the third prioritized environmental issue in Nigeria based on a significant level of awareness and perception.

Table 4: Students Expression of Climate Change

Dept.	Atm. Condition (%)	Climate change (%)	Weather conditions experienced (%)	Negative change in climate (%)	Global warning/ozone depletion (%)	means any significant (%)	Deviation from normal atmos. Condition (%)	Average atmospheric condition of a place over a period time (%)	Total (%)
Med. & Sur.	73 (24.3)	30 (10.0)	10 (3.3)	15 (5.0)	23 (7.7)	11 (3.7)	10 (3.3)	10 (3.3)	182 (60.7)
Physiotherapy	13 (4.3)	8 (2.7)	1 (3)	-	1 (3)	-	-	-	23 (7.7)
Dental Surgery	8 (2.7)	2 (7)	2 (7)	2 (7)	4(1.3)	1(3)	3 (1.0)	3 (1.0)	25 (8.3)
Physiology	7 (2.3)	3 (1.0)	-	2 (7)	2 (7)	2 (7)	2 (7)	1 (3)	19 (6.3)
Human nutrition	7 (2.3)	3 (1.0)	2 (7)	1 (3)	1 (3)	1(3)	1 (3)	1 (3)	17 (5.7)
Biochemistry	14 (4.7)	5 (1.7)	1(3)	1 (3)	-	-	-	-	21 (7.0)
Nursing	4 (1.3)	2 (7)	-	-	2 (7)	1 (3)	1 (3)	3 (1.0)	13 (4.3)
Total	126 (42.0)	53 (17.7)	16 (5.3)	21 (7.0)	33 (11.0)	16 (5.3)	17 (5.7)	18 (6.0)	300 (100.0)

The various sources of information about climate change available to the students was also examined as shown in Table 6. The internet (38.7%), newspapers (34.7%), office reports (14.3%), Television (7.3%), Bulletin (1.7%), radio (1.0%) and social media (2.3%) provided the respondents at various times with needed information about climate change.
Puttick and Talks (2021) reported four sources of information for teachers on climate change to be the Internet; government sources; mass media and professional development courses. The students in turn obtain the same information directly or in edited form from the teachers. The problem with the internet as a source of information is the overabundance of information on the internet and social media still makes it a necessity for teachers to guide students such that only quality and beneficial information will be harnessed.

Table 5: Students Source of Information on Climate Change

Department		Main sources of Information							Total
		Internet	Newspaper	Office report	TV	Bullet	Radio	Media	
Medicine & Surgery	Freq	80	60	29	11	2	0	0	182
	%	26.7	20.0	9.7	3.7	0.7	0	0	60.7
Physiotherapy	Freq	9	11	0	1	1	0	1	23
	%	3.0	3.7	0	0.3	.03	0	0.3	7.7
	Freq	9	8	1	3	2	1	1	25
Dental Surgery	%	3.0	2.7	0.3	1.0	0.7	0.3	0.3	8.3
	Freq	4	7	4	3	0	0	1	19
Physiology	%	1.3	2.3	1.3	1.0	0	0	0.3	6.3
	Freq	3	8	2	2	0	2	0	17
Human Nutrition	%	1.0	2.7	0.7	0.7	0	0.7	0	5.7
	Freq	8	8	3	2	0	0	0	21
Biochemistry	%	2.7	2.7	0.7	0.7	0	0.7	0	7.0
	Freq	3	2	4	0	0	0	4	13
Nursing	%	1.0	0.7	1.3	0	0	0	1.3	4.3
Total		116 (38.7%)	104 34.7%	43 14.3%	22 7.3%	5 1.7%	3 1.0%	7 2.3%	300 (100%)

Perception on Possible Challenges Associated with Climate Change
In 2011, Oruonye *et al*., observed that the developing countries of the world such as Nigeria will suffer most from the impacts of climate change as was evident in subsequent years in poor agricultural yield, flooding, drought among others. Table 6 showed that 14.3% and 1.7% respondents from the department of medicine and surgery and human nutrition respectively agreed that poverty and famine were problems associated with climate change. This is because poverty has been known to push people into collecting firewood from the forest for sale as well as cooking which consequently leads to deforestation. These two factors are also major problems that could arise from climate change when agricultural harvests are low, famine and poverty may likely set in. The Physiology (7%) and Physiotherapy (2.3%) respondents each agreed that desertification and flooding were major problems causing and consequences of climate change. Meanwhile those in Dental surgery (3%) and Biochemistry (7%) both submitted ozone depletion as a major problem associated with climate change. However, ocean circulation was the major problem identified by the nursing department respondents.
Different problems were identified by the students but majority of them agreed poverty or famine problem is associated with climate change. The problem can be caused by flooding or drought, which affects planted crops and in turn affect the supply of the crops. This cause famine and as a result causes poverty to the farmers. Planting of more trees can help this situation in other to protect the environment. This study supports the position of Ojomo *et al*., (2015) that Nigeria is currently exposed to and/or will be directly exposed to sea level rise, flooding, drought, coastal erosion, rising temperatures, desertification with an exception of melting glaciers as a result of climate change according to *Nigeria's First National Communication under the United Nations Framework Convention on Climate Change* (NFC-NFCCC, 2003).

Perception on Aspects of Climate Change to be studied by Respondents
The respondents sampled for this study have revealed the things that could interest them in climate change (Table 7); such that 48.7% were found to be interested in the educational aspect probably because this might enlighten them on the whys, extent and consequences of climate change. Another larger set seemed to be more interested in the adaptation aspect. This may be as a result of uncertainty in putting an end to the menace of climate change and so have resigned them to learning the various ways of managing or adapting to climate change effects and consequences.

Table 6: Problem Associated with Climate Change

Department	Ocean circulation Freq %	Desertification flooding Freq %	Poverty famine Freq %	Ozone layer Freq %	Sun intensity Freq %	Sea level Freq %	Drought Freq %	Deforesta. Freq %	Env. Degrading Freq %	Total Freq %
Med& Surgery	37(12.3)	38(12.7)	43(14.3)	33(11.0)	11(3.7)	7(2.3)	6(2.0)	4(1.3)	3(1.0)	182(60.7)
Physiotherapy	13(4.3)	2(7.)	4(1.3)	4(1.3)	-	-	-	-	-	23(7.7_
Dental Surgery	8(2.7)	8(2.7)	6(2.0)	1(3)	1(3)	-		-	-	25(8.3)
Physiology	4(1.3)	7(2.3)	6(2.0)	1(3)	1(3)	-	-	-	-	19(6.3)
Human Nutrition	1(3)	3(1.0)	5(1.7)	3(1.0)	3(1.0)	1(3)	-	-	1(3)	17(5.7)
Biochemistry	5(1.7)	6(2.0)	4(1.3)	2(7)	3(1.0)		1(3)	-	-	21(7.0)
Nursing	2(7)	1(3)	4(1.3)	2(7)		1(3)	1(3)	2(7)	-	13(4.3)
Total	70 (23.3)	65 (21.7)	72 (24.0)	46 (15.3)	19 (6.3)	9 (3.0)	9 (3.0)	6 (2.0)	4 (1.3)	300 (100.0)

One can only be interested in what is tangible as opposed to abstracts. Had there been a solution designed to ensure a kind of community participation, it would have given the students hope while creating a channel to express their interest. A design for students by Cordero *et al*. (2020) presented real life climate change situations where students were allowed to compete for workable solutions. The experiment had the benefits of developing the students' interests on causes of, consequences of and their proffered solution to climate change.

Table 7: Perception on Aspects of Climate Change to be studied by Respondents

Department	Educational Freq (%)	Adaptation Freq (%)	Mitigation Freq (%)	Total Freq (%)
Medicine & Surgery	96 (32.0)	16 (5.3)	70 (23.3)	182 (60.7)
Physiotherapy	16 (5.3)	4 (1.3)	3 (1.0)	23 (7.7)
Dental Surgery	13 ()4.3	5 (2.3)	7 (0.3)	25 (8.3)
Physiology	9 (3.0)	5 (1.7)	5 (1.7)	19(6.3)
Human Nutrition	3 (1.0)	6 (2.0)	8 (2.7)	17 (5.7)
Biochemistry	7 (2.3)	4(1.3)	10 (3.3)	21(7.0)
Nursing	5 (1.7)	4 (1.3)	4 (1.3)	13 (4.3)
Total	149(48.7%)	133(44.3%)	15(6.0%)	300(100%)

Factor Responsible for Climate Change

From Table 8 below, deforestation (36.4%) followed by gases released (26.0%) into the atmosphere as well as anthropogenic activities (19.4%) were the major factors submitted by the respondents as being responsible for climate change. This is evident in the areas of forested lands available as at two decades ago compared to the status quo. Also, human activities affecting the environment are not encouraging despite the many propaganda on sanitation, health issues and clean environment among others.

Gone are the days when climate change was blamed on volcanic eruptions and solar heat changes (National Academy of Science, 2020). According to Lehtonen *et al* (2018), human activity is the most important factor determining our future. Although various activities such as flooding, urban settlement were noted by the respondents to be responsible for climate change, majority agreed that deforestation was responsible for climate change. Deforestation by humans is the major factor responsible for climate change and it keeps increasing geometrically. This is in line with the submission of the IPCC (2013) working group that past records showing that climate varied naturally over a wide range of time scales, does not explain the observed warming since the 1950s, as the over 95% human activities being the dominant cause of that warming. Afforestation, clean energy, reduced carbon emissions are some of the ways to stop its effect; hence, people should be sensitized in these aspects.

Table 8: Factor Responsible for Climate Change

Departments	Deforestation (%)	Human activities (%)	Gases effect (%)	Weather condition (%)	Flooding (%)	Urban settlement (%)	Total (%)
Medicine Surgery	63 (21.0)	39 (13.0)	49(16.3)	7 (2.3)	14 (4.7)	10(3.3)	182 (60.7)
Physiotherapy	14 (4.7)	2(.7)	6(2.0)	1(3) .	-	-	23(7.7)
Dental Surgery	8(2.7)	6(2.0)	6(2.0)	1(3) .	-	4(1.3)	25(8.3)
Physiology	9(3.0)	5(1.7)	4(1.3)	1(3) .	-	-	19(6.3)
Human nutrition	7(2.3)	2(7) .	5(1.7)	1(.3)	1(3) .	1(.3)	17(5.7)
Biochemistry	8(2.7)	4(1.3)	8(2.7)	1(3)	-	-	21(7.0)
Nursing	6(2.0)	1(0.3)	5(1.7)	1(0.3)	-	-	13(4.3)
Total	115 (38.3)	59 (19.7)	83(27.7)	13 (4.3)	15 (5.0)	15 (5.0)	300(100.0)

Conclusion

This study was carried out to assess the perception level of climate change among the medical students of the University College Hospital. From the study, it can be inferred that the level of perception of the respondents is low; probably due to the lack of basic courses related to climate change. Moreover, the causal factors, problems associated with climate change were not new to the students as information on all these is readily available on the internet. The introduction of climate change studies in universities has a fundamental role in helping the general public, especially the next generations, to recognize the global challenges of climate change and to find ways of adapting to the changing climate.

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CLIMATE CHANGE AND INSECURITY IN NIGERIA: FORESTRY TO THE RESCUE

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Abstract
The climate change as a phenomenon that portrays abnormal variations in the expected climate of an area at particular period of time has been found to be connected with issues on insecurity in Nigeria. Flood, drought, desertification as resultant effects of climate change have led to violence, herders and farmers conflicts and food insecurity. This paper reviews the concept of climate change and insecurity in Nigeria. The main causes of climate change: population increase, urbanization, industrialization, deforestation and their effects are discussed. Adaptation and mitigation strategies in combating climate change and insecurity were looked into as well as the significant roles of forest in mitigating climate change. It is concluded that climate change adaptation and mitigation strategies as well appropriate forest management could be a right step in the right directions in safeguarding the menace.

Keywords: *Anthropogenic activities, Adaptation, Mitigation, Amelioration, Forestry*

Introduction
Globally, the concept on climate change is no more a news to deliberate upon. It has become issues in the present times with manifestation of variations in different climatic elements such as cloud cover, precipitation, temperature, humidity, sea and other water bodies levels, wind, light intensity and vapour pressure (Ministry of Environment of the Federal Republic of Nigeria (MOEFRN, 2003). Climate change was viewed by The Intergovernmental Panel on Climate Change IPCC (2007), as statistically significant differences in either mean values of the climate or in its variation over a long period of time, (typically for decades or longer). The United States Environmental Protection Agency (USEPA, 2020) defined climate change as any long-term conspicuous changes in the expected average weather of any place over an appropriate period of time. Invariably, climate change portrays abnormal variations in the expected climate of a region. According to Haider (2019), there is existence of changes in climatic conditions in Nigeria. This changes in country's climatic conditions are evident in; increase in temperature; inconsistent rainfall pattern; rising in sea level, frequent flooding, elongated drought, desert encroachment and land degradation. All these harsh weather conditions thereby leads to negative effects on fresh water resources, loss of biodiversity, disappearance of grazing land, loss of agricultural land, increase in livestock diseases which all resulted in food insecurity (Haider, 2019). As a result of all consequences of climate change, there was hunger, increased unemployment, conflicts among herders and farmers, cattle hustling and insurgency. United State Geological Survey (USGS, 2020) reported that climate change is caused by several factors. These factors are both natural and anthropogenic but basically by the later, and the main route out of the ugly occurrence is forestry via different programmes such as afforestation, reforestation, agroforestry practices and enrichment planting

Causes of Climate Change and their effects on insecurity
Anthropogenic activity is the major global cause of climate change over the last few decades aside from natural cause (IPCC, 2007). The natural causes of climate change consist of volcanic eruptions and solar activities, while human activity in Nigeria as it is obtainable in several regions of the world has been a major cause for the buildup of greenhouse gases (GHGs). Carbon dioxide (CO_2) is one of the main greenhouse gases and contributors to the greenhouse effect. When fossil fuels like coal, oil and gas are burnt, they release greenhouse gases (Haider, 2019). Anyadike, (2009) reported that human activities which involve energy combustion as it occurs in generation of warmth in homes and building via heating, use of fuels (in cars, bus, train or plane), water treatment towards provision of portable water, manufacturing process, refrigeration, gas flaring and bush burning emitted carbon dioxide into the atmosphere. Since the industrial revolution as far back as 18th century, there has been sporadic increase in the amount of CO_2 that are released into the atmosphere, the estimate of which has attained 35%. Nigeria is reported to be among countries that emits highest greenhouse gases in Africa most especial with the Niger Delta region of the country alone having more than 123 gas flaring (FAO, 2012). The resultant effects of degrading the environment especially in the coastal region have rendered many youths jobless and made them to become members of militant groups and kidnappers.

Deforestation
This is a situation, where forests are indiscriminately felled without replacement. It is one of the major cause of climate change and accounts for 20 percent of the world's carbon emissions (more than what the entire transport sector produces) (IPCC, 2007). When trees are indiscriminately cut, there are fewer trees left to absorb CO_2, and then it will build up in the atmosphere. With deforestation, GHGs such as carbon-dioxide, carbon-monoxide, methane, nitrous oxide, are released, offsetting the natural balance immensely, consequently contributing to global warming (Moutinho and Schwartzman, 2005). According to the FAO (2008), Nigeria ranks first among ten countries with the highest rate of deforestation in the world in succession during the 1990-2000 and 2000-2010. In

the period between 1990 and 2010 in Nigeria, about 3,3% annual rate of deforestation was reported as the forest cover reduced to about 10% of its total land area (FAO 2012). With this decrease in the forest, desertification is ushered into the land. Thus, several people sought where environment is conducive for inhabitant, farming and grazing. Then conflicts erupt over limited resources.

Human Population Increase and impacts on climate change and insecurity

As the world's population grows, there are more people who need food, livestock and energy.

In the year 2012, the estimated population of Nigeria was 170.1million and it was projected to rise to 402.4million by 2050 (USAID, 2012). This will eventually have corollary increase in deforestation for agricultural land, residential buildings and manufacturing companies which will consequently contribute to the emission of carbon and other lethal substances to the environment. Mainly, population increase aggravates urbanization and industrialization which are main causes of changes in climate (Ausbel *et al*., 2004). The population upsurge has led to raising of different people of different characters; many are indolent, fraudulent, greedy, self centered, domineering and violent. With all these callous attitude, terrorism emerged among human race

Effects of Climate Change on economy

Generally, Nigeria is predisposed to severe negative effects of climate change due to its fragile economy, weak resilience and low adaptive capacity. Much of the sensitive economic resources are dependent on climate. For instance, over 70% of the workforce in Nigeria are employed in forestry, agriculture and aquaculture sectors. (FAO, 2012). The heavy concentration of GDP generating industry in locations that are highly vulnerable to climate change - induced sea level rise, e.g. Lagos and the Niger Delta makes the country extremely vulnerable. The 2011 Climate Change Vulnerability Index (CCVI) published by the UK - based risk company, Maplecroft, classifies Nigeria as one of the counties that are on the high risk list failing economy (FGN, 2012). This could be ascribed to the fact that the more the harsh climatic condition, the lower the agricultural crops yield which in turn has significant influence on the generality of the country's economy. (FAO, 2012).

Effects of Climate Change on Crop Yields

Higher CO_2 levels affect crop yields. Some studies suggest that elevated CO_2 levels can increase plant growth. However, other factors that affect plant growth and development such as moisture, temperature and nutrient can counteract these potential increases in yield if they are insufficient or provided in excess. Harsh climatic conditions have also been found to enhancing several pest and diseases as well as parasites that seriously affect livestock production and crop yields. (Ausbel *et al*., 2004).

Climate Change and Security of Nigeria Populace

Insecurity is defined as an absence of protection or safety. It entails peril, death trap, ambiguity, dearth of fortification and lack of security. Insecurity could be a state of being prone or vulnerable to danger or threat of danger. The state of worry as a result of inadequate security measures can also be regarded as insecurity (Achumba et al.*, 2013). Beland (2005), defines insecurity as a state of fear or anxiety stemming from a concrete or alleged lack of production. It is a lack of or inadequacy of freedom from danger. This definition shows insecurity that can be felt directly and it is directly linked to other tourist security including, economic, social psychological, and so on. Insecurity can also be seen as a situation whereby one is being subject to all forms of dangers of both natural and human activities towards society or individuals. It is the anxiety that one experience when one feels vulnerable, insecurity and lack of confidence. More so, failure of institutions to play their roles that brings about dysfunction in society is described as insecurity (Achumba* et al.*, 2013).*

Human security according to the United Nations "is a people-centred notion of security that seeks to integrate the various determinants of well-being such as economic, food, health, environment, personal, community and political security." There are several studies that have established that climate change has adversely affected serene human existence in several regions of the world (Kelechi *et al*., 2021). According to Human Security Network (1999) "building human security is essential for the establishment of a humane world where citizens can enjoy a life that is secured with dignity free from poverty, despair and fear of want." The United Nations categorized human security in terms of acute risks from sudden disruptions such as natural disasters and chronic threats such as disease, hunger and conflict (Kelechi *et al*., 2021).

The achievement of national and conventional security architecture cannot be realizable without reference to human security. Human security is complementary to national security in the same way that national security complements international security (Kelechi *et al*., 2021). This approach, according to the resolution calls for people-centeredness (HSN, 1999). Therefore, the appraisal of climate change effect on national and international security can be better understood from human security approach.

Climate change constitutes an emerging threat to human security in Nigeria (Kelechi *et al*., 2021). The phenomenon through its various manifestations has precipitated violent conflicts thereby disrupting public safety and stability. Idumah *et al.* (2016) noted that vagaries in climatic conditions occasioned by climate change has decreased agricultural productivity prospects and has resulted to increasing aridity of pasture areas in parts on northern Nigeria thereby forcing the pastoralists down south and pitching them against local farmers in the south as they compete for scarce resources in their locality. According to HSN (1999), climate change affects human security by reducing access to notable and valuable natural resources and in turn negating the security apparatus that could promote human security." Flood, drought. Land degradation, and desertification have led to population displacement and loss of farmland, then food shortage. Based on the fact that "an hungry man is an angry man" The condition has led to violence, conflicts and insurgency in parts of Nigeria. Climate change has been reported as the major cause of farmer-herder conflicts in parts of Nigeria (Oladele, 2010; Odo, 2012; Folami, 2013; Adishi and Oluka, 2018). The loss of loss of grazing fields as result of degraded land in the Northern part of the country has influenced the movement of pastoralists to the South and the major consequences of this migration pattern is the incessant violent clashes farmer in the host communities and herders. The persistent drought in the Sudan, Sahel savannah areas being one of the major effects of climate change has forced many pastoralists out of the region towards the guinea savannah and rain forest areas of Nigeria ecological zones.. This has resulted to increased pressure on lands in these areas. The herdsmen and their flocks often destroyed a vast area of farmland in quest for water and forage, this always bring them in conflict with local farmers. The ugly scenario of farmers-herdsmen conflicts have been a recurring incident in the middle belt region and parts of southern Nigeria (Oladele, 2010; Odo, 2012; Folami, 2013).

Climate Change Adaptation and Mitigation; the way out

Climate Change Adaptation

Adaptation involves responding to the changes induced by climate change. It involves all steps taken towards adjustment to real or unexpected changes in climate and their effects (IPCC, 2007). It's all about practicing what we can to live with changes in the climate and reduce to the barest minimum the negative effects that resulted from climate change. Adaptation can be reactive or anticipatory. Where possible, anticipatory actions will provide the most cost-effective response to reduce risk (Anyadike, 2009). Various climate change adaptations cut across different sectors, from coastal and urban area management, natural resources management to agricultural and many more. Some strategies are:

- Improved engineering measure such as construction of drainage channels, elevation of infrastructure couple with abstinence from building along water ways.
- Reducing and recycling water use due to drought**.**
- Using prescribed fires to prevent uncontrollable wildfires.
- Developing of improved varieties of crops such as drought/flood-tolerant crops

Climate Change Mitigation

Mitigation involves the reduction in emissions of any greenhouse gases that contribute to climate change. Carbon dioxide is the most considered gas among other ones in several programmes of climate change, as is in the case with carbon offset programmes. However, methane (CH4), Ozone (O_3), Nitrous Oxide (N_2O), Chloro-Fluoro-Carbons (CFCs) contributes to climate change much more than carbon dioxide (Moutinho and Schwartzman, 2005). In a climate context, IPCC (2007) describes mitigation as human efforts in reducing sources/causes or enhance the sequestration of greenhouse gases in any. In practice, mitigation activities can be carried in many ways such as:

- Use of renewable energies such as solar, wind, and geothermal in place of fossil fuels
- Replacing traditional internal-combustion vehicles with electric options (ideally charged with renewable energy).
- Planting trees and conservation of forest estates of more to enhance storage of more CO_2 from the environment.

The Significance of Forest on Climate Change

An area of land that covered by appropriate number of trees per unit area is referred to as forest. According to FAO (2012), a forest is described as "A land area that is over half (0.5) of an hectare with woody perennials/trees with height higher than 5 meters and canopy covering more than 10 percent." This is with stern exception of land that is predominantly under agricultural or urban use. The existence and survival of all living beings rest on the forests. They are important to our life as they provide oxygen, food, shelter, fuel, and means of livelihood for the tribal people living in and around the forested area. Forests serve as habitat to 80% of the global terrestrial and arboreal biodiversity and are the source that fulfills all basic needs for adjacent human settlements especially on climatic amelioration (FAO, 2012). Therefore, the management of forest is very essential. However, managing forests in response to climate change is just one component of the broad and complex task of sustainable natural resource management. Appropriate management activities can produce healthy and sustainable forests to help offset impacts of climate change (Haider, 2019).

Carbon dioxide is utilized by the green plants through the process called photosynthesis. These plants thereby store carbon in the form of wood and vegetation otherwise known as biomass in the process called *carbon sequestration* (IPCC, 2000). It has been by found that carbon constitutes 20 per cent of total dry weight of trees and the overall biomass of forests also acts as a carbon sink (IPCC, 2001). However, Destruction of forests through deforestation or fire adds billions of tonnes of carbon into the environment each year (IPCC, 1997). Therefore, in attempt to combat global warming and conserve the environment, there must be increase in the storage of carbon and the stored ones must be prevented from being released to the environment.

Several studies have found that wood products that are gotten from harvested timber serve as potential carbon repository. The longevity of the carbon stored in the wood products is subjective to kind of forest produce. For instance, it could be less than a year for fuel wood and many decades or centuries for lumber (IPCC, 2001). In summary, the participation of forests in climate change according to IPCC (2000) can therefore be categorized into three:

- ✓ they are carbon pools
- ✓ they release CO_2 into the environment during bush burning and other natural or human disturbances.
- ✓ they serve as CO_2 storage with their developed biomass.

Methods to mitigate Climate Change through Afforestation

Increasing afforestation

An option to continue to increase CO_2 absorption is to plant new forests. The rate of carbon accumulation, and the maximum at maturity, will depend on the species, site and management system used. Depending on the objectives and constraints of each situation, trees may be planted in farm forestry systems (e.g. shelterbelts) or in continuous blocks, in a single year or over successive years. Each system will have different characteristics as a sink and reservoir. **Managing forests to store carbon**

There are several ways to increase a forest's carbon sink (the rate at which carbon is sequestered or absorbed from the air and turned into carbon in a plant) or reservoir (its capacity to store carbon). Increasing the rotation age allows the trees more time to grow and increases the carbon reservoir in the mature forest. A change in forest management may also increase carbon storage potential, for example a regime with no thinning or pruning may contain more carbon than a more intensive regime (IPCC, 2007).

It is possible to retain a forest as a carbon reservoir and not harvest it. Some species are more suited to this than others. If the trees are not harvested, the carbon content will not increase past a given point. However, if they are harvested they may be turned into wood products, and could thus extend the time before the carbon is released back to the atmosphere (IPCC, 2001).

Saving forest from being criminal's hideout

It is an established fact that the most valuable roles of forest cannot be substituted as regards to its provision of goods and services. Though, many forest reserves in many parts of globe especially in Nigeria have bastardized, many have been degraded while several exiting ones have been converted to the den of men of underworld; arm robbers, kidnappers, drug barons, terrorists and bandits. The existence of these ganglands is not enough to wipe out forest estates. Therefore the following measures can be put in place to take over forests from criminals:

- Continuous monitoring of forest activities with the use of satellite-based solutions as well as drones or small aircraft
- Periodic management of forest resources. The following aspects of forest management should be considered:

(i) Survey of forest,
(ii) Compartmentalization of forest.
(iii) Economic use of forest,
(iv) Administrative setting for forest management,
(v) Training programmes for persons engaged in forest management and conservation activities,
(vi) Use of forest land as tourist centers,
(vii) Social and agro-forestry,
(viii) Development of new techniques for the management and conservation of forests,
(ix) Research for efficient use and conservation of forest, and
(x) Policy decisions and their proper implementation.

- Employment of more forest guards with optimum military training.
- Relocation of military cantonment to most of volatile forests
- Training and empowerment of rural/forest area based vigilante.
- Stringent security measures at borders.

Conclusions

Climate change is real and it has adversely affected serene human existence in many parts of the world. One of its consequential effects is insecurity in Nigeria, irregular rainfall patterns; flood, drought and desertification have led to food insecurity, incessant violence, conflicts and insurgency. Climate change adaptation and mitigation strategies as well appropriate forest management could be a right step in the right directions in safeguard the menace.

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SECURITY CHALLENGES: CONTRIBUTION OF NON-TIMBER FOREST PRODUCTS TO RURAL LIVELIHOODS IN MOKWA LOCAL GOVERNMENT AREA, NIGER STATE

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Abstract
Insecurity has posed a very serious problem in Nigeria recently and these have in one way or the other affected the livelihoods of communities surrounding forest reserves. This study looked at the contributions of NTFPs species to the livelihood of Mokwa rural people, determine the types of NTFPs exploited and their roles in the lives of the communities and also determine the security challenges faced by the Mokwa rural people while collecting NTFPs. Data were collected using structured questionnaire and oral interviews to acquire information from sampled members of the Mokwa LGA communities. The data was analyzed using descriptive statistics (tables and charts). The findings from this study inserted that NTFPs is abundant in the study area and are found in all the forest land areas within the communities. NTFPs collection for utilization is usually carried out throughout the year. The number of households involved in the collection of NTFPs was highest in the Ja'agi community (95%), while only (28%) households were involved in Mokwa town. The chi-square test revealed that there were high significant differences (P< 0.05) between the number of respondents involved in the collection and non-collection of NTFPs in Mokwa LGA. Twenty (20) plants by-products and fruits were the major types of NTFPs being collected. About 50% respondents agreed that banditry is affecting their daily activities and scaring them from entering the forest. It is therefore, recommended that Government should improve the security networking system in order to checkmate the activities of herders/ bandit in the area.

Keywords: *Non-Timber Forest Products, Livelihood, Humans, Insecurity. Mokwa.*

Introduction

Non-timber forest products (NTFPs) are biological resources other than timber which are extracted from either natural or managed. Examples of plant products include fruits, nuts, oil seeds, latex, resins, gums, medicinal plants, spices, dyes, ornamental plants, and raw materials such as firewood, bamboo and rattan (Chassot, 2003; Bhattarai *et al*. 2006). NTFPs are instrumental in conservation, rural livelihoods and poverty reduction (Banjade and Paudel 2008). NTFPs provide a low-cost survival system, foods and medicine, so the importance of NTFPs cannot be over stated (Bhattarai *et al*. 2006). NTFPs have a potential to play a vital role in reducing seasonal and long-term malnutrition and food insecurity.
Insecurity is the greatest problem that affects forest product utilization in Nigeria today. Insecurity arising from herdsmen banditry activity, Boko Haram and ISWAP insurgency in the northern part of the country including Niger state is a very big challenge facing the protection and utilization of the forest produce by the surrounding communities of a named reserve. Banditry is a type of organized crime committed by outlaws typically involving the threat or use of violence. A person who engages in banditry is known as a bandit and primarily commits crimes such as extortion, robbery, and murder, either as an individual or in groups. Bandits attack farm settlements, villages, highways resulting in kidnapping and cattle rustling in the region and these poses heavy security challenges to the nation's forest. Generally banditry is undermining security, peace and development in Nigeria's northern region (Olaniyan, 2018). Hence affected communities' relies on local vigilantes for protection, while others arm themselves to resist attacks.

Niger state communities are majorly farmers who cultivate yams, legumes, beans, millet, tomatoes, and rice in their farms located around the forest fringes. The extent to which the Niger State Plantation Forest Mokwa is able to meet the natural resources need of the Mokwa rural populace at this period of insecurity is not known yet. There is therefore the need to compile, synthesis of information on the utilization of NTFPs in the area. Adequate information about the rural communities' interaction with the forest is an important tool for the development of sustainable forest programme, which will enhance the livelihood of the people. The essence of this study is to provide in-depth information on the utilization of some NTFPs that can potentially alleviate poverty in the surrounding areas of Mokwa populace. It will be useful for researchers, farmers, as well as entrepreneurs and traders as it will give an insight on the market-trend on these NTFPs. The objectives of the study includes to: ascertain the proportion of humans involved in the collection of NTFPs in the study area, determine the types of NTFPs collected, to determine the actual contribution of NTFPs species to the livelihood of Mokwa rural populace and examine the extent to which insecurity has limited or enhanced trading in these products.

Materials and method

The study area

Mokwa Local Government Area lies within Latitude 7'3 and 9'12 and Longitude 5'2' and 9'36'E. it shares borders with Moro Local Government Area in Kwara state, Borgu, Lavun, Agale, Kacha and Mashegu Local Government Area of Niger State. The people are predominantly Nupe who are mainly peasant farmers, fishermen and cattle rearers. The population is approximately 244,937, (lga, 2011).

Data Collection Techniques

Data were collected using structured questionnaire and oral interviews to acquire information from sampled members of the communities' in Mokwa Local Government Area. Personal interview and direct observation was carried out. 160 structured questionnaires were administered randomly to respondents in 4 selected communities in Mokwa Local Government Area namely; Mokwa central, Kpaki, Kudu and Ja'agi. While 40 questionnaires were administered in each community and this was used to elicit information on the uses of NTFPs in the study area. A period of three months was used for data collection. The study was conducted between January and July 2015.

Data analysis

Descriptive statistics was used to analyze the data obtained. The statistics include; - tables, charts and percentages as well as the chi-square test.

Result and discussion

The findings from this work revealed that NTFPs is abundant in the study area and are found in all the forest land areas within the communities. Collection for utilization is usually carried out throughout the year. Male and females were involved in the collection of NTFPs, with the number of female (57.5%) being higher than the male (42.5%).

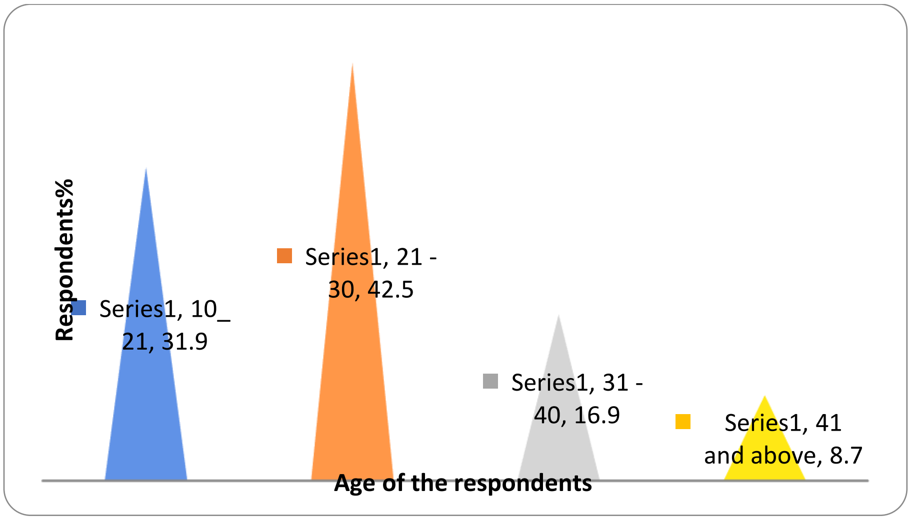

Fig.1. Age of the respondents (%)

The age of the respondents were classified into three categories. Young 10-20, middle age 21-30, elderly age 41years and above. Among all respondents, the middle age accounted for higher percentage of representation in both working and elder age groups having (42.5%). Overall mean age of all the respondent was 21 – 30 years. The majority of respondents were from the working age group.

Education:

The education of respondents was categorized into two groups: literate and, illiterate. Majority of the respondents are educated up to tertiary school level with the highest frequency of respondents (87.5%) having obtained certificate in education at National Diploma or National Certificate of Education level. Only few respondents were found to be illiterate, who did not have the opportunity of going to school and group includes the elderly people. Ja'agi had the highest percentage of educated respondents (23.75%), while Kpaki with (18.75%) has the least. Similarly Kpaki had the highest percentage of illiterate (6.25%), while Jagi (5%) had the least percentage in both illiterate categories. Overall literate and illiterate percentages of all total sampled households were (87.5%) and (12.5%) respectively. The chi-square test showed that there were significant differences between literate and illiterate respondents among the Mokwa town, Kpaki, Kudu and Ja'agi (table 1).

Table 1: Education of respondents'%

Communities	Literate	Illiterate	χ 2	Df	P
Mokwa town	36 (22.5%)	4 (2.5%)	8.2286	3	*(P< 0.05)
Kpaki	30(18.75%)	10(6.25%)			
Kudu	36(22.5%)	4(2.5%)			
Ja'agi	38(23.75%)	2(1.25%)			
Total	140(87.5%)	20(12.5%)			

Source: Field Survey, 2015 (χ2 = Chi Square; df = degrees of freedom); (N = 160)

Occupation

Respondent's occupation was categorized into four groups namely, Farming, trading, employment in government organizations and students. Faming is the major occupation of the communities, while other activities are considered secondary. From the response students are the majority (33%) being the highest while those who take farming as the only occupation (17%) are the lowest. Nineteen percentage of the respondents were employed at government services and these fall under the literate members of the communities, followed by trading (31%), Fig.2.

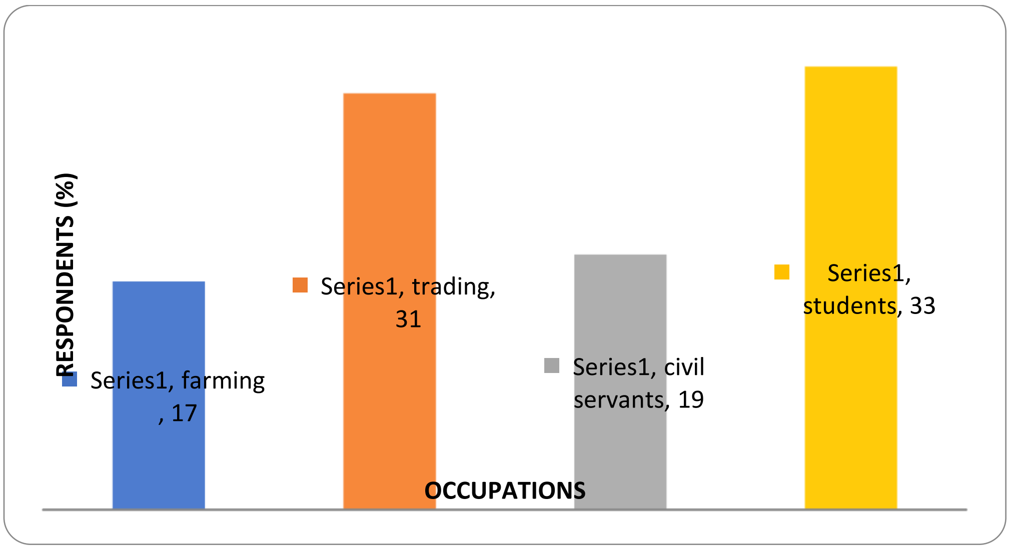

Fig. 2. Occupational of the respondents (%)

NTFPs collection

Table 2 shows the involvement of respondents in NTFPs collection%. The result showed that the number of households involved in the collection of NTFPs was highest in the Ja'agi with (95%) households being involved, whereas for Mokwa town only (28%) are involved. The total number of households involved in NTFPs collection in all the four communities was (80%). The chi-square test revealed that there were high significant differences between the number of respondents involved in the collection and not-collection of NTFPs in Mokwa LGA.

Table 2: Involvement of respondents in NTFPs collection%

Communities	Collection	Not collected	Total	χ 2	Df	P
Kudu	30 (75%)	10(25%)	40	8.75	3	* (P< 0.05)
Kpaki	32(80%)	8(20%)	40			
Mokwa town	28(70%)	12(30%)	40			
Ja'agi	38(95%)	2(5%)	40			
Total	128(80%)	32(20%)	160			

(Source: Field survey, 2015); (χ2=chi square; df = degrees of freedom); [N = 160]

Table 3 shows the number of women and household involved in NTFPs collection, The table showed that the number of women involved in NTFPs collection was higher from the Kpaki community having (60%) than the other three communities, while in Mokwa town the whole household involvement is higher with (90%) respondents being involved, and the chi-square test revealed that there was a highly significant difference between the number of women and the whole household 's involvement in NTFPs collection among all the communities.

Table 3: Women and Household involved in NTFPs collection%

Communities	Women only	Whole household	Total	χ 2	Df	P
Mokwa town	4(10%)	36(90%)	40	31.453	3	*** (P<=0.001)
Kpaki	24(60%)	16(40%)	40			
Kudu	18(45%)	22(55%)	40			
Ja'agi	6(15%)	34(85%)	40			
Total	52(32.5%)	108(67.5%)	160			

(Source: Field survey, 2015); (χ2=chi square; df = degrees of freedom); [N = 160]

Fig. 3 shows the places where the NTFPs are collected, the result shows that the rural people collect the non timber forest products in the forest surrounding the government established forest reserve having (50%) response being the highest, while (13%) respondents gathered the non timber forest product from the forest within the forest reserve being the lowest. The collection is usually on a part time basis.

Table 4. shows the major types of NTFPs collected and their status in the study area. The result showed that 20 plants by- product and fruits are being collected for direct consumption and for other uses, while many of these plants are still highly abundant in the area.

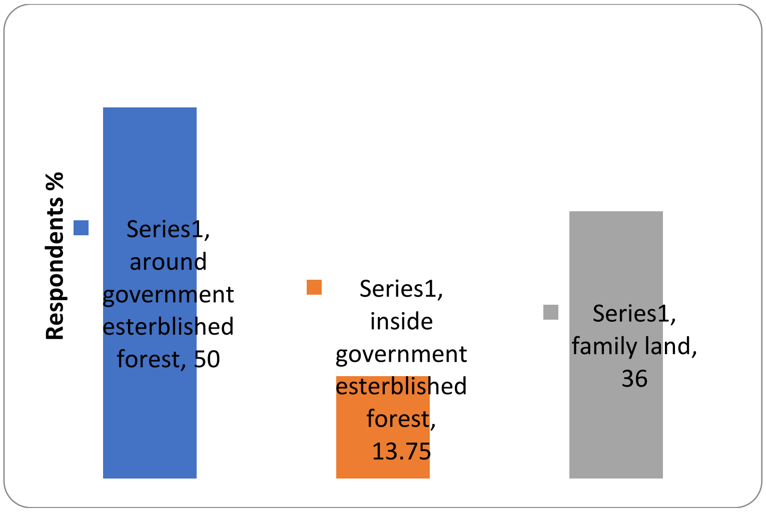

Fig. 3. Places were the NTFPs are collected

Table 4: Major types of NTFPs collected and their status in Mokwa LGA.

S/No	Plant: Scientific name	Common name	Consume	Use for other purpose	Availability
1	*Detarium macrocarpum Ham (tree)*	Tauraa	x	X	Abundant
2	*Adansonia digitata Linn*	Baobab, kuka, oshe	x	X	Abundant
3	*Elies guinesis*	Palm tree	x	X	Scarce
4	*Annona senegalensis*	Wild custard apple, Grandar -daajii,		X	Abundant

5	*Phoenix dactylifera*	Date palm		X	Scarce
6	*Azadirachta indica*	Neem tree		X	Abundant
7	*Anogeissus leiocarpus*	Marike		X	Abundant
8	*Mangifera indica*	Mango	x	X	Abundant
9	*Bombax costatum*	Kurya, gurjiya		X	Abundant
10	*Piliostigma thonnigii*	Kalgo	x	X	Abundant
11	*Cochlospermum planchoni*	Zunzuna	x	X	Abundant
12	*Eucalyptus regnans*	Eucalyptus		X	Abundant
13	*Afzelia africana Sm*	Kawo	x	X	Abundant
14	*Grewia mollis*	Dargaji		X	Abundant
15	*Pakia biglobosa (jacq.) R.Br.*	Dooroowa locust bean	x	X	Abundant
16	*Tamarindus indica*	Tsamiya	x	X	Abundant
17	*Vitellaria paradoxa Gaertn.F*	Shea butter tree, Kadanya	x	X	Abundant
18	*Tectona grandis*	Teak		X	Abundant
19	*Gmelina arborea*	Gmelina		X	Abundant
20	*Bamboo (Poaceae* family)	Bamboo		X	Abundant
	Total		10	20	

(Source: Field survey, 2015)

Usages of NTFPs species

NTFP species such as edible plants and medicinal plants have been regularly utilized in daily livelihood in Mokwa LGA. Edible plants parts were consumed with daily meals whereas medicinal plants were used for primary health care at household whenever necessary and also for trading to make money Peters *et al*. (1989). The daily meal taken by households are mostly supplemented with wild edible plants parts such as the tender leaves of the *Adansonia digitata* which are used as vegetable in preparing soup and sauces. These edible plants are being utilized in daily livelihood to mitigate the problem of food deficit, and nutritional demand. Burlingame (2000) asserted wild edible foods are nutritionally superior even to cultivated vegetables. Also in some regions, wild edible foods can be the main source of food (Sundriyal *et al.*, 2003), and medicine (Chassot, 2003; Bhattarai *et al*. 2006).Wild animals including, small antelopes, francolin, rabbit, guinea fowl, tortoise, pigeon, and monitor lizards are also collected and used as for or sale to generate income for the household.

Table 5 shows list of NTFP species and their uses in Mokwa LGA, The study found that 20 different NTFPs species have been consumed and utilized in everyday livelihood as wild edible, medicinal and other plants. 10 NTFPs species were found to be wild edible plants. Most NTFPs species were medicinal plants, and most plants act as supplements in everyday meal as vegetables and curries. The study revealed that NTFPs are consumed throughout the year as per seasonal availability.

Table 5: List of NTFPs species and their Uses in Mokwa LGA.

S /No	Scientific name	Common name	Uses
1	*Detarium macrocarpum Ham (tree)*	Tauraa	The ripe fruits are eaten by man The leaves are cooked and use as steam bath against fever
2	*Adansonia digitata Linn*	Baobab, kuka, oshe	Young leaves are use as vegetable in preparing soup and sauces. Young leaves are dried very well, then ground and added to hot pap, drunk to cure diabetics, cough and asthma. Ash from the burnt wood is use as fertilizer and in making soap. Fruits are eaten by goat.
3	*Elies guinesis*	Palm tree	Oil is use in cooking and frying food stuffs, Palm front use in making broom, root burnt and use in making soap.
4	*Annona senegalensis*	Wild custard apple, Grandar - daajii,	Root or Leaves are boiled, then drunk to cure diarrhea, and venereal diseases The mature fruit is edible, and is eaten by primates and human
5	*Phoenix dactylifera*	Date palm	Palm front use in making local hart and hand fan

S /No	Scientific name	Common name	Uses
6	*Azadirachta indica*	Neem tree	Leaves, stem, bark use to treat malaria
7	*Anogeissus leiocarpus*	Marike	Leaves are boiled, cool and drink to cure or prevent malaria. The plant is use as chew-stick
8	*Mangifera indica*		Plant is use in constructing house. The mature fruit is edible, and is eaten by man
9	*Bombax costatum*	Kurya, gurjiya	The wood is use for making articles-chairs Fruit contains white floss use for stuffing mattress , Barks boil and drink to prevent and cure pile
10	*Piliostigma thonnigii*	Kalgo	Young leaves chew and the fluid use to treat fresh cut/ wound
11	*Cochlospermum planchoni*	Zunzuna	Root soaks in water and drunk to cure yellow fever/malaria Roots pounded sieved and use to colour soup, The plant is also use to make rope
12	*Eucalyptus regnans*	Eucalyptus	Use as pole, building, firewood,
13	*Afzelia africana Sm*	Kawo	Leaves use to feed cattle; Seeds are grounded and used in thickening soup by man
14	*Grewia mollis*	Dargaji	The ripe fruits are edible
15	*Pakia biglobosa (jacq.) R.Br.*	Dooroowa locust bean	The fruit is prepared as spices for seasoning food; The root is cooked with little potash and drunk to cure stomach ache
16	*Tamarindus indica*	Tsamiya	Fruits are soak in water and drink to prevent malaria and cure body pains
17	*Vitellaria paradoxa Gaertn.F*	Shea butter tree, Kadanya	Oil is used in cooking and fraying, Root and Bark are soaked in water, drink daily to treat west paid and venereal diseases. The fruits are edible
18	*Tectona grandis*	Teak	Use as pole, firewood, leaves use in rapping food stuffs
19	*Gmelina arborea*	Gmelina	Use: building, firewood, leaves use in rapping food stuffs
20	*Bamboo (Poaceae family)*	Bamboo	Use in construction of building, furniture, canes, fishing rods

(Source: Field survey, 2015)

Table 6, showed the rate NTFPs are consumed and use for other purpose%, in Ja'agi (80%) respondents use NTFPs for other purpose, while only (20%) consumed NTFPs directly. The chi-square test shows that there is no significant difference between NTFPs consumed directly as food and those utilized for purposes other than food in all the communities.

Table 6: NTFPs Consumed and use for other purpose%

Communities	Consumed	Use for other purpose	Total	$\chi2$	Df	P
Kudu	15 (37.5%)	25 (62.5%)	40	3.3082	3	(P>0.05)
Kpaki	10(25%)	30(75%)	40			
Mokwa central	12(30%)	28(70%)	40			
Ja'agi	8(20%)	32(80%)	40			
Total	45(28%)	115(72%)	160			

(Source: Field survey, 2015); ($\chi2$=chi square; df = degrees of freedom); [N = 160]

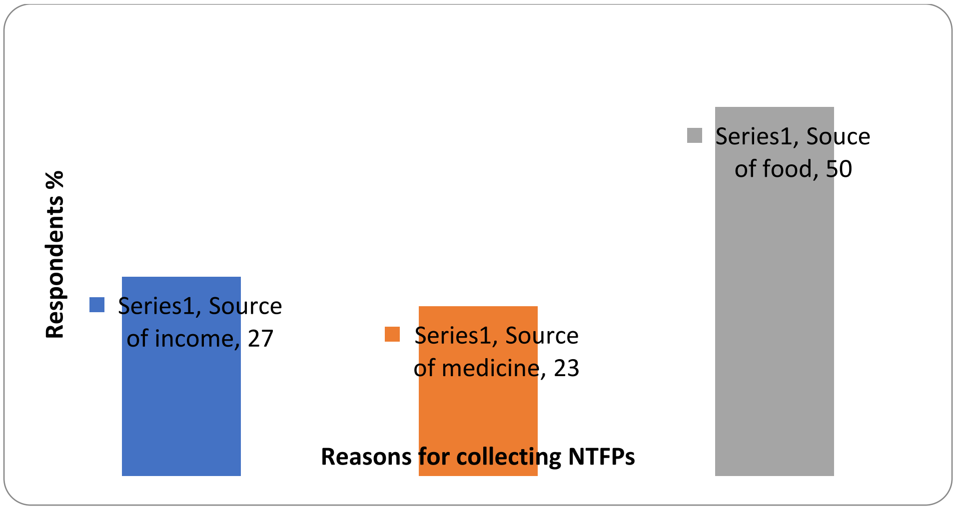

Fig. 4. The reasons for collecting NTFPs (%)

The fig. 4 showed the reasons for collecting NTFPs (%). The finding indicated that majority of the respondents collects NTFPs for food purposes (50%) being the highest, while (23%) collects it for medicinal purpose. This indicated that high demands are being placed on NTFPs in the forest/ woodlands around. This agreed with Bhattarai *et al*. (2006) report that the Non Timber Forest Products (NTFPs) are one of the important natural resources of which majority of the rural people depends on them as a source of food, fodder, fiber, medicine, condiment, dye, and other useful materials.

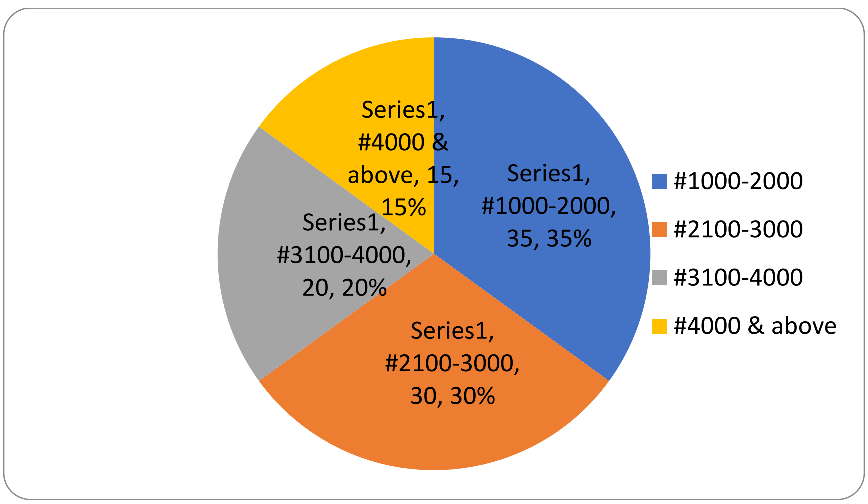

Fig 5. Income generated from the sale of NTFPs per month(%)

The fig.5 showed the income generated from the sale of NTFPs in the study area. The study found that Mokwa LGA communities earned some money from the collection of NTFPs such as *Pakia biglobosa*, *Mangifera indica* and *Vitellaria paradoxa*. Average income of ₦ 1000-2000 naira per month was realized at the household level in the area, this being enough to solve household needs for the day. This agrees with Olsen and Larsen (2003) report that in some rural hilly areas of Nepal, NTFPs contributes up to 50 per cent of total annual family incomes. However, the number of households involved in the collection of NTFPs was high in Mokwa LGA communities but not all the NTFPs collected are being sold. The rural communities are highly dependent on a range of NTFPs for their subsistence needs which contribute a lot to their total annual family income (Olsen and Larsen 2003). The NTFPs therefore generate little income to the people, but continues utilization will reduce the forest and land resources in the area. For the reasons behind the depletion of NTFPs species were both over-collection and premature harvesting. As a result of food deficiency, people are under pressure to make money from NTFPs collection. There is also a competition among primary collectors to collect more NTFPs. In addition, traders sometimes encourage the primary collectors to collect more quantities, particularly of those species with a higher market demand, hence, the availability of NTFPs species have been depleting day-by-day. There is a

need to educate rural communities on the sustainble collection of economically valuable NTFPs species because there is, an opportunity of income and employment generation through cultivation of economically valuable NTFPs species
Table 7. show the major security challenges faced by the communities in Mokwa LGA. The result shows that herdsmen/ bandits are present in and around the forest in the area (46.88%) and that the rate of banditry across the communities is minimal having (75%) response.

Table 7: Major Security Challenges Faced by the Communities in Mokwa LGA.

S/No	Challenge	Yes %	No%	Undecided	
1	Do you see herdsmen/ bandits in and around the forest	46.88	37.5	15.63	
2	Has any of your family member been confronted by bandits before	18.75	56.25	25	
3	Is banditry affecting your daily activities	50	37.5	12.5	
The rate of banditry					
		Minimal	High	Very high	
1	How is the rate of banditry in your community	75%	25	0	
Activities of bandits					
		Burning of houses	Killing of some family members	Kidnapping of men and women in the farm/ journey	Destruction of farm crops
1	What has bandit done in your area recently	12.5	25	25	37.5
Community response					
		Report to government authority	Form community vigilantes for protection	No action taken	Help government to make arrest
1	What have your community done to stop banditry in your area	18.75	43.75	25	12.5

(Source: Field survey, 2015)

From the findings bandits are present in the community, although moving about like every other community member , they are not easily identified from others because of their religious affiliations,however the local populace tend to know them but may not willingly point them out for fear of being attacked. If the bandits know through their informant the person that pin point them, that family is not safe. Mokwa is on a major highway with tight security personnel banditry is not common. Hence the communities still carry out normal daily activities including harvesting of NTFPs.

Conclusion

To supplement the low agricultural production in the rural areas of Niger state, the citizens of Mokwa has given due consideration to NTFPs as an effective means to enhance the economic benefits to rural people and to help in improving livelihood, household food security and nutrition. The study revealed that the utilization of the NTFPs by the communities helped to bring development to the communities. It was also recorded that the utilization helped to promote the image of the communities as it was noticed that companies as well as individuals from nearby towns and cities come to purchase these NTFPs from these communities, especially shea butter oil. The study also showed that the utilization of these NTFPs also boost the use of herbal medication among humans both in the local communities and urban areas. Insecurity have really affected collection and trading in NTFPs because roads are not secured for traders to easily move their products from one community to another. It is therefore, recommended that Government should as a matter of urgency improve the security networking system in order to checkmate the activities of these herders/ bandit and thereby ensure that the forests are safe for the rural communities to enter unhindered.

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A REVIEW OF PLANT MIGRATION RATES, INDIVIDUALISM, AND PLANT COMMUNITY CONSEQUENCES IN RESPONSE TO CLIMATE CHANGE

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Abstract
Climate change in the coming century is expected to be comparable to the last deglaciation's warming. Since then, there has been no other incident of such scale. The palaeoecological evidence of animals' responses to historical temperature change, particularly plants' responses, suggests that evolutionary adaptation played only a minor role and that migration is the most common reaction to climatic change. Individualism in response has significant consequences for changes in vegetation and ecosystems. Even if the greatest realized rates of migratory response by trees may match the maximum prospective rates, they are near to the utmost that such long-lived sessile animals are thought to be capable of. Climate change is expected to accelerate 10-100 times quicker in the future than it did during the last ice age. The likelihood of widespread extinction is high unless actions are done to promote organisms' migratory responses to predicted changes. Artificial dispersal of trees and other organisms with limited dispersal and/or migratory capacity, a broadening of the legal protection currently afforded to some threatened organisms only within designated reserves, and the integration of wildlife habitat requirements and wildlife corridors into human landscape usage are all likely to be required. Stringent measures to limit the extent of future climate change by limiting emissions of greenhouse gases will also be necessary if the possibility of widespread and even catastrophic extinction is to be avoided.

***Keywords**: Tree, climate, extinction, habitat, vegetation*

Introduction

Global system changes are not a new phenomenon; they have occurred throughout the history of the planet. A system of alternating glacial and interglacial conditions characterized the most recent Quaternary geological epoch (Zalasiewicz *et al.,* 2008, Huntley *et al.*,1991, Bridgland and Westaway 2008, Ruddiman and Raymo, 1988). The last glacial period ended at 10000 bp, according to Start and Prell (1984). Glacial conditions existed over much of the last 0-75 Ma (Huntley1991, Bridgland and Westaway 2008, Huntley, 1989), and it is thought that, absent human intervention, the world environment would return to glacial conditions within a few millennia at most (Huntley1991, Bridgland and Westaway 2008, Lamb, 1982).
Human populations have increased enormously over the last two centuries, exploiting fossil fuel deposits, destroying ever wider areas of natural ecosystems, practicing more intense agriculture, and polluting their surroundings to levels that are only now becoming apparent (Schneider, 1989). Changes in the composition of the atmosphere caused by human activity have the potential to have the most devastating repercussions. During the last two centuries, the levels of a variety of so-called "greenhouse gases," both naturally occurring and those present only as presented by Pielke 1998, pollutants, have grown dramatically (Change *et* al 2006 Siegenthaler and Oeschger, 1987; Khalil and Rasmussen, 1987). The level of CO_2 has risen by 23% from 280 ppmv to > 345 ppmv, and is estimated to be rising at c. 4% per decade; the level of CH4, which is 25 times more potent as a greenhouse gas than CO_2, has risen by c. 250 percent from 650 ppbv to 1650 ppbv, and is estimated to be rising at c. 1% per annum (Raynaud *et al.*, 1998,). A conservative consensus of predictions made using atmospheric General Circulation Models (GCMs) is c. 2-5°C for an effective doubling of atmospheric CO2 that will be reached by about ad 2050 at current rates of increase, and estimates range as high as an 8°C rise in global mean temperature during the next century (Schneider, 1989). The Quaternary fossil record must be examined in order to uncover the biosphere's response to global and regional climate changes associated with a global warming of this magnitude. Even at the time of alleged maximum post-glacial warmth, c. 6000 bp, Webb and Wigley (1985) determined that global mean temperature was unlikely to be more than 1°C greater than it is today. We only detect larger shifts in global mean temperature when we compare glacial and interglacial circumstances. Although some regions experienced temperature increases of up to 10°C or more at the end of the last glacial period (Jouzel et al., 1987), Schneider (1989) estimated that the global mean temperature change during the last glacial termination (i.e. between c. 15000 and 10000 years ago) was only about 5°C.

Today, vegetation accounts for the vast bulk of the biomass on the planet. Understanding how vegetation responds to such changes will be critical if we are to predict how the biosphere will adapt to climatic changes of the magnitude predicted for the next centuries. Quaternary palynological data give a record of vegetation's responses to climate changes of comparable scale that have happened frequently throughout the last 0-75Ma. The past 18ka record is particularly significant since it falls within the 14C dating range and includes the most recent period of rapid global warming. The use of isopoll maps to depict late Quaternary palynological data is discussed in this work. These maps show how individual taxa have responded to past large climate shifts, allowing estimations of their reaction rates to be established (Huntley and Birks, 1983; Huntley, 1989). Pollen-climate response surfaces (Bartlein, Prentice, and Webb, 1986) demonstrate the climatic reaction of pollen taxa, and a comparative research employing these has showed

the long-term stability of the climate response of taxa (Huntley, Bartlein and Prentice, 1989). As a result, the fundamental reaction of taxa to rapid and continuous climate change has been migration (Good, 1931; Huntley and Webb, 1989), with each taxon behaving individually (Huntley and Birks, 1983; Webb, Cushing and Wright, 1983; Webb, Richard and Mott, 1983; Huntley and Webb, 1989). Palynological data can also be used to create palaeovegetation maps with the help of proper analysis (Huntley and Birks, 1983; Jacobson, Webb and Grimm, 1987; Huntley,1990).
The characteristics revealed by such maps are explained, and the implications of taxa's individualistic reactions to climate change are explored in connection to plant community responses (Huntley,1990). Although the scale of late-Quaternary climate changes is comparable to future predicted human-caused changes, the maximum rates of change differ by an order of magnitude (Schneider, 1989). The ramifications of this are examined in light of historical evidence of climate change responses. Huntley and Webb, 1988; Davis, 1989; Graham and Grimm, 1990; Huntley, 1991) examine the prospect that rapid human-induced climate change will result in extinction and impoverishment of populations.

Evidence from Palynological Data from the Last Quarter
Pollen diagrams have been created from late Quaternary sedimentary sequences by researchers from all around the world. Since around 1960, the majority of workers have also obtained 14C dates on sediment samples from these profiles, allowing them to be compared on a temporal scale separate from the palynological data. These statistics have been used as the foundation for several workers' syntheses (Flenley, 1979; Ritchie, 1984; Huntley and Webb, 1988). The data can be shown in a variety of ways, some of which are explained here, along with the insights and information they convey, are described below.

Isofil maps
Isopoll maps show the distribution and abundance patterns of individual pollen taxa at specific periods for a given geographical area using contours (the 'isopolls'). Szafer (1946) was the first to utilize the approach to map the postglacial spread of diverse trees across Poland, but its utility was restricted before the availability of 14C dating (Libby, 1955). More recently, with the availability of multiple 14C-dated pollen diagrams, it has become possible to build isopoll maps for specific times on a radiocarbon time-scale, with the advantage that the dating is now completely independent of the palynological record (Huntley and Birks, 1983). The compilation of isopoll maps for Europe by Huntley and Birks (1983) was the first extensive use of this technique to examine the late and post-glacial history of many individual pollen taxa and of the vegetation of a subcontinental scale region, despite a number of more geographically, temporally, and/or taxonomically restricted studies (Birks, Deacon, and Peglar 1975; Birks and Saarnisto, 1975). The technique has now been applied to both big and small areas (Huntley and Webb, 1989). The presentation of palynology data as isopoll maps, as well as the compilation of data into databases that must precede the preparation of the maps, has revealed information and insights that could not be obtained as easily from individual pollen-stratigraphic records, and has enabled new analyses of these data that contribute to our understanding of biosphere responses to climate change (Bartlein .,1986; Jacobson *et al* ., 1987; Huntley, 1990,; Huntley *et al* ., 1989). Two more types of data analysis, as well as two of the conclusions acquired directly from the isopoll maps, are particularly pertinent to discussions of vegetation's reaction to rapid climate change, and are discussed below. Surfaces of pollen-climate reaction Bartlein *et al.*, (1986) demonstrated how modern climate data might be linked with pollen surface-sample data to identify patterns of distribution and abundance of distinct pollen taxa in a climatic area. For their study of the climatic response of several eastern North American pollen taxa, they selected to use the mean temperatures of January and July, as well as the mean annual precipitation. The selection of these climatic variables is discussed by Bartlein *et al.*, (1986), and is justified by their easy availability from the conventional meteorological record, as well as their close correlation with variables that may be more clearly mechanistically implicated in determining plant, and thus pollen, distribution and abundance patterns (winter minimum temperature, growing-season temperature sum, exposure to growing-season drought). Surfaces for pollen-climate response have since been developed using these factors for a wide range of eastern North American and European pollen species, as well as utilizing only the seasonal temperature variables

When the data for taxonomically equivalent taxa from the two continents were compared, the pollen-climate response surfaces on both continents are strikingly similar (unpublished results). The seasonal temperature response surfaces for one pollen taxon were found to be almost identical and can be utilized interchangeably, according to a study (Huntley *et al.*,1989). Because the pollen taxon represents a single species across all, or nearly all, of both continental regions, and because it is a taxon whose response to factors other than climate has been given prominence in the interpretation of its late-Quaternary history, especially in Europe, Fagus was chosen for investigation (Iversen, 1973). The findings of this study, which show a great deal of similarity between the climatic responses of North American and European Fagus spp., led to the conclusion that these taxa have a climatic response that is unique to the genus and has not evolved since the separation of Fagus populations on the two continents between 10 and 25Ma bp, despite the magnitude of continuous, but often rapid, climate change since then. Although similar systematic comparisons for other taxa have not yet been made, the frequency with which they show subjectively similar pollen-climate response surfaces (unpublished results) and their migratory response to postglacial climate change (Huntley and Webb, 1989) indicate that the vast majority of taxa have responded to Quaternary climatic changes by migration rather than evolution (Huntley and Webb, 1989), and that their climatic tolerances and/or adaptations are likely (Huntley *et al.*, 1989). Rates of migration Examining sequences of isopoll (Huntley and Birks, 1983) or isochrones (Davis, 1976) maps can be used to assess the rates of migratory response of taxa to climatic change.

The migration rates indicated in this method are the actual rates; the extent to which migration may have trailed behind exceptionally rapid climatic change is still a point of contention (Davis, 1984; Bennett, 2018; Birks, 1986). Most trees' maximum migration rates are in the range of 150-500m year"1, and the maximum rates of migration reached by certain taxa are remarkably consistent across geographical locations (Huntley, 1989). However, the maximum rates of 1000 to 2000 m year"1 achieved by a few taxa in Europe are slightly higher than those recorded in eastern North America, as Huntley and Birks (1983) have discussed. Isoline maps for events in a taxon's pollen record; the isolines connect sites where the event took place at the same time. The first rise in pollen values to a level indicating local presence of pollen-producing plants is mapped in order to assess migration.
Some aquatic plant (Iversen, 1954; Huntley and Birks, 1983) and Coleoptera (Coope, 1977) taxa, however, traveled even quicker than the trees. The evidence of these faster migrations has been used to back up the theory of migratory lag among trees (Birks, 1986; Davis, 1983; Huntley and Birks, 1983). The isopoll maps of European and eastern North American pollen data, as discussed by Huntley and Webb (1989), do not support any of the suggested sources of lag, and strongly suggest that it could not have been of any considerable significance. A simple estimation of the possible maximum migration rate also reveals that they are surprisingly comparable to the observed maximum realized migration rates. The apparent disparity between tree migration rates and aquatic plant and Coleoptera migration rates can be explained most economically by assuming that these organisms were responding to various components of the climate that altered at different rates and/or at separate times. The orbitally driven changes in solar radiation, as well as changes in the height and extent of the residual ice-sheets in North America and, to a lesser extent, Europe, were the primary forcing processes determining climatic change during the latest deglacial warming (COHMAP Members, 1988).

Summer insolation in the Northern Hemisphere increased, whereas winter insolation decreased. At c. 9000 bp, when summer insolation was c. 8% higher than today and winter insolation was c. 8% lower, this enhanced seasonality of insolation reached its apex. This insolation trend started around 18000 B.P., when seasonal insolation in the northern hemisphere was close to what it is The volume of the major ice sheets was decreasing throughout this time, but it was still estimated to be > 50% of the maximum 18000 bp volume at 12000 bp. Only at the time of the peak seasonality of insolation, c. 9000bp, did the ice sheet volume become insignificant. While increased summer radiation would lead to higher summer temperatures, particularly over ice-free continental areas, reduced winter insolation would lead to lower winter temperatures. Any increase in winter temperatures during this time was primarily due to the ice sheets' waning effect. Kutzbach and Guetter (1986) used atmospheric GCM simulations to validate this general pattern. The July mean temperature had recovered from a M mean dip of c. 3°C at 18000 bp to a zonal mean depression of 0-5°C at 12000 bp, then rose to a zonal mean c. 2°C higher than today at 9000 bp in the northern hemisphere's mid-latitudes. For the January mean temperature zonal averages, comparable data are depressions of c. 11-5°C at 18000 BP and c. 3-5°C at 12000 BP, with little difference from the current 9000 BP 2000 bp and no difference from present at 9000 bp.
The discrepancies in migration rates and timing of trees, aquatic plants, and Coleoptera can all be explained by these variances in seasonal temperature responses. Because they are either latent in the lake-bottom muck or overwintering as eggs or in a state of hibernation throughout the winter season, the latter groups are particularly sensitive to high summer temperatures. Trees' aerial portions, on the other hand, must withstand winter exposure. As a result, the rapid return of summer temperatures to levels comparable to or even exceeding current levels allowed aquatic plants and Coleoptera to migrate more quickly at a time when winter temperatures were still much below current levels, preventing tree migration. In addition, the temperature gradient varies by season; in Europe, the summer temperature gradient is around half that of the winter. This would result in variations in possible migration rates across organisms, depending on whatever component of seasonal temperature their range margin tracked. Organisms that were more sensitive to summer temperatures migrated faster than those that were more sensitive to yearly mean temperatures or winter temperatures. Any test of this theory will require high-resolution temporal examinations of trees, aquatics, and Coleoptera from the same strata, as well as precise 14C dating of the sediments and macrofossil remains contained within them. For the time being, organisms migrate in response to climate change (Huntley and Webb, 1989), and that their actual migration rates are comparable to the potential rates required of them during deglacial warming, which is thought to be representative of the most rapid climate changes in recent geological history. It's also worth noting that there's some debate about whether longer-lived sessile organisms have a migrational lag, and that current knowledge of dispersal, vegetation dynamics, and population growth suggest that the realized migration rates of trees during déglaciation may be close to the maximum that such organisms could achieve.

Individualism among species is a common feature of the sets of isopoll and isochrones maps generated for various geographical locations. While plant ecologists have widely accepted the individualistic response of taxa to spatial variations in their current environment since the work of Whittaker (1954) and Curtis and McKintosh (1951), palaeoecologists have only recently recognized the individualism of response to temporal environmental changes. Pollen maps illustrate that taxa migrate at different times, speeds, and directions, and that no two taxa have distribution and abundance patterns that consistently correspond in space and time (Davis, 1983; Webb, 1981; Huntley and Birks, 1983; Webber al., 1983; Huntley, 1988, 1989; Huntley and Webb, 1989). Individualism in reaction has a lot of significant. Communities arise as transient assemblages of species whose constituents will dissociate as they respond individually to environmental change and form new associations under new environmental conditions, as detailed below. Even if such qualitative shifts do occur, Individualism in responding has several key ramifications. Communities arise as transient assemblages of species whose constituents will dissociate as they respond individually to environmental change and form new relationships under new conditions, as detailed below. Even if such qualitative changes in community composition do not occur, quantitative changes in relative abundance of component species do occur, which can alter the community's structural and functional characteristics. As a result, neither the history nor the evolution of communities should be discussed because they are temporary associations of taxa, each of which is responding to changes in the environment in an individualistic manner, and each of which is likely to be sensitive to different environmental variables. Second, because certain former habitats are likely to have differed from current ones, some previous communities or assemblages of species must be expected to differ from those found now. This is demonstrated by so-called "4 no-analogue" fossil assemblages, such as pollen spectra (Huntley, 1990), vertebrate remains (Stuart, 1982; Graham and Grimm, 1990), or Coleoptera remains (Graham and Grimm, 1990). (Coope, 1977). Overpeck et al. (1985) investigated quantitative measures of degree of analogy and applied them to the eastern North American pollen record. Anderson et al. (1989) used similar approaches to study the pollen record from northwestern North America, and Huntley (1990) studied the European pollen record. Since 13000 bp, Huntley (1990tf) has created maps illustrating patterns in the degree of analogy at millennial intervals. Most post-glacial pollen spectra in Eastern North America had modern parallels, whereas in Europe, many recent post-glacial pollen spectra lack modern analogues. Huntley (1990) has examined the causes behind this discrepancy.

Maps of palaeovegetation, or any other historical communities, cannot be constructed using present-day vegetation units or communities due to the individuality of taxa's responses to environmental change. There have been a number of approaches to palaeovegetation mapping from pollen data (Huntley and Birks, 1983; Jacobson *et al.,* 1987), but they have all been subjective to some degree in terms of the species and/or isopolls to combine in order to map assemblages. Huntley (1990) has recently used multivariate classification to the whole time-space dataset of European pollen data represented at millennium intervals in a database derived mostly from Huntley and Birks (1983) and Peterson (1983) databases (1983). The classification yielded a set of 32 pollen spectra clusters that were not bound by spatial proximity or temporal coincidence. These clusters have been mapped for millennia, and the resulting maps can be thought of as palaeovegetation maps down to the formation level (Huntley, 1990). Only 18 of the 32 clusters mapped are represented at this time. The nature of the compositional changes in European post-glacial forest vegetation was later studied by Huntley (Huntley, 1990). The maps show a number of general characteristics of vegetation's response to climate change (Huntley,1990). They also point to two aspects of European and eastern North American vegetation responses that are particularly important in light of future climate change concerns. (1) The persistence of no-analogue assemblages in Europe during the postglacial, in contrast to results from eastern North America (Overpeck *et al.,* 1985), suggests that European climate may be more sensitive to insolation and other changes, and thus more variable, than the climate of eastern North America (Huntley, 1990). (2) Major changes in atmospheric circulation, such as those seen during deglaciation, result in changes in broadscale vegetation pattern and community composition, which are documented in palynological records from both Europe (Huntley and Birks, 1983; Huntley, 1988) and eastern North America (Huntley,1990).

Discussion

Pollen data from places on a continental or at least subcontinental scale was mapped and analyzed to illustrate how vegetation, the biosphere's most important component, responds to climate change. The preceding findings lead to six major general conclusions. (1) The majority of plants and, most likely, other organisms have not adapted to Quaternary climate variations by adaptive evolutionary modifications (Coope, 1977). Since the Tertiary, at least some taxa have showed no major change in their climate sensitivity (Huntley *et al.,*1989). (2) When faced with Quaternary climate changes, most, if not all, taxa have responded by migrating (Huntley and Webb, 1989). (3) Trees' actual maximum migration rates (Davis, 1976; Huntley and Birks, 1983; Huntley, 1989) are comparable to the anticipated maximum migration rates needed to track deglacial warming. Many researchers believe that tree migrations lagged climate change during rapid deglacial warming because such rates are near to or even constitute the absolute maximum that trees are capable of (Birks, 1986; Pennington, 1986; Bennett, 2018). (4) Taxa responded to past climate changes in an individualistic manner (Davis, 1983; Huntley and Birks, 1983; Webb, 1981; Webb et al, 1983; Huntley, 1989; Huntley and Webb, 1989), which is similar to taxa's individualism in response to aspects of their current environment (Davis1983; Huntley and Birks, 1983; Webb, 1981; Webb (Whittaker, 1951, 1953). (5) As a result of individualistic migratory responses, communities and vegetative units arise as transient assemblages of species that dissociate and reassemble in new assemblages as climate changes. Past climates, unlike today's, produced communities unlike today's. (6) Major re-arrangements of atmospheric circulation, such as those that occurred during deglaciation, result in changes in broadscale vegetation patterns and the orientation of major vegetation gradients and ecotones, as well as quantitative and qualitative changes in the composition of plant communities (Huntley and Birks, 1983; Webb, 1988; Huntley, 1990). How useful are these findings for predicting how vegetation will react to future climate changes caused by the release of greenhouse gases into the atmosphere as a result of human activities? Many experts now believe that an increase in global average temperature of at least 2-5 degrees Celsius by the middle of the twenty-first century is likely to occur (Schneider, 1989; Houghton, Jenkins and Ephraums, 1990).

This is the largest shift in global mean temperature since the last deglaciation (i.e., since the rise of about 5 degrees Celsius between c. 15000 and 10000 years ago, which signaled the end of the last glacial period). As a result, evidence of the biosphere response to glacial warming can be used to help forecast the response to current warming. The rate of warming predicted for the next century, on the other hand, is expected to be between 10 and 100 times greater than the rate of deglacial warming. As a result, the biosphere will be responding to a rate of climate change that has never been seen before, at least in the recent geological past. Any indicator of the biosphere's ability to adjust to such rapid changes, whether positive or negative, will be extremely valuable. Given the facts presented above, the first unavoidable conclusion is that organisms would migrate in response to predicted climatic change. It is also certain that they will do so in an individualistic manner, resulting in changes in the composition of communities and ecosystems. The amount to which they will be able to achieve this answer will be determined by a variety of things. In the case of trees, past maximum migration rates are thought to be close to the maximum rates feasible by these long-lived sessile creatures; some researchers assume that trees lagged behind deglacial climate changes due to migration rate constraints. As a result, most trees are thought to be unlikely to attain the migration rates required by predicted climate changes that are one to two orders of magnitude quicker than those seen during the last deglaciation (Davis, 1989; Huntley, 1990). Furthermore, all organisms will be forced to travel across landscapes that have been significantly transformed by human activity, and in which the habitats available to them are limited in size and fragmented (Huntley, 1991). This will put more restrictions on the amount of migration they may achieve. Many animals have had their populations significantly decreased by human activities, even in less-developed countries, and today only live in designated reserves. Although their migration may not be limited by the availability of habitat outside of the reserve areas in these cases, the legislative protection provided to many is limited to the reserves; any individuals moving outside the reserves as part of a migratory response will frequently face severe human persecution, effectively preventing their migration (Huntley and Webb, 1988; Huntley, 1991).

The prognosis for many organisms is currently bleak. If many trees are to survive, proactive actions to aid their migration in the face of future climate change may be required (Roberts, 1989; Huntley, 1991). Other animals whose small and fragmented populations limit their ability to disperse to what are frequently remote, small regions of suitable habitat may require the same artificial dispersal. Threatened taxa whose current survival is contingent on legal protection within designated reserves may only survive if their protection can be extended, allowing them to migrate to places that, in many cases, are not now protected. Few current reserves are large enough to accommodate significant migrations, and even fewer provide the option of altitudinal migrations rather than geographical migrations. If we wish to reduce the need for artificial dispersal, we must seek to integrate wildlife demands into our use of the environment rather than relying primarily on isolating them in limited designated reserves, in addition to extending legal protection to regions outside reserves. In addition, we must reassess our policy on the designation of such reserve areas (Hunter, *et al.*, 1988; Huntley, 1991). Reserves cannot be chosen only on the basis of the rarity of the creatures present inside their bounds; these organisms may migrate elsewhere in the future. Instead, in order to establish resiliency in our network of reserves, we must conserve as much land as feasible and as varied a range of physical habitats as possible. We must also place a larger emphasis on creating a connected network that facilitates migratory movements; so-called "wildlife corridors" will become increasingly important in the future and must be included in every structure or development plan. If such steps are not taken, many organisms will face extinction within the next one or two millennia if global climate change is not avoided (Roberts, 1989; Huntley, 1990). Even if strict measures to reduce greenhouse gas emissions are enacted in the near future, the return of the global system to equilibrium will require significant warming, which will induce significant migrations by many organisms (Schneider, 1989). If large-scale declines in the populations of many organisms and the extinction of others are to be avoided, policies that allow organisms to migrate will be required, regardless of future greenhouse gas emission regulations. Even if means are taken to encourage, if not artificially aid, organism migration, extinction of some species appears to be inescapable. Large-scale extinction is highly likely if these steps are not taken. If no measures are made to reduce greenhouse gas emissions, the number of extinctions will rise. It could become disastrous if potential positive feedbacks, such as those generated by the release of methane from hydrate deposits beneath permafrost zones and the oceans (Leggett, 1990), start to operate and accelerate the rate of climate change.

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ACTIVITIES OF RURAL WOMEN IN COLLECTION OF NON-TIMBER FOREST PRODUCTS (NTFPs) IN ALLEVIATING HOUSEHOLD FOOD INSECURITY IN KADUNA STATE

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Abstract
Rural women's economic empowerment is fundamental to enhancing and strengthening their food security status. Non-timber forest products (NTFPs) make significant contributions to food security of the rural women. This study examined the activities of rural women in collection of NTFPs in alleviating household food insecurity in Kaduna state. Multistage sampling procedure was used to select 120 respondents for the study and structured questionnaire was used for data collection. Data were analysed using descriptive statistics; Chi-square and Pearson Product Moment Correlation (PPMC) were used to test the hypotheses. The results showed the mean age of 40.12 years. Majority (70%) of the respondents considered forest leaves, extraction of medicinal plants, honey and beewax as the most important product in NTFPs. PPMC result revealed that age (r =0.207, p = 0.023) and monthly income (r= 0.175, P=0.056) were significantly related to food security status. Chi-square revealed that the major constraints were insecurity issues (χ^2=4.693,p=0.030), pest and diseases (χ^2=29.091,p=0.00) and lack of harvesting technology (χ^2=2.325,p=0.00). In conclusion, NTFPs was identified to play major role in enhancing household food security, providing primary health care and empowerment for rural women to ensure household food security. The study recommends that rural women should be supported by providing adequate security measures which will help to increase their confidence for increased level of participation and contribution to households' food security without the fear of being kidnapped.

Keywords: *Rural women, Non-timber forest products, Household food insecurity*

Introduction

Forests and Non–timber Forest Products (NTFPs) plays a key role in promoting the economic advancement, welfare of rural women and it is also accepted as a veritable means of alleviating poverty among rural communities as it helps in sustaining livelihood and rural well-being (FAO, 2012). NTFPs are described as tradable products derived from the forest excluding timber (Olawoye, 2016). FAO (2013) also defined NTFPs as goods of natural origin, and services derived from forest or any land under similar use excluding wood in all its forms. NTFPs includes useful materials and items used as food, fuel, fodder, medicine, cottage and wrapping materials, biochemical, birds, reptiles and fishes, for food and fodder, fruits and nuts, food and beverages, fish and game, vegetables, fuelwood, honey, medicinal plants, essence and different kind of barks and fibre such as bamboo, rattan and a lots of other palm and grasses are parts of diets many rural dwellers consumed as food supplements in Nigeria especially during off season to enhance adequate food security (Shackleton and Shackleton, 2014; Jimoh, 2016).

Household food security was described by FAO, (2006) as a condition that occurs when all the people within a household at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. When all the occupants of a household do not live in hunger or fear of starvation, such household is considered food secured. However, food insecurity simply means scarcity of food. It is linked with fluctuation in a household's own food production and availability (Babatunde *et al*., 2017). It is also associated with food productions, general economic and social development variables. Many of these variables such as rise in world food prices, increased food commodity speculation, changing climatic conditions caused by global warming, increasing demand for arable land for cultivation of biofuel and poor governance to cope has aggravate the food security situation in most parts of the world including Nigeria (Dirorimwe, 2013).

In Nigeria, rural women are more vulnerable because they spend most of their time providing support to their husbands, children, elders and other members of their family; consequently, they become economically dependent, educationally backward, and disadvantaged both politically and socially (FAO, 2015). They are more exposed and vulnerable to insecurity attacks of kidnappers and bandits, which in turn generate social, economic, and environmental costs on rural well-being (Hill, 2011). It is therefore necessary that adequate attention should be granted to rural women's access to economic empowerment through the provision of adequate security and enablement through adequate access to NTFPs which in turn would help to promote development efforts by increasing rural women's access to economic resources such as job opportunities, financial services, skills development and market information (OECD, 2013). The main objective of the study is to assess the activities of rural women in the collection of NTFPs in alleviating household food insecurity in Jema'a Local Government Area of Kaduna State. The sub objectives are: (i) describe the socio-economic characteristics of the rural women (ii) identify the activities of rural women in gathering NTFPs (iii) determine the household food insecurity status and (iv) find out the constraints faced by rural women in NTFPs activities in the study area.

The hypotheses of the study is stated in null for as follows
Ho: There is no significant relationship between
i. socio-economic characteristics of the rural women and household food insecurity status.
ii. activities of rural women in gathering NTFPs and food insecurity status
iii. constraints faced by rural women in NTFPs gathering and food insecurity status.

Methodology

Study area

The study was carried out in Jema'a Local Government Area (LGA) of Kaduna State. Jema'a LGA is situated between latitudes 8° 30' to 8° 34' N and longitudes 9° 23' to 9° 31' E. It covers an area of about 15643 km² with population density of 110,008; with the mean monthly temperature of 35 °C and annual rainfall of 715 mm. Some of the activities taking place in the study area includes crop farming such as ginger, rosette, maize and sorghum, while the animals reared there include goat, poultry, pigs and cattle (NPC, 2006).

Sampling Procedure and Data Collection

A multi-stage sampling technique was adopted. The first stage involved purposive sampling of six wards out of fourteen wards in the LGA because of accessibility of forest and high concentration of rural women in NTFPs. In the second stage, one village was randomly selected from the six wards. In the third stage, twenty (20) rural women were randomly selected from each village to make of 120 respondents. Interview was conducted using structured questionnaires to elicit information from the rural women.
The Household Food Insecurity Access Scale (HFIAS) (FANTA Scale) of the United States Agency for International Development (USAID) (2007) was used to categorize households. The HFIAS Score for each household was calculated by summing the scores for each household. The maximum score for a household is 27 while the minimum is 0. The higher the score, the more the food insecurity (access) the household experienced. The lower the score, the less food insecurity (access) a household experienced. Furthermore, 6 dichotomize items were developed to ascertain the level of participation in the activities that they do in collecting NTFPs. A Yes/No response were asked with a score of 2 and 1. Maximum score was 12 while the minimum was 6.

Data Analysis

Descriptive statistics was used to analysed data collected, Fanta scale (3 point Likert scale statement in order of rarely, sometimes and often) and Inferential statistics - Chi-square and Pearson Product Moment Correlation (PPMC) were used to test the hypotheses.

Results and discussion

Socio- economic characteristics of the respondents

Table 1 showed that 27.10% of the respondents are within 41-50 years of age. This indicates that majority of the respondents were in their active age to carry out NTFPs activities that can improve their household food security status. This agreed with the findings of John (2013) who stated that, most rural women in their active ages support their households through their livelihood activities in NTFPs. Also from Table 1, some (31.40%) of the respondents have tertiary education, while others (20.30%) and (8.5%) had both secondary and primary education respectively. This implies that the level of education brings about exposure and empowerment that influence the rural women as they carry out NTFPs activities which enhance household food security and empowerment for better living (Shively and Newton, 2016). Table 1 further revealed that some (21.20%) of the respondents have monthly income of less than ₦10,000 while few (11.0% and 8.50%) had an estimated monthly income of ₦41,000 and above ₦51,000 respectively.

Table 1: Distribution of respondents based on their socio-economic characteristics

Variable	Frequency (n=120)	Percentage
Age (years)		
Below 20	12	10.20
21-30	23	19.50
31-40	26	22.00
41-50	32	27.10
51 years and above	25	21.00
Educational Status		
Non-Formal education	29	24.60
Arabic Education	18	15.30
Primary education	10	8.50
Secondary education	24	20.30
Tertiary education	37	31.40
Monthly Income		
10, 000 and below	25	21.20
11, 000 – 20, 000	34	28.80

21, 000 – 30, 000	25	21.20
31, 000 – 40, 000	11	9.30
41, 000 – 50, 000	13	11.00
50, 000 and Above	10	8.50

Source: Field Survey, 2021

Activities of rural women in NTFPs gathering

Table 2 showed the activities of rural women in NTFPs gathering. Majority (90.0% and 86.7%) of the respondents were into collection of leaves and planting of vegetables and extraction of medicinal plants respectively. This implied that cutting of leaves is a major activity of the rural women in NTFPs, they does this to assist their household by providing food and shelter. This was supported by Uwalaka *et al*, (2010) that people always depends on plants and animals for their medical care ever before the introduction of western drugs in Nigeria. Schreckenberg (2013) emphasized that the demand related to natural health and beauty products are enormous, opportunities abound for the collection of NTFPs especially the medicinal leaves for processing into beauty products. Most (65.0%) of the respondents were into harvesting of products, while fifty percent (50.0%) of the rural women are into hunting of game. NTFPs can be collected in forest plantation or from trees outside the forest. The uses of these NTFPs range from being food or food additive (nuts, wild fruits, herbs) as plant materials and animal products (honey, silk, bush meat). NTFPs are perceived by many as a sponge and their use in traditional activities are giving ways to other businesses and products as the economy improves (IFAD, 2015).

Table 2: Distribution of rural women based on their activities in NTFPs

Activities of rural women in NTFPs	*Frequency	Percentage
Planting of vegetables	104	86.7
Collection of leaves	108	90.0
Extraction of medicinal plants	104	86.7
Harvesting of products (Shea, fruits, nut honey and beewax)	78	65.0
Hunting	60	50.0

Source: Field survey, 2021 *Multiple responses

Food insecurity status of the respondents

Table 3a showed that some (26.7%) of the respondents worry about food and some (16.7%) of the respondents were unable to eat the kind of their favourite foods because of lack of resources. Few (6.7%) eat limited variety of foods due to lack of resources. This implication of this is that the food secured household experiences none of the food insecurity variables or conditions, or just experience worry but rarely. While slightly food insecure households is unable to eat desired food or monotonous diet than they preferred. There were no cases of severely food insecure households. Having access to sufficient food for healthy and productive life in right quantity and at the right time is food security. NTFPs added to the quantity of rural household diet directly by providing medicine, fruits, nuts, bush meat, mushrooms, honey and fuel wood for food processing, and shortage may directly affect food security (FAO, 2017).

Table 3a: Distribution of the respondents based on their food insecurity status

Household Food Security Questions	Yes	No	Rarely	Sometimes	Often
Did you worry that your household would not have enough food to eat in the past four weeks?	33(26.7)	88(73.3)			
How often did this happen?			100(83.3)	20(16.7)	
In the past four weeks, were you or any of your household members not able to eat the kind of foods you wanted because of a lack of resources?	20(16.7)	100(83.3)			
How often did this happen?			98(81.7)	22(18.3)	
Do you or any of your household members have to eat a limited variety of foods due to lack of resources in the past four weeks?	8(6.7)	112(93.3)			
How often did this happen?			112(93.3)	8(6.7)	

In the past four weeks, did you or any household member have to eat unwanted foods because of lack of resources to obtain other types of food?	20(16.7)	100(83.3)			
How often did this happen?			98(81.7)	22(18.3)	
In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	50(41.7)	70(58.3)			
How often did this happen?				88(73.3)	16(13.3)
In the past four weeks, do you or any other member of your household have to eat lesser meals in a day because there was not enough food?	32(26.7)	88(73.3)			
How often did this happen?			100(83.3)	20(16.7)	
Was here ever no food to eat of any kind in your household because of lack of resources to get food in the past four weeks?	20(16.7)	100(83.3)			
How often do this happen			98(81.7)	22(18.3)	
In the past four weeks ,did you or any of your household members go to sleep hungry at night because there was no food	8(6.7)	112(93.3)			
How often do this happen			112(93.3)	8(6.7)	
Did you or any of your household member go a whole day and night without eating anything because there was not enough food in the past four weeks?	12(10.0)	108(90.0)			
How often do this happen			110(91.7)	10(8.3)	

Household food insecurity access scale (HFIAS)

Food security status of the respondents

Table 3b further bring out the household food security status of the respondents. Most (55%) of the respondents were food secured while some (45%) were mildly food insecure and there were no cases of severely food insecure. NTFPs contribute substantially to nutrition of the household, either as part of family diet or as a means to achieve health attention through the prevention and treatment of diseases i.e. the use of medicinal plant for curing certain diseases. Nigeria government and other development agencies need to provide more grant or fund to household so as to reduce food shock and aid household food security (Tollens, 2018).

3b: Distribution of the respondents based on food security status

Status of food security	Frequency	Percentage
Food secure	66	55.0
Mildly food insecure	54	45.0
Tota	120	100

Source: Field survey 2020

Constraints faced by the respondents in NTFPs activities

Table 4 showed the ranking of some constraints facing the respondents with regards to NTFPs activities. Paramount among the constraints is insecurity issue (76.7%). Insecurity keeps rural women in perpetual fear and does not allow free moment of rural women to the forest and farm lands. Other constraints include lack of machine (68.3%) for adequate processing of NTFPs, Unstable demand for products (66.7%) and Price fluctuations (55%) respectively

Table 4: Distribution of Respondent based on Constraints faced in NTFPs

Constraints	Frequency	Percentage
Inadequate rainfall	88	73.3
Lack of machine	82	68.3
Unstable demand for products	80	66.7
Pest and disease	72	60.0
Price fluctuation	66	55.0
Activities of rodents	66	55.0
Insecurity	92	76.7

Source: Field survey, 2021

Test of hypotheses

Correlation analysis between some selected socio economic characteristics and food insecurity status

Correlation analysis showed that there is a significant relationship between age (r = 0.207, p = 0.023), monthly income (r= 0.175, P= 0.056) and food security status. This revealed that most of the respondents are in their youthful age hence they are able to work better and faster to contribute in NTFPs, they can also cope with intensive labour demand in collecting the NTFPs. Age play a key role in the activities of rural women in NTFPs because young rural women are more active and get things done easily (Mulenga *et al*., 2011).

Correlation analysis between socio-economic characteristics of the respondents and household food security

Variables	r	p-value	Remark
Age	0.207	0.023	S
Monthly income	0.175	0.056	S

Correlation analysis between activities of respondents in NTFPs and food insecurity status

Correlation analysis between activities of respondents in NTFPs showed the significant relationship between cutting of leaves (r= 0.302, p =0.001) and household food security. Adekunle (2015) said that ethno medicine has gained much mire acceptance as the only alternative to drugs which were gotten from the leaves of the plant which can be said that wood and leaves of trees gotten are very much important

Chi-square analysis between respondents' constraint and household food insecurity

Chi-square analysis revealed that insecurity issues (χ^2=4.693, p=0.030), unstable demand for products (χ^2=5.455, p=0.020), pest and diseases (χ^2=9.091, p=0.00), activities of rodents (χ^2=18.623, p=0.00) and lack of machine (χ^2=12.325, p=0.00) were significant to household food insecurity. The activities of rodents cause a lot of damages to the products and it will lead to lots of loss to the rural women. This finding is in line with Braun, (1985) who confirmed that Nigeria forest resource is mostly under managed and is faced with the problem of poor implementation and protection rules. The upsurge of kidnapping and banditry especially in northern Nigeria is a major threat to the agricultural activities and also gathering of NTFPs in the rural area. Kidnapping and insurgency affected the movement of products and increase in price of NTFPs. It made it difficult for extension workers to go to those areas and also farmer to access their farms. Infestation of pest and disease reduces the quantity and quality of NTFPs products. While activities of rodents also threatening the survival of NTFPs in Nigeria, rodents attacked NTFPs either in the farm or at home resulted in loss of NTFPs quantity, this also affected rural women participation in NTFPs activities respectively. The null hypothesis which stated that there is no significant relationship between the constraints faced by rural women and food security status is hereby rejected.

Table 5: Chi square between respondents' constraint and food insecurity

Variables	χ^2	Df	p-value	Remark
Land acquisition	0.808	1	0.369	NS
Security issues	4.693	1	0.030	S
Inadequate rainfall	0.028	1	0.868	NS
Unstable demand of products	5.455	1	0.020	S
Fluctuating of price	0.393	1	0.531	NS
Pest and disease	29.091	1	0.00	S
Activities of rodents	18.623	1	0.00	S
Lack of machine	12.325	1	0.00	S

Conclusion

The study concluded that rural women are actively engaged in NTFPs activities. Such activities include cutting of leaves, extraction of medicinal plants, harvesting and hunting. NTFPs have been identified to play major role in providing primary health and nutritional needs for the rural women. It ensured food security is beyond basic consumption but also an avenue to financial support and empowerment of rural women.

Recommendations

The following recommendations were made from the findings of the study;

i. Rural women should be empowered and supported to improve in their ability in providing medicinal plant to improve health sector through prevention and treatment of diseases.
ii. Rural women should also be financially supported to gain more trade material thereby having the ability to buy more quality, nutritious and safe food at all time in order to be food secure.
iii. Government with the help of non-governmental organization should provide security measures; this will help in securing lives and properties of rural women and also increase the level of participation and contribution to the food security of household.

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COMPARATIVE EVALUATION OF NUTRITIVE VALUES OF FOUR FODDER PLANT SPECIES IN UMUDIKE ABIA STATE, SOUTH-EASTERN NIGERIA

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Abstract
As essential as animal production is to mankind, there is a challenge of nutrient inadequacy especially with the local animal farmers. This study was conducted to evaluate the nutritive value dry matter (DM), moisture content (MC), crude protein (CP), crude fiber (CF), ash content, ether extract (EE), carbohydrate (CHO) and calorific value (CV) of fresh leaf and leaf litter of four fodder plant species (Maesobotrya barteri, Cola millenii, Napoleonaea vogelii and Uvaria chamae) in Umudike, Nigeria. Maesobotrya barteri and Napoleonae vogelii had similar DM results (95.48% and 94.95%, respectively) while Cola millenii had the least (93.08%). The MC contents of the species were within the range of 4.53 – 5.41%. U. chamae had a CP value of 22.86% while others ranged between 18.71% – 19.82%. M. barteri had the highest CF value (10.15%). N. vogelii recorded the highest ash content (8.51%), while U. chaemae had the least (6.95%). The EE values of U. chamae and C. millenii (7.38% and 7.09%) were significantly higher than those of N. vogelii and M. barteri (5.26% and 4.71%). The CHO value of N. Vogelii and M. barteri were 60.17g and 58.67g, respectively and were higher than those of U. chamae and C. millenii (54.73g and 56.68g, respectively). The CV values for U. chamae and M. barteri were the highest and the least (376.78 J/kg and 352.35 J/kg, respectively). The study concludes that the incorporation of these species into fodder banks, home gardens and alley farms can help to overcome problems of livestock nutrition.

Keywords*: Animal production, nutrient inadequacy, nutritive value, fodder banks, home gardens*

Introduction

Animal production is an essential component of traditional agriculture in the humid tropics. The lack of forage is a significant cause of insufficient animal protein, especially in the developing world. In Southeastern Nigeria, livestock production contributes to food security and rural livelihood. However, inadequate nutrient supplies especially during the dry season is a major challenge to livestock production. The impact of this challenge is more evident in the small-scale sector (Odeyinka, 2001; Anyanwu *et al*., 2021). Fodder trees and shrubs have always played a vital role in feeding livestock and could be planted to overcome the effects of troughs in fodder supply and guard against the risk of drought or fire (Khan *et al*., 2014). Thus, leaves, twigs, and fruits of naturally occurring browse trees, shrubs, and other woody plants species have been incorporated as a significant component of livestock production in many regions of the world, mainly on grasslands (Aganga and Tshwenyane, 2003; Khan *et al*., 2014).

Any fodder crop's forage value depends on its nutritional content and palatability; fodder is fed to animals to meet specific productive purposes (Waziri *et al.*, 2013). Reports have shown that trees and shrubs provide animals with protein and energy to keep rumen microbes active, increase their ability to digest fiber and enable livestock to use dry season pastures. Their availability almost all year round further increases their dietary contributions (Asefa *et al*., 1992).

Fodder trees and shrubs have relatively higher concentrations of crude protein, mineral, neutral detergent fiber (NDF) and acid detergent fiber (ADF) and lower average dry matter digestibility than grasses (Wilson, 1977). However, choosing fodder crops with low nutrient contents and nutritive value could be detrimental to sustainable productivity in animals (Waziri *et al.*, 2013). There is a need to recognize, evaluate and select browse plants (trees and shrubs) with the fodder characteristics to incorporate them into the sustainable production systems. Therefore, this study was undertaken to determine the nutritive values of fresh leaves and leaf litters of four bush fallow fodder plants commonly found in south-eastern Nigeria.

Materials and method

The Study Site

This study was carried out in Umudike, South-Eastern Nigeria, which is in the tropical rainforest zone of Nigeria (Agro-Metrological Station, NRCRI, Umudike). Umudike lies between latitudes 5º25' and 5º32'N and longitudes 7º32' and 7º35'E. It has two distinct seasons; the rainy and dry seasons. The dry season lasts from November to March, while the rainy season kicks off in Mid-March and ends in October, with peaks in July and September. The average annual rainfall range is 2,238 mm, while the mean minimum and maximum temperatures are 23ºC and 30ºC, respectively (Tembe, 2005). The relative humidity is usually high, between70-85% during the rainy season as low as 45% during the peak of the dry season. The soil is well-drained, deeply weathered, sandy loam of up to 30cm depth and rich in organic matter with an overlying uniform clay content all through the profile depth (Federal Department of Agricultural and Land Resources (FDALR), 1990).

Sample Collection and Processing

The plant species studied were: *Maesobotrya barteri, Cola millenii, Napoleonaea vogelii* and *Uvaria chamae*. The four bush fallow species' fresh leaves and leaf litter were collected, enclosed into brown envelopes, and then oven dried at 70°C for 48 hours at the National Root Crop Research Institute (NRCRI) Umudike, Nigeria. The oven-dried leaf samples were milled then sieved with a 0.5 mm sieve and stored in the harvest brown envelope for chemical analysis.

Laboratory Analysis

The milled samples were used to determine the nutritive values of dry matter (DM), moisture content (MC), Crude protein (CP), Crude fiber (CF), total ash, ether extract (EE), carbohydrate (CHO), and Calorific value (CV) of the fresh leaves and leaf litters of the bush fallow fodder species. Also, the Percentage Nitrogen (%N) was determined to get the Crude Protein (CP) (Gosukonda *et al*., 2020).

Extraction of Samples for Analysis by Wet Acid Digestion Method

0.2g of each of the milled samples was weighed and put into a 100ml conical flask. 5ml of the multiple nutrient extraction reagents ($H_2SO_4^-$ selenium catalyst + salicylic acid) was added to a milled sub-sample, covered and allowed to stand for about 16 hours. Each sub-sample was placed on a hot plate set at 30℃, heated for 2 hours, and then brought down. 5ml of concentrated perchloric acid ($HClO_4$) was added and heated vigorously until the sample became clear, indicating complete digestion. 20ml of water was added to the digest, heated gently for just two minutes (2minutes), and then allowed to cool. The digest was transferred into a 50ml volumetric flask and made to mark with distilled water ready for mineral nutrients analysis (Okafor *et al*., 2018).

Determination of Total Nitrogen (N)

Nitrogen (N) was determined from the sample using the semi-micro Kjedhal distillation method (Jackson, 1962). From the multiple nutrient digests, 10ml of the sample was gradually introduced (pipetted) into the Markhan distillation apparatus for the semi-micro Kjeldahl nitrogen distillation. 10ml of 45% sodium hydroxide (NaOH) was added to the digest and allowed to distil out into a 10ml of 4% boric acid indicator through a condenser where about 50ml of the distillate was collected in a conical flask and titrated with 0.02 N of H_2SO_4 to a point. A blank distillation was also carried out and titrated 0.02 N of H_2SO_4 to a pink endpoint. The values obtained were used to calculate the percentage nitrogen (%N).

Determination of Nutritive Values

The ether extract (EE) carbohydrate (CHO) and calorific value (CV) were determined using the procedures of the Association of Official Analytical Chemists (AOAC, 1990). Crude fiber (CF) was determined by the Weende method and crude protein was by the semi-micro Kjeldahl in accordance with AOAC (1990) standard procedures. The formulas for the determination of the various nutritive values are as follows.

a. Ether extract (EE) (%) = $\frac{\text{Weightofoil}}{\text{weightofsample}} \times 100 \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$

b. % Carbohydrate (CHO) = $100 - (\%\,\text{CP} + \%\,\text{CF} + \%\,\text{Ash} + \%\,\text{EE} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$

c. Calorific value (CV) (g cal^{-1}) = $(\%\,\text{EE} \times 9) + (\%\,\text{CP} \times 4) + (\%\,\text{CHO} \times 4) \ldots\ldots\ldots (3)$

d. %Crude protein (CP) = $\%\,\text{N} \times 6.25 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$

e. % Ash = $\frac{\text{weight of Ash}}{\text{weight of sample}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$

Where: Weight of Ash = Ash + crucible-weight of the crucible

Experimental Design and Analysis

The nutritive values of four bush fallow fodder plant species in Umudike, South Eastern Nigeria, were determined using a 2x4 factorial experiment in a randomized complete block design (RCBD) with three replications. The study involved two factors which are the leaf types and the four bush fallow fodder plant species studied. The two leaf types are the fresh leaves and leaf litters which were randomly selected from bush fallows. Fisher's Least Significant Differences (F-LSD) at $P \leq 0.05$ was used to determine the significant differences between means.

Results and discussion

Dry Matter (DM)

Table 1 shows that the similar dry matter results of *M. barteri* and *N. vogelii* were significantly greater than the DM values of *C. millenii* which gave the least result. The DM of *N. vogelii* and *U. chamae* were statistically similar. Leaf litter had significantly higher DM than fresh leaf, in terms of SXL treatment interactions, the similar DM results of the leaf litters of *M. barteri*, *U. chamae*, *C. millenii* and *N. vogelii* were statistically greater than the DM of the fresh leaves of the four plant species.

Moisture Content (MC)

Table 1 shows that the fresh leaves of *C. millenii* had significantly highest MC while *N. vogelli* had the least. However, the MC values of *C. millenii* and *U. chamae*; *M. barteri* and *N. vogelii*, and U. chamae and *N. vogelii* were similar. The SXL treatment interactions (Table 1) show that the moisture contents of the leaf litters of the four species were significantly lower than those of the fresh leaves of the same species.

Crude Protein (CP)

Table 1 also shows that *U. Chamae* had significantly higher crude protein (CP) than *N. vogelii*, *M. barteri* and *C. millenii* which had statistically similar CP values. Fresh leaf had significantly higher CP values than leaf litter. However, no significant differences existed between the CP contents of the SXL treatment interactions (Table 2).

Crude Fiber (CF)
In terms of the species, *M. barteri* followed by *C. millenii* had the highest crude fiber content significantly. *N. vogelii* gave the least CF results. Thus, the order in descending magnitude of the various species' CF contents were significantly as follows: *M.barteri* > *C. millenii* > *U. chamae* > *N. vogelii*. Leaf litter had significantly higher CF content than fresh leaves. The SXL treatment interactions (Table 1) show that the leaf litter of *C. millenii* had significantly the highest CF value while the fresh leaf *of N. vogelii* gave the least. Except for the leaf litter of *N. vogelii*, the leaf litters of *M. barteri*, *U. Chamae* and *C. Millenii* had significantly higher CF contents than the fresh leaves of three species.

Ash
Leaf type (L) and the SXL treatment interactions had no significant effect on the ash content. *Uveria chamae* had statistically lower ash content than *N. vogelii* and *C. millenii*. However, the ash contents of *U. chamae* and *M. barteri* were similar (Table 2).

Table 1: Nutritive values (Dry Matter, Moisture Content, Crude Protein, Crude Fibre, Ash) of leaves and leaf litters of four bush fallow fodder plant species in Umudike Nigeria

Species	DM (%)			MC (%)			CP (%)			CF (%)			Ash (%)		
	Fresh	Litter	Mean	Fresh	Litter	Mean	Fresh	Litter	Mean	Fresh	Litter	Mean	Fresh	Litter	Mean
Maesobotrya barteri	94.97	95.99	95.48	5.04	4.01	4.53	19.69	17.84	18.77	8.87	11.44	10.15	5.95	9.35	7.65
Uvaria chamae	92.92	96.09	94.51	7.08	5.17	6.13	24.28	21.44	28.86	6.45	9.71	8.08	6.76	7.14	6.95
Cola millenii	90.23	95.93	93.08	9.77	4.07	6.92	19.03	18.38	18.71	7.37	11.53	9.45	10.51	5.16	7.84
Napoleonaea vogelii	93.60	95.59	94.59	6.40	4.42	5.41	22.38	17.25	19.82	4.92	4.92	6.51	8.19	8.82	8.51
Mean	92.93	95.90		7.07	4.42		21.35	18.73		6.90	9.40		7.85	7.62	

Table 2: Statistical result for interaction between factors in the experiment nutrient content (Dry Matter, Moisture Content, Crude Protein, Crude Fibre, Ash)

	DM	MC	CP	CF	Ash
Bush fallow species (S)	0.19	1.12	1.16	0.31	0.85
Leaf type (L)	0.64	0.79	0.82	0.22	NS
Interaction (SXL)	1.29	1.58	NS	0.44	NS

Ether Extract (EE)

Table 3 shows that, *U. chamae* and *C. millenii* had similar ether extracts (EE) which were significantly higher than those of *M. barteri* and *N. vogelii*. *M. barteri* gave significantly the least EE. Table 3 also shows that fresh leaf had significantly higher EE than leaf litter. The SXL interaction shows that the fresh leaves of *M. barteri*, *U. chamae*, *C. millenlii* and *N. vogelii* had significantly higher EE values than the leaf litters of the same species. The fresh leaf of *U. Chamae* had statistically the highest EE while the leaf litter of *M. barteri* had similar EE value with the leaf litter of *N. vogelii* which was less than the EE values of the fresh leaves and leaf litters of *C. millenii* and *U. chamae*.

Carbohydrate (CHO)

Napoleonaea vogelii and *M. barteri* had statistically similar CHO contents, which were significantly greater than those of *C. millenii* and *U. chamae*. *U. chamae* gave significantly the least CHO content. Thus, the order of CHO contents in decreasing magnitude as shown in Table 3 is significantly as follows: *N. vogelii* >*M. barteri* > *C. millenii* >*U. chamae*. Table 3 also shows that the fresh leaf had significant high CHO content than the leaf litters. In terms of SXL interactions (Table 4), the leaf litter of *N. vogelii*, followed by *C. millenii*, had the significantly highest CHO content. The fresh leaf of *U. chamae* had the least CHO value.

Calorific Value (CV)

Table 3 shows that *U. chamae* gave the highest calorific value (CV) among the browsed plants studied. The CV of *C. millenii* and *N. vogelii* were statistically similar. However, *M. barteri* had significantly the least calorific value. In terms of the leaf types, fresh leaf had significantly higher CV than leaf litter. The SXL treatment interactions (Table 3) show that the leaf and leaf litter of *U. chamae* had the least CV results significantly. However, the fresh leaves of *U. chamae, N. vogelii, C. millenii* and *M. barteri* had significantly higher CV than the leaf litters of the four species.

Table 3: Nutritive Values (Ether Extract, Carbohydrate, Calorific Value) of fresh leaves and leaf litters of four bush fallow fodder plant species in Umudike Nigeria

Species	EE (%)			CHO (g)			CV (J/kg)		
	Fresh	Litter	Mean	Fresh	Litter	Mean	Fresh	Litter	Mean
Maesobotrya barteri	6.19	3.23	4.71	59.30	58.04	58.67	371.70	332.99	352.35
Uvaria chamae	10.07	4.69	7.38	52.44	57.02	54.73	397.51	356.05	376.78
Cola millenti	9.15	5.02	7.09	53.44	59.92	56.68	372.23	358.34	365.29
Napoleonaea vogelii	6.83	3.68	5.26	58.19	62.14	60.17	381.71	350.74	366.23
Mean	8.06	4.16		55.84	59.28		380.79	349.53	

Table 4: Statistical result for interaction between factors in the experiment Nutrient content (Ether Extract, Carbohydrate, Calorific Value)

	EE	CHO	CV
Bush fallow species (S)	0.44	1.51	2.74
Leaf type (L)	0.67	0.06	4.15
Interaction (SXL)	1.34	0.99	08.31

The dry matter (DM) values (93.08-95.48%) of the four bush fallow fodder species were within the range reported by Waziri (2013) except for crude protein value, which ranged from 4.19 -7.12%. The species' relative moisture contents (MC) show the need for inclusion/incorporation of the species into fodder banks as moisture supplies necessary minerals and helps plants in growth and development (Attah-Krah, 1989). The crude protein (CP) values (18.71-22.86%) agree with Omokanye *et al.* (2001). Since research has shown that fodder trees and shrubs can be considered a supplement to protein-deficient pastures (Cheema *et al*., 2011), the findings of this study show that the species studied are enormous potential sources of protein for ruminants in the tropics.

The crude fiber (CF) contents (6.51-10.15%) were lower than the results (20-30%) obtained by Miraglia *et al.* (2008). The values obtained for ash (6.95-8.51%) were greater than the ash results of 1.66% and 1.48% reported by Onyekwelu *et al.* (2015) for seeds and fruits of *Chrysophyllum albidum*, respectively.

The ether extract values (4.71-7.38%) were lesser than an average of 14.1% and 34.7% reported by Silva *et al.* (2011) for forage and concentrates, respectively. The carbohydrate (CHO) value (54.73-60.17%) and the calorific value (CV) of (352.35-376.78g J/kg) are within the range of 51.9% and 351.30 J/kg, respectively reported by Antia *et al.* (2006).

The variability observed among the nutritive values of the four fodder plant species studied could be due to the genetic characteristics of the species, site factors, species age, etc. However, the results obtained indicate the high potential of leaf litters in the tropics, especially during the dry season and periods of environmental stress.

Conclusion and recommendations

This study has provided information on the nutritive values of four bush fallow fodder plant species commonly found in Umudike, Nigeria. The results of this study have shown that the four bush fallow species studied have comparatively good nutritive values, especially *Uvaria chamae* (which gave the highest results significantly). This makes them highly recommended for incorporation into fodder banks and home gardens and encourages bush fallows and alley farms to overcome livestock nutrition problems. The results further show that these species' fresh leaves and leaf litter could be used to overcome seasonal feed shortages. Therefore, the information provided in this study will help enhance the overall development, management, and production of fodder banks and livestock production in the humid tropics.

The study recommends that the fodder species studies should be established in fodder banks, home gardens, and alley farms, while bush fallows should also be encouraged to reduce farmers-herders clash. Also, leaf litter of the studied species should be used as supplementary feed for livestock during the dry seasons. Furthermore, the agronomic evaluation, including seed production and seed storage techniques of the four studied fodder species and other potential fodder species, should be embarked upon to encourage their growth and development in fodder banks. Therefore, further research should be conducted on the food and industrial utilization potentials of these four studied fodder species and other browse plants as there is a need to incorporate these studied fodder species in livestock feed composition to boost the nutritive value of the feed given to animals since this will enable them to grow healthy, attain maturity on time, and increase livestock production in the country.

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A REVIEW ON ENHANCED WELL-BEING DERIVED FROM FORESTS

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Abstract
Forests provide enormous opportunity, Research have shown that forest being a vast source of plant, microbial material and medicine especially for developing continent. The use of forest can enhance well-being by reducing health care budget and enhancing lives. Issues in providing health from forests are due to various factors ranging from ecosystem and biodiversity degradation, deforestation and climate change. More so research findings are inadequate, As a result of poor policy-making and personnel knowledge of the benefit of green areas in enhancing human health. Ln this regard, there should be a synergy between health and environmental professionals in different sectors.

***Keywords**: Forests, Human health, Bioactive compounds, Forest food, infectious diseases.*

Introduction
Green spaces and trees provide sufficient ecosystem services thereby enabling a good living environment and reintroducing degraded ecosystems. Apart from tangible products, Green areas for instance mitigate floods, droughts and the effect of noise, purify water, bind toxic substances, maintain water quality and soil fertility, aid in erosion control, protect drinking water. Moreso ecosystem services and goods that trees supply are endangered by deforestation, pollution, biodiversity degradation and climate change.
The effect of green areas on human well-being is a case not very visible very within the framework of biodiversity, climate change, poverty and human well-being. This review aims to contribute to the subject about human well-being, ecosystem services and biodiversity by emphasing on the relationships between forests and human well-being.

1. Green areas improve physical and mental health
Instances of poor health have increased in cities due to urbanization and modern living related to high in active lifestyle and physcological stress. Lately, the benefits of green areas in promoting human well-being has been known (Bjork *et al*, 2008, Coifer *et al*, 2006, Dulger *et al*, 2004, Hakkinen *et al*,1999, Hartig *et al*,2003.)
Natural and green spaces enhance physcological and physiological well-being in many ways: Green areas aid in minimizing stress, promote both mental and physical recovery.Green areas may help in corping ill-health caused by mental processes such as stress and in curing cases such as burn-out and depression. (lrvine *et al*, 2002.).
Some survey report that Green areas enhance well-being (Hartig *et al*, 2006).These facts, for instance lower levels of blood pressure, heart rate, skin conductivity and muscle tension in green settings than in urban areas(Hartig *et al*, 1991.).Some studies show that activities in can alleviate the signs of attention-deficit/hyperactivity disorder (AD/HD) in children (Herzog *et al*, 2003.).The knowledge on the good health effects of green settings in urban areas are weakened by increased buildings and land - use changes.The insight on the positive health effects of forests needs to be better integrated into land-use planning in order to protect green settings near homes.
2. Green areas provide bioactive components and drugs.
Forest gives rich source of substances that can be used in pharmaceutical and nutraceuticals.Tree and plant extracts have various bioactive compounds such as polyphenols (including flavonoids, phenolic acids, tannins), phytoestrogens (including lignans), stilbenes, carotenoids,sterols,etc(John *et al* 2006.) which has biological activities such as anticancer activity,antiatherogenic and antioxidant benefit ,for instance xylitol,which can treat tooth decay (dental caries) (John *et al* 2006.),is sourced from hardwood trees.The health benefit of mushrooms is a global convention mostly in Asian countries.Fungi are known to have high medicinal benefit (Kreuels *et al*,2008).Macrofungi have antimicrobial effects, they tend to suppress the growth of bacteria, fungi,protozoa and cancerous cells (Kuo *et al*, 2004). It should be known there has been a sequence of facts where known antitumor agents have been manufactured by fermentation of endophytic fungi isolated from plants (Lindequist *et al*, 2005).One of the issues affecting this use in recent times is the declining rainforests, which harbors a large source of new bioactive substances.. While sourcing for medicinal plants and pharmaceuticals, the rights and living of local indigenes and communities should be considered. (Irvine *et al*, 2002).
3. Food security is assured by the forest.
Natural environment helps to fight inadequate and infections of the less privelage people in low-income countries. Food from the forest gives a safety in case of food scarcity and alleviates lack of proper nutrition. Most foods from the forest are fruits, nuts,

wild leaves, palms, wild roots and tubers, mushrooms and insects. Foods from the forest gives proteins and fat, carbohydrates, vitamins and minerals (Irvine *et al*, 2002).

Conservation of green spaces and woodlands is beneficial for the provision of forest food. The conventional ideas of local people and communities in getting foods from the forest and medicine from forest plant species should be given more cconsideration. Sustainable forest practices that maintain important species and their food value need to be enhanced and known (Moutsatsou, 2007).

4. Forest- associated infection and dangers

Inhabitants of forest areas may encounter forest-associated diseases include the pathogen, the vector and the human. The vectors are mostly insects, could also be mammals. Examples of forest related diseases are Puumala virus (PUUV), Lyme borreliosis, Hantaviris cardiopulmonary syndrome (HCPS), Malaria are related with forests, which are the favorite sites for vector and host populations (Newman *et al*, 2007). Deforestation outcome has brought about the replacement of volatile vector vector for instance when mosquito species decreases, the existing surviving species are more volatile vectors for malaria .The synergy between forest ecosystem and disease transmission is complex. Restoration of forest ecosystems is of importance, but is not enough to cause an epidemic. (Zell, 2004).

Conclusion

Despite the incorporation of research outcome into policy making and actual work, most implementation of research outcome is not sufficient. The benefit of stress-reducing effects of green spaces is not yet known and only a percentage of pharmaceutical and nutraceutical compounds obtained from forests is known.While the conventional idea of indigenous communities in forest foods and medicine is not documented enough .forest plant species is not recorded to a sufficient extent.There should be a synergy between medicine obtained from forest species for pharmaceuticals and sustainance of local indigenes.forest species for pharmaceuticals and maintaining local livelihoods. Moreso the enhancement of research and ideas about the health effects of forests calls for strong synergy among stakeholders,most especially the health and environmental professionals.

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IMPACT OF FOREST AS SUCCOR TO RURAL DWELLERS DURING THE COVID 19 PANDEMIC IN DELTA STATE NIGERIA

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Abstract
Forests are endowed with natural resources for mans of survival. In periods of socioeconomic disruptions, forest serve as natural insurance to providing mans' need. This study examined the impact of forest in rescuing rural household from hardship during the covid-19 pandemic. Two villages were selected each from six towns in Ughelli North Local Government Area purposively on their proximity to forest. Twenty five household were randomly selected from each village and interviewed using structured questionnaire. Data on forest resources utilized and their exploitation rate were collected. Descriptive statistics was used to analyse forest resources utilized, a 3 point likert scale was used to rate the level of resources exploitation while Chi-square tested the association of residence and exploitation rate of forest resources. Most (77.3%) respondents were indigene of the community, married (69.3), have household size of 5-8 (58.0%), do not have personal land (63.3%) and migrated to the community (65.7%). Resources utilized from forest served as medicine (Garcinia kola, Senna alata), fuelwood, protein (Agaricus bisporus, Neotragus pygmaeus, Cirrhinus molitorella) and substrate for raising other crops (forest land). Exploitation rate of bush-meat (2.36±0.05) and Forest land (2.28±0.07) were high. The $\chi 2$ result displayed significant association between resident and rate of forest resources exploitation with values of 8.12 and 38.13 for bush-meat and forest land, respectively. The increased utilization of forest land heightened deforestation a major anthropogenic activity of climate change. Forest land restoration with increased community involvement is recommended for forest conservation and resource.

***Keywords:** Forest community livelihood, Natural Insurance, Forest Resources, Deforestation, Climate Change*

Introduction
The Covid-19 pandemic caused untold disruption to socio-economic activities globally. The lockdown approach to managing the virus from spreading further instilled countless hardship to man (FAO, 2020). The ripple effect of this approach was public health challenge and brief economic recession (FAO, 2021). Developing countries were worse hit as facilities to cater for citizens' were not in place. Households were exposed to hunger, inaccessibility to medical help, zero to no income and depressions in some worst case scenario (Egger *et al*., 2021). The pandemic also had multiple impacts on forest resources, the forest sector and forest dependent communities. However, the pandemic highlights the usefulness and worldwide necessity for forest and its products (Pebke *et al*., 2020).
Forests an eminent resource to man's survival from creation till date and shall be for years to come in provisioning, protecting, regulating and various cultural and spiritual functions (Ohwo and Nzekwe-Ebonwu, 2021). Provisioning, forest house various fauna and flora species use by man for food, shelter, furniture, medicine and income (Ohwo *et al*., 2021). The forest land and soils serves as fertile ground for cultivating various domesticated crops and minerals such as calcium, potassium, fine clay and precious stones are all obtained from forest soils. In Nigeria, 51.4 % of rural household obtain about 20 percent of family income forest provides (Ohwo and Nzekwe-Ebonwu, 2021) and serves as natural insurance to rural communities in times of disaster.
Rural dwellers have a noticeable tie with forest and retain traditions between human and nature on the basis of meeting basic need and saving the environment for posterity (Sajeva *et al*., 2019). They obtain fuel-wood, vegetable, protein (snail, bushmeat, fish, mushroon), and crops cultivated via agro-forestry systems to survive (Ohwo *et al*., 2021) in times of unavailability of market and products. With the announcement of a global lockdown during the Covid-19 pandemic, individuals perceiving the imminent hunger decided to secure a safety nest by moving from city to their respective villages as a result of accessibility to forest resources for survival especially with the heightened price and scarcity of food (Osahon, 2020). Delta State was no exception as citizens flocked in from various part of the country. Literature capturing the forest resources utilized by rural dwellers during the lock down period in Delta State is limited. This study examined the impact of forest in providing the basic need of rural dwellers during the global lockdown period in Delta State x-raying the forest resources utilised by the rural dwellers and prioritised the forest resources according to the rate of exploitation for immediate management.

Materials and Methods
Data were collected from rural household in Ughelli North Local Government Area of Delta State. Two villages were selected from six towns (Ododegho and Ujode from Ughelli; Ehwahwa and Ihwrejdu from Agbarha-Otor; Ejekuta and Ovwodokpokpo from Ogor; Unenurhie and Ivwrorode from Evwreni; Ogode and Ohoro from Owheru; Okan and Ophori from Agbarho) purposively

based on their proximity to the forest. Twenty five household were randomly selected from each village and interviewed for the study. A total of 300 rural dwellers were interviewed for the study.

Data analysis

Descriptive statistics of table, frequency and percentage occurrence was used to identify the forest resources utilized by rural dwellers while a three point likert scale was used to rank the level of forest resources exploitation as high (3), medium (2) and low (1). A mean score of 1.5 was used to rank forest resources utilization as over exploited or under exploited. Chi square test was used to check for degree of association between residence (resident and non-resident) on intensity of the most exploited forest resources using the model below

$$\chi^2 = \sum \frac{(O-E)^2}{E} \text{ ....Equation (1)}$$

Where,
χ^2 = Chi square
O= observed frequency
E= Expected frequency

Results and Discussion

The demographic characteristic of rural household present in Table 1 shows that majority 45.3% were within the age bracket of 41-50 years, 54.0% were male, 69.3% were married, 46.7% were involved in other religion, 75.3% were secondary school certificate holder, 58.0% have family size of 5-8, 56.0% were farmers, 37.3% receives ₦11000-30000 income monthly, 63.3% of the respondent do not have personal land with 77.3% members of the community. About 65.7% of the people do not reside in the community. The dominance of youths in rural communities and non residents during this period was due to reverse migration of families from cities to villages whose jobs were affected by the pandemic and depend mainly on forest products for survival (Osahon, 2020; Egger *et al*. 2021). This dependence was further stimulated by family size of respondents. The unnoticeable difference between the male and female plaintiff indicates the collective effort of parents to meet household need. Basically, the males were more involved in hunting, collection of fuel-wood and clearing of forest land for farming while the females focused on collection of NTFPs, fruits and medicinal herbs for their household (Ohwo *et al*. 2021). However, all members of household were involved in planting of arable crops on forest land. The utilization of forest land for food production was unavoidable as majority of the plaintiff do not have access to land. Hence, they rely solely on the forest land for crop/food production for their household, a major reason for migrating from city to community to combat the challenge of food insecurity and low income (Egger *et al*. 2021)

Table 1: Demographic characteristics of rural dwellers

Variable	Frequency	Percentage	Variable	Frequency	Percentage
Gender			**Monthly income**		
Male	162	54.0	less 10000	20	6.7
Female	138	46.0	11000-30000	112	37.3
Total	300	100.0	31000-50000	70	23.3
Marital status			above 50000	98	32.7
Single	24	8.0	Total	300	100.0
Married	208	69.3	**Occupation**		
Widow	46	15.3	Farming	168	56.0
Divorced	22	7.3	Trading	48	16.0
Total	300	100.0	civil servant	74	24.7
Age			Others	10	3.3
20-30	24	8.0	Total	300	100.0
31-40	106	35.3	**Personal land**		
41-50	136	45.3	Yes	110	36.7
above51	34	11.3	No	190	63.3
Total	300	100.0	Total	300	100.0
Religion			**household size**		
Christianity	108	36.0	1-4	84	28.0
Islam	52	17.3	5-8	174	58.0
Others	140	46.7	above 9	42	14.0
Total	300	100.0	Total	300	100
Education			**Community indigene**		
Primary	62	20.7	Yes	232	77.3
Secondary	226	75.3	No	68	22.7
Tertiary	12	4.0	**Total**	300	100

Total	300	100.0	**Reside in community**		
			Yes	103	34.3
			No	197	65.7
			Total	300	100

Source: Data analysis (2021)

Forest resources utilized by rural dwellers during the covid-19 lockdown

The result of the forest resources utilized by rural dwellers during the Covid-19 lockdown presented in Table 2 shows that 94.7% of rural dwellers utilized forest resources during this period (Pebke *et al*., 2020). Table 3 show that leave, fruits, wood and stems of various forest trees were utilized. Proteins in form of bush-meats (*Cercopithecus mona, Phacochoeurus africanus*), fishes, mushrooms and edible worms were utilized as source of food and income. Wood of *Daniella ogea, Senna alata, Hevea brasileiensis* and *Terminalia superba* were used as source of energy (fuelwood and charcoal), leaves and roots of *Magnifera indica*, leaves of *Moringa oleifera*, *Cymbopogon citrates and Citrus aurantiifolia* were boiled and used as medicines as reported by Adeyemi *et al*., (2015) and Walter *et al*., (2021). The forest land was used to grow vegetables such as *Talinum triangulare, Amaranthus retroflexus, Ocimum gratissimum* and short span cereals such as *Zea mays* (Table 3) for immediate consumption by rural dwellers to boost immunity of the body against the virus. As instructed by health practitioners, individuals are to improve their immune level by consuming fruits and vegetables as well as being hydrated (Shakoor *et al*. 2021). Importantly, these products were scarce in the markets and when available, the prices are outrageous. The forest fertile land was the only alternative for rural dwellers to grow and access veggies during this period.

Table 2: Forest resources utilized by community during the Covid-19 lockdown

Variable	Frequency	Percentage
Utilized forest products		
Yes	284	94.7
No	16	5.3
Total	**300**	**100.0**
Forest resources utilized		
Did not use any forest product	16	5.3
Timber	33	22.0
Forest land	53	17.6
Bush-meat	10	3.3
Herb	16	5.4
Firewood	22	7.3
Fish	10	3.3
Forest fruit	24	8.0
Herbs and snail	38	12.7
Timber and bush-meat	2	0.7
Firewood and herbs	4	1.3
Bush-meat, herbs, mushroom and forest fruit	24	8.0
Herbs, snail and firewood	20	6.6
Timber and herbs	28	9.3
Total	**300**	**100.0**

Source: Data analysis (2021)

Table 3: Forest resources, part harvested and uses

S/N	Scientific name	Common name	Part harvested	Uses
	Forest resources			
1	*Lophira alata*	Ironwood	Stem	Sold and fuelwood
2	*Nauclea diderrichii*	Opepe	Stem	Sold
3	*Entandrophragma cylindricum*	Mahogany	Stem	Sold
4	*Daniella ogea*	Rice leaf	Leaf	Sold
5	*Juglans regia*	Walnut	Fruits	Sold/medicine
6	*Piper guinensis*	Uziza	Leaf	Sold
7	*Garcinia kola*	Bitter cola	Fruits	Fruits and herbs
8	*Terminalis ivorensis*	Black afara	Stem	Sold
9	*Terminalis superb*	White afara	Stem	Roofing
10	*Senna alata*	Candle bush	Leaf and root	Medicine (pile)
11	*Milicia excelsa*	Iroko	Stem	Sold

12	*Magnifera indica*	Mango tree	Root and leaf(herbs)	Medicine (malaria)
13	*Ceiba petandra*	silk cotton tree	Stem	Sold
14	*Agaricus bisporus*	Mushroom	Full	Protein
15	*Irvingia wombolu*	Ogbono	Fruits	Soup
17	*Monodora myristica*	Local nutmeg	Fruits	Spices/sold
18	*Spondia mumbi*	Hug plum	Fruits	Fruits
19	*Pseudotsuga menziesii*	Cone wood	Stem	Sold
20	*Moringa oleifera*	Moringa	Leaves and fruits	Medicine
	Wildlife resources			
21	*Achatina marginata*	Snail	Full	Protein
22	*Neotragus pygmaeus*	Antelope	Full	Protein
23	*Cercopithecus mona*	Monkey	Full	Protein
24	*Cirrhinus molitorella*	Mud carp (fish)	Full	Protein
25	*Clarias gariepinus*	Tilapia	Full	Protein
26	*Synodontis sorex*	Catfish	Full	Protein
27	*Pleurotus tuberregium*	Mushroom	Cap and gills	Medicine (headache)
28	*Termitomyces microcarpus*	Mushroom	Cap and gills	Medicine (Malaria)
29	*Sylvicapra grimmia*	Duiker	Full	Protein
30	*Phacochoeurus africanus*	Warthog	Full	Sold
31	*Artherurus Africana*	Porcupine	Full	Sold
32	*Oryctolagus cuniculus*	Rabbit	Whole	Eaten/sold
33	*Thryonomys swinderianus*	Grass-cutter	Whole	Eaten/sold
	Resources from forest land			
34	*Cymbopogon citrates*	Lemon grass	Leaves	Medicine
35	*Citrus aurantiifolia*	Lime	Fruits and leaves	Medicine
36	*Amaranthus retroflexus*	Green vegetable	Leaves	Vitamins
37	*Telfairia occidentalis*	Pumpkin	Leaves	Vitamins
38	*Ocimum gratissimum*	Scent leaves	Leaves	Medicine, spices
39	*Talinum triangulare*	Water leaves	Leaves	Vitamins/food
40	*Vernonia amygdalina*	Bitter leaves	Leaves	Food/medicine
41	*Zea mays*	Maize	Fruit/silk	Food/medicine
42	*Abelmoschus esculentus*	Okra	Fruits	Food/sold

Source: Data analysis (2021)

Prioritized forest resources according to exploitation rate

The result of exploitation rate of forest resources by rural dwellers during the lockdown as shown by their mean values is presented in Table 4. The exploitation rate of bush-meat (2.36±0.05), Forest land (2.28±0.07), Iroko (2.24±0.06) were high while snail (1.42±0.05), fuelwood (1.39±0.05) and fish (1.28±0.04) were low. Saidur *et al*., (2021) and Brancalion *et al*., (2020) reported that the rate of wildlife killing during this period was high in Bangladesh and deforestation rate increased globally, respectively. An overall mean of 1.66±0.01 shows a medium rate of resources exploitation in rural communities. The percentage response of the community dwellers on exploitation rate of forest resources shows that Forest land (43.3%) and Iroko (43.3%) were highly exploited, followed by bush-meat (46.7%) and Moringa (46.7%) with medium exploitation rate (Table 5). The above observation validates reports of Escobar (2020) and Walter *et al*., (2021) who reported that rural household in nations with rich ecosystems results in land clearing, illegal logging, hunting and exploitation of medicinal herbs from the forest. The conversion of forest land to farmlands is a major cause of deforestation. Saidur *et al*., (2021) reported that 2500 hectares of forest land was cleared in Taknaf and Ukhiya sub-districts of Bangladesh.

The heightened rate of deforestation is a major cause of climate change. Deforestation increased by 63.0% in America, 136.0% in Africa and 63.0% in Asia-Pacific (Brancalion *et al*. 2020). For continuous supply of the benefit of forest estate, there is need for forest land restoration. Forests function to regulate air and sinks carbon via wood production (Arshas *et al*. 2014). Globally, deforestation affects the absorption of CO_2 by forest trees and soils. Forests regulate worldwide climatic pattern via biological, chemical and physical, chemical, and biological course which controls atmospheric structure, hydrological cycle and temperature permanence (Bennett, 2017). Measures such as intensive agro-forestry and afforestation activities should be carried out to restore forest land to its original use.

Table 4: Prioritized natural resources according to exploitation rate

Forest resources	Mean	Standard error
Bush-meat	2.36	0.05
Iroko	2.25	0.06
Mahogany	1.77	0.07
Forest land	2.28	0.07
Silk cotton tree	1.70	0.05
Rice leaf	1.69	0.06
Opepe	1.67	0.06
Conewood	1.67	0.05
Uziza	1.62	0.06
Moringa	1.54	0.05
Hug plum	1.57	0.06
Mushroom	1.57	0.04
Ironwood	1.54	0.07
Candle bush	1.51	0.05
Walnut	1.48	0.05
Herb	1.46	0.05
Bitter cola	1.42	0.05
Snail	1.42	0.05
Fuelwood	1.39	0.05
Fish	1.28	0.04
Total mean	1.66	0.01

N.B: 3 (high), 2 (medium) and 1 (low)

Source: Data analysis (2021)

Table 5: Percentage response of respondent on rate of exploitation of resources during covid-19 lockdown

S/N	Variables	High	Medium	Low
1	Ironwood	64(21.3)	34(11.3)	202(67.3)
2	Opepe	48(19.3)	86(28.7)	156(52.0)
3	Mahogany	80(26.7)	72(24.0)	148(49.3)
4	Rice leaf	54(18.0)	100(33.3)	146(48.7)
5	Walnut	18(6.0)	108(36.0)	174(58.0)
6	Forest land	130 (43.3)	126 (42.0)	44 (14.7)
7	Uziza	42(14.0)	102(24.0)	156(52.0)
8	Moringa	116 (38.7)	134 (46.7)	50 (16.7)
9	Bitter cola	28(9.3)	70(23.3)	201(67.3)
10	Snail	28(9.3)	70(23.3)	202(67.3)
11	Bush-meat	134(44.7)	140(46.7)	26(8.7)
12	Fuelwood	12(4.0)	94(31.3)	194(64.0)
13	Candle bush	26(8.7)	102(34.0)	172(57.3)
14	Iroko	130(43.3)	114(38.0)	56(18.7)
15	Fish	6(2.0)	72(24.0)	222(74.0)

Source: Data analysis (2021)

The Chi-square result of the association between resident in the community and the most exploited forest resources presented in Table 6 displayed significant association between resident and rate of forest resources exploitation with (χ2) values of 8.12 and 38.13 for bush-meat and forest land but no significant relationship was evident for Iroko (3.44). A weak strength of association was observed with Phi values of 0.36 (forest land) and very weak association of 0.17 (bush-meat) and 0.11(Iroko) between residence in the community and exploitation of the listed forest resources. The above finding relates the finding of Ohwo *et al*., (2021) who observed a weak and very weak association in profit and educational level of traders of non wood forest products in Asaba, Delta State.

Table 6: Association of Resident and Exploitation Rate of Forest Resources

Variables	Values	Degree of Freedom	Asymp. Sig.
Bushmeat	*8.12	2	0.02
	^0.17	2	0.02
Forest land	*38.13	2	0.00
	^0.36	2	0.00
Iroko	*3.44	2	0.18
	^0.11	2	0.18

Source: Data analysis (2021)
*** = Pearson ($\chi 2$) value (significant association)**
^ = phi value (strength of association)

Conclusion
Forests and its resources are phenomenal in the survival of man in times of emergencies. The covid-19 pandemic has further proved the importance of forest in providing meat, herbs and fruits for man. The forest land served as fertile ground for the growth of arable crops in Ughelli North Local Government Area of Delta State. However, these benefits were without destruction of the forest. Deforestation was prominent in the use of the forest by rural dwellers (migrant and residents) during this period thus contributing to climate change. For the continuous supply of the benefit of the forest, forest land restoration needs urgent attention.

Recommendations
Integrated forest management technique can be an effective strategy to mitigate the increasing effect of deforestation on climate change as a post Covid-19 recovery method for the forestry sector. Forest land use and forest fortification instructions should be applied earnestness and with approval from the community. The need to communicate the importance of protecting the forest and administer training to volunteers of the community is important to attain successful forest restoration and conservation.

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AGROFORESTRY: A VIABLE OPTION FOR CLIMATE CHANGE MITIGATION AND SUSTAINABLE ENVIRONMENT

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Abstract
African ecosystem comprises a variety of flora and fauna which constitute about 20 percent of all known species in the world. However, unsustainable land use practices and increased human pressure on natural resources have led to environmental degradation, climate change and loss of biodiversity. This has threatened and distorted ecological balance, resource conservation and management. This paper reviews and highlights the importance of agroforestry practices in all ramifications especially as they relate to climate change. To mitigate climatic challenges and maintain a healthy and sustainable environment, the adoption of sustainable agroforestry practices, therefore, becomes a viable option and strategy

Keywords: *Sustainability, Environment, Agroforestry, Ecosystem, Climate change*

Introduction

Climate change is a global phenomenon that imposes economic, social and ecological challenges on the global community. It is unarguably the most threatening environmental, social and economic threat facing sub-Saharan African countries today stimulating discourses with respect to the causes, long-term effects, as well as how to forestall its prolonged and frustrating impacts (Ozor *et al*, 2015). Climate change refers to a change in the state of the climate that can be identified by variability in the mean of its properties (average temperature, wind and rainfall patterns) that persists for an extended period (IPCC, 2007). Climate change distorts ecological balance and affects functional habitat networks of the natural environment. Its impacts such as rising temperature and declining rainfall in combination with other indicators could result in shifting of ecological zones and an overall reduction in ecological productivity in Africa.

The evidence of climate change manifests when there is an increase in ocean temperature due to excess carbon dioxide in the atmosphere, melting ice in the Arctic, and melting glaciers around the world; we equally experience irregular rainfall, flooding, and rising sea levels, intense drought and desertification. According to Oloyede (2008), the interaction of man with the environment through human-induced activities such as agriculture; deforestation; burning of fossil fuel etc. generates greenhouse gas emissions which builds up in the atmosphere and act like a blanket wrapped around the Earth, trapping the sun's heat and raising temperatures causing climate change. Its consequences are more pronounced in African societies because of its geography, its sole dependence on rain-fed agriculture, high level of poverty and its generalized incapacity to cope with the extremes of climate (Amonum *et al.*, 2009). Mitigating the impacts of climate change, however, becomes crucial for developing countries. Based on this, Kalu *et al.*, (2014) suggested the need to plant and grow more trees due to their numerous contributions to climate change, ecological balance, food production and medicine.

There is an increased concern at the highest international policy levels about the sustainability of the ecosystem in the light of the apparent rapid depletion of the natural resources base and this has brought agroforestry even further into the limelight (FAO, 2004). Agroforestry simply represents a combination and interrelationships between people, domestic animals, crops and trees, designed to rehabilitate land or to sustain and increase the production of certain desired social benefits. Thus, Agroforestry concerns the structure and functioning of the human ecosystem and not merely the biophysical system (Khot, 1999). This has been reported to contribute to climate change mitigation. Climate inconsistencies and ecological imbalances, however, can be restored and buffered by agroforestry practices. Even though agroforestry is not primarily designed for carbon sequestration, research has revealed that it is a unique and sustainable measure of maintaining ecological sustainability and increasing carbon stock in the terrestrial biosphere (Jacob *et al.,* 2013). Nair (2011) described agroforestry as a collective term for land use systems and technologies where woody perennials are deliberately planted on the same land management unit as crops and animals in some forms of spatial arrangements or temporal sequences with implied ecological and economic interactions between the different components including social and economic benefits. Agroforestry is a problem-solving land management system that accommodates the production of foods and forest products on the same piece of land. The application of Agroforestry science plays a potential role in achieving ecological balance and sustainability. It has been recognized as a mitigation and adaptation strategy for African smallholder farmers at risk of the impacts of climate change (Adekunle, 2009). Human activities that adversely affects the ecosystem and biodiversity are increasingly causing ecological shifts and degradation. Recognizing the potentials of agroforestry systems to address multiple ecological, social and economic challenges, this paper further review the importance of agroforestry systems in environmental sustainability and climate change mitigation.

Classification of Agroforestry Systems

Agroforestry can be classified into three main groups on the basis of components which can be combined in numerous spatial and temporal arrangements for different functions (Nair, 2011). The classes of the systems are described below:

- Agrisilviculture system: This is the integration of annual and perennial crops with woody perennials
- Silvopastoral system: This is the combination of trees with pastures/animals
- Agrosilvopastoral system: This is the integration of all the three elements namely- crops, trees and pastures/animal

Benefits of agroforestry systems

The deliberate incorporation of trees into the farming system has enormous potential to moderate the impact of climate, restore ecological balance and ameliorate environmental challenges. Agroforestry is increasingly promoted for restoring degraded environments, reducing greenhouse gases, enhancing food security, abating the impact of drought, preventing desertification, increasing soil organic matter and moderating micro-climate (Richards *et al.,* 2009). Agroforestry systems improve ecological resilience to climate change impacts through the following:

- **Regulation of micro-climatic condition**

There is the steady rapid depletion of natural resources through human activities that has a striking effect on the environment. This results in climate change. Trees are naturally equipped to sustain the health of the environment by regulating climate both at local, regional and global levels. Microclimatic improvement through the use of trees as shelterbelts and windbreaks controls high climatic temperatures. Trees produce atmospheric moisture, regulate the ecosystem and protect biodiversity. Trees reduce atmospheric carbon dioxide (CO_2) by sequestering carbon in the biomass of trees and reducing the concentration of the atmospheric greenhouse gases that induce global warming. Trees also provide green cover via shade which regulates the atmospheric temperature through evapotranspiration and breeze. Research has shown that climate change mitigation goals cannot be met without the incorporation of trees on farmlands and improved sustainable forest management (Federici *et al.,* 2017).

- **Enhancement of Biodiversity**

Loss of biodiversity affects ecological quality and sustainability and makes the ecosystem vulnerable to the consequences of climate change. Traditional agroforestry systems conserve biodiversity through in-situ conservation of tree species on farmlands, provision of suitable habitat for plant and animal species on farmlands and protection of forest estates and forest resources. Agroforestry is recognized as a panacea for the conservation and enhancement of biodiversity globally, especially in tropical areas.

- **Restoration of degraded land**

Trees act as environmental buffers by absorbing and inhibiting the formation of secondary pollutants in the ecosystem and keeping the ozone concentration at a level that is not hazardous to a human thus, contributing to environmental sustainability and stability. Agroforestry systems play an intrinsic role in increasing soil organic matter through the decomposition of leaves and twigs litter. It improves soil structure, increases soil nitrogen content and enhances nutrient retention by making the soil suitable for arable crops. Oke and Kadeba (2001) observed that alley cropping on sloppy land strengthens soil physical properties, restores degraded lands, and reduces soil erosion and runoff. Agroforestry practices such as alley cropping and improved fallow yield more benefits for soil productivity.

Environmental sustainability and climate change mitigation through agroforestry practices

With the increasing effect of unsustainable land use practices and anthropogenic pressure on natural resources in the country, agroforestry, therefore, becomes a viable option and strategy for restoring ecological balance, mitigating climate change and maintaining biodiversity. To ameliorate environmental challenges, it is essential to adopt the under-listed sustainable agroforestry practices:

- **Taungya System:** This is a forest plantation establishment system in which forest trees are raised in combination with the temporary cultivation of crops. Many lands have been degraded due to economic development activities such as; mining, irrigation, agricultural activities etc. There is a need to restore ecological balance and improve the capacity of the environment to meet the needs of the people. Planting of trees can be used to repair these damages caused by human activities. Trees used in the Taungya system include *Tectona grandis, Gmelina arborea,* while crops like *Vigna unguiculata, Brassica spp, Gossypum spp* and others can be grown in conjunction with these forest trees.

Plate 1: Taungya System
(Source: Williams et al., 2022)

- **Improved Fallow**: Fallowing is defined as leaving a land that is normally cultivated temporarily uncultivated. An improved fallow is thus defined as the enrichment of a natural fallow with trees, shrubs or herbaceous legumes planted at high density to improve soil fertility, restore degraded lands, control soil erosion and reduce runoff (Jacob *et al.,* 2013). Examples of leguminous woody species that can be used include *Acacia* spp, *Gliricidia sepium, Parkia* biglobosa, *Prosopis africana*, *Pterocarpus angolensis*. Grain and forage legumes that can be planted in the understorey include *Sesbania sesban*, *Tephrosia vogelii*, *Pisum sativa*, *Vicia faba* etc.
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Plate 2: Improved Fallow
(Source: Williams et al., 2022)

- **Shelterbelt Establishment:** These are strips of trees, shrubs and vines planted closely together along the edges of croplands to shield crops from adverse weather like winds and storms. This system was described by Otegbeye and Famuyide (2005) as an important land use system commonly adopted by farmers in the arid and semiarid regions of Nigeria to control wind erosion, increase soil organic matter and strengthen soil physical properties. Examples of trees used for shelterbelt include *Azadirachta indica, Acacia senegal, Eucalyptus camadulensis, Acacia albida,* etc.

Plate 3: Shelterbelt Establishment
(Source: Williams et al., 2022)

- *Alley Cropping:* ***Alley cropping is also known as Hedge row intercropping. It is a simultaneous Agroforestry system where food crops are grown between hedge rows of planted shrubs and/or trees, preferably leguminous species. Rows of trees are planted at wide spacing with a companion crop grown in the alleyways between the rows. Species are periodically pruned to prevent shading of the companion crops and the pruning*** *is* ***applied as mulch to the crops to enhance the soil nutrient status and physical properties.***

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Plate 4: Alley Farming/cropping
(Source: Williams et al., 2022)

- **Homestead Planting of Trees:** Different types of economic tree species are planted by the road sides and within the surrounding of a house. Trees help to purify the air by removing harmful substances and maintaining balanced levels of oxygen. Trees absorb pollutants like ammonia and sulphur dioxide and traps them in leaves and bark. These trees also provide green cover via shade which regulates the atmospheric temperature. Examples of trees used for homestead planting include *Moringa oleifera, Adansonia digitata, Tectona grandis, Gmelina arborea and Azadirachta indica.*

Conclusion

The roles of agroforestry systems in maintaining a sustainable environment and mitigating climate change cannot be over-emphasized. A sustainable and healthy environment is more resilient to negative environmental challenges than ecosystems under stress whose ecological process is impaired and unbalanced. Agroforestry, therefore is a major option and strategy for increasing environmental resilience because it can be used in enhancing biodiversity, regulating micro-climate, restoring degraded land and maintaining ecological balance to a healthy state.

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ASSESSMENT OF SOCIO-ECONOMIC FACTORS INFLUENCING THE ADOPTION OF AGROFORESTRY PRACTICE AS ADAPTATION STRATEGY TO CLIMATE CHANGE HAZARDS IN SUDAN SAVANNA AGRO-ECOLOGICAL ZONE OF KADUNA STATE

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Abstract
This paper adopted a well-structured questionnaire to collect primary data from 225 farmers from Kubau LGA of Kaduna State. Twenty-Four Socio-economic factors were formulated and grouped into four major categories namely – demographic, agro-based, economic and locational factors. The study was presented in form of frequency table, and mean in some cases. The result from the study under demographic characteristics showed that the farmers have the mean value of 39 years in age, with 96% male farmers, and 94% were married in which only 8% have tertiary education. The result from the agro-based characteristics revealed that the farmers have mean value of 13.2 years' experience, with the mean value 3.8 hectares for farm-land size, with 54% have untarred road access to the farm while 58% were visited by extension officers quarterly. Results of the economic factors revealed the mean monthly income value of the farmers were #96,000, with 46% had access to government grant and 71% also had access to credit facilities. While the result of the locational factors showed that 71% had their farms farther than 10km from the forest reserves, and 82% had their farm less than 10km from the market while 68% had their farm farther than 10km from urban center. The result indicated that low level of education, lack of good road, lack of formal agroforestry training and lack of access to extension officers regularly were greatly influenced the adoption of agro-forestry and recommended to be improved so as to encourage adoption of agroforestry.

***Keywords**: Socio-economic Factors, Agroforestry Practice, adoption, Adaptation Strategy, Climate Change.*

Introduction

Climate change phenomenon is rapidly emerging as a global critical development affecting many sectors and is one of the most serious problems to sustainable development. An increase in greenhouse emissions has led to climate change impacts. Agricultural activity is ranked third after energy consumption and chlorofluorocarbon production in contributing immensely to climate change by enhancing greenhouse emissions because it accounts for some 15% of recent anthropogenic activities in greenhouse gas emissions (Ozor and Nnaji, 2011).

The impacts of climate change on agriculture, economic growth and sustainable development, are the growing interest in sub-Saharan Africa as a result of increased drought, increased temperature and reduced rainfall in recent times. The adversely impacts of climate change on agricultural activities include crop resilience, timing/length of growing seasons, changes in soil moisture and soil quality, yield of crops and animals, weed insurgence, sea level rises, unprecedented flooding and droughts, atmospheric temperatures and many more (Ozor and Nnaji, 2011). Another similar worst factors include over dependence on rain fed agriculture, inadequate research and extension, inequitable land distribution, widespread poverty, limited access to capital and technology, long term weather forecasts and lack of good roads (IPCC, 1998). Adapting to climate change entails taking the right measures to reduce the negative effects of climate change (or exploit the positive ones) by making the appropriate adjustments and changes. The Intergovernmental Panel on Climate Change defines adaptation as adjustments in natural or human systems in response to actual or expected climatic stimuli or effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007). It also refers to actions that people, countries, and societies take to adjust to climate change that has occurred. Adaptation has three possible objectives: to develop the capacity to cope with unavoidable damages; to reduce exposure to the risk of damage and to take advantage of new opportunities.

Agroforestry provides a set of innovative practices that are designed to enhance productivity in a way that often contributes to climate change hazards mitigating through enhanced carbon sequestration, and can also strengthen the system's ability to adapt to adverse impacts of changing climatic conditions. This study tried to assess the socio-economic factors influencing adoption of agroforestry practice as adaptation strategy to hazards associated with climate change in sudan savanna agro-ecological zones in Kaduna State, and explores sustainable agroforestry practices that will enhance resilience and thereby reduce vulnerability of small land farmers, with a view to providing information to natural resources planners and managers for mitigating the impact of climate change in the study area.

Materials and methods

Study Area

The study was carried out in Sudan Savanna agro-ecological zones in Kaduna state which lies within the Latitude 8^{o} 55'N - 11^{o}27'N of Equator and Longitude 5^{o}55'E - 9^{o}45'E of Greenwich Meridian. Sudan savanna comprises of eight local government areas of the state namely: Lere, Zaria, Sabon Gari, Kubau, Soba, Kudan, Markafi and Ikara.

Kaduna state generally falls under the Tropical Continental climate which is considered as seasonal variations with alternation of moist maritime, air mass and dry continental air mass resulting into two major different seasons.

The ethnic group in the zone predominantly comprises of Hausa, Kataf, Igbo, Fulani, Yoruba. The main occupations are farming, trading, self-employment, civil service. The major economic activities of the people in the rural areas are cultivating, processing and marketing of agricultural products. The major crops cultivating, processing and marketing are rice, guinea corn, millet, maize, groundnut, millet, soya beans and pepper.

Research Methodology

The study basically adopted primary data with the use of well-structured questionnaire to collect information about the farmer's socio-economic characteristics influencing the adoption of agroforestry in the study area. The questionnaire was designed to contain open-ended and close- ended format, to obtain adequate information. The respondents for this study was the crop farmers in Kubau Local government area of Kaduna State.

The study used multi-stage sampling technique, the first stage was purposive sampling method which was used to select the local government that has most populous number of registered farmers in Sudan Savanna ecological zones. Out of eight local government areas in the zone Kubua Local Government has the highest number of registered farmer with the total number of registered farmers of One Thousand, nine Hundred and Thirty-Six (1936). It was from this that Two hundred and Fifty- Two (252) respondents were selected for the administration of questionnaire out of sampled population of 1936, through the application of Yamane (1967) sample size selection formula.

Face to face interviews were conducted in the month of April and May 2021, with farmers using a well-structured questionnaire for each farmer. This captured information on some demographic variables such as age, education, skills and knowledge, Years of farming experience, farmland size, and other factors influencing adoption of agroforestry practices as adaptation strategy to the climate change hazards in Sudan Savanna agro-ecological zones.

The data was analyzed and presented by using descriptive statistics, namely percentages, frequencies tables, means and standard deviation in some cases.

Results and discussion

The data collected during the field survey involved socio-economic characteristics of small land farmers. The data was presented through the use of frequency distribution tables and quantitatively and qualitatively discussed in different major categories such as demographic characteristics of farmers, agro-based characteristics of farmers, economic factors and how distance from farm to forest reserve, market and urban centers influence the adoption of agroforestry in Sudan Savanna agro-ecological zones of Kaduna state.

Demographic Characteristics Influencing the Adoption of Agroforestry

The active ages of this study are considered to be between 31 and 60 years, while below 30 years are expected to be in schools or be under their parents, and above 60 years are expected to have retired and taken care by their children, these two age groups are considered to be dependent age groups. The distribution of the ages as shown in the Table 1 showed the bulk of the sampled population in Kubua (sudan savanna) 76% were in the active ages of 31 to 60 years and 24% were in dependent age groups, the mean age is 39 years. This implied that most of the respondents were in their active years and as such could participate effectively in agroforestry activities.

Age is one of the factors that influences the adoption of agroforestry. Older farmers may not have preferential access to new information or technologies through extension services or development projects that operate in the study area. Also, in the age factor, active age group farmers gather more personal financial capital, and may lead to higher investment in innovations (Nkamleu and Coulibaly, 2000). Active age farmers also have access to new technologies and were regarded to be early adopters (Alavalapati *et al*. 1995). In agreement with Ogunsumi (2004) age is a significant factor for adoption of technology, because active age groups have more energy to work and have better opportunity to investment in the long-term, these are the strategy to adapt to climate change hazards because they still have capacity and ability to farm for a long time on the same plot of land.

Table 1: Demographic Characteristics of Farmers

Variables		Frequency	%	Mean Value
Age:	21 – 30 Years	61	24	
	31 – 40 Years	83	33	
	41 – 50 Years	68	27	
	51 – 60 Years	40	16	
	Above 60 Years	0	0	
	Total	**252**	**100**	**39 Years**
Gender:	Male	243	96	
	Female	9	4	
	Total	**252**	**100**	
Marital Status:	Single	11	4	
	Married	237	94	
	Widowed Divorced	1	0.4	
	Total	3	1.6	
		252	**100**	
Education Level:	Primary Ed	55	22	
	Secondary Ed	48	19	
	Tertiary Ed	20	8	
	Adult Ed	105	41	
	No Formal Ed	24	10	
	Total	**252**	**100**	
Household Size:	< 3	24	10	
	3 – 5	47	19	
	6 – 10	84	33	
	> 10	97	38	
	Total	**252**	**100**	**10 Persons**
Sec Occupation:	Civil Servant	39	15	
	Artisan	28	11	
	Self Empl	43	17	
	Trading	37	15	
	None	97	38	
	Others	8	4	
	Total	**252**	**100**	

Sources: Author's Field Survey, 2021

From Table 1, 96% of the sampled farmers in sudan savanna were male and 4% were female. The low number of females reflects the predominance of Islamic culture which allows the practice of Puddah (women are restricted inside houses). Thus accessibility to interview female farmers in large number was not possible. The few interviewed were either widow or came from other region to reside Kubau Local Governmengt. Generally, the cultural practice does not allow women to engage in the work like farming. This implies that there is participation of male gender in farming activities and also in the adoption of agroforestry practices. Alfred (2001) and Adedotun (2010) stated that male farmers usually out-number female farmers in many communities in Nigeria.

Information relating to the marital status of the respondents is also presented on Table 1. Majority of the farmers sampled 94% were married, 4% were single, 0.4% were widows, 1.6% were divorced.

The distribution of respondents according to educational level as presented in Table 1. It was significant to note that majority of the respondents in the zone had one form of education or another, 41% had adult education, 22% had primary education, 19% had secondary education, 10% had no formal education and only 8% had tertiary education. This was expected to have significant impact on ability of farmers to effectively adopt agroforestry as better strategy to adapt to climate change hazards in the study area. This result was in agreement with the findings of Abdulazeez *et al,* (2014) that, education influences the adoption of agroforestry practices positively. A popular belief was that highly educated farmers were early adopters of new technologies (Kebede *et al*. 2015). It was also hypothesized that education was positively related to the adoption of agroforestry as a strategy to adapt to climate change hazards.

Information relating to the household size of respondents is presented on Table1. Majority of farmers had above 6 persons per house, in sudan savanna, 71% were more than 6 persons per household and 29% were less than 6 persons, with a mean size of 10 persons per household. Secondary occupations of respondents were also considered in Table1. The result showed that 38% were not into any other occupation apart from farming, 17% were self-employed, 15% were civil servant and traders, 11% were artisans, and 4% were into other occupations that were not mentioned.

Agro-Based Characteristics Influencing the Adoption of Agroforestry

Years of farming experience is another major factor that contributed to the effectiveness and influenced the adoption of a new strategy in this type of occupation. From Table 2, the result showed that, 33% had farming experience of 16 – 20 years, 28% had spent 6 – 10 years, 13% had more than 20 years, 13% also had 11 – 15 years and less the 5 years of farming knowledge, with the mean of 13.2 years.

Majority of the respondents 62% had farm sizes ranging between 2 and 7 hectares per farmer, 28% had less than 2 hectares while 5% each had 8 to 10 and more than 10 hectares, with the mean value of 3.8 hectares. Table 2 showed the type of land ownership system among the respondents. In sudan savanna, 76% purchased the land, 11% hired the land, 6% inherited it, 4% rented the land and only 3% leased the land.

From Table 2 the sources of labor for majority 47% of farmers in the study area were either family or hired labour, 33% depended only on family, 18% only on hired labour, while only 2% engaged cooperative for labour on their farm, while 1% depended on cooperative society to do labour for them. However, 30% people depended solely on family labour.

Some villages that were difficult access faced several constraints as result limited their access to new innovations like agroforestry, this was also considered in Table 2. The result showed that 54% had un-tarred road leading to their farms, and 27% had easy access of tarred road to their farms, while only 19% found it difficult to gain access to their farms. Free Access to farm refers to a situation where the farmers had access to good road network from home to farm and from farms to the market as the case may be to sell their farm produce.

Membership of farmer's association could enhance access to credit facility and other agricultural technological innovations hence influenced the adoption of agroforestry as adaptation strategy to climate change hazards. Iwasaki *et al*., (2009) noted that lack of social cohesion and community ties and disaster awareness can lead to loss and damage of material assets. Parry *et al.*, (2007) observed that investing in social relationships and communities for support during difficult times, and building social relations and network to increase cooperation, and the sharing of ideas and technological innovations can increase the adaptive capacity of the farmers. From the result, 91% are in one farmers' association or the other, while only 9% are not in any association. (See Table 2). This implies that majority of the respondents were members of one farmers' association or the other, which might have given them access to credit facilities, and other agricultural technological innovations hence influenced them to adopt agroforestry practice as adaptation strategy to climate change hazards.Agricultural research often produces technologies that have high potential for benefiting large segments of the population, particularly farmers in the rural areas. The influence of agriculture oriented institutions is very crucial and necessary for agricultural technology adoption. Heidi (2005) argued that technology like agroforestry that can improve the performance of African agriculture exist and new innovations that can be adopted to adapt to climate change hazards were developed but the problem is that the learning of these new technologies to farmers were slow, incomplete and many times not accessible to the farmers. This is the case in the sampled farmers in the study area, 74% had no agroforestry training, while only 26% had access to agroforestry training. Results from this study showed access to information on tree planting positively associated with adoption of agroforestry. Result showed that 83% had access to information about benefits of agroforestry, while only 17% had no access to information about agroforestry. (See Table 2). This corroborated with Chija (2013), who found out that farmer's awareness and access to information were some of the most critical factors that influenced farmers' adoption of agroforestry to adapt to climate change hazards in sudan savanna agro-ecological zones of Kaduna state.

Access to the input in agricultural activities is also one of the important factors that determine the choice or the adoption of some innovations. Likewise access to input like tree seedlings by the farmers will strongly influence their decision to adopt agroforestry. The result in Table 2 showed that 91% had access to major agroforestry input which is tree seedlings, while only 9% had no access to tree seedlings. This attested to some studies that access to cash incentives, subsidies and other agroforestry inputs promote adoption of agroforestry practices as a strategy to adapt to climate change hazards. (Jhariya *et al*, 2015). While low levels of incentives, self-financing and difficult to access tree seedlings may lead to a slower pace of adoption or lack of interest to adopt agroforestry (Okunade and Yekini, 2007).

Contrary to the assertion that farmers' access to information from extension officers on tree planting aid the decision to adopt agroforestry. The result in Table 2 showed that 88% had no access to extension officer's information and their services, while only 12% had access to extension officers. The frequent visits of extension officers to the farm increase the level of awareness and information about certain agricultural technology innovations. The result from Table 2 showed that the visitation of extension officers to render service to the farmers is very low. 58% had access to extension officers on quarterly basis while 32% had access to them once in a year, and only 10% had access to them monthly, and none of the farmer had access to them on weekly basis.

Table 2: Agro-Based Characteristics of Farmers

Variables		Frequency	%	Mean Value
Farming Exp:	Less than 5 Years	34	13	
	6 – 10 Years	70	28	
	11 – 15 Years	34	13	
	16 – 20 Years	80	33	
	More than 20 Years	34	13	
	Total	**252**	**100**	**13.2 Years**
Farm Size:	< 2 Hectare	71	28	
	2 – 4 Hectare	102	40	
	5 – 7 Hectare	55	22	
	8 – 10 Hectare	12	5	
	> 10 Hectare	12	5	
	Total	**252**	**100**	**3.8 Hectare**
Land Acquisition:	Rent	9	4	
	Lease	8	3	
	Hired	27	11	
	Inheritance	14	6	
	Purchase	194	76	
	Others	0	0	
	Total	**252**	**100**	
Sources of Labour:	Family	83	33	
	Hired	47	18	
	Family & Hired	117	47	
	Cooperative	5	2	
	Others	0	0	
	Total	**252**	**100**	
Accessibility:	Tarred Rd	69	27	
	Un-tarred Rd	137	54	
	Difficult Access	46	19	
	Total	**252**	**100**	
Farmers" Association:	Yes	229	91	
	No	23	9	
	Total	**252**	**100**	
Formal AGF Training:	Yes	66	26	
	No	186	74	
	Total	**252**	**100**	
Information About AGF:	Yes	208	83	
	No	44	17	
	Total	**252**	**100**	
Access to Input:	Yes	229	91	
	No	23	9	
	Total	**252**	**100**	
Access to Ext Officers:	Yes	31	12	
	No	221	88	
	Total	**252**	**100**	
Visit of Ext Officers:	Weekly	0	0	
	Monthly	3	10	
	Quarterly	18	58	
	Yearly	10	32	
	Total	**31**	**100**	

Sources: Author's Field Survey, 2021

Economic Factors Influencing the Adoption of Agroforestry

The income earned from farming activities was also examine in Table.3, The result showed that, 38% realized between #50,000 and #100,000 per month, 26% realized between #101,000 and #150,000 per month, 19% realized less than #50,000 and 15%

realized between #151,000 and #200,000 per month while only 2% realized above #200,000 per month, the mean value was #96,000 which is the highest value of the three agro-ecological zones.
Table 3 also shows percentage distribution of respondents according to non-farm income per month. The respondents had varied monthly income based on their secondary occupations. In Sudan Savanna 37% had monthly income of between #50,000 - #100,000, 24% earned between #101,000 - #150,000, 15% earned less than #50,000 per month, 13% earned #151,000 - #200,000 per month and only 11% earned more than #200,000 per month, with mean value of #110,000. This amount is far above the national minimum wage of #30,000 per month, implying that majority may have more money to practice agroforestry to adapt to climate change hazards in their respective farms. This was in line with Ozor (2009) who observed that with high income, farmers will adopt different innovative strategies to improve the soil so as to increase the farm productivities.
Another important factor examined in the Table 3 is famer's source of capital to finance their farm, the result revealed that 46% received grants from federal and state government, 27% received loans from their cooperative societies. 11% re-invested their last year profit to finance the farming activities, 10% got capital through the bank loans, while only 6% got their capital from friend or members of their family. This finding indicated that majority of farmers embarked on one loan or the other, this was possible because they were sure of paying back with ease since there was adaptation strategy in place which had been adopted to reduce climate change hazards in the farm.
Access to the credit facility is another important determinant economic factor influencing the choice of various technological innovations on the farm. This finding is line with Yamo (2007), who observed that most people affected by climate change are unable to have access to formal bank loans due to lack of collateral. Table 3 also showed that, 71% had access to credit facility while only 29% had no access to credit facility. Accessibility to formal or informal credit facilities is important in agricultural occupation and may influence adoption of agroforestry practice.

Table 3: Economic Factors Influencing the Adoption of Agroforestry

Variable		Frequency	%	Mean Value
Farm Income:	< #50,000	49	19	
	#50,000 - #100,000	96	38	
	#101,000 -#150,000	65	26	
	#151,000 -#200,000	38	15	
	> #200,000	4	2	
	Total	**252**	**100**	**#96,000**
Non- Farm Income:	< #50,000	37	15	
	#50,000 - #100,000	92	37	
	#101,000 -#150,000	61	24	
	#151,000 -#200,000	34	13	
	> #200,000	28	11	
	Total	**252**	**100**	**#110,000**
Sources of Capital:	Bank	25	10	
	Relative/Friend	14	6	
	Govt Grant	117	46	
	Coop Society	68	27	
	Re-Inv Profit	28	11	
	Total	**252**	**100**	
Access to Credit Fac.:	Yes	178	71	
	No	74	29	
	Total	**252**	**100**	

Sources: Author's Field Survey, 2021

Location Factors Influencing the Adoption of Agroforestry
Farmers in communities in more proximity to forest reserves were likely to adopt agroforestry. Involvement of the Ministry Agriculture and Rural Development, Ministry of Environment and Forestry Research Institution of Nigeria in these reserve areas provides much extension services and supervision mostly through the governmental tree planting programmes (Taungya programme). Farmers in these areas are therefore more informed by tree planting and agricultural technology innovations such as agroforestry. The result in Table 4 showed that 71% had their farm at distance farther than 10km to the forest reserves, while only 29% had their farm at distance less than 10km. Farmers' preferences for on-farm trees are expected to influence their decision to adopt agroforestry.
The result of proximity of farm to the market place showed that 82% had their farm at distance less than 10km to the market, while only 18% had their farm at distance farther than 10km to the market place.
Land availability may permit farmers to practice longer fallows. The result from Table 4, showed that 68% had their farms farther than 10km while only 32% had their farms less than 10km to the main town. This is contrary to the popular belief that the further the village from the urban area, the lower the probability of the adoption of agroforestry (Nkamleu and Manyong, 2005). This result

is contrary to expectation. This implies that the farther the farm is from the town, the higher the farmer to adopt of agroforestry practice as result agroforestry practices are more common in villages far from urban areas.

Table 4: Location Factors Influencing the Adoption of Agroforestry

Variables	Frequency	%
Forest Res.: < 5km	28	11
6km – 10km	45	18
> 10km	179	71
Total	**252**	**100**
Market: < 5km	91	36
6km – 10km	115	46
> 10km	46	18
Total	**252**	**100**
Urban Center: < 5km	29	12
6km – 10km	51	20
> 10km	172	68
Total	**252**	**100**

Sources: Author's Field Survey, 2021

Conclusion and recommendations

The adoption of agroforestry technologies is important because it offers the prospect of increasing production and hence increase farmers' income. Sustainable development through agroforestry practice can be achieved through a jointed effort to actively and continuously encourage farmers' involvement in agroforestry activities. Recognizing and tackling main factors that determine involvement of farmers in agroforestry practices predisposes an agroforestry project to successful local farmers' participation. This study is relevant to the adoption of agroforestry technologies involving economic as well as sociological considerations.

The result in this study has demonstrated that some factors influencing farmers' adoption of agroforestry practices in different agro-ecological zones are not necessarily the same, therefore generalization should be avoided. The results have a number of implications for strategies to promote agroforestry among farmers in different agro-ecological zones. Government agencies, policy makers, environmental managers and planners need reliable information on the effects of various socio-economic variables on the adoption or rejection of a technology for a sustainable development.

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MEDICINAL PLANTS CONSERVATION: A STRATEGIC METHOD TO MITIGATE CLIMATE CHANGE

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Abstract

Forestry is very essential to human life as it involves the activities that sustain humanity with various ecological services. Forest is the source of non-timber products, particularly medicinal plants which include trees, shrubs, herbs, grasses, and lianas. These plant types have been engaged in varieties of uses for medicinal purposes from ancient times till the present age and yet preferred to modern medicine by many people – especially in regions characterized by tropical climates on the globe, including Sub-Saharan Africa – because of their ready accessibility, supposed low toxicity, cheapness, and effectiveness, among others. Their demand for diversified utilization among large populations tends to over-exploitation and forest biodiversity loss which leads to climate change. Climate change, associated with temperature extremities, may further lead to the extinction of valuable medicinal plants. Conservation through the cultivation of medicinal plants is of utmost importance as forestry, involving forest resources management, contributes immensely to the development of safe remedies, a clean environment, and organic-based drug for the management of health conditions and diseases.

Keywords: *biodiversity, forest management, cultivation, herbal medicine, over-exploitation*

Introduction

Forest cover is arguably the first phenomenon in existence on the earth. The scriptures give credence to the fact that early men of the human race interacted with the forest and relied on its resources. Thus, forest activities predate history. Forestry is very essential to human life. The reduction in human life expectancy rate has been attributed to adverse health conditions emanating from massive industrialization and deterioration of the forest (Ajiola and Ilesanmi 2017) which perform the great function of purifying the environment. Forest trees remove toxins from the air through their various parts such as the leaves and bark. They absorb these toxins through their leaves' pores and also convert the carbon dioxide we exhale into fresh oxygen through photosynthesis. Absorption of volatile organic compounds and removal of metabolized toxic compounds in the soil water and air are brought about by the action of trees. Forests also can degrade heavy metals in polluted soil through the bioremediation process. It can be said that a safe environment depends on the availability of trees. Sustainable life and increased life expectancy rate could be ascertained in a less polluted environment.

The livelihood of people in most rural communities is dependent on forest resources. Forests also provide essential needs for humans including life-saving pharmaceutical agents. The strategies mostly used by many rural households to overcome food insecurity and health problems are the use of non-timber forest products (NTFPs).

While considering the unsustainable utilization of the forest resources and indiscriminate forest mining practices, Appanah (2004) highlighted those forests go far beyond timber with market value into influencing local and regional climate, protecting soil, providing potable water, and mitigating floods to mention a few. Shah *et al*. (2015) and Guga *et al*. (2015) argue that population growth can instigate a huge pressure on natural resources and contribute to environmental problems such as rising levels of atmospheric carbon dioxide, biological diversity loss, global warming, and pollution. Appanah (2004) further noted that we are finally confronted with reality. The forests have gone, mostly, the governments are not richer, the environment has deteriorated, and people are impoverished. The problem caused by the taking away of the forest can be resolved by restoring the forest and utilizing it sustainably.

Forest Ecosystem Services

The Millennium Ecosystem Assessment (2005) suggested that ecosystem services can be classified into four categories:

i. **Provisioning services** provide goods such as food, fresh water, timber, and fibre as well as medicinal plants for direct human use.

ii. **Regulating services** maintain a world in which it is biophysically possible for people to live and provide benefits such as pollination of crops, water damage mitigation, and climate stabilization.

iii. **Cultural services** make the world a place in which people want to live; they include recreation as well as aesthetic, intellectual, and spiritual inspiration.

iv. **Supporting services** are the underlying ecosystem processes that produce direct services such as nutrient cycling, soil formation, etc.

Medicinal Plants as Provisioning Service Item

A very important and inevitable provisioning service made available by the forest ecosystem is the medicine that is widespread across the forest ecological community and its environment ranging from the extraction of animal parts, materials, and fluid to tree roots, bark, leaves, fruit, pod, flowers, etc., and herbs from non-tree forest products (NTFPs) in the forest. All of these have greatly contributed to traditional medicine in Africa and the world at large which is gradually gaining traction and renown as an effective therapy and viable alternative medicine.

Medicinal plants in Forests

Medicinal plants cover a wide range of plant types such as trees, shrubs, herbs, grasses, and lianas. Forest trees and other plants contain a wide variety of bioactive compounds with potential as anticancer drugs, anti-atherogenic compounds, and antioxidants. Forest animals also provide a source of medicines, including toxins purified from venomous snakes, spiders, insects, and scorpions. There is a wealth of indigenous and local knowledge on forest medicines. Lawal *et al.* (2018) demonstrated that plants (found in the forest) serve as a reservoir for the storage of several classes of compounds; these compounds act as a defense mechanism against foreign bodies and therefore help in the management and cure of several ailments and health conditions in humans and animals. Their use in traditional medicine dates back to time immemorial and has contributed immensely to health care delivery in rural communities as their main source of medicines (Ahmad et al. 2009). Commonly used ethnomedicinal species in the forest are *Adansonia digitata, Albizia spp, Alstonia boonei, Morinda lucida, Anarcadium occidentale, Anona muricata, Vernonia amygdalina, Senna alata, Sanseviera liberica*, just to mention a few.

Preferential Utilization of Medicinal Plants

The use of traditional herbal medicine is very common in most parts of the countries of world, despite modern development in the treatment of the human body, herbal remedies have been continuously used. Modern medicine, in the beginning, depended on herbal remedies because plants were the fundamental sources of therapeutic products (Kelly 2009; Petrovska 2012) for professional and non-professional healers of the earliest times. Over 25% of prescribed medicines in industrialized countries are derived directly or indirectly from plants, despite the remarkable progress in synthetic organic medicinal products of the twentieth century (Newman *et al*. 2000). The efficacy of herbs has been confirmed in different disease conditions all over the world. Herbs have succeeded where conventional or synthetic medicine has failed, especially in chronic infectious diseases. An example, as reviewed by Ju-Young *et al.* (2018), is the herbal antiviral targets that were found to inhibit the replication of influenza strains resistant to oseltamivir – a standard antiviral drug also known as Tamiflu. Apart from this efficacy, it is very important to mention the little or no side effects in the treatment of diseases because they act as foods and as medicines.

Akerele (1998), elucidated that the high cost of allopathic drugs and side effects led to the highest popularity of medicinal plants in rural areas. In the treatment of hypertension, for instance, the herb is used first to lower the blood pressure; clean the arteries, slow and regulate the heart rate, improve blood circulation, and relax the mind, unlike the conventional ones that will dilate the arteries or the veins until they reach their maximum elastic point which may suddenly burst and cause a vascular accident, causing stroke or death (Nakano *et al.* 2002; Ben *et al.* 2006; Tabassum and Ahmad 2011). There are a few or no synthetic drugs that will do all of the above.

Medicinal Plants Diversified Uses

The use of herbs for the treatment of different kinds of diseases is popular in African countries. In Ghana, for example, more than 800 wild plants and many other herbaceous species are known for their medicinal properties (Burhan *et al.* 2006). The history of how long herbs have been in use is as far back as man's history. The properties of herbs show clearly that they have direct relevance to the chemistry of the body and are therefore used to repair and activate the system more effective without side effects. The body's acceptance and assimilation of herbs show that herbs are natural needs of the body. Some essential elements required by the human body are found in fruits, vegetables, and herbs. Deficiency in any of these minerals in the body can result in one type of disease or the other (Ogboru *et al*. 2017). Medicinal plants are engaged in the following diverse use:

1. **Vegetables:** Quite a large number of African indigenous leafy vegetables have long been known and reported to have health-protecting properties and uses. Several of the indigenous leafy vegetables continue to be used for prophylactic and therapeutic purposes by rural communities (Igoli *et al*. 2002). Some herbs are common and others are not common. The common ones have become so well known that they are daily used as vegetables, it is a well-known fact that the body's requirement is more in what we get from vegetables, herbs, and fruits than in any other food. Because of this, it is easier and more natural to repair worn-out organs, cleanse the blood, and keep the body fit by the use of herbs.
2. **Dietary supplements:** People all over the world have used herbs in the form of dietary supplements to cure and control different diseases that are peculiar to their sub-regions.
3. **Tea:** Preparation from leaves, roots, bark, flowers, fruits, and seeds are employed for curing elements in various ways, some are cooked together and taken as a tea. These are commonly used for ailments such as fever, piles, and dysentery.
4. **Strong drinks:** Some herbs may be cut into pieces such as roots, stems, fruits, and infused; seeds are soaked in cold water for strong drinks.

5. **Floss:** *Vernonia amydgdalina, Garcinia kola* powdered form is used to treat toothache. Roots of *Cola nitida* and *Cola acuminata* are excellent chewing sticks. They clean the teeth, disinfect the mouth and strengthen dental gums (Farombi *et al*. 2005).
6. **Soup:** Some medicinal plants are cooked as soup especially for pregnant women. These plants are traditionally employed in a variety of ways: anti-infection, molluscicides, anti-malaria, laxative, and cardiovascular nervous disease treatment.

Medicinal Plants Harvesting: Its Demand and Utilization

Human beings have depended on nature for their simple requirements as being the sources for medicines, shelters, foodstuffs, fragrances, clothing, flavours, fertilizers, and means of transportation throughout the ages. The development and recognition of medicinal and financial aid for these plants are on the rise in both industrialized and developing nations (WHO, 1988). According to WHO, around 21,000 plant species have the potential for being used as medicinal plants. Plants and plant extracts, which are more than 30% of the entire plant species, are depended on by over three-quarters of the world population mainly for their health care needs as per data available (Khan 2016).

Based on the importance and diversified use of medicinal plants, much harvesting pressure is being exerted on them. To compete with the growing market, there is the urgency to expeditiously utilize and scientifically validate more medicinally useful plants while conserving these species, which seems a difficult task ahead.

Over-exploitation: A Threat to Forest Biodiversity

Many of the threats to medicinal plant species are similar to those causing endangerment to plant diversity generally. The most serious proximate threats generally are habitat loss, habitat degradation, and over-harvesting (Hamilton 1997). As far as a collection for medicines is concerned, there is general agreement that it is the collection for commercial trade rather than home use that is overwhelmingly the problem. Another reason why medicinal plants have become increasingly threatened has been the weakening of customary laws that traditionally have regulated the use of natural resources. Such laws have often proved to be easily undermined by modern socio-economic forces (Pant 2002).

The major threats to plant diversity include habitat loss, fragmentation and degradation, overexploitation, invasive species, pollution, and anthropogenic climate change (Harrison *et al*. 2013; Kettle and Koh 2014; Sharrock *et al*. 2014; Buse *et al.* 2015; Specht *et al.* 2015; ter Steege *et al*. 2015; van Kleunen *et al*. 2015). Destructive harvesting of medicinal plant parts such as the uncontrolled collection of barks and roots of trees and shrubs is another major concern. Human activities are already impairing the flow of ecosystem services on a large scale and if the current trends continue, humanity will dramatically alter virtually all of the remaining natural ecosystems within a few decades. Many of the human activities that modify or destroy natural ecosystems may cause deterioration of ecological services whose value, in the long term, dwarfs the short-term economic benefits.

For example, Brenan (1978) noted that about 205 species of plants found in Nigeria are endemic such that they are not found anywhere in the world. This places uniqueness on some of the plants' biological resources endowed in the country. Federal Environmental Protection Agency (1992) in their survey revealed that over 848 algal species have been identified in the marine and freshwater habitats while a few less than 200 lower plant species have been identified. The wide diversity of plant species found in Nigeria and some parts of the world is a function of many factors, namely, the diversity of ecosystems and varying habitats. However, today, the population explosion is a great threat to plant biodiversity. The past has threatened today while today may threaten the future following the current population growth rate. Therefore, there is an urgent need for sustainable ecosystem management. This involves growing and sustaining natural assets according to the principles of sustainable development. This will help to keep the balance between ecological, economic, and social-cultural components of sustainable development.

Climate Change effects

The documentation of medicinal uses of African plants is becoming increasingly urgent because of the rapid loss of the natural habitats of these plants due to human activities. The African continent is reported to have one of the highest rates of deforestation in the world. This loss is all the greater because the continent has a high rate of endemism, with Madagascar topping the list at 82% (Green and Sussman, 1990). As demand for medicinal plant values rises with increasing population, and over-exploitation resultantly transpires, man will be faced with a very high risk of loss of biodiversity and climate change which are caused by anthropogenic activities (deforestation and forest degradation). Climate change is associated with temperature extremities (Buse *et al*. 2015; Ge *et al.* 2015) which can further lead to the loss or extinction of some valuable medicinal plants. Researchers have found that due to the rise in temperatures, some cold-adapted alpine species are migrating upward until there are no higher areas to inhabit, at which point they may be faced with extinction (Salick *et al.* 2009).

Conservation of Medicinal Plants

The conservation (in-situ and ex-situ) of plant genetic resources has long been realized as an integral part of biodiversity conservation. The threat of over-collection (to meet the rising demand for medicines) could be addressed by the cultivation of some medicinal plants, or by a system of certification to make wild harvesting sustainable (Kling 2016). Recommended management strategies are as follows:

Medicinal plant reserve: The creation and development of medicinal plants reserve is the main component of the management strategy. Pal and Samant (2005) suggested that medicinal plant reserves will go a long way to protect the existing genetic diversity and help in the rational exploitation of medicinal plant resources in the Himalayas for overall economic development. This strategy has been adopted in some agricultural and forestry institutions in sub-Saharan Africa and more can be achieved.

Cultivation as a means of conservation: Conservation practices include domestication; beliefs in the sacredness of trees; beliefs in sacred forests; respect of cultural forests; protection of plants at the burial sites; selective harvesting; secrecy; a collection of deadwood for firewood; and use of energy saving traditional stoves. Cultivation has pharmacological advantages over wild collection. In cultivation, the variation and the resulting uncertainty of therapeutic benefit are much reduced (Amujoyegbe *et al.* 2012).

The urgent need to conserve tropical forests as biological resources for sustained availability of known and yet undiscovered medicinal substances for future generations as noted by Brian (2002) prompted the Forestry Research Institute of Nigeria (FRIN) through the Biomedicinal Research Centre (BMRC) to establish a herbal garden for *ex-situ* conservation of endangered medicinal floras especially indigenous plant species, for herbal drug development and training.

Conservation developments by the Forestry Research Institute of Nigeria (FRIN)

One of the efforts (initiatives and actions in the form of strategies, programs, activities, and interventions) of the Federal Ministry of Environment toward ensuring environmental protection and sustainable development is the execution of relevant forestry research projects through the activities of the Forestry Research Institute of Nigeria (FRIN).

FRIN has successfully substantiated its vision to be the foremost research centre of excellence in terms of knowledge-based forestry activities in the areas of forest management and biodiversity conservation by establishing conservation areas, nurseries for indigenous tree seedlings, and Sustainable Forest Management department. The institute also established the Biomedicinal Research Centre alongside herbal gardens to ensure sustainable plant research for the better advancement of herbal medicine in Nigeria, and conserve medicinal plants for laboratory-based standardization of herbal-based drugs.

Conclusion

Forest is the home of ecological materials and sources of products and services that sustain human life, especially the medicinal plants which provide remedies to several health conditions. However, uncontrolled exploitation aggravated by human population pressure on these plant species poses a serious threat to their sustainability. Over-exploitation leads to biodiversity loss and climate change. These effects further bring about temperature extremities which may lead to the extinction of valuable medicinal plants. Conservation through the cultivation of medicinal plants is of utmost importance as forestry, involving forest resources management, contributes immensely to the development of safe remedies, a clean environment, and organic-based drugs for the management of health conditions and diseases.

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ROLES OF FOREST BIOTECHNOLOGY IN TREE IMPROVEMENT

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Abstract
Biotechnology is one of the areas of scientific investigation in which rapid improvements have been made in modern centuries. It plays a vital part in the improvement of tree species and can be of significant importance in the era of rise in human civilization. Biotechnology is the application of systematic and designing principles to the dispensation of materials by biological means to offer goods and services. Biotechnology includes the hereditary control and duplication of any living organism through novel strategies and innovations such as tissue culture and genetic engineering in order to yield novel organisms and or products that can be used in various ways. The major effect of recent biotechnological development in tree improvement includes; production of high yielding plants resistant to biotic and abiotic stress, improvement of nutritional value of plants and production of diseases resistant plants. The general purpose of this review is to give highlight on the significance of biotechnology towards realizing a harmless and viable improvement of tree species.

Keywords: *Biotechnology, tree, improvement, Forest*

Introduction

Biotechnology provides a major role in sustainable development of forestry and agriculture and can be of major importance in meeting the food necessities of increasing urban population. The problems of food safety and sustainable forest management within the emerging world and especially in sub-Saharan Africa proceeded to control communal argument and have remained a problem of worldwide concern. As a result of overwhelmed population growth, economic insatiability, and rapid climate change, attaining sustainable forest management has become one intractable challenge for several nations of the world (Ohikere and Ajogwu, 2012). Sustainable forest management needs to be improved with modern and effective technology such as biotechnology in order to meet the growing demand of forest and forest products due to rapid growth of world population (Abah *et al.*, 2010). The word biotechnology was first invented to describe the commercial use of living organisms. Nevertheless, with the intensification in evidence of Deoxyribonucleic Acid (DNA) and introduction of recombinant DNA technology, all activities related to gene manipulation have also been involved in the domain of biotechnology. According to International Union of Pure and Applied Chemistry, biotechnology is the application of biochemistry, microbiology, biology and chemical engineering to manufacturing process and products and on environment (Dubey, 2012).

The arena of contemporary biotechnology is really considered as unique fields of systematic investigation in which the fastest developments have been made in modern years. Forest biotechnology contributed significantly towards the improvement of silvicultural and forest management practices (Gyanaranjan and Afaq, 2020). Biotechnology in forest has remained a unique prospect for producing trees that are resistant to biotic and abiotics stresses, improvement of nutritional value and production of diseases resistant plants.

Generating high-yielding plants resistant to the biotic and abiotic stresses

Stress in plants is the outward situations that unfavorably affect progress, improvement or output of plants (Verma *et al.*, 2013). Stresses in plants can lead to altered gene expression, plant cell metabolism, changes in development rates and crop harvests. Plant stress commonly imbibes certain rapid modifications in environmental situation. Nevertheless in stress lenient plant species, contact to a specific stress tips to acclimatization toward that particular stress with phase. Plant stress can be grouped in two key classifications viz:- abiotic stress and biotic stress. Abiotic stress forced on plants via environment can be physical or chemical, whereas biotic stress visible to the plants is a biological component like ailments and pests. Some stresses towards the plants damaged them in such a way that the plants display some metabolic disorders (Verma *et al.*, 2013). The plants may be improved from the damages if the stress is trivial whereas prolonged stresses can cause death of the plants (Zhu, 2002).

Biotic stress in plants is triggered by living organisms, especially viruses, bacteria, fungi, nematodes, pests and unwanted plant. The means triggering biotic stress unswervingly divest their host of its nutrients and may cause death to the plants. Abiotic stresses like water scarcity, excess water, very high or very low temperatures, salty water and mineral poisonousness harmfully influence progress, improvement, vintage and seed value of plants. In the upcoming years, it is projected that additional water shortage will rise and eventually the strength of abiotic stresses will also rise. Therefore, there is need to produce plant species that are strong to abiotic stresses to ensure sustainable forest management and care in future (Audil *et al.*, 2019). This would lead to rise in international food production by dropping plants damage and increasing harvest, while safeguarding farmland and plummeting burden on unique natural resources such as rain forests. Similarly, it offer additional engagement chances for people and rise output.

Improvement of nutritional value of plants

Plants contain bioactive constituents that can utilize physiological effects such as nutrition, supporting fitness and human safety. Improvement of nutritional value of plants especially fruits and vegetables help in reducing the risk of ailments to consumers (Nieves, 2017). In order to gratify the diet requirements of the worldwide population, agriculturalists of all the nations employed the green revolution skill, which has triggered harmful effects on the environment and which also denotes a hidden delinquent for human wellbeing (Baez-Rogelio *et al.,* 2017). Hence, biotechnology need to pool dual intentions that appear to be commonly fashionable; to fulfill the dietary requirements of a growing populace and to lessen the harmful effect on the environs (Duhamel and Vandemn, 2013). These dual purposes are comprised in the objective of the 2030 Program for Sustainable Development of the United Nations; 'End hunger, accomplish food safety and better nutrition'.

Significant development to biotechnological advance of nutritional value has been prepared in the previous years. In order to successfully plan a particular metabolic characteristic in plants, information of the biosynthetic and/or passage trails involved are vital. Well-designed genomics and additional gene finding approaches are valued for clarifying such pathways. It is also required to know the interactions between altered biosynthetic pathways since modification of individual pathways can have effects on related pathways. Since ample of the investigation on biosynthetic pathways is piloted on typical plants, like Arabidopsis, it is vital that this information be conveyed to argonomically significant crops. Investigation on the bioavailability of the composite and the actual dosage for a biological outcome are important to assess nutritional value. Bioavailability can be influenced by numerous causes such as biochemical procedure of the nutrient, solubility in food background, co-presentation with nutritional garnishes or anti-nutritional mixtures and food handling circumstances. A remarkable case is on the investigation on bioavailability of lycopene in tomato (Unlu *et al*., 2007). However the cis-isomer stood to be favorably fascinated by individuals, all-trans-lycopene stood to be the major isoform in treated and fresh tomatoes. Treatment of the tomato matrix in high temperature in the presence of oil boosts cis-isomerization and hints to better bioavailability, stressing the need to reflect all potential contributors to bioavailability. Vitamin A bioavailability of Golden Rice indicated that β-carotene is conveniently improved to vitamin A when used up by individuals (Tang *et al.,* 2012). A moment ago, β-carotene in Golden Rice was revealed to be as active as β-carotene in oil to offer vitamin A for progenies (Tang *et al.*, 2012). Nevertheless, the intelligences on the bioavailability of phytonutrients are inadequate. Biotechnology has demonstrated positive result in improving the nutritional significance of a extensive assortment of tree classes, however merely a few of such tree classes are permitted for human intake. (ISAAA, 2012).

Production of diseases resistance plants

Plant ailments are a risk to biosphere food production and overall food safety. Essential harvest fatalities payable to the outbreak of pathogen happen in most of the cultivated and gardening crop species. For Instance; in Nigeria, twenty five million Naira was missing after about 70 % of the cocoa made was missing to black pod infection in 1995. Additional 75% of all key crops illnesses are triggered by fungi. Old plant breeding approaches have been recycled to improve cultivars resistant to several ailments. Yet, this progression is time intense and inadequate means to obtain the genetic materials for most of the crops has left insignificant scope for improvement (Mehrotra and Aggarwal, 2003).

Several plant species, which spread through vegetative means, are systematically infested by bacteria, nematodes, virus and fungi. The inoculum of such plant species are carried over numerous generations leading to constant antagonistic effect of production and quality harvests. In demand to certify maximum potential harvest and quality in plants, it is essential to offer disease free standard plants to farmers. Tissue culture procedures have resolved the delinquent and reduced the period of biological challenges. Recent skills such as metabolics, proteomics and transcriptomics are currently verified to be beneficial in understanding metabolic pathways in plants and the role of main genes linked with their regulation. Hence, this enabled novel visions towards the intricate metabolite areas that leads to a specified phenotype and can permit detection of novel target genes to adjust a particular pathway. Such genes can then be a theme to fresh metabolic engineering efforts and uses. It has become predictable to relocation genes from unique organism to another. The transfer of such gene might be consummate by direct approaches. Examples include the gene or biolistic technique and agrobacterium mediated method. Biotechnology allows the precise analysis of plant ailment. PCR and ELISA play a vital role in the identification of viral and bacterial diseases.

Conclusion

Biotechnology has several ecological and social remunerations. Plants established via biotechnology will nurture faster and plays a significant role in the improvement of tree species through lessening the request for wood harvested from old trees and natural forest trees. Biotechnology contributes to the forest production in advancement of its objectives of providing wood harvests for humanity while guarding the natural forests that offer attractiveness and vital ecological benefits.

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EFFECT OF LEAF LITTERS OF SELECTED NITROGEN-FIXING *ALBIZIA* SPECIES ON THE GROWTH OF AFRICAN STAR APPLE (*Gambeya albida* (G.Don) Aubrév. & Pellegr.) SEEDLINGS

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Abstract
The paucity of quantified information on the growth response of G. albida to plant-based organic manure has limited its propagation. In an attempt to improve the slow growth of G. albida seedlings through an environmentally friendly organic fertilizer, the investigation was conducted to assess the effect of leaf litters of some nitrogen-fixing albizia trees on its growth. The experiment adopted a Completely Randomized Design (CRD) with six treatments replicated five times. The treatments consisted of leaf litters of selected nitrogen-fixing albizia trees (Albizia zygia, Albizia coriaria, Albizia ferruginea, Albizia lebbeck, Albizia saman) and control on the growth of G. albida. A total of thirty seedlings were used in the experiment. A year-old G. albida seedlings were carefully transplanted into polythene pots with and without 200g of leaf litters of nitrogen-fixing albizia trees and subjected to 200ml of water twice daily for six months. Data collected were subjected to one-way Analysis of Variance (ANOVA). The leaf litter of selected nitrogen-fixing albizia trees significantly ($P<0.05$) enhanced the growth of G. albida. A significant height (43.94cm)., girth (1.80cm)., number of leaves (15.00)., leaf area (93.08cm^2)., total fresh weight(18.25g) and total dry weight (7.30g) were recorded from seedlings planted in the soil influenced with leaf litters of A. lebbeck., while least growth parameters were recorded from control. Planting of G. albida in the soil amended with leaf litters of A. lebbeck enhanced its growth.

Keywords: *Leaf litters, Plant-based manure, Nitrogen fixing trees, Slow growth, Indigenous tree species*

Introduction

The increasing demand for forest products has steadily depleted the tropics of their natural forest resources (Abod and Siddiqui, 2002). The genetic erosion of our indigenous tree species is affecting species necessary for survival of present generation as *Gambeya albida*. *Gambeya albida* synonymns *Chrysophyllum albidum* is an indigenous economic tree species **(**Akaneme, 2008; Maurice, 2014; Olayode and Otufale, 2018; The plant list, 2022). *Gambeya albida* is a climax tree species of tropical rainforest that belongs to the family Sapotaceae (Olaoluwa *et al.,* 2012; Wole, 2013) which has up to 800 species and makes up almost half of the order (Ehiagbonare *et al.,* 2008). The World Agroforestry Centre (ICRAF) has identified *G. albida* as one of the top five priority tree species for domestication in the African humid tropics (Tchounjeu *et al.,* 2002). The Yoruba name is "Osan Agbalumo" (Rahaman, 2012) while in Igbo and Hausa languages, it is called "Udara" or "Udala" (Wole, 2013) and Agwaluma or Agwaluba respectively (Adelani *et al.,* 2018).

ICRAF (2007) reported that the popular, edible fleshy and juicy fruits of *G. albida* are a potential source of a soft drink. The different parts of the tree are used in the preparation of medicine for the treatment of fibroids and female sterility (Egunyomi *et al.*, 2005). Intake of *G. albida* fruit helps in the prevention of mouth gum disease, treatment of toothache and sore throat as well as helping people to lose weight (Adaobi, 2019). Agustin (2018) stated that the post-birth diagnosis of diabetic disease for pregnant women can be prevented by consuming *G. albida* fruits which contains hypoglycemic that helps to lower blood sugar levels.

Despite the enormous benefits of *G. albida* it has been greatly neglected particularly for its regeneration (Adelani *et al.,* 2014, Adelani *et al.,* 2016, Adelani *et al.,* 2017). Adelani and Muhammed (2017) stated that *G. albida* is a slow-growing tree that needs to be fertilized for fast growth to meet the population demand for its ample benefits. Many studies have highlighted the role of local plants as low-cost fertilizers as an alternative to chemical fertilizers (Palm *et al.,* 2000; Leblanc *et al.,*2006; Kaizzi *et al*., 2007; Abebe *et al.,* 2015).

Chen (2006) stated that commercial N fertilizers are expensive, with only a fraction of this nutrient reaching the plant, which limits efficiency and potentially increases water contamination. Chemical fertilizers contain high nutrients and are readily available to be taken up by plants. However, excess usage of it results in several challenges, such as nutrient loss, surface water and groundwater contamination, soil acidification or basification, reductions in useful microbial communities, and increased sensitivity to harmful insects (Chen, 2006). Chadzon (2003) stated that rapidly-growing tree species, particularly nitrogen-fixing legumes, can increase organic matter in the soil, prevent erosion, and enhance nutrient cycling. Nitrogen fixation is the characteristic of nitrogen fixing trees.

N-fixation also occurs in over 200 non leguminous plants species in 25 genera of 8 families associated with Frankia (Actinomycetes), which are filamentous bacteria (Franche *et al.,* 2009; Russo, 2005). The percentage of N derived from the atmosphere (NDFA) is more than 59% according to a recent analysis of 38 cases using N isotopic analyses (Nygren *et al.,* 2012). Giller (2001) stated that the range of N_2-fixation capacity varies greatly amongst these trees. Many leguminous trees and a few non-leguminous ones have the ability to fix atmospheric nitrogen through symbiosis with bacteria or fungi in root nodules (WAC, 2018). WAC (2018) reported that the fixation of nitrogen has been proven and found to be a significant factor in soil fertility. Nitrogen-fixing tree species have the ability to fix nitrogen to increase soil fertility through the process of nitrogen fixation.

The most popular N_2–fixing trees used in tropical agroforestry systems include the legumes *Acacia spp, Erythrina spp, Gliricidia spp*., *Inga spp* and *Leucaena spp* which form symbiotic associations with a wide variety of N_2-fixing bacterial species (Bala *et al.,* 2003). Sileshi *et al.* (2014) stated that agroforestry practices as alley cropping, improved fallows, cereal-tree legume inter cropping, relay cropping, biomass transfer, fodder banks, multistrata agroforestry, parklands and silvopastoral systems capitalize on biological nitrogen fixation (BNF) from fertilizer trees for the supply of N and organic matter to annual and perennial crops. Among the widely used fertilizer trees are acacia (*Acacia spp*.), albizia (*Albizia spp.)*, alder (*Alnus spp*.), calliandra (*Calliandra calothyrsus*), casuarina (*Casuarina equisetifolia*), erythrina (*Erythrina spp*.), faidherbia (*Faidherbia albida*), flemingia (*Flemingia spp.)*, gliricidia (*Gliricidia sepium*), inga (*Inga edulis*), leucaena (*Leucaena spp*.), sesbania (*Sesbania* spp.), tagasaste (*Chamaecytisus palmensis*) and tephrosia (*Tephrosia spp*.).

Winrock International (2022) and WAC (2009) also gave comprehensive lists of nitrogen-fixing trees where most of albizias were mentioned. Some albizias are nitrogen-fixers and soil-enhancers. Nygren *et al.* (2012) stated that the potential for N_2-fixing trees to improve soil fertility within perennial-crop agroforestry systems is clear. Nitrogen-fixing trees normally have higher nitrogen concentrations in the biomass than non-fixing species, but this characteristic also varies widely among species (Palm, 1995). Litter improves soil quality by adding the organic matter and nutrients to the soil (Ngoran, *et al.,* 2006; Mahmood and Hoque, 2008; Triadiati *et al.*, 2011). Hossain *et al.* (2011) and Park and Kang-Hyun (2003) reported that relative to other litter types, leaf litter is the main and fastest source of organic matter and nutrients to the soil. Researches have been conducted on the effect of leaf litters of selected nitrogen-fixing acacias (on crops and trees) (Adelani *et al.*, 2020a; Adelani *et al.,* 2021), albizias (on crops) (Adelani *et al.*, 2020b), but remain unexplored for trees as *G.albida*. In this light, an investigation was conducted into the influence of leaf litters of selected nitrogen-fixing albizias on the growth of *Gambeya albida* seedlings with a view to enhancing its growth.

Materials and Method

The research was conducted in the screen house of Federal College of Forestry Mechanization, Afaka, Kaduna State during the wet season of 2018. The College is located in the Northern Guinea Savannah ecological zones of Nigeria. It is situated in Igabi Local Government Area of Kaduna State, Nigeria. It lies between Latitudes 10 º 35' and 10 º 34' and Longitudes 7 º 21' and 7 º 20' (Adelani, 2015). The mean annual rainfall is approximately 1000 mm (Otegbeye *et al.,* 2001). The vegetation is open woodland with tall broad leave trees (Otegbeye *et al.,* 2001).

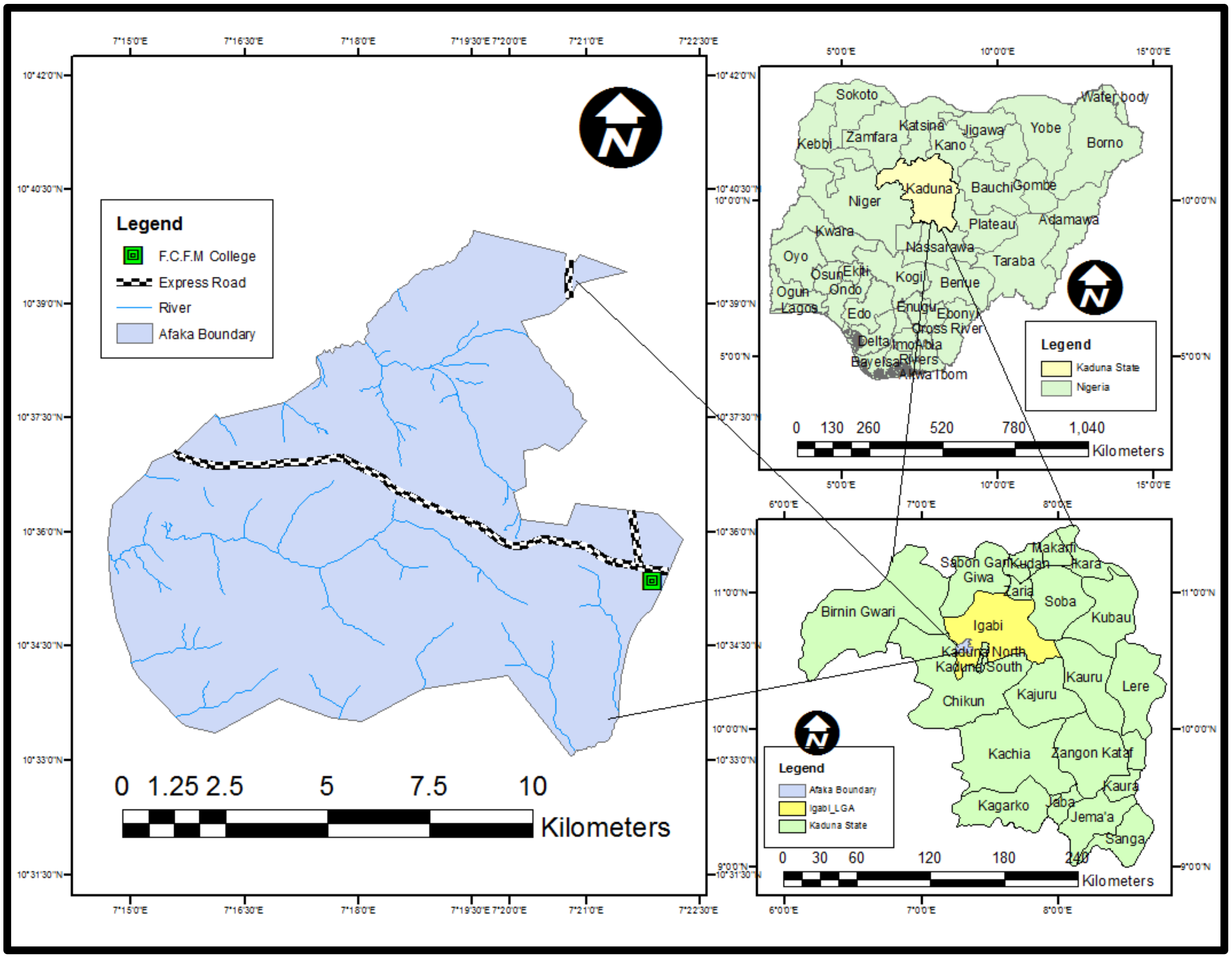

Fig 1: The location of Federal College of Forestry Mechanization, Afaka, Kaduna State, Nigeria
Field survey, 2022.

Experimental Procedure

The fruits were sourced from Osiele village in Odeda Local Government, Ogun State and transported to Kaduna State. The seeds were extracted from fruits and air dried for thirty minutes. Three hundred seeds were extracted from fruits. The viability of the randomly selected seed samples was assessed using the cutting method (Schmidt, 2000). The sowing media (river sand), which was collected from the floor of the College dam was made to pass through a 2mm sieve and then sterilized at 160°C for 24 hours. The polythene pots used were 20x10x10cm^3 in dimension and filled with the sterilized river sand and arranged in the screen house. After a year of germination of seeds, uniform seedlings were available for growth experiment.

The experimental design adopted for investigation of the effect of leaf litters of selected nitrogen-fixing albizia trees (*Albizia zygia*, *Albizia coriaria*, *Albizia ferruginea*, *Albizia lebbeck* and *Albizia saman*) and control on the growth of *G. albida* was a Completely Randomized Design with five replicates. The choice of selected albizias was based on the earlier reports of Adelani *et al.* (2020b) who stated that leaf litters of nitrogen-fixing albizia trees significantly enhanced the growth and yield of *Zingiber officinale* and the same selected albizias was investigated for *Gambeya albida*. A year-old seedlings were carefully transplanted into a potting mixture packed in larger poly pots of 25x20x15cm^3 dimensions. The potting mixture contained samples of sterilized sand thoroughly mixed with each leaf litter of nitrogen-fixing albizia trees at same quantity of 200g.

Each sample of pulverized leaves of nitrogen-fixing trees was analyzed chemically for nitrogen, phosphorus and potassium (NPK). The sand without the addition of leaf litter was analyzed for nutrient content under untreated soil (control). The 200ml of distilled water per seedling was used to water the seedlings twice daily. Growth parameters were monitored every month for 6 months. Growth parameters assessed include; Seedling height (using meter rule); girth (using venier calliper); the number of leaves was counted manually and Leaf area was obtained by linear measurement of leaf length and leaf width as described by Clifton-Brown and Lewandowski (2000).

LA=0.74xLxW (1)

Where, LA =Leaf area=Product of linear dimension of the length and width at the broadest part of the leaf.

The fresh and dry weight were determined by the use of Mettler Top Loading Weighing Balance, but dry weight was taken after oven dried the seedlings at 70ºC for 72 hours (Umar and Gwaram, 2006).

Data analysis

The data on the effect of leaf litters of selected nitrogen-fixing albizia trees on the growth of *G. albida* seedlings were subjected to one-way analysis of variance (ANOVA) using SAS (2003). Comparison of significant means was accomplished using Fisher's Least Significant Difference (LSD) at a 5% level of significance.

Results

A significant height of 43.94 cm was recorded from seedlings planted in the soil influenced with leaf litter of *A. lebbeck* at 24 weeks after transplanted, WAT. The least value of 17.88 cm was recorded from seedlings planted in the soil without amendment of leaf litters of nitrogen-fixing albizia trees at 4 WAT (Table 1).

Table 1: Effect of leaf litters of selected nitrogen-fixing albizia trees on the height (cm) of *G. albida* seedlings

NFAT			WAT			
	4	8	12	16	20	24
A.lebbeck	19.94^{a}	22.50^{a}	25.68^{a}	28.00^{a}	37.02^{a}	43.94^{a}
A.zygia	18.08^{b}	19.18^{b}	23.40^{b}	24.34^{ab}	28.58^{c}	30.94^{ab}
A.coriaria	18.42^{ab}	22.98^{a}	24.34^{ab}	25.22^{b}	31.60^{b}	34.44^{b}
A.ferruginea	18.52^{ab}	19.44^{b}	19.74^{c}	20.96^{c}	28.02^{cd}	30.24^{c}
A.saman	18.04^{b}	18.70^{b}	19.96^{c}	20.08^{c}	20.78^{d}	21.50^{d}
Control	17.88^{b}	18.86^{b}	20.50^{c}	20.68^{c}	20.99^{d}	21.00^{d}
SE+	0.69	0.63	0.66	0.71	0.70	1.45
p-value	0.01	0.01	0.01	0.01	0.01	0.02

*Means on the same column having different superscripts are significantly different (p<0.05)
Key: NFAT=Nitrogen Fixing Albizia Trees, WAT= Weeks After Transplanting

A significant girth of 1.80cm was recorded from seedlings planted in the soil enhanced with leaf litters of *A. lebbeck* at 24 WAT. The least value of 0.89 cm was recorded from seedlings planted in the soil without the influence of leaf litters of nitrogen-fixing albizia trees (control) at 4WAT (Table 2).

Table 2: Effect of leaflitters of selected nitrogen-fixing albizia trees on the girth (cm) of *G. albida* seedlings

NFAT			WAT			
	4	8	12	16	20	24
A.lebbeck	1.10^{a}	1.12^{a}	1.22^{a}	1.24^{a}	1.56^{b}	1.80^{a}
A.zygia	0.90^{a}	0.92^{a}	0.96^{c}	1.10^{a}	1.68^{ab}	1.79^{ab}
A.coriaria	0.92^{a}	0.98^{a}	1.06^{b}	1.18^{a}	1.30^{c}	1.48^{b}
A.ferruginea	1.06^{a}	1.06^{a}	1.08^{b}	1.08^{a}	1.74^{a}	1.78^{ab}
A.saman	1.00^{a}	1.06^{a}	1.20^{a}	1.36^{a}	1.38^{c}	1.40^{b}
Control	0.89^{a}	0.92^{a}	0.95^{c}	1.00^{a}	1.10^{d}	1.20^{c}
SE+	0.13	0.11	0.04	0.70	0.07	0.05
p-value	0.01	0.01	0.00	0.01	0.00	0.00

*Means on the same column having different superscripts are significantly different (p<0.05)
Key: NFAT=Nitrogen Fixing Albizia Trees, WAT= Weeks After Transplanting

A significant number of leaves of 15.00 was recorded from seedlings improved with leaf litters of *A. lebbeck*., while the least value of 7.50 was recorded from seedlings planted in an unamended soil (control) at 24 and 4 WAT respectively.

Table 3: Effect of leaf litters of selected nitrogen-fixing albizia trees on the number of leaves of *G. albida* seedlings

NFAT	WAT					
	4	8	12	16	20	24
A.lebbeck	8.00^{ab}	8.80^{a}	11.80^{a}	13.00^{a}	13.00^{a}	15.00^{a}
A.zygia	7.60^{b}	8.40^{a}	9.60^{c}	9.89^{c}	12.60^{a}	14.20^{ab}
A.coriaria	8.20^{ab}	8.80^{a}	8.80^{d}	9.40^{c}	10.00^{b}	13.00^{b}
A.ferruginea	7.80^{b}	9.00^{a}	11.00^{b}	11.20^{b}	12.00^{a}	13.40^{ab}
A.saman	8.60^{a}	8.80^{a}	9.60^{c}	9.80^{c}	13.40^{a}	14.80^{a}
Control	7.50^{b}	8.98^{a}	9.30^{d}	9.50^{c}	9.99^{b}	10.50^{c}
SE+	0.31	0.29	0.31	0.33	0.72	0.71
p-value	0.04	0.04	0.04	0.05	0.02	0.02

*Means on the same column having different superscripts are significantly different (p<0.05)
Key: NFAT=Nitrogen Fixing Albizia Trees, WAT= Weeks After Transplanting

A significant leaf area of 93.08cm^2 was recorded from seedlings planted in the soil enhanced with leaf litters of *A. lebbeck* at 24 WAT. The least value of 10.09 cm^2 was recorded from seedlings planted in the soil without enhancement of leaf litters of nitrogen-fixing albizia trees (control) at 4 WAT (Table 4).

Table 4: Effect of leaf litters of selected nitrogen-fixing albizia trees on the leaf area (cm^2) of *G. albida* seedlings

NFAT	WAT					
	4	8	12	16	20	24
A.lebbeck	18.75^{a}	27.37^{a}	28.47^{a}	52.99^{a}	64.08^{a}	93.08^{a}
A.zygia	16.84^{a}	21.16^{a}	21.86^{ab}	33.18^{b}	39.79^{c}	83.06^{a}
A.coriaria	19.06^{a}	27.04^{c}	29.63^{a}	40.63^{b}	55.19^{ab}	62.94^{b}
A.ferruginea	17.81^{a}	18.19^{b}	30.25^{a}	43.35^{ab}	44.60^{b}	46.42^{c}
A.saman	15.11^{ab}	20.26^{ab}	21.01^{ab}	36.72^{b}	36.82^{c}	55.91^{bc}
Control	10.09^{b}	15.11^{b}	16.53^{b}	16.80^{c}	19.30^{d}	21.00^{d}
SE+	2.35	3.03	4.11	4.73	5.62	6.54
p-value	0.02	0.03	0.04	0.04	0.04	0.05

*Means on the same column having different superscripts are significantly different (p<0.05)
Key: NFAT=Nitrogen Fixing Albizia Trees, WAT= Weeks After Transplanting

A significant total fresh weight (18.25g) and total dry weight (7.30g) were recorded from seedlings planted in the soil influenced by leaf litters of *A.lebbeck*. The least values of 2.79g and 1.25g were recorded for total fresh weight and total dry weight of seedlings planted in the soil without amendment of leaf litters of nitrogen-fixing albizia trees (control).

Table 5: Effect of leaf litters of selected nitrogen-fixing trees on the fresh and dry weight (g) of *G. albida* seedlings

NFAT	FW(g)			TFW(g)	DW(g)			TDW(g)
	L	R	S		L	R	S	
A.lebbeck	10.45^{a}	4.75^{a}	3.05^{a}	18.25^{a}	3.45^{a}	2.05^{a}	1.80^{a}	7.30^{a}
A.zygia	9.75^{ab}	2.65^{b}	3.50^{a}	15.90^{ab}	2.05^{ab}	1.07^{b}	2.00^{a}	5.12^{ab}
A.coriaria	3.40^{b}	1.15^{b}	1.00^{b}	5.55^{b}	1.35^{ab}	0.65^{b}	0.50^{b}	2.50^{b}
A.ferruginea	3.85^{b}	2.25^{b}	1.25^{b}	7.35^{b}	1.30^{ab}	1.03^{b}	0.78^{b}	3.11^{a}
A.saman	1.50^{b}	3.55^{ab}	2.10^{ab}	7.15^{b}	0.52^{b}	1.65^{ab}	1.06^{ab}	3.23^{ab}
Control	1.03^{b}	0.98^{b}	0.78^{b}	2.79^{b}	0.45^{b}	0.41^{b}	0.39^{b}	1.25^{b}
SE+	2.68	0.70	0.66	4.04	1.14	0.36	0.35	1.85
p-value	0.02	0.03	0.03	0.05	0.02	0.03	0.03	0.04

Means on the same column having different superscripts are significantly different (p< 0.05)
Key: NFAT=Nitrogen Fixing Albizia Trees, FW= Fresh Weight, TFW-Total Fresh Weight, DW=Dry Weight, TDW=Total Dry Weight, Rs=Rates, L=Leaf, S=Shoot, R=Root

Discussion

The highest growth parameters recorded from seedlings planted in the soil improved with leaf litters of *A. lebbeck* was adduced to its ability to release its rich nutrients. A similar observation has been recorded by Adelani *et al.* (2021) who recorded the highest growth parameters from *Vitellaria paradoxa* seedlings planted in the soil enhanced with *Acacia leucophloea* and linked the performance of *Acacia leucophloea* to the release of its rich nutrient for plant growth.

The excellent growth performance recorded from seedlings planted in the soil enhanced with *A. lebbek* could be traced to the release of its phosphorus content. Adelani *et al.* (2020b) reported the highest phosphorus content for *Albizia lebbeck* used to enhance the growth of *Zingiber officinale.* Phosphorus enhances seedling growth. This aligns with the report of Chotchutima *et al*.(2016) who stated that the maximum rate of P (750 kg/ha) application gave the highest *Leucaena leucocephala* height and stem diameter compared to the other rates during a 2 year study period. The observations revealed that the *Acacia auriculiformis* seedling growth was enhanced significantly with the application of P fertilizer (Uddin *et al.,* 2007).

Conclusion

The use of affordable, accessible and environmentally friendly plant based organic manure to enhance the growth of *G. albida* is important. Investigation conducted into the leaf litters of nitrogen-fixing albizia revealed that planting of *G. albida* in the soil influenced with leaf litters of *A. lebbeck* enhances its growth.

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ENGAGING LOCAL COMMUNITIES TO ENHANCE CLIMATE CHANGE MITIGATION AND ADAPTATION FOR SUSTAINABLE DEVELOPMENT

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Abstract

Climate change has come to stay and we can only look for ways to mitigate its impacts. Several approaches have been developed to address the causes, mitigate and adapt to climate change and its consequences. This paper discusses the engagement of grassroot communities as an approach to combat climate change. It addresses barriers to the successful engagement of these communities. We believe local communities possess knowledge of their environment that can tell us how to harness these environmental resources to adapt to climate change. Lots of processes are involved and lots of questions are to be answered. We explored the importance and ways of engaging the locals in decision making to mitigate climate change. The contemporary top-bottom approach is also compared with the engagement of local communities which is considered a bottom-top approach. These approaches have their merits and demerits in the decision-making process when formulating and implementing climate change mitigation and adaptation measures. Enlightenment of these local people can be improved by direct relationship and communication of opinions, to ensure that the problem of ignorance is solved by proper understanding from the side of these communities. Effective communication for resolving the problem of misinformation and misinterpretation by a larger percentage of the local communities, which is one of the major barriers to their engagement as key agent in combating climate change, is involved. It is vital to see them as important agents in combating climate change because most rural communities are at higher risk of this global threat.

Keywords: *Climate change, impacts, adaptation, sustainable development, local communities*

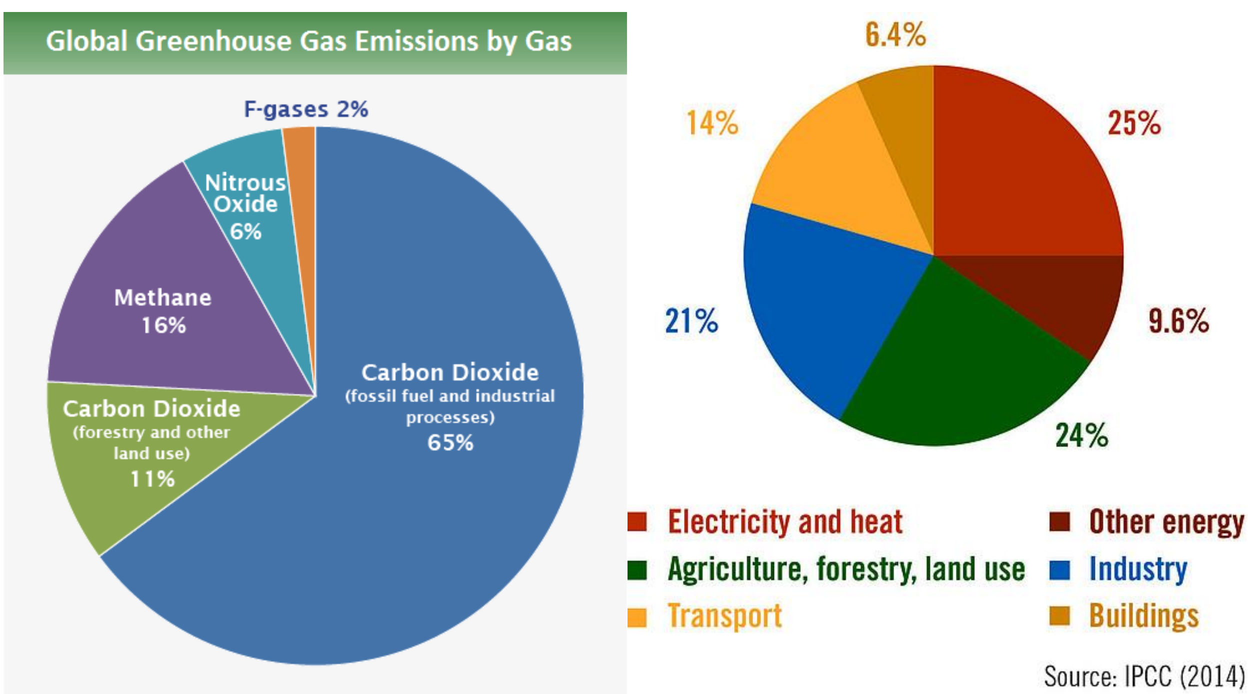
Introduction

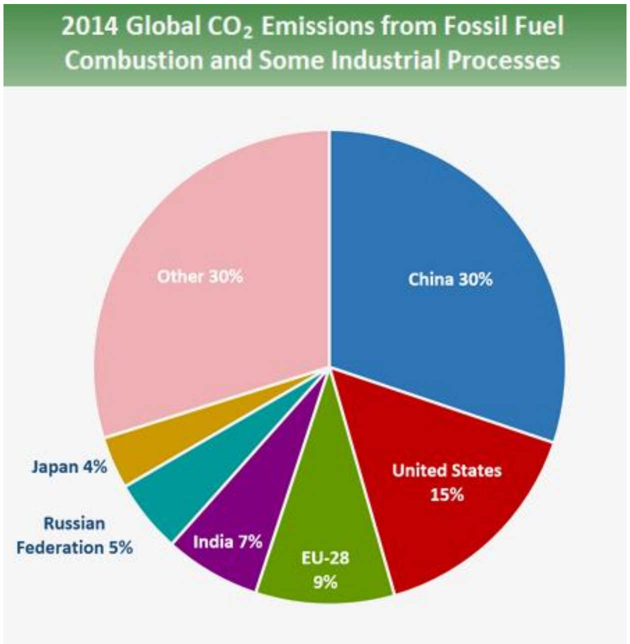
Erratic rainfall, increasing temperatures and a number of other environmental issues are rapidly emerging as one of the most serious global problems affecting many sectors in the world. These so-called environmental issues are all subsets of the biggest threat to life on Earth called Climate Change. According to United Nations, Climate Change refers to the long-term shifts in temperature and weather patterns and this can be caused by both natural and artificial events. These Natural causes includes the Earth's orbital changes, variation in solar radiation, volcanic eruptions, movement of crustal plates while the artificial causes are largely due to anthropogenic activities in terms of industrialization, changes in land use cover, deforestation, agricultural activities among the host of others. It is considered to be one of the most serious threats to sustainable development with adverse impact on environment, human health, food security, economic activities, natural resources and physical infrastructure. The impacts of climate change include severe weather conditions in terms of floods, storms, and drought, polluted air, species extinction among others. These impacts of climate change faced by different communities or regions varies depending on their geographical location, and are felt mostly by those whose means of survival is solely dependent on the resources provided by the environment otherwise known as Local Communities. The vulnerability of individuals and communities to climate change impacts is not simply dependent on the location of their settlements, but also by how those settlements are serviced, how effective and capable their local governments are and to what extent communities are able to cope with climate change impacts. The term "community" is most times loosely defined and as a matter of convenience, it is used to draw boundaries around people and links them to a particular location or territory (Agrawal & Gibson 19999; Flint *et al*. 2008; Blokland 2017), through the application of reductionist assumptions, which most times turns a spatially defined community into a homogenous group of people who share a set of norms and interests (Agrawal & Gibson 1999), the diversity of the target population and the complexity of social relations are on the whole disregarded. Thus, to accommodate diversities that may exist in the "notion" of community classification, it can be stated that a community can be homogenous or heterogenous. Homogeneous refers to a local community in which all that dwell in it hails from the same culture, ethnic group or ancestry which over the years their culture has been passed down to subsequent generations. Heterogeneous community refers to people from different cultures living in the same geographical location. A local community can also be located in rural areas or suburban areas.

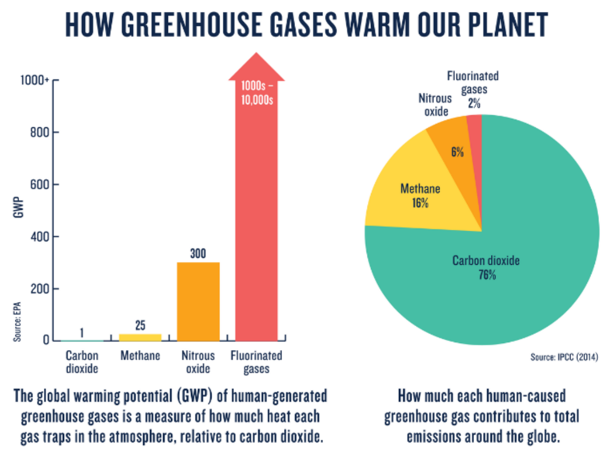
Usually, local communities are at the heart of those affected by climate change due to the fact that they live proximally to natural resources and depend on them directly for sustenance (Melillo, Jerry M. et al). As said by (Sebastian Bathiany, 2018) "those who contributes least to climate change are most affected by it" and this statement is found to be true. For rural dwellers whose occupation is majorly farming, obtaining maximum yield of their crop produce is dependent on suitable environmental factors which includes: optimum temperature, rainfall, sunlight and suitable soil. Sadly, this has been altered as a result of climate change which has inadvertently caused a wide variation in climatic and weather patterns thereby making it difficult to predict these seasonal conditions which in turn reduced their crop productivity and yield causing a decline in food production (Agbola & Fayiga, 2016). Due to this decline, the economy of the country became affected. In 2021, between July and September agriculture accounts for 30% of the Gross Domestic Product which indicates an increase by about 6% point compared to the previous quarter thereby establishing it a major source of revenue generation for the country after oil (Statista, 2022), but as a result of this global threat, the generation of revenue from agriculture is being threatened. This, in no doubt, infers that, local communities are important frontiers that needs to be considered in developing strategies to curb the effects of climate change. Although, international bodies are making efforts to involve local communities in climate change related issues such as the project called Amazonas Originaria which helped Venezuelan indigenous families mitigate the degradation of the Amazon forest. However, over the years, the awareness level is still minimal thereby making most of them ignorant of it.

Furthermore, International initiatives such as the Intergovernmental Panel on Climate Change (IPCC), United Nations Framework Convention on Climate Change (UNFCCC), The Paris Agreement spends time formulating policies on greenhouse gas emissions, climate change adaptation and mitigation strategies and climate financing. These policies when formulated are passed on to the governments who in turn force this policies down on the masses. Nonetheless, the local communities are important players in renewable natural resource management which is a key factor in climate change mitigation and adaptation; involving local communities in combating climate change will commensurate the efforts exhibited by the international bodies which means that; involving them will widen their knowledge on how the environment works, enable their involvement in setting policies to curb climate change, and proffer solutions which in turn would be a source of benefit to their well-being.
According to Indigenous People and Climate Change: from Victims to Change Agents through Work (TLO 2016), "local communities are essential to the success of policies and measures directed towards mitigating and adapting to climate change". Likewise, the Rio+20 Outcome Document of 2012 emphasized the importance of local communities in the achievement of sustainable development through developing strategies on how to curb the menacing effect of climate change in conjunction with the importance of the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) in carrying out these strategies for sustainable development. This highlights climate change as not just an environmental issue but also a social issue as its impacts is faced locally by people within a particular geographical location, besides, the adaptation and mitigation strategies used by communities depends on the resources available and joint decisions made by the members of the communities. It therefore becomes expedient to examine the roles, barriers and solutions entailing the engagement of local communities in combating climate change.

The pie chart below gives a breakdown of climate statistics







Synergy between Climate Change and Sustainable Development

Climate Change have significant impact on economic development, natural resources, and poverty alleviation, to overcome this problem, it became an integral part of Sustainable Development. It is essential for climate change to be curbed, as it is a major constraint to the development of any country. There is a dual relationship between the two concepts, on one hand, climate change affects natural systems and human living conditions on the other hand, sustainable development influences the GHG emissions causing climate change and vulnerability. (IPCC Fourth Assessment Report: Climate Change, 2007)

In the United Nations Conference on Sustainable Development called the Rio+20 Conference (held in Rio De Janeiro in June 2012), the 2030 Agenda for Sustainable Development was developed, where the Member states expressed their commitment to protect the planet from degradation and to take urgent action on Climate Change which is "one of the greatest challenges of this time" and how its adverse impacts may reduce the ability of all countries to achieve Sustainable Development. This led to the launching of the 17 Goals, of which SDG 13 aims to " take urgent action to combat climate change and its impact" with the UNFCC primary international forum to negotiate global response to Climate Change (Katowice Climate Change Conference COP24, Katowice, Poland, 2018)

Engaging the Local Communities through Awareness

Less energy is geared towards the education and awareness of the masses found in local communities compared to the energy pumped into carrying out researches that aids the formulation of policies which are used by international initiatives such as UNFCC, Cancun Agreement, Paris agreement among the host of others in developing strategies in climate change mitigation and adaptation measures thus leaving the former in the dark concerning the phenomenon called Climate change.

Research has shown that more than 6 out of 10 Nigerians' never heard about climate change and this was buttressed by (Odjugo P.A Ovuyovwiroye 2013) on a research he conducted on the analysis of climate change awareness in Nigeria. He stated that 25% of the respondent have no knowledge about climate change, 52% had little knowledge of climate change and 22% had adequate knowledge on climate change while stressing the fact that the percentage of those that are aware about climate change are mainly from the urban areas than the rural area with a statistic of 34% from the urban area and 9% from the rural areas. From this, we can cull out that a larger percentage of individuals found in the rural communities lacks awareness about climate change. The little fraction of the rural dwellers that are aware about climate change confirmed their sources to be mainly from the radio while the urban dwellers had their sources from television, radio presentations, newspapers, newsletters, journals and leaflets. Furthermore, from the statistics explained above, it can be deduced that climate change awareness is quite lacking in the rural areas and they need more enlightenment to improve their knowledge base on climate change.

Over the years, rural farmers rely on indigenous knowledge in predicting seasonal patterns in order to adjust their agricultural practices to suit these patterns. However, the tide has turned against their favor due to the turbulence caused by climate change limiting the accuracy of their prediction. In other to curb this, they need to be enlightened about climate change so as to mitigate its rampaging effect. Enlightening these people will be of utmost benefit in the aspect of decision making for their farming activities, conservation of their natural resources among others. In recent times, Farmers tend to use a combination of meteorological information and indigenous knowledge in their seasonal forecasting, as they primarily rely on indigenous knowledge but are also open to receiving scientific forecasts (Mapfumo et al., 2015; Orlove et al., 2010; Roudier et al., 2014). This trajectory of change highlights how farmers in a study conducted in West Africa more than a decade ago entirely relied on their experience and intuition to make decisions on their farms in a given season (Hansen, 2002) to currently where they make use of a combination of indigenous and modern forecasts in parts of southern Africa (Mapfumo et al., 2015). Climate information appears to be particularly important and in many cases a prerequisite for coping and adapting to the negative impacts of climate variability and change, given that most of the rural livelihoods in southern Africa depend on climate and environmental dynamics (Goddard et al., 2010). What is emerging from a number of studies is that farmers tend to make decisions on farming practices based on potential evidence of climate occurrences, particularly in relation to rainfall patterns (Goddard et al., 2010; Mapfumo et al., 2015; Roudier et al., 2014). Studies further highlight that farmer crop management strategies (planting time, weeding, fertilizing, application of pesticides) are shaped by predictive climate information, particularly rainfall related forecasts (Moeletsi et al., 2013; Roudier et al., 2014).

Causes of the lack of climate change awareness hindering the active engagement of local communities

The causes can be summarized into three distinct yet interwoven parts, which are; lack of amenities, religious beliefs and ignorance. Lack of social amenities in terms of electricity is a major challenge in rural communities. A minor sect of the rural communities has access to electricity and majority of those that have electricity do not possess television, leaving those without electricity to depend on their radio. As a result of this deficiency in information, the rate of ignorance about climate change became a wide gap among rural communities and this gap needs to be breached. It is worthy of note that most elements of delivering information, the media-print or electronic media depend on a power source to disseminate information. These power source can either be electricity, fossil fuels or simple batteries, but these are deficient in rural areas. Thus, putting them in the dark. The only way they have access to information is through community gossips or when they meet at local gatherings such as local market.

Lastly, the strong mythical and superstitious belief of the local people stands as an obstacle for them to believe in the effects of climate change. Although, they are well aware of the changes in climatic and weather patterns, they never attribute these changes to climate change. Rather, they believe these changes are a result of the reoccurring and unpardonable acts of man towards God. These acts include; man's greed for wealth, human trafficking, corruption from the government, kidnapping and money rituals. They hold on to their belief that God needs to be appeased for these changes to be abated.

How do we resolve this issue?

We must understand that creating awareness or enlightenment of our local communities is way beyond carrying placards and organizing rallies parading the streets. Although, this helps in the promotion of publicity but it does not actually inform them about what is needed to know. Most of the inhabitants of these local communities are not literates, a higher percentage of the people in local communities are illiterates; they can neither read nor write. How then can they read or interpret what is on a placard or a poster? Most times, when campaigns/rallies take place, these rural dwellers are fascinated and might show enthusiasm in joining in the fun fare (as they see it) rather than finding out what exactly is the campaign for. Perhaps, they get a literate to give a detailed explanation about what the rally is set to achieve, the person who receives the first-hand information may exaggerate or subtract as he passes it down to others, this process goes on and eventually may lead to misinterpretation of the original information reaching the larger proportion of the local people.

One approach that can be adopted to solving this is direct relationship, connection and interaction with the community head or a respectable figure that the members of the community hold in high esteem, also known as Opinion Leaders. Throughout the diffusion of information process, there is evidence that not all individuals exert an equal amount of influence over all individuals. Opinion Leaders have the most influence during the evaluation stage of the innovation-decision process (Rogers, 1976). In addition, opinion leaders have a set of characteristics that set them apart from their followers and other individuals. They typically have greater exposure to the mass media, more cosmopolitan, greater contact with change agents, more social experience and exposure, higher socioeconomic status, and are more innovative. The opinion leaders don't necessarily have to be the ruling leader in the community, it can be individuals within the community that have influence on the people in the community. Such a person together with the existing stakeholders in the community will know how to pass information across to the locals on climate change. . .

Also, another approach is the participation and involvement of local community members in the communication process, decision strategy and implementation on how they can collectively combat climate change. It is not enough for people to know about climate change in order to be engaged, they also need to care about it, be motivated and be able to take action. It is imperative for effective communication and participation of all stakeholders be carried out for the local communities' strategies to be productive. This strategy should be all round inclusive; provision of necessary information for proper understanding among all important stakeholders to make sure that everyone is involved in the decision-making at household, local and global level. This can be achieved through roundtable discussion, dialogue, debate, public meetings, stakeholder forums / advisory groups, submissions and comments on district/regional plans and community workshop (Barth et al). Environmental solutions that come alive by engaging local communities are most likely to be successful compared to policies made by environmental offices and international initiatives. When community dwellers are involved in decision making, they feel more involved and have a sense of belonging to the whole concept rather than ideas that seems imposed on them. This will also make the proposing stakeholders penetrate the community easily and make the process of implementation smooth especially when emphasis is made on incentivization and improving their standard of living. To ensure proper implementation and substantial result of solutions, there should be effective communication between stakeholders and the locals to ensure both parties understand what is at stake and avoid assumptions. The locals are most times not used to technological approach of solving problems, therefore, stakeholders should ensure their proposals are done in simple, understandable form to ensure their comprehension of the proposed invention. This will enable the locals to consecutively give their advice at every stage of implementation as they have better indigenous knowledge of the locality and will be the guardian of the invention afterwards.Although, members of local communities devise means of coping with climate crisis based on indigenous knowledge, the methods are not so effective because what the local people have been using is also becoming unreliable due to climate change. . For example, Coffee cultivation in Uganda was not common until the 1940s, and so the habit of observing the flowering of the coffee tree as a sign for the onset of the rain must have developed after this time (Orlove et al., 2010). Signs that there will be rains in a few weeks include the flowering of trees, especially coffee trees in Uganda (Orlove et al., 2010). Hence, the shifting of tree fruiting patterns is likely to render this indicator less reliable. Integration of indigenous knowledge and scientific seasonal forecast seems to be a key possible thrust to reduce vulnerability, enhance resilience of indigenous communities and increase their adaptive capacity. The indigenous knowledge provides a crucial foundation for community-based adaptation and mitigation actions if successful synchronized with relevant skills and science-based innovations e.g., planting of tree species that are flood tolerant at specific sites and at the same time will still be able to serve the local communities benefits e.g., fodder for livestock, edible fruits and seeds, etc.

Lastly, international bodies should adopt a bottom-top approach by having direct relationship with the local communities, this way, they can understand the issues of climate change each locality is facing and track their progress which will in turn help the organisational bodies to document their strategies which can serve as models for other communities. Before the popularization of making use of community-led initiatives which is a bottom-top approach, contemporary policy implementation which most times involves impractical technologies encourages little or no consultation of the community, which results in ideas being enforced on them was the major trend of combating climate change- top bottom approach. Compared to this top-bottom approach, community-led initiatives create room for understanding the impacts of climate change, consultation with the community, reduction in risk of failure of policy implementation and increased trust between proposing stakeholders and the locals. According to Bulkeley et al. 2013; Holland 2017, the 'bottom up' approach which involves decision being agreed upon first by the local communities before going up to the government was recommended instead of the usual 'top-bottom' approach because government policies are imposed without considering the specificities of place, use of indigenous knowledge and little to no consultation of the locals which creates resistance in local communities who should be part of the decision making. A method only outweighs the other depending on the situation and community to be penetrated. However, both methods can still be combined for the greater cause of combating climate change. The incorporation of local knowledge with the scientific method on the issues relating to climate change has helped over the years according to various research in restoring the planetary health such as rehabilitation of lost habitat, prevention of siltation in water bodies and so on, thus, reducing the risks that climate change can bring, not only on the present generation but also on the future generation.

Conclusion

Engagement of local community as a major means of combating climate can never be a wrong approach because of their invaluable contribution to the society and even to the global world at large. Appropriate approach and strategies in enlightening the local communities as highlighted in this paper should be adopted to eradicate the menace of ignorance, misinformation and superstitious belief about climate change. Effective communication with the stakeholders of the community such as the opinion leaders will go a long way in reaching out to the members of the community and ensuring their unflinching participation in the decision making process. Likewise, international bodies should strongly recognize every local community, their request, suggestions, inputs, and contributions as this might be put together to help in their policy formulation and serve as models for future reference.

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ECOTOXICOLOGY AND ITS EFFECTS ON THE QUALITY AND QUANTITY OF FORESTS AND FOREST PRODUCTS

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Abstract
Ecotoxicology is an important aspect in sustainable development providing knowledge that helps in improved preservation and productivity of environment. The abundance of forest ecosystems is of utmost concern because of the benefits derived from forest resources such as timber, firewood, wildlife habitat, soil and water protection, and refuge from environmental stress. Air pollution is one of the important pollution that causes havoc to forest trees. The injury caused by air pollution is so enormous to the extent that it damages the tree living tissue, affects photosynthetic activities and respiration ability. Air pollutants make the trees weak, predisposing them to more attacks by insects and disease. Plants that absorbed pollutants becomes harmful affecting the abundance of forest resources. The impact of some air pollutants can make the plants to become unhealthy affecting their normal physiological processes such as soil chemistry and nutrient cycling. This may account for impaired growth and reduced tree efficacy that can lead to tree mortality causing low abundance of tree resources. This paper compiles past literatures on air pollution and how much it affects the quantity and quality of forests and their products. Appropriate recommendations to protect forests were made.

Keywords: *Air, Pollution, Forest, Ecotoxicology, Ecosystem.*

Introduction

A world without forest is unimaginable, forests provide a lot of benefits at the local, national and global levels; forest resources is an integral part of natural resource based of any community, region or country and they increase socio-economic well-being of the people of those communities (Sheil, 2013). Most rural farmers especially in sub-Sahara Africa depend on natural resources gotten from the forest for their source of income (Amulya, 2015). Forest is known to provide food, medicine, timber and many other products, it also plays protective roles against soil erosion, drought, floods, and intense radiation. In addition of the performance of other functions like recreation and aesthetics centres as well as housing for different wildlife (Anjaneyulu, 2005).

*The efficient use of forest ecosystem depends not only on the forest quantity, but also on the forest quality (*Garcia *et al.*, 2020*). There is utmost need to sustain the forest management in order to improve forest quality which in essence will improve the forest quantity over time (Kumar* et al; *2013). Ecotoxicology is the study of environmental pollution that poses* toxic effects of chemical and physical agents on living organisms, especially on populations and communities within defined ecosystems like forest (Butler, 1978). The effects of pollutants on trees in one way or the other affects the value and abundance of forest resources (Christopher & Wayne, 2005).

Forests especially on high altitudes are often faced with serious effects of air pollutants. The harmful effects of air pollution on forests were identified for quite a number of years, there were several issues recognized and prevalent on forest damage (Lorenz *et al*., 2010).

Air pollutants that affect forest quality and quantity

Air pollution occurs as a result of emissions of its pollutants, the main air pollutants involved in forest damage are sulphur compounds, nitrogen compounds, ozone, and heavy metals; they react in the atmosphere with water, oxygen, and oxidants to form various acidic compounds (Gheorghe & Ion, 2011). The chemical compounds affect the chemistry of water and soils predisposing them to environmental stressor (Ashraf *et al.,* 2014). The particles occur in dry which fall to the ground or can be in wet form dropped to the ground as rain, snow, and fog; they destroy their leaves by reducing the nutrients available to them, or gradual exposure of the soil to toxic substances (USDA, 2021).

Air pollution damage and their effects on forest trees

The damages caused by air pollution can affect the tree slowly or becomes visible with immediate effect and become permanent resulting to decrease in number of trees in the forest (Gheorghe & Ion, 2011). The symptoms of tree damage occurs first in the foliage; changing the leaf pigmentation, patches between the veins or the tips swindled (Christopher & Wayne, 2005). The risk poses by air pollution injury is hard to identify because they are quite similar to the signs of nutritional deficiencies and drought plants (Clattebuck, 1999).

Air pollutants may affect trees in two ways;

1) The wet deposition
2) The dry deposition

The wet deposition involve the rain, hail, and snow, and at high percentage determined by atmospheric activities while the dry deposition involve gases, aerosols, and dust, and mostly affected by physical and chemical composition of the receptor surface (Lorenz *et al.*, 2010). There is usually larger deposition in forests than open spaces based on the species of the tree and the composition of the canopy (Erisman & Draaijers, 2003). Factors such as leaf area index, shape of leaf, leaf surface roughness, and size of the stomata determines pollutants intercept by the foliage. A canopy with a high degree of roughness results to increase air turbulences which creates more relationship between the air and the foliage (Nowak *et al.*, 2000). The dry deposition absorbed by the foliage is later washed off by precipitation to encourage the deposition under the canopy (throughfall) (Balestrini *et al.*, 2007). The throughfall is largely determined by canopy leaching and canopy uptake of elements (De Schrijver *et al*., 2007). Over the years, sulphur dioxide (SO_2) emission and deposition of acids has greatly decreased forest areas around the world (Bytnerowicz *et al.,* 2007). It is present in the air by fossil fuels burning directly damaging trees through their foliage; the foliar damage results in loss of chlorophyll and also disrupts photosynthesis (Sha *et al.*, 2010) (Figure 1). High concentration of sulphur dioxide reduces tree growth in that it reduces the stem diameter and height leading to physical damage of needles and leaves (Dincer *et al.*, 2003). Nitrogen oxides (NO_2) are also introduced into the air during various burning processes when nitrogen (N) in the air is modified mainly to nitrogen monoxide (NO), and reduce nitrogen dioxide (NO_2) (Klimont *et al.*, 2001). During the day, NO is converted easily to NO_2 by photochemical processes involving hydrocarbons present in the atmosphere, both gases, especially NO, are also formed biologically by soil bacteria during nitrogen cycle (FinlaysonPitts & Pitts 2000). They *endanger* trees as dry deposition directly via the foliage (Lorenz *et al*., 2010).

Figure 1: Foliage injury caused by sulphur dioxide (Canadian Forest Services)

Another pollutant that poses the most toxic effect on forest ecosystems is ozone, it is found in photochemical smog produced by conversion of its precursors (nitric oxides, organic compounds and carbon monoxide); it affects various physiological processes, especially photosynthesis and water absorption in plants, (Baciak *et al.*, 2015). High ozone concentration decreases the rate at which forests absorb carbon dioxide (Karlsson *et al.*, 2006).
The effects of Ozone, SO_2, NO_2, and Ammonia are direct which include visible leaf damage, decrease in the number of needle age classes in conifers, and increased pollutant concentrations in plant tissues causing falling off of leaves (Legge & Krukpa, 2004). Indirect damage is caused by the toxicity of air pollutants through soil-mediated processes which results to soil acidification, leaching of base cations, thereby producing toxic species of aluminum (Al) (Gbondo-Tugbawa & Driscoll 2002). Atmospheric pollution results to imbalances in uptake of nutrients and water, increased predisposition to frost, droughts and diseases (De Vries, 2021). Snoeijers *et al.*, (2000) highlighted that the damages posed by increased deposition of nitrogen causing plant disease is still understudied whereas studies have shown foliage to increase bacterial and fungal diseases (Deveau *et al.*, 2018).
Emission of greenhouse gases for example carbon dioxide, methane (CH_4), and nitrous oxide (N_2O) produced naturally and through human activities, are dangerous to forest health. They affects forests directly or indirectly through the foliage or the soil respectively (Wu *et al.*, 2019). The sensitivity of forest trees to pollutants in the air is very high, especially sulphur dioxide (SO2), nitric oxides and ozone (O3) disrupt their growth and make them susceptible to insect attacks (Paoletti *et al.*, 2010).

Conclusion and recommendation

Air pollutants disrupts good tree conditions, tree physiology, and biogeochemical cycling; making trees susceptible to insects and diseases causing tree death hereby reducing the high yield value of forest resources. Air pollution destroys forest ecosystems over an area of 39000 km^2 indicating a low forest quantity. The abundance of forests decreases over significantly larger areas due to the effects of damages caused by air pollution in addition with other factors, such as fires, fungal diseases, and insect attacks. Air pollutants do not only cause visible damages but adversely affect growth, yield, and quality of forest products. More awareness should be created on the damages to forest caused by air pollutants which should enhance more research and monitoring for possible air pollution controls. Researches on different concentrations of air pollutants should be conducted in different forest layers.

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CONTRIBUTION OF AGROFORESTRY PRACTICES TO RURAL HOUSEHOLD FOOD SECURITY STATUS IN CHIKUN LOCAL GOVERNMENT AREA OF KADUNA STATE

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Abstract
Agroforestry is crucial to economic growth, its practice is a powerful tool that can be used to end extreme poverty and enhance food security of the household. The study assessed the roles of agroforestry practices to rural household food security status in Chikun Local Government Area (CLGA) of Kaduna State. Fifty percent of the twelve (12) wards in Chikun LGA were randomly selected. One village was randomly selected from each ward to give a total of six villages. Twenty rural households were randomly selected from each village to give a total of one hundred and twenty (120) respondents. Data were collected using structured questionnaire and analyzed using descriptive statistics. Chi-square was used to test the hypotheses. The study revealed that the mean age of the respondents was 34.0 years. Majority (71.1%) of the respondents were married, most of the respondents (68.3%) were Christians. Chi-square analysis revealed that age (χ^2 = 25.473 p = .001), religion (χ^2 = 17.722, p =.002), household size (χ^2 = 28.923, p = .004) and source of land (χ^2 = 73.216, p = .000) had significant relationship with household food security status. The agroforestry practices were aquaculture, alley farming and apiculture respectively. Bad road network, insecurity issues and lack of technical know-how were the constraints to agroforestry practices. This study recommends that there should be good road network to rural communities to improve the movement of forestry produces and adequate security should be provided to protect the lives and properties of the people.

Keywords: *Contribution, Agroforestry practices, Rural household, Food security, Kaduna*

Introduction
Agroforestry can be defined as a system of land use where trees are deliberately planted into the same land management unit along with annual agricultural crops and/or animals synchronously with the aim of getting diverse outputs on a sustained basis (Kang, 2011; Huxley and Ranasingher, 2016). It is also described as the combination of trees with annual crop cultivation, livestock production and other farm activities. It is a series of land management approaches practiced by many people in the world and provide a wide variety of products and services that are important locally, nationally and globally. However, much attention has not been paid to their roles and acknowledged adequately in development policies and practices by which they affect the society at large (Sileshi *et al*., 2010). Agroforestry practices, also promote the diversification of production system and interaction of resource conservation, improvement and sustainability, which contribute a lot more to the livelihood of the agrarian community as it assigns a pivotal role in efforts to ensure household food security (Alexandratos, 2015).
Household food security is simply described as the availability of food within the household and everyone's access to it; a household is considered food secure when its occupants do not live in hunger or fear of starvation., household food security exists when all people within the household at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (Joseph, 2014; FAO, 2016). Lack of access to food remains a major concern for numerous rural households in Nigeria who rely on agriculture as their main source of livelihood (Kebebew *et al*., 2013; FAO, 2016). Rural household food security status depends on their food production and efforts to produce enough food are hindered by various factors such as; unpredictable rainfall, a major issue among others and high population density that puts a lot of pressure on land as more of it is required for settlement, leading to land fragmentation, hence, negative effect on food production and resulting in food insecurity (Musotsi *et al*., 2018). Agroforestry practices increases food productions and enhanced better life for the people. It is therefore important to investigate the roles it plays in household food security (Brusal, 2015). The objectives of the study are (i) describe the socio-economic characteristics of rural households in CLGA of Kaduna state (ii) identify types of agroforestry practices by rural households (iii)describe the household food security status and identify constraints of agroforestry practices by rural households CLGA of Kaduna state.

Hypotheses
H_{01}: There is no significant relationship between socioeconomic characteristics and household food security status.
H_{02}: There is no significant relationship between agroforestry practices and household food security status.
H_{03}: There is no significant relationship between constraints to agroforestry practices and household food security status.

Materials and methods

The research was conducted in Chikun Local Government Area (CLGA) of Kaduna State. It covers an area of about 445,659 km and the geographical coordinates are 10° 16' 0" North, 7°6' 0" East. CLGA is situated in Northern Guinea Savanna Zone. It shares boundaries with Igabi and Kaduna South LGA to the North and with Kajuru to the East, Birnin Gwari and Giwa LGA to the West and Kachia LGA to the South. The ethnic groups comprise Gbagyi predominantly, Hausa, Kataf, Igbo, Fulani and Yoruba. The main occupation is farming; crops cultivated include rice, yam, maize, guinea corn, millet and cassava, while animals such as goats, sheep and cows are reared. A multistage sampling technique was employed. The first stage involved purposive sampling of six (6) rural wards which include; Nasarawa, Maraban Rido, Danbushiya, Sabon Gayan, Kujama, and Kudandan out of the twelve (12) wards in the study area. In the second stage, twenty (20) households that were into agroforestry practices were purposively selected because of the focus of the study. This gave total of one hundred and twenty (120) respondents. Primary data were collected using well-structured questionnaires. Personal interview were conducted for farmers who can neither read nor write. Simple descriptive statistics was used to achieve the objectives of the study, while Chi-square was used to test the hypotheses. The Household Food Insecurity Access Scale (HFIAS) (FANTA Scale) of the United States Agency for International Development (USAID) (2007) was used to categorize households. The HFAIS Score was calculated for each household by summing the codes for each frequency of occurring item. The maximum score for a household is 27 while the minimum is 0. The higher the score, the more food insecurity (access) the household experienced while the lower the score, the less food insecurity (access) a household experiences.

Results and discussion

Socio-economic characteristics of respondents

The highest (39.2%) of the respondents are within the age of 21-30 years (Table 1), this implied that the majority of the respondents were in their youthful age and very energetic to carry out agroforestry practices so that, they can provide adequate food and nutrition for their households. This agreed with the report of Ogunjobi *et al*., (2008) which stated that people within this age group are agile and strong to carry out farming operations; hence their involvement in agroforestry practice can serve as employment opportunities and generate means of livelihood for rural households. Table 1 also showed that some (45.0%) of the respondents had household size of 6-10, it was observed that large household size is necessary in order to satisfy labour requirement on the farm. On the other hand, a large household size will increase household consumption expenditure which will compete with the money the farmer would use for other production purposes (Azeez, 2012). Table1 further revealed that most (35.8%) of the respondents purchase the land they use for agroforestry practices for their household, some (29.2%) of the respondents inherited their land, some others (19.2%) go for rent, about (11.7%) of the respondents obtained their land through gift while very few 4.2% were leasehold respectively.

Table 1: Distribution of respondents based on socio- economic characteristics

Variable	Frequency (N=120)	Percentage
Age		
> 20	5	4.2
21-30	47	39.2
31-40	29	24.2
41-50	24	20.0
50 and above	51	12.5
Household size		
1 – 5	24	20.0
6 – 10	54	45.0
11 – 15	23	19.2
16 – 20	10	8.3
20 and above	9	7.5
Monthly income		
₦10, 000 and below	34	28.3
₦11, 000 - ₦20, 000	25	20.8
₦21, 000 - ₦30,000	34	28.3
₦31,000 - ₦40, 000	9	7.5
₦41, 000 and ₦50,000	5	4.2
₦50,000 and above	13	10.8
Source of land		
Purchased	33	35.8
Rented	23	19.2
Inherited	35	29.2
Leasehold	5	4.2

Gift	14	8.3

Source: Field survey, 2021

Distribution of the respondents based on types of agroforestry practices

Table 2 showed the types of agroforestry practices that rural households were involved. The majority (96.7%) of the respondents practices the aquaculture system of agroforestry practices, which involved planting trees around fish ponds in other to provide fodder and herbivorous fish. The majority (95.8%) of the respondents were practicing Taungya system of agroforestry, this implies that nowadays rural household embraces food crops and inter-planted with the trees in the same piece of land, which causes an increase in food supply to their households, and most (92.5%) of the respondents were practicing alley farming and apiculture respectively. This result agreed with Shilabu, (2018) that aquaculture system of agroforestry increases rural household income and also provides food and shelter which serve as food security to the household.

Table 2: Distribution of respondents based on their agroforestry practices

Agroforestry practices	Frequency	Percentage %
Taungya	115	95.8
Aquaculture	116	96.7
Apiculture	111	92.5
Alley farming	115	95.8

Source: Field survey 2021

Distribution of respondents based on food insecurity status

There are several factors that may be responsible for household food insecurity. However, inability to access adequate food due to insufficient funds is one of the major factors. Table 3a showed that some (64.2%) of the respondents worry about food and (55.8%) of the respondents were hindered from eating the kind of foods they wanted due to lack of resources. Few of the respondents (49.2%) eat few foods due to the lack of resources to eat enough foods. The implication of this is that rural household experiences a shortage of food (food insecurity) because of the lack of resource to them. Table 3b showed that the majority (75.80%) of the respondents were mildly food insecure, they emphasized that they were unable to eat preferred food or take a more monotonous diet than they desired. Only a few (9.12%) of the respondents were food secure and there were no cases of severely food insecure households. Agroforestry practices contribute to the quantity and quality of rural household diet through the provision of a variety of food items, income, medicine and employment.

Table 3a: Distribution of the respondents based on their food security status

Household food security	Yes	No	Rarely	Sometime	Often	Remark
1. In the past four week did you worry that your household will not have enough food to eat?	70(64.2)	43(35.8)				
How often did this happen?			86 (71.7)	24(20.0)	10 (8.3)	
2. In the past four weeks did you or any household member not able to eat the food you prefer because of lack of resources?			49(40.8)	71(59.2)		
How often did this happen?			54 (45.0)	48(40.0)	18 (15.0)	
3. In the past four week did you or any household member have to eat a limited variety of food due to lack of money to purchase food?	67 (55.8)	53(44.2)				
How often did this happen?			63 (52.5)	38(31.7)	19 (15.8)	
4. In the past four weeks did you or any household member have to eat food that you really did not want?	62(51.7)	48(3)				
How often did this happen?			48 (40.0)	38(31.7)	34(28.3)	
5. In the past four weeks did you or any household member have to eat fewer meals in a week because there was not enough food?	59(49.2)	61(50.8)				
How often did this happen?			40 (33.3)	48(40.0)	32 (26.7)	

Household food security	Yes	No	Rarely	Sometime	Often	Remark
6. In past four weeks was there ever no food to eat of any kind in your household because of lack of resources to get food?	87(72.5)	33(27.5)				
How often did this happen?			63(52.5)	38(31.7)	19(15.8)	
7. In the past four weeks did you or any household member not able to eat the food you prefer because of lack of resources?	70(64.2)	43(35.8)				
How often did this happen?			86(71.7)	24(20.0)	10(8.3)	
8. In the past four weeks, did you or any household member have to eat some foods that you really did not want to eat because of lack of resource to obtain other types of food?			49(40.8)	71(59.2)		
How often did this happen?			54(45.0)	48(40.0)	18(15.0)	
9. In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	67 (55.8)	53(44.2)				
How often did his happen?			63(52.5)	38(31.7)	19(15.8)	

Table 3b: Distribution of the respondents based on the household food security status

Food security status	Frequency	Percentage (%)
Food secure	10	9.12
Mildly food insecure	91	75.80
Severely food insecure	19	15.08
Total	120	100

Source: Field survey, 2021

Distribution of respondents based on constraints to agroforestry practices

Table 4 showed the constraints faced by rural households in agroforestry practices. The majority (95.8% and 95.8%) of the respondents faced problems of unpredictable rainfall and high cost of land for tree planting, most (88.3%) of the respondents had inadequate seeds, the seed is limited in their rural households to plant and used of agroforestry trees species to be incorporated with crops, some (75.8%) faced problems of the high cost of labour, while others (66.7% and 59.3%) of the respondents had challenges of technical know-how and insecurity to contend with. This implied that unpredictable rainfall and high cost of land for tree planting are the major constraints facing the agroforestry system by rural households in the study area.

Table 4: Distribution of respondents based on constraints to agroforestry practices

Constraints	Frequency	Percentage %
Unpredictable rainfall	115	95.8
High cost of land	115	95.8
Inadequate seeds	106	86.3
High cost of labour	91	75.8
Technical know-how	80	66.7
Insecurity/kidnapping issues	71	59.2

Source: Field survey, 2021

Test of Hypotheses

Chi-square analysis on Table 5 revealed that age (χ^2 = 25.473, p = .001), education (χ^2 = 18.937, p =.015), religion (χ^2 = 17.722, p =.002), household size (χ^2 = 28.923, p= .004), other income generating activities (χ^2 = 18.101, p =. 001), monthly income (χ^2 = 55.517, p= .003) membership in organization (χ^2 = 43.120, p= .000), source of labour (χ^2 = 12.213, p =. 016), source of capital (χ^2 = 31.216, p =. 002), and source of land (χ^2 = 73.216, p= .000) were significant to household food security status. The null hypothesis which states that there is no significant relationship between the selected socio-economic characteristics and agroforestry practices is hereby rejected. The implication of this is that age plays a significant role in agroforestry practices, at a young age they are very strong and energetic. Religion also improved and allow rural households to participate in agroforestry practices, farmers who belong to religious groups obtained seeds, fertilizer and also income to rural households. Size of households also contributes and boost level of agroforestry production among rural households, larger households' size supports their farming household regularly than smaller households. Land is a major factor to agroforestry farmers, land successfully contribute to about 90% agroforestry practice where most of the rural household farm using simple and local farm toots, land play a vital role in assisting household food security status.

Table: 5 Chi-square analyses on the socio-economic characteristics and agroforestry practices

Variable	χ^2	df	p-value	Remark
Age	25.473	8	0.000	S
Religion	17.722	2	0.002	S
Household size	28.923	8	0.000	S
Source of land	73.216	8	0.000	S

Source: Field survey, 2021

Chi-square analysis between agroforestry practices and household food security status

Table 6 showed that, significant relationship exists between agroforestry practices -alley cropping (χ^2 = 27.735, p = .000), alley farming (χ^2=11.771, p=.003) and household food security. This implied that rural households involved into alley farming and alley cropping as a means of their livelihood. Therefore, the null hypothesis which stated that there is no significant relationship between agroforestry practice and household food security status is hereby rejected.

Table 6: Chi-square analysis between agroforestry practices and household food security of the respondents

Agroforestry practices	χ^2	df	p.value	Remark
Taungya	1.663	2	0.435	NS
Aquaculture	1.319	2	0.517	NS
Apiculture	3.101	2	0.212	NS
Alley cropping	27.735	2	0.000	S
Alley farming	11.771	2	0.003	S

Source: Field survey, 2021

Chi-square analysis between constraints and household food security status

Table 7 showed a significant relationship between some identified constraints to agroforestry practices such as bad road network (χ^2 = 10.419, p = .005), technical know-how (χ^2 = 21.826, p= .000), farm mechanization (χ^2=10.751, p=.005), insecurity (χ^2 =6.341, p=.042) kidnapping (χ^2 = 7.231, p=.027) and household food security. This implied that rural household faced problems of bad road network which make it difficult for rural households to move their good and service from one place to another, this could also reduce the activities of agroforestry practice in the study area, technical know-how affect rural household, this is another major problems of agroforestry practice because they are not fully well trained and equipped with agroforestry practice and techniques that will harness massive production from their farms. Thus, the null hypothesis which stated that there is no significant relationship between constraints to agroforestry practice and household food security status is hereby rejected.

Table 7: Chi-square analysis of constraints to agroforestry practice and household food security

Constraints	χ^2	df	p.value	Remark
High cost of land	1.663	2	0.435	NS
Bad road network	10.419	2	0.005	S
Technical know-how	21.828	2	0.000	S
Farm mechanization	10.751	2	0.005	S
Insecurity	6.341	2	0.042	S
Kidnapping	7.231	2	0.027	S

Source: Field survey, 2021

Conclusion

The study concludes that age, religion, household size, and land were significant to household food security status. Alley cropping and alley farming were the two types of agroforestry practices engaged by the respondents which are significant to food security. Few of the respondents were food secured and no cases of severely food insecure household. Bad road network, insecurity and lack of technical know-how were the significant constraints to agroforestry practices.

Recommendations

Based on the findings of the study, the following recommendations were made;

i. The respondents should be encouraged to practice agroforestry, this will enhance the food security of the rural households

ii. There should be good road network to rural communities to improve the movement of forestry, agricultural inputs and produces from one location to another.

iii. Adequate security should also be provided to protect the lives and properties of the rural households in the study area.

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GROWTH AND YIELD RESPONSES OF *Pleurotus ostreatus* (Jacq. Ex Fr. P.Kumm) CULTIVATED ON SELECTED WOOD RESIDUES

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Abstract
The study evaluated the growth, yield and the antioxidant potentials of Pleurotus ostreatus grown on the wood residues of Tectona grandis, Albizia zygia, Swietenia macrophylla and Terminalia superba. Complete Randomize Design (CRD) method was adopted and replicated 7 times, data collection was initiated one week after inoculation and was done every week for a period of four weeks. Parameters measured include mycelia growth, height, weight, tips (Diameter of pileus) and the phytochemical composition of the mushroom. Analysis of Variance (ANOVA) was used to test the data collected. Least Significant Design (LSD) at 5% level of probability was used to separate means. The result indicated that the mycelia growths were completed within four weeks, Terminalia superba recorded the highest for the mycelia growth, total phenolic, saponin, alkaloid and lowest in flavonoid while Albizia zygia substrates recorded the highest mean value for diameter of pileus, total mushroom yield, flavonoid, tanning and lowest in total phenolic. Tectona grandis recorded highest height, least in saponin and alkaloid while Swietenia macrophylla recorded least tannin. The wood residue of Terminalia superba and A. zygia recorded the best among the four treatments. Using A. zygia and T. superba as substrates in cultivation of mushroom supports maxima growth and yield.

Keywords: *Antioxidant potentials, Growth, Pleurotus ostreatus, Wood residues, Yield*

Introduction

Mushrooms are the fruiting body of macro fungi (i.e. *Basidiomycota*). The life cycle of mushrooms can range between 1-2 days and up to many years, the mycelial network of fungal species can exist for up to hundreds or thousands of years. Maria *et al*., (2015) documented that mushrooms have been consumed since earliest history, ancient Greeks believed that they provided strength for warriors in battle, and the Romans perceived them as the food of the gods.

Mushrooms are reliable source of nutriments and their protein is between the well known animals and vegetables (Girma and Tasisa., 2020). Mushrooms have played crucial parts as human cuisine due to their nutritional and medicinal properties. Several species of oyster mushroom can be grown on lignocelluloses, plants and agricultural wastes (Biswas and Biswas, 2015).

Based on their chemical composition and benefits, mushroom can be classified as poisonous and edible, where edible mushroom can also be categorized into those collected from the wild and the already cultivated edible mushrooms. Krishnamoorthy (2014) added that mushrooms epitomise an essential parts of human nourishment, and recently the amounts of feeding have escalated due to it high nutritional value, market expansion, changing of consumer's behavior and development. Dipan *et al.*, (2018) reported that mushrooms are expressed as essential nutriment, which can provide care insurance beyond the traditional nutrients they contain. Oyster mushrooms are one kind of edible saprophytic fungi growing on dead organic matters of vegetative origin belonging to the genus *Pleurotus* under the class Basidiomycetes (Grabarczyk, *et al.*, 2019). Oyster mushrooms can be grown on various wood residues with the use of different technologies. They are appetizing with fan shaped pileus which is essential source of small and large nutrients. Oyster mushroom has no starch, low sugar content and high amount of fiber, hence it serves as the least fattening food (Girma and Tasisa., 2020). Oyster mushrooms is nutritious with fat (2-5%), minerals (potassium, phosphorus, calcium, sodium) of about 8-12%, mycocellulose (7-38%), sugars (17-47%) and dried protein (25-50%). Recently, its significance has been realized and well utilized in human diet, livelihoods can be refined because the request for mushroom has escalated due to population increase, booming market and changing of consumer attitudes (Celik and Pekker, 2009).

Finimundy *et al.*, (2013) reported that more than 100 medicinal functions and uses are attributed to mushrooms including; antioxidant, anticancer, antidiabetic, anti-allergic, immune modulating, cardiovascular protector, anti-parasitic, antifungal, have detoxification, and hepatoprotective effects. Adebayo and Oloke, (2017) added that they also hinders tumor development and inflammatory processes in humans.

There are numerous species of *Pleurotus* recognized and are suitable for cultivation, some of them are *P. ostreatus*, *P. florida P. sajor-caju, P. eryngii* (Nadir *et al.*, 2016). However, *Pleurotus ostreatus* is the most cultivated species being easier to culture, favorable thrive on diverse agriculture by-products i.e. rice straw, sawdust, wheat straw, corn silk, sugarcane bagasse and other plant fibers having cellulose content (Ju, 1994; Kong, 2004). Substrates having elevated nitrogen and carbohydrate contents are rated as perfect for mushroom growth (Khare *et al., 2010*). Hence, this study is to determine the growth and yield responses of *Pleurotus ostreatus* on four different wood residues and to determine the antioxidant potentials of *Pleurotus ostreatus* on the four different wood residues.

Materials and methods

The experiment was executed at the Mushroom Unit laboratory of Pathology Section, Forest Conservation and Protection Department, Forestry Research Institute of Nigeria, Ibadan. The Institute is situated in Jericho hill, Ibadan North West Local Government Area of Oyo State. The area lies between latitude 7°26'N and longitude of 3°54'E. The climatic condition of the area is tropically dominated by rainfall pattern from1400mm-1500mm. The average temperature is about 30°C, average relative humidity of about 80-85% (FRIN, 2019).

Materials used

Wood residues (Saw-dust) from four (4) forest trees namely: *Tectona grandis, Albizia zygia, Swietenia macrophylla, Terminalia superba*, Wheat bran, Water, Mushroom seed, White polythene nylon, Rubber band, 30 cm long ruler, Methylated spirit, Cotton wool, Weighting scale (sensitive), Vernier caliper, Bowl, Inoculating rod or spoon, Holestick and Hand Sprayer were used .

Sources of materials used

The wood residues were obtained at Sango and Apete sawmills, and the wheat bran was obtained at Pathology section. The spawn (Mushroom seed) were obtain at the Pathology section.

Substrate preparation

Mixing and bagging

The wood residues from the selected forest trees were mixed separately with 1% agricultural lime and 5% wheat bran to enhance growth of the mushrooms and bagged into transparent poly-ethylene bag (0.2mm) at 1kg per bag. The bags were thereafter tied with rubber bands and taken for pasteurization.

Pasteurization

Pasteurization was carried out immediately after bagging which was meant to remove harmful organisms that may impede the growth of the desired mushrooms. The substrate bags were pasteurized for four hours. Materials such as bowls and workbench for arranging the bags after pasteurization were sterilized with cotton wool dabbed with methylated spirit.

Inoculation

The pasteurized bags were untied and a hole bored in the middle of the bag using an inoculating rod to accommodate the spawn (mushroom seed). Thereafter, spawn was introduced at 2% of the fresh weight of the substrate.

Incubation

After introducing the spawn, the bags were tied back with rubber bands labeled and arranged accordingly.

Data collection

Data gathering commenced a week after inoculation and records were taken weekly. The following parameters were measured; mycelia growth, height, weight and diameter of pileus.

Mycelium growth was measured once a week with a 30 cm long transparent ruler. The length of the harvested mushroom and the diameter of pileus were measured with 30 cm long ruler and the diameters of the mushrooms were measured with vernier caliper. Sensitive weighing scale was used for weighing the harvested mushrooms.

Data analysis

Analysis of Variance (ANOVA) was used to test the data obtained, while Least Significant Design (LSD) at 5% level of probability was used to separate the means.

Phytochemical analysis of harvested mushrooms

Fresh mushrooms (Pileus + stipe) were rinsed thoroughly to get rid of extraneous materials and sun-dried on blotting paper by constant exposure to sunlight for 2 – 4 days while turning the mushrooms to avoid fungal growth (Johnsy *et al*., 2011). Then it was cut into pieces and later milled to obtain mushroom meals (MRMS) using mortar and pestle and was stored in a container until needed for analysis (Egwim *et al.,* 2011). The quantitative Screening (determination of tannin, determination of alkaloid, total phenolic content, test for saponin and total flavonoid content) of phytochemical compounds in *Pleurotus ostreatus* cultivated on the four wood residues were carried out after harvest.

Results and discussion

P. ostreatus mycelia growth on the four wood residues is recorded in Table 1, the result indicated that all the wood residues supported the mycelia growth and was completed within four weeks. *T. superba* recorded the fastest ramification rate (mycelia growth) after three weeks followed by *T. grandis.* At the end of four weeks, the least mean value was recorded in *A. zygia* (15.76cm)

Table 1: **Weekly mean mycelia growth on four different wood residues (cm)**

Mean treatment	week 1	Week 2	Week 3	Week 4
Tectona grandis	5.67	11.67	16.97	18.13
Albizia zygia	4.90	12.20	15.54	15.76
Swietenia macrophylla	5.54	11.24	16.23	16.56
Terminalia superba	5.58	13.84	18.56	19.04
LSD (P≤0.05)	0.57*	0.98**	1.68**	0.77**

Table 2 reported that the mushrooms grown on the four wood residues were not different significantly from each other in height, although the mushroom raised on *T. grandis* recorded the highest mean value of 7.47cm in height while the least mean value was recorded in *T. superba* with the values of 4.96cm.

Table 2: Mean mushroom height on four different wood residues

Treatment	Mean height (cm)
Tectona grandis	7.47
Albizia zygia	6.79
Swietenia macrophylla	6.90
Terminalia superba	4.96
LSD (P≤0.05)	2.60^{NS}

Table 3: Mean mushroom diameter of pileus on four different wood residues

Treatment	Mean diameter of pileus (cm)
Tectona grandis	5.66
Albizia zygia	6.46
Swietenia macrophylla	5.49
Terminalia superba	4.39
LSD(P≤0.05)	3.32^{NS}

Table 3 shows *P. ostreatus* diameter of pileus on different wood residues. The result indicated that *Albizia zygia* recorded highest diameter of pileus (6.46cm) while *T. superba* recorded the least diameter of pileus with the mean value of 4.39cm. There were no significant differences among the diameter of pileus from the four wood residues used.

Table 4: Mean mushroom stem diameter on four different wood residues

Treatment	Mean stem diameter (cm)
Tectona grandis	0.81
Albizia zygia	1.49
Swietenia macrophylla	0.72
Terminalia superba	0.83
LSD (P≤0.05)	0.41**

Table 4 shows *P. ostreatus* stem diameter on the four different wood residues. The result reported significant differences in the stem diameters of the mushrooms raised on the wood residues. *Albizia zygia* recorded the highest mean value of 1.49cm in stem diameter and significantly different from others. *S. macrophylla* recorded the least mean value of 0.72cm but was not significantly different from *T. superb* and *T. grandis* with mean values of 0.83cm and 0.81cm respectively.

Table 5: Mean mushroom Yield on four different wood residues (g)

Treatment	Mean yield
Tectona grandis	34.1
Albizia zygia	48.1
Swietenia macrophylla	20.7
Terminalia superba	34.9
LSD (P ≤ 0.05)	19.81^{NS}

Table 5 reports *P. ostreatus* yield on wood residues. *Albizia zygia* recorded highest mushroom yield of 48.1g followed by T. *superba*, and *T. grandis* with 34.9g and 34.1g mean values respectively. The least mean value was reported in *S. macrophylla* with 20.7g mean value. Although *A. zygia* recorded the highest yield, it wasn't different significantly from other three substrates.

Table 6: Quantitative phytochemical screening of *P. ostreatus* grown on four Indigenous wood residues

SAMPLE	TOTAL PHENOLIC Mg/g	FLAVONOID Mg/g	SAPONIN Mg/g	TANNIN Mg/g	ALKALOID Mg/g
Tectona grandis	0.2042	0.16	0.3063	0.5496	3.676
Albizia zygia	0.2017	0.18	0.7361	0.7487	8.8336
Swietenia macrophylla	0.2112	0.1467	0.5547	0.437	6.656
Terminalia superb	0.2138	0.13	0.9715	0.5832	11.6576

Table 6 shows *P. ostreatus* total phenolic, flavonoid, Saponin, Tannin and Alkaloid grown on wood residues The result showed that *T. superba* recorded highest total phenolic (0.2138mg/g), Saponin (0.9715mg/g), alkaloid (11.6576mg/g) and lowest flavonoid (0.13mg/g) respectively. *Albizia zygia* recorded highest flavonoid (0.18mg/g), tannin (0.7487mg/g) and lowest total phenolic (0.2015mg/g). *Tectona grandis* recorded least saponin (0.3063mg/g) and alkaloid (3.676mg/g) respectively. *Swietenia macrophylla* recorded least tannin (0.437mg/g) respectively. This upholds the report by Unekwu *et al*., (2014) that mushroom contain different compounds. The result also indicates that the chemical compounds in mushroom depend on the substrate used. With the presence of these compounds in mushroom, their consumption will help to remove toxins from the body as a result of their free radical scavenging activities and hence they help in making us healthy. Garcia-Lafuente *et al.*, (2011) also explained that mushrooms have been used in medically to manage simple and age-old epidemics like skin eruption and to prevent some compound and pandemic diseases such as AIDS.

Conclusion and recommendation

The wood residues of *T. superba* and *A. zygia* recorded the best among the four wood residues used for this experiment. Moreover, supplement such as lime ($caco_3$), wheat bran increase the pH of the water, causing the mold spores, bacteria, and other contaminants in the straw to be killed off thus enhancing the richness of the substrate which resulted into high yield of *P. ostreatus* on the wood residu*es*. Furthermore, the use of wood residues as medium for mushroom cultivation will aid reducing environmental pollution as a result of high amount of lignocelluloses waste. Also protein intake can be improved and poverty eradicated when the cultivation of mushroom is encouraged among the populace. The antioxidant properties of mushrooms also depend greatly on the substrate used.

This study recommends the need for more research on different wood residues for mushroom cultivation to explore their suitability for mushroom cultivation.

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SUSTAINABLE CONTRIBUTION OF BEEKEEPING TO CLIMATE CHANGE MITIGATION FOR NATURE CONSERVATION AND BIODIVERSITY SECURITY: A REVIEW

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Abstract
The important role of honey bee in world food production, climate change mitigation, forest and biodiversity conservation and their economic values cannot be overemphasized. Forests, most especially ones with no direct agricultural activity, provide a source of organic nectar that are necessary for the honey bees (Apis mellifera) because they are nature's very important agent of pollination. The original concept of ecosystem is majorly understood in the aspect of the services and benefits that it provides to the living, both human and animals. This can be categorized into different functions such as provisioning, regulating, cultural and supporting services. Beekeeping activity has over the years helps in preserving nature, agriculture, sustains livelihoods as well as provides food security. Bee products provide healthy, high-nutrient food, safe medicines (apitherapy) and raw material for industries as well as enhance pollination. This paper, therefore, explores the important role and contribution of bees as a NTFPs in climate change mitigation and adaptation which go further to strengthen the intimate and reciprocal relationship between humans and the natural world thus eliminating the inaccuracy of considering the ecosystems as mere providers of services to humans.

Keywords: *Forest, Climate change, Beekeeping, Biodiversity, Conservation.*

Introduction

Climate change is a significant variation in the statistical distribution of weather patterns over periods ranging from decades to millions of years (Adejuwon, 2006). Climate change over any particular place around the world is caused by a host of interacting factors that are both natural and man-made (Okali, 2007). These factors include greenhouse gases of carbon dioxide, nitrous oxide, methane, and halocarbons (Aluko, 2008). Since the dawn of life, the ozone layer has protected the globe from dangerous UV radiation (Agnew and Fennessy, 2001). Additionally, the ozone layer sends out to the earth 70% of the less harmful fraction of ultraviolet light. The loss of it could endanger both plants and animals, causing them to grow more slowly (Odeyemi *et al*., 2001). Fruits and nuts, vegetables, medicinal plants, resins derived from plants or animals, essences, dyes, fish and game, and a variety of barks and fibres are all examples of non-timber forest products (NTFPs) (Jimoh, 2005). Wild honey and Brazil nuts are examples of NTFPs that are well-known worldwide (FAO, 2009).

Beekeeping activities are usually integrated with the conventional crop, livestock, and agro-forestry farming systems. Through beekeeping, households may have access to food, fruits, medicines, poles, and organic manure (Joni, 2004). The potential of beekeeping is directly proportional to the presence of virgin forests and low human population density, which provide an environment conducive to beekeeping (Agera, 2011). Beekeeping can increase respect for bees while also encouraging humans to try to protect their habitat and foraging areas as much as possible.

The Contribution of Beekeeping to Food Production

Beekeeping provides numerous economic and agricultural benefits to both farmers and ecosystems worldwide. Except for cereals, many food crops rely on insects for pollination. Pollinators such as bees, birds, and bats influence 35% of global agricultural production (FAO, 2009). In the last 50 years, the area covered by pollinator-dependent plants has increased by more than 300 percent (Aizen and Harder, 2009). It is critical to emphasize the importance of bees in pollination. Bees pollinate approximately 0ne-third of all the plants and plant products consumed by humans, thereby contributing to biodiversity conservation (FAO, 2009). Bees are the main and excellent insect pollinators that play an important role in maintaining natural plant communities and ensuring seed production in most flowering plants because they spend the majority of their time collecting pollen (Oyerinde *et al*., 2014). Whereas the performance of bee colonies, as well as the production of honey, wax, and other hive products, is dependent on forage plants (Teklu, 2016).

Beekeeping is a viable way to help people work their way out of poverty while preserving natural diversity (Agera, 2011). Honey bees are valued for producing honey and beeswax, which generates income and medicines. Beekeeping allows some of the world's poorest people to harvest commodities of international quality and value (Havsteen, 2002). Poverty, climate change, deforestation, biodiversity loss, water scarcity, pollution, and urban sprawl are all current issues facing our world, and they frequently have the greatest negative impact on the most vulnerable people (Eaton and Eaton, 2000). It has also been revealed that beekeeping leads to a reduction in global warming (Oyerinde *et al*., 2014). Beekeeping has been described as competitive for on-farm integration because of its low start-up cost, less labour, and large-scale dependency on traditional beekeeping technology. The dependency on traditional beekeeping techniques implies the impact of weather conditions on the beehives with the attendant consequences of climate change (Okoso-Amaa *et al*., 2004).

As a result, the nation's ability to address food and nutritional insecurity, and poverty, and to stimulate and sustain national economic growth and development is highly dependent on agricultural performance. Beekeeping, as one of the important livestock subsectors, makes a significant contribution to the improvement of the nation's population's livelihoods.

The Contributions of Bees to Environmental Health

The key role of pollinators in food production has been under increased scrutiny (Lebuhn *et al.*, 2013). However, it has been estimated that around 35% of global crop production is dependent upon animal pollinators (Klein *et al*., 2007), which also maintain the biodiversity of wild plants (Aquilar *et al*., 2006). Land-use change (Hendrickx *et al*., 2007; Rader *et al*., 2014), pesticides (Brittain *et al*., 2014), pollution (Rortais *et al*., 2005), and reduced resource diversity have all contributed to pollinator decline (Biesmeijer *et al*., 2006). The decline is critical due to the need to feed a growing population with dwindling resources (FAO, 2017; Campbell *et al*., 2017). Pollination increases crop yields without additional land use and resource inputs.

Pollinators, in addition to increasing yield through pollination, can provide honey and protein sources, such as drone broods (DBs) (Lindström *et al*., 2016). Moreover, life cycle assessments (LCAs) of beehives usually focus solely on honey production (such as; Kendall *et al*., 2013; Mujica *et al*., 2016). Whereas, the global warming potential (GWP) of DB production with honey production has also been analysed (Ulmer *et al*., 2020). Pollination services and by-products might cause net-positive environmental impacts (Grönman *et al*., 2019). This is because increasing crop yields and replacing land-based protein production could increase bee populations, among other things. Pollinators, in addition to increasing yield through pollination, can provide honey and protein sources, such as drone broods (DBs) (Lindström *et al*., 2016). Honey can be used as a sweetener to replace sugarcane or sugar beet production, which requires agricultural land. It can also provide protein that can replace animal-based protein sources (Kahn *et al*., 2007). Furthermore, the environmental impact of beekeeping, such as global warming potential (GWP), land use (LU), and freshwater use with the inclusion of pollination services and by-products such as DB and pollen protein, requires much attention in recent times.

Enhancement of Honeybee Farming to Climate Change Adaptation Strategies

Climate change is caused as a result of natural factors like alterations in the earth's path around the sun, volcanic activity, and fluctuations within the climate system (Adejuwon, 2006). Furthermore, by burning fossil fuels and destroying rainforests, humans are exerting an increasing influence on the climate. Deforestation emits a massive amount of carbon dioxide into the atmosphere (Markson, 2004). Bees are critical for maintaining and protecting ecological balance and biodiversity in nature, both for plants and animals. Bees are generally used to assess the state of the environment (FAO, 2009). They are important pollinators, and many ecosystems rely on them for pollination. A decline in bee colonies could endanger plant species survival. They also play an important role in crop pollination (FAO, 2007). Beekeeping is extremely beneficial and necessary for forest resource management. This is because where beekeepers have placed their hives, bushfires are protected and avoided, and people are discouraged from cutting timber, poles, and other forest resources. Eventually, vegetation grows and these areas turn green. There is also fresh air in these areas due to forest vegetation cover, which helps to improve the environment. Human activities are hampered in those areas due to the fear of being stung by bees; additionally, grass and other plants have more space (Lalika, 2008). Examples of tree species that are conserved through beekeeping include *Brachystegia spiciformis, Dalbergia melanoxylon, Dalbergia nitidula, Julbernadia globiflora, and Pterocarpus angolensis* (Lalika, 2008).

Beekeepers must engage in activities that improve climatic conditions, allowing the right environment conducive to bee growth and fecundity. Bee activity contributes to climate change mitigation. A colony of honey bees comprises a cluster of several to 60,000 workers (sexually immature females) and a queen. Bees form a tight cluster to conserve heat as temperatures drop below 57° F. Young bees survive the winter, while the old ones gradually die (Mannering, 2014). During early spring, the lengthening days and new sources of pollen and nectar stimulate brood rearing. The bees also gather water to regulate temperature and liquefy thick or granulated honey (Mannering, 2014). The colony's temperature must be kept at around 93 degrees Fahrenheit (30 degrees Celsius) during hot summer days, which means the bees must keep their bodies cool (Mannering, 2014). After reproduction, all colony activity is geared toward winter survival. In addition to their role in forest resource management, bees are important pollinators of both wild and agricultural plants. Bees also bring about cross-pollination, in which pollen from one plant is transferred by bees to another plant, which is one sure way to obtain mixed genes in plants. In this manner, the offspring have a better chance of survival. The bees can also set in motion many symbiotic relationships that could keep the forest healthy for centuries. Therefore, the uncertainty of climate change's short- and long-term effects on agricultural production has become a societal issue (Markson, 2004). Beekeeping improves the nation's economy. From time immemorial, Beekeeping and honey have been considered by many cultures as a valuable commodity that is used in traditional rituals, in healing, or as food. Beekeeping can be practiced as an additional source of income for farmers in rural areas and has been successfully implemented in poverty-alleviating projects (Popo-ola *et al.*, 2013). Beekeeping requires few resources to commence production, it is not a labor-intensive activity and honey harvesting generally takes place during lean periods in agriculture (when most farmers have reduced pressure from farm work). The collected bee products can be sold to generate additional income to pay for school fees or health expenses, especially during periods of reduced income from agriculture. Beekeeping can eventually also lead to the development of other activities within the community such as the making of protective gear, smokers, and beehives; or the production of value-added products such as honey beer, beeswax candles, or wood polish (Popo-ola *et al*., 2013).

Conclusion

Climate change is defined as a significant shift in the statistical distribution of weather patterns over periods ranging from decades to millions of years. Climate change over any given location on the planet is caused by a variety of interacting natural and man-made factors. Beekeeping can increase respect for bees while also encouraging humans to try to protect their habitat and foraging areas as much as possible. The potential of beekeeping is directly proportional to the presence of virgin forests and low human population density, which provide an environment conducive to beekeeping. Beekeeping provides numerous economic and agricultural benefits to both farmers and ecosystems. Beekeeping is a viable way to help people work their way out of poverty while preserving natural diversity. Bees are critical for maintaining and protecting ecological balance and biodiversity in nature. A decline in bee colonies could endanger plant species survival. Beekeeping can be an additional source of income for farmers in rural areas and has been successfully implemented in poverty-alleviating projects. Beekeeping can thus be considered a viable commercial and protective measure that can be integrated into national forestry and other strategic planning programs.

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SUSTAINABLE FOREST MANAGEMENT PRACTICES: A VIABLE PANACEA TO THE CHALLENGES OF CLIMATE CHANGE IN NIGERIA

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Abstract
The numerous contributions of forest to man and the environment cannot be overemphasised as it serve as a panacea to several environmental disasters currently facing the world today. Forests are tremendously endowed to sustain the health of the environment by regulating the earth's climate. However, unsustainable forest operations and human pressure on forest resources has led to forest degradation, climate change and loss of biodiversity. This has threatened and distorted ecological balances, resource conservation and management. Climate change mitigation efforts targeted at forests focused only on trees as a means to protect and create forest carbon stocks. Forests however, are more than just trees. They can be diverse and multi-functional. This paper reviews and highlights the importance of forest and forest trees in all ramifications especially as they relate to climate change. In order to restore ecological balance and ameliorate climatic challenges, the paper then recommends the adoption of sustainable forest management and conservation practices as a vital tool in the re-creation of forest ecosystems and re-establishment of functional habitat networks for the maintenance of biodiversity.

Keywords: *climate change, forest trees, environment, sustainable forest management*

Introduction

Climate change is a major environmental problem threat facing sub-Saharan African countries today because of its geography, their reliance on rain-fed agriculture, high levels of poverty, low levels of human and physical capital and poor infrastructure (Ozor *et al.,* 2015). Climate change has stimulated discourses in respect to the causes, long term effects, as well as how to forestall its prolonged and frustrating impacts. Climate change according to Intergovernmental Panel on Climate Change (IPCC, 2007) refers to the state of climate that can be identified by variability in the mean of its properties (average temperature, wind and rainfall patterns) that persists for an extended period due to natural variability or as a result of human activities. On the contrary, the United Nations Framework Convention on Climate Change (UNFCCC, 2005) defines climate change as a change in climate which is attributed directly or indirectly to human activities that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. Odjugo (2010) described climate change as a gradual but systematic increase in global temperatures experienced over a long period of time. Going by the various definitions, climate change can be fundamentally summarized to be a long-term shift or alteration in global temperature, precipitation, wind patterns and other measures of climate that occurs overtime.

A forest is a land with a tree canopy cover of more than 10% on an area of more than 0.5 hectares (ha) and a minimum tree height of 5 metres (FAO, 2010). Forest ecosystems covers more than 4.1 billion hectares of the earth's surface contributing greatly to the global carbon cycle and acting as carbon sequestration reservoirs (FAO, 2020). However in Nigeria, forest encroachment and exploitation, legal and illegal felling, collection of fuel wood and industrialization etc. have rendered protected forests degraded resulting to several environmental challenges. According to a report by NCF (2018), Nigeria is one of the countries with the highest deforestation rate globally losing about 96% of its forest cover approximately 450,000-600,000 hectares as a result of human induced activities. To abate the impacts of the aforementioned, Boegelsack et al. (2018) considered forestry as a vital and sustainable measure for promoting sustainable forest management (SFM) and regulating the carbon storage level of managed natural and or artificial forests. Sustainable forest management is a dynamic and evolving concept that maintains and enhances the environmental, economic and social values of all types of forests ecosystems for the benefit of present and future generations (CCFM, 2008).

Forests are tremendously endowed to sustain the health of the environment by regulating climate both at regional and global levels. This unique and practicable remedy protects people and also create a basis for more sustainable economic and social development. However, this natural mechanism is often hampered by human activities which disrupts the atmospheric structure of the Earth. Climate change amelioration efforts targeted at forests focused only on trees as a means to protect and create forest carbon stocks. Forests however, are more than just trees. They can be diverse and multi-functional. Considering the aforementioned, it is imperative as envisioned by this paper to further review the importance of forests and forest conservation practices especially as they relate to climate change.

Drivers of climate change
Anthropogenic/human activities is mostly emphasized as a major driver of climate change.
Deforestation: Deforestation, through legal and illegal felling of tree species is a major cause of climate change. Cunningham and Cunningham (2002) defined deforestation as the total or partial clearance of trees for a particular purpose. According to Oloyede (2008), nearly 50% of the earth's land surface has been transformed by deforestation with significant consequences on biodiversity, soil and climate. When trees are indiscriminately felled, greenhouse gases such as carbon-dioxide are released and built up in the atmosphere distorting the natural balance and consequently contributing to climate change. Nigeria, in the last three decades has suffered greatly from rapid deforestation losing about 400 hectares of forest and woodland annually owing to the collection of fuel wood and improved standard of living which has rendered most of our forest estates degraded. This calls for urgent action considering the importance of forests in controlling the build-up of greenhouse gases.
Industrialization: The advent of industrial revolution created the modern world with the establishment of global commerce, factories, large cities, construction of roads, public and private buildings. Forest estates are infringed upon by industrial and residential development as population increases and cities extend outward. The improvement in technological breakthrough has polluted the earth and regenerative capacity of the Earth lacks the strength to repair the imbalances.
Agricultural Practices: Forests estates and vegetation cover are destroyed every day to provide land for food crops, tree plantations or grazing of cattle. These practices causes environmental degradation by increasing the pressure on forest estates via farming.

An Overview of Nigeria's Forest Estate
The total land area of Nigeria is 923,768km^2 with a population of over 216 million people (NPC, 2022). The country is blessed with vegetational zones cutting across the entire nation resulting into diverse range of habitats from desert zones (Arid region) in the northeast to tropical rain and swamp forests along the south coast. According to FAO (2015), Nigeria's forest estate is 7.7% of the country's land area which is far below the country's target of a minimum requirement of 25% forest estate as recommended by (FAO, 2010). The obvious reason for this steady decrease is the rapid depletion of the forest through deforestation without commensurate reforestation and afforestation. Nigeria is one of the countries with the highest deforestation rate globally losing about 450,000-600,000 hectares of its forest cover as a result of human induced activities such as urbanization, agriculture, overgrazing, bush burning, and indiscriminate logging. The overall carbon stock in forested areas is estimated to be 1,292 million metric tons (FAO, 2015). Meanwhile, investment into the forest sector by the various governments (federal and state) is minimal and the involvement of the private sector (organizations and individuals) in forest development is insignificant.

Importance of Forest
The importance of forests can be classified as follows: Ecological, Socio-economic benefits and Medicinal values.
Ecological Values
Forest trees have the capacity to capture and store large amounts of carbon that would otherwise contribute to climate change making them one of the cheapest solutions to mitigating climate change. It is noteworthy that forest trees act as environmental buffers by absorbing and inhibiting the formation of secondary pollutants in the ecosystem and keeping the ozone concentration on a level that is not hazardous to human thus, contributing to the biosphere stability. Trees contribute to the aesthetics of the environment and also provide green cover via shade which regulates the atmospheric temperature. Other ecological benefits of forest trees includes prevention of soil erosion, conservation of soil nutrient, detoxification of the environment to maintain balanced levels of oxygen and conservation of ground water (Adedayo, 2018).

Socio-economic Values
Forest products constitute an essential component of food and livelihood security to the survival of man. This improves ecosystem quality and thus confers socio-economic benefits to human society. Every component of a tree including leaves, branches, stem, bark, fruits, seeds and roots are useful. Forest outputs are broadly classified into wood and non-wood forest products. The wood products include timber, poles, pulpwood, firewood and products derived from woody climbers and shrubs (Fuwape, 2000). The non-wood products are wild plants and animal products harvested from forests such as wild fruits, nuts, edible roots, honey, palm, medicinal plants, snails, etc. (Shomkegh and Tem, 2008). Many people throughout the world make use of these products and the increase in demand for these products has enhanced rural livelihoods and enabled the expansion of domestic markets, particularly in urban areas where fuel wood and other forest resources are scarce.
Forest based rural industries in Nigeria such as wood crafts, cane furniture, and fabrication of tools handles also creates employment for a large number of people who are involved in harvesting, processing or marketing of these products. This has placed forests in the limelight as an integral part of national development.

Medicinal Values
Trees play important roles in the health of the people. Trees are the basis of a healthy life. The use of forest plants for medicinal purposes in Nigeria has long historical roots especially among the rural dwellers. According to Pierce Colfer et al. (2006) people living in or near forests often depend more on forest-derived medicines for a wide array of ailments. The extracts, seeds, roots, leaves and bark from trees and other plants are used to treat several diseases. Some of the forest products used for medicinal purposes in Nigeria includes: *Garcinia cola* (Bitter Kola) seed which is highly effective for the treatment of respiratory tract

diseases and other bacterial infections because of its anti-bacterial, detoxification and cleansing properties. *Parkia biglobosa* (Locust bean) bark is very effective for the treatment of hypertension, skin rash and wounds while *Khaya senegalensis* bark is used for the treatment of pile and malaria.

Climatic Amelioration through Sustainable Forest Management Practices

African ecosystem comprise of a variety of flora and fauna which constitute about 20 percent of all known species in the world (Scholes and Biggs, 2004). However, unsustainable forest operations and human pressure on forest resources has led to forest degradation, climate change and loss of biodiversity threatening and distorting ecological balance, resource conservation and management. The evidence of climate change manifests when there is an increase in ocean temperature due to excess carbon dioxide in the atmosphere, melting ice in the arctic, melting glaciers around the world; we equally experience irregular rainfall, flooding, rising sea levels, intense drought and desertification which calls for immediate action. Sustainable forest management and conservation therefore, becomes a vital tool in the re-creation of forest ecosystems and re-establishment of functional habitat networks for the maintenance of biodiversity. In order to restore ecological balance and ameliorate environmental challenges, it is essential to adopt the under listed sustainable forestry practices:

- **Plantation Establishment and Development**: There is need to balance our ecosystem, increase the forest cover and promote sustainable forest management through the establishment of forest plantations. Afforestation and reforestation of degraded lands will enhance the growth of a sustainable environment. It is noteworthy that the federal government under the National Afforestation program has embarked on massive reforestation and afforestation of several hundreds of hectares of land in the North and South of Nigeria in recent years. The program is sponsored by the Green bond initiative of the Federal Ministry of Environment. Government and relevant stakeholders still need to embark on more sustainable afforestation and reforestation programs especially at state and local government levels.
- **Ex-situ Conservation**: Ex-situ conservation involves preservation of living species or genetic materials in gene banks, botanical gardens and sites other than their natural habitats. Forest ecosystems such as forests and wetlands store vast amounts of carbon in them. When the ecosystem is threatened and destroyed, carbon escapes into the atmosphere causing global warming. Therefore, in order to protect biodiversity, ameliorate climate and achieve ecological balance, forest ecosystems must be conserved.
- **Conservation of Protected Forests**: The role of protected forests in ameliorating climate change has increasingly been recognized over the last few years. Existing forests should be conserved because they contribute to climate change mitigation by maintaining or increasing ecosystem health. They act as carbon reservoirs, protect people from sudden climate events and reduce their vulnerability to weather-induced problems such as floods and droughts. Such conservation entities includes, Man and Biosphere reserves, Strict Nature reserves, permanent sample plots, National Parks, Botanical gardens etc.
- **Conservation of Sacred Grooves**: Sacred grooves also known as fetish forests are patches of remnant natural forests dedicated for spiritual purpose and protected through social laws by the local communities. Conservation of sacred groove is of utmost importance for the survival and sustenance of mankind. They have higher tree cover that enhance carbon storage and it is one of the best practices to halt desertification and ameliorate the impact of climate change (IPCC, 2011).
- **Review of Forest Laws**: Forest management laws and policies should also be reviewed with maximum penalties to reduce environmental degradation/destruction.

Conclusion

It is evidently clear now that Nigeria has suffered greatly from the consequences of climate change with increasing discourse that it will accelerate in the years ahead with significant impacts. Nigeria as a nation is highly vulnerable to its consequences due to several human induced factors. These factors have great impact in depleting the ozone layer which causes several environmental challenges. In order to restore ecological balance and mitigate climatic challenges, it is essential to adopt sustainable forest management practices as a vital tool in the re-creation of forest ecosystems and re-establishment of functional habitat networks.

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TREE SPECIES DIVERSITY AND CARBON SEQUESTRATION POTENTIALS OF THE TREES IN THE THREE ONDO STATE OWNED UNIVERSITY CAMPUSES, SOUTHWEST, NIGERIA

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Abstract
This study assessed carbon sequestration potentials and compared the tree species diversity of the three Ondo State owned University campuses. All trees within developed areas of the university campuses with ≥10 cm diameter breast height (Dbh) were identified by forest taxonomist and their Dbh as well as diameter at the base (Db) were measured using girth tape. The diameter at the middle (Dm), diameter at the top (Dt) and the total height were measured with Relaskop for volume estimation. Density of each tree species was obtained from literatures to estimate the tree biomass and carbon. A total number of 220 individual trees were encountered in Adekunle Ajasin University, Akungba Akoko (AAUA) with 22 tree species and 14 families. A total carbon stock of 208,480.40 kg was estimated. In Olusegun Agagu University of Science and Technology, Okikitupa (OAUSTECH), a total number of 40 individual trees were encountered with 8 tree species and 6 families with a total carbon stock of 2,391.70 kg. In addition, 10 individual trees were enumerated in University of Medical Sciences (UNIMED) campus with 3 tree species and 3 families with a total carbon of 1,226.70 kg. The AAUA campus gave the highest in Shannon-Weiner and Margalef indices while UNIMED had the highest value in Evenness diversity index. The result of tree species diversity indices varied amongst the three university campuses but not significantly different at $P<0.05$. The universities campuses are encouraged to adopt conservation policy to increase tree species diversity which will in turn intensify ecosystem services within the universities.

Keywords: *Benefits, Margalef, erratic, drought, Shannon, species diversity*

Introduction

The environmental benefits of trees in campus ecosystems are numerous and well acknowledged in forestry benefit account. Campus trees improve air quality, cool local air temperatures, filter and retain storm water, phytoremediation and sequester carbon, among others (Nowak *et al*., 2008). It improved social, cultural and physical health as well as enhance mental health, reduces mortality and provide oxygen amongst its benefits (Nowak *et al*., 2008). It does also contribute to healthier and more beautiful cities (Nowak *et al*., 2008). In addition, trees provide numerous benefits to humans as well as provide essential habitat and food sources to wildlife in and around the fragmented landscape of urban forest ecosystems (Nowak *et al*., 2008). Even single urban tree provide significant resting point for local and migrating birds (Rega *et al*., 2015). Trees on streets and in the university campuses are now recognized as more than just enjoyable features with associated maintenance costs; this ecosystem serve as the pillar of urban forestry. According to Berto, (2005) exposure to nature and restorative environments increases sustained attentive capacity for learners, e.g. students. Easy access to green outdoor environments from workplaces has been found to significantly reduce work stress (Lottrup *et al*., 2013). More importantly, academic institutions and hospitals have noted that nature and trees results in quantifiably positive impacts on students and patients wellbeing (Alvarsson *et al*., 2014). Also, the benefits of urban trees are not only well recognized by the academic community but by municipalities and other institutions around the world such as health facilities (Bassett, 2015).

Trees as well as green plants are imperative for life sustenance and healthy state of the planet earth but these entities are disappearing at a terrifying rate. The forest resources are fast becoming degraded in most natural forests as a result of deforestation due to anthropogenic activities such as urbanization; overexploitation as well as poor regeneration mechanism which do not guarantee sustainability. It has been noted that development as well as change in climate aggravates the disappearing of many indigenous and exotic tree species (Olajuyigbe *et al*., 2013). The climatic variability of the present earth limits the ability of trees to adapt to the changing climate (Olajuyigbe *et al*., 2013). Many tree species are threatened by climate change effects and some trees are more vulnerable than others. Though, there is a broad gap in the knowledge of the genetic diversity of tree species owing to lack of up-to-date documentation of plant genetic resources (Olajuyigbe *et al*., 2013). Similarly, tree species diversity is decreasing due to the rate of habitat destruction and over-exploitation which are far greater than the rate of genetic diversity collection and conservation (Olajuyigbe *et al*., 2013). The presence of many indigenous and exotic tree species on university campuses as well as urban forests enhance conservation of these trees species that are scarce in most natural forests ecosystems (Olajuyigbe *et al*., 2013). Therefore, urban forests as well as university campuses are important as live gene bank (Olajuyigbe *et al*., 2013). Consequently, there is need to document information on the tree taxonomy, diversity and growth features of the trees on university campuses. This information is very important for the conservation and sustainable management of these tree species (Olajuyigbe *et al*., 2013). Simply planting or retaining trees on the university campus without considering their species, health, and status will limit their benefits. As such, this study aimed at identified and enumerated the tree species in the campuses of the three Ondo State owned universities. But the primary aim of this study was to assess carbon sequestration potentials and compared the tree species diversity of Ondo State owned University campuses, Southwest Nigeria.

Study area

This study was conducted in the three Ondo State owned university campuses namely: Adekunle Ajasin University, located in Akungba Akoko, North Senatorial District, established in year 2000, Olusegun Agagu Univeristy of Science and Technology located in Okitipupa, South Senatorial District, established in 2008 and the University of Medical Sciences located Ondo town, Central Senatorial District, established in 2015. Ondo State is one of the seven states created on February 3, 1976. It was carved out of the former Western Region of Nigeria. The state is made of eighteen Local Government Areas and three senatorial districts (Fig 1). Ondo State land area was estimated to be 15,500 km^2 (Omonijo and Matzarakis, 2011). The State is situated on latitude 5°45′ N to 8°15′ N and longitude 4°45′ E to 6°00 ′ E in the Southwestern humid area of Nigeria. It has the tropical wet-and-dry climate with mean annual rainfall of about 1,500 mm and 2,000 mm in the derived savannah and humid forest zones respectively (Omonijo and Matzarakis, 2011). The State is bounded in the North-West by Ekiti State, West-Central by Osun State, South-West by Ogun State, South-East by Delta State and in the South by Atlantic Ocean (Omonijo and Matzarakis, 2011).

The State has texture of topsoil with mainly sandy-loam in the south and the vegetation belongs to tropical rainforest with species such as *Melicia excelsa*, *Terminalia superba* and *Triplochiton scleroxylon* (Onyekwelu *et al*., 2008). In the north, the shallow valleys and cracks of rocks accommodate small trees and shrubs while the gentler slopes form substrates for various families of grass. Some areas of the north have big and tall trees e.g. *Alstonia congensis*, *Baphia nitida* and *Diospyros monbuttensis* etc. These tree species take the opportunity of using the deep soil directly from weathering of the base rocks (Olugbenga *et al*., 2011).

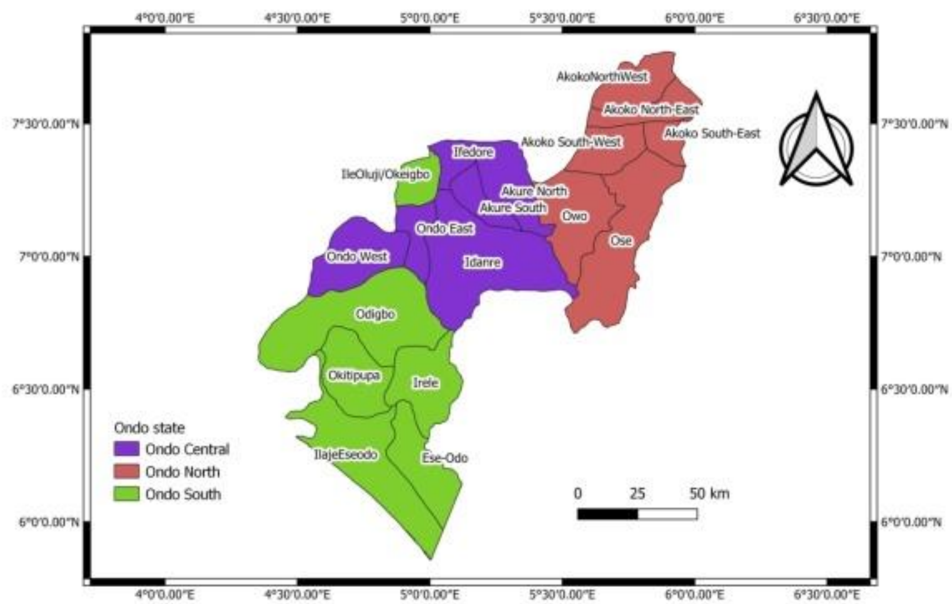

Fig. 1: Map of Ondo State showing the Senatorial districts with Local Government Areas

Data collection

The developed areas of the three university campuses were used for this study. All trees found around the developed facilities (buildings, lawns, parks and playing grounds) with diameters at breast height (Dbh) ≥10 cm were identified by forest taxonomist and their Dbh as well as diameter at the base (Db) were measured using girth tape. The diameter at the middle (Dm), diameter at the top (Dt) and the total height of trees were measured using Spiegel Relaskop for volume estimation. Density of each tree species was obtained from literature to estimate the tree biomass and carbon. Data collected were entered into Microsoft excel sheet, screened and stored.

Data Analysis

Stem of living trees grows both horizontally and vertically. Biomass accumulation also occurs in trees in both directions. The horizontal growth was measured by the diameters and the vertical growth was measured by the tree height. Newton's formula was used to estimate the tree volumes for this study (Equation 1).

$$Volume = \frac{\pi h}{24}(D_b^2 + 4D_m^2 + D_t^2) \qquad \text{Equation 1}$$

Where:

Volume is Volume of the stem, π is 3.142, h is Tree total Height, D_b is Diameter at the base, D_m is Diameter at the middle, D_t is Diameter at the top.

Estimation of biomass

Biomass is the volume multiplied by a wood dry mass (density) (Oke *et al.*, 2020). Biomass of each tree was estimated using the volume and density as obtained from respective tree and Equation 2 was employed.

$$Biomass = Density \times Volume \qquad \text{Equation 2}$$

Estimation of Carbon

Tree biomass obtained in Equation 2 was used to estimate carbon stock for each tree. The standard factor of 50 % was used for conversion of biomass to carbon (Equation 3) (Losi *et al.*, 2003).

$$Carbon = 0.5 \times Biomas \qquad \text{Equation 3}$$

Species Diversity

The data collected were imported into PAST (4.03) software for diversity analysis. The output of species diversity; Shannon-Weiner, Evenness and Margalef indices were compared using analysis of variance in R-Studio/Script software. The species diversity estimates include species richness and evenness as well as Shannon-Wiener Diversity Index (Brashears *et al.*, 2017). The species richness refers to the total number of species recorded in the inventory forest. The Shannon Diversity Index was estimated with Equation 4.

$$H = -\Sigma p_i ln(p_i) \qquad \text{Equation 4}$$

The Shannon Diversity Index (H), p_i is the number of individual of species in a given area (plot) divided by the total number of individuals in the area, ln is the natural logarithm, and Σ is the sum of the calculation. The evenness in species abundance was assessed using Equation 5 according to Buzas and Gibson's Evenness Index (Yang *et al.*, 2008).

$$E = \frac{ln(H)}{S} \qquad \text{Equation 5}$$

The Buzas and Gibson's Evenness Index (*E*), *H* is the Shannon Diversity Index and S is the total number of species.

Margalef Index

Margalef Index (*M*): Margalef index which is a measure of the number of different species represented in the forest area (species richness) was computed as adopted in (Margalef, 1982) and Equation 6 was used.

$$M = \frac{S-1}{lnN} \qquad \text{Equation 6}$$

Where; Margalef Index (M), S = total number of species; N = total number of individual in the site

Results and Discussion

In AAUA a total of 220 individual trees were encountered comprising of 22 different species (Table 1). *Terminalia mantaly* had highest number of individual with 37 stems representing 17 % of the trees enumerated followed by *Acacia auriculiformis, Eucalyptus camaldulensis* and *Tectona grandis* with 31, 30, and 30 stems each respectively representing 14 % each of the population (Table 1). The result of this study is consistent with findings of Ajayi, (2021) that the AAUA campus is dominated by *Terminalia mantaly* and *Acacia auriculiformis* tree species. Also, in OAUTECH a total of 40 individual trees with 8 tree species were encountered. *Gmelina arborea* (Verbenaceae) is the most abundant in OAUSTECH with 9 individual trees, followed by *Delonix regia* with 7 trees and *polyanthia longifolia* with 7 trees (Table 2). Again, in UNIMED, the total of 10 individual trees was enumerated composed of 3 tree species. The *Swietenia macrophylla* species had the highest occurrence with 5 individual trees, followed by *Tectona grandis* with 3 trees and *Azadirachta indica* with 2 individual trees (Table 3). Tree assessment and documentation of tree species taxonomy, diversity and growth features of the trees on university campuses provide information for the conservation and sustainable management of these tree species (Nowak *et al.*, 2008).

Table 1: Mean height, Biomass and Carbon Sequestered by Tree species in AAUA

S/N	Scientific Name	Family	Freq	M-Height (m)	Biomass (Kg/m^3)	Carbon (Kg/m^3)
1	*Acacia auriculiformis*	Fabaceae	31	41.1	39,557.50	19,778.70
2	*Albizia lebbeck*	Fabaceae	4	34.5	5,852.90	2,926.40
3	*Azadirachta indica*	Meliaceae	17	33.9	27,441.00	13,720.50
4	*Bauhinia forficate*	Fabaceae	2	38.6	3,399.80	1,699.90
5	*Blighia sapida*	Sapindaceae	1	37.5	917.30	458.60
6	*Cassia siamea*	Caesalpinoideae	2	31.5	2,756.20	1,378.10
7	*Delonix regia*	Fabaceae	6	35.0	1,734.30	8,671.10
8	*Eucalyptus camaldulensis*	Myrtaceae	31	43.7	52,009.80	26,004.90
9	*Ficus exasperate*	Moraceae	1	23.5	2,044.50	1,022.20
10	*Ficus benjamina*	Moraceae	6	37.0	7,190.40	3,595.20
11	*Gmelina arborea*	Verbenaceae	15	51.7	117,823.80	58,911.90
12	*Hildergardia barteri*	Malvaceae	13	24.6	13,382.40	6,691.20
13	*Hura crepitans*	Euphorbiaceae	1	39.0	6,513.10	3,256.50
14	*Khaya senegalensis*	Meliaceae	2	38.6	2,294.90	1,147.40
15	*Leucaena leucocephala*	Fabaceae	7	37.8	5,971.60	2,985.80
16	*Pinus caribaea*	Pinaceae	1	53.3	640.40	320.20
17	*Polyalthia longifolia*	Annonaceae	6	49.8	3,524.30	1,762.10
18	*Pterocarpus osun*	Papilionoideae	1	45.0	2,556.50	1,278.20
19	*Spondias mombin*	Anarcardiaceae	1	22.5	424.70	212.30
20	*Tectona grandis*	Verbenaceae	30	51.1	49,453.70	24,726.80
21	*Terminalia catappa*	Combretaceae	5	43.6	11,451.10	5,725.50
22	*Terminalia mentally*	Combretaceae	37	32.1	44,113.80	22,206.90
	Total		**220**		**401,054.00**	**208,480.40**

Table 2: Mean height, Biomass and Carbon Sequestered by Tree species in OAUSTECH

S/N	Scientific Name	Family	Freq	M-Height (m)	Biomass (Kg/m^3)	Carbon (Kg/m^3)
1	*Bauhinia purpurea*	Fabaceae	3	6.2	153.80	76.90
2	*Delonix regia*	Fabaceae	7	7.9	1,631.00	815.50
3	*Gmelina arborea*	Verbenaceae	9	9.8	606.00	303.00
4	*Hura crepitans*	Euphorbiaceae	4	11.5	789.00	394.50
5	*Moringa oleifera*	Moringaceae	1	8.5	104.80	52.40
6	*Polyalthia longifolia*	Annonaceae	7	10.4	776.30	388.10
7	*Terminalia catappa*	Combretaceae	6	9.4	195.30	97.60
8	*Terminalia mantaly*	Combretaceae	3	15.8	527.40	263.70
	Total		**40**		**4,783.60**	**2,391.70**

Table 3: Mean height, Biomass and Carbon Sequestered by Tree species in UNIMED

S/N	Scientific Name	Family	Freq	M-Height (m)	Biomass (Kg/m^3)	Carbon (Kg/m^3)
1	*Swietenia macrophylla*	Meliaceae	5	13.4	896.10	448.00
2	*Tectona grandis*	Verbenaceae	3	10.3	155.30	77.60
3	*Azadirachta indica*	Meliaceae	2	19.5	1,402.00	701.10
	Total		**10**		**2,453.40**	**1,226.70**

Species Diversity

The Shannon-Weiner index of 2.46 was recorded for AAUA followed by OAUSTECH with 1.85 and 0.93 was recorded for UNIMED (Table 4). Evenness index highest value for this study was recorded for UNIMED campus with 0.84 followed by OAUSTECH with 0.80 while AAUA campus had 0.53 evenness value amongst these university campuses. The results of Margalef's index of species diversity recorded the highest in AAUA with 3.89 followed OAUSTECH with 1.90 and the lowest was recorded from UNIMED with 0.87 for the index (Table 4). The Shannon-Weiner index obtained in this study was lower than the findings of Ogundele *et al*., (2021), and Akindele, (2013) who reported 3.37 and 3.74 Shannon-Weiner values in their articles respectively. Pielou's evenness index obtained from UNIMED and OAUSTECH as 0.8445 and 0.7980 were higher than 0.68 reported by Ogundele *et al*., (2021). But AAUA Pielou's evenness of 0.53 was lower than the value reported by Akindele, (2013). Again, Margalef's index obtained in this study for the three university campuses were lower than the values reported in Ogundele *et al*., (2021). The report of Akindele, (2013) on "tree species diversity and structure of a Nigerian strict nature reserve had 64.72 Margalef's index of species diversity which is far higher than the values obtained for this study. The Shannon-Weiner and Margalef's diversity indices with high values revealed forest ecosystem with diverse tree species and abundance. The Shannon-Weiner and Evenness indices obtained for this study are higher than the values reported by Rajkumar and Parthasarathy, (2008) who reported 0.18 evenness species diversity index in the article published on "tree diversity and structure of Andaman Giant Evergreen Forests, India". The evenness index ranges from 0 to 1, with result of 1 indicating that all species have the same abundance (Kanieski *et al*., 2010). In addition, Shannon index as reported by Durán *et al*., (2006) ranges between 2.69 and 3.33 and this is also higher than the result of this study. This indicated that there is less diversity of species in these campuses but offered varied ecosystem services. The result of comparison of the species diversity indices was not significantly different from one another at $P < 0.05$ (Table 5). But AAUA offered higher tree species diversity as evident from the result. It is encouraged that diverse tree species be planted or retained in and around university campuses for maximum benefit.

Table 4: Tree species diversity of AAUA, UNIMED and OAUSTECH

Diversity indices	AAUA	UNIMED	OAUSTECH
Shannon-Weiner	2.4630	0.9297	1.8540
Evenness	0.5335	0.8445	0.7980
Margalef	3.8930	0.8686	1.8980

Table 5: ANOVA result for comparison of species diversity indices values

Source of Variation	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Diversity Indices	2.0	3.016	1.508	1.400	0.317 *ns*
Residuals	6.0	6.464	1.077		

ns means not significantly different (P < .05)

Conclusions and Recommendations

The presence of many indigenous and exotic tree species on university campuses enhances carbon sequestration and encourages conservation of these trees species that are scarce in most natural forests ecosystems. Therefore, the university campuses are regarded as live gene bank of tree species. The AAUA campus holds more tree species than the other two campuses considered for this study. Also, the diversity indices are higher in AAUA compare to UNIMED and OAUSTECH except the evenness index where

UNIMED provide the lead but the results of the diversity indices were not significantly different. The tree species benefits will be higher in AAUA campus due to more individual and tree species present. Consequently, it is recommended that diverse tree species should be planted or retained in and around university campuses for maximum benefit.

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LIFE-FORM DISTRIBUTION AND STOCK DENSITY OF PLANTS OF FOOD AND PHARMACEUTICAL IN A COMMUNITY-PROTECTED RAINFOREST IN AKWA IBOM STATE, NIGERIA

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ABSTRACT
Sustainable management of the remaining tracts of Nigerian rainforest for production of multiple forest goods cannot be realized with paucity of quantitative and qualitative ecological data and information on the constituent plant species. Thus, a community-owned lowland rainforest in Akwa Ibom State, Nigeria was assessed for plants producing edible and pharmaceutical products using the combination of systematic and simple random sampling techniques. The identified plant species were classified into life-forms. The stock density of individual species was determined on per/ha basis, and data obtained were also analysed employing descriptive statistic of pie-chart.The results indicated that thirty-nine (39) plant species were encountered. With respect to population density, *Nephytytis constrita* had the highest population density of 323 per/ha, while *Melastomastrus capitatum* had the least of 4 per/ha under herb life-form; *Microdermis puberula* had the highest of 33 per/ha, while the least of 2 per/ha was recorded by *Araliopsis soyanuxii* under herb; in the climber life-form, *Icacina trichanta* had the highest of 35 per/ha and *Abrus precatorius* had the least of 1 per/ha; *Canarium schwinfurthii* has the highest 42 per/ha, while the least of 2 per/ha a piece was recorded for *Brachystegia nigerica*, *Colamillenii* and *Dacryodes edulis*under the tree life-form. The distribution of the encountered plant species among the life-forms indicated that 31% was herb, 28% tree, 26% shrub and 15% climber. Sustainable management of the forest for production of multiple forest goods is strongly proffered to engender the conservation of the forest's biodiversity.

Key Words: Rainforest, plants, food, medicine, sustainable forest management.

INTRODUCTION
The importance of tropical rainforest biome in the well-being of human cannot be over-stressed. The tropical rainforest is acornucopia of basic needs of man for food, medicine, shelter energy and healthy environment. The world tropical rainforest is the most biological diverse ecosystem on earth, that is, the richest in term of diversity of plant and animal species (Turner, 2001; Gillespies *et al*., 2004; ITTO, 2011).The Nigerian rainforest is an integral part of the world tropical rainforest. The rainforest covers 95,372 km^2 of the Nigerian landmass of 983,213km^2 (Akindele, 2012 and Akpan-Ebe, 2015).

A tract of rainforest is often erroneously exclusively valued for the population of density of desirable timber trees present therein, while much more valuable non-timber plant resources were ignored. Consequently, vast areas of rainforest considered poor in desirable timber tree species, but richly stocked with diversity of valuable non-timber plant resources have been converted to farmlands, plantation agriculture and far less valuable monoculture forests of mostly fast-growing exotic tree species. The non-timber products from many of the rainforest plants include items of food, medicine, livestock fodder and raw materials for cottage industries. Until recently little or no recognition was given to the non-timber forest products (NTFPs) in the scheme of forest management. Incomes generated from most NTFPs do not get entered into the national economic ledger to calculate the actual total contribution of forestry sub-sector to the gross domestic product [GDP] (Lorbach *et al*., 2000, Ella and Domingo, 2014). The Nigerian rainforest is stocked with diversity of plants that are sources of edible and medicinal products in the forms of fruits, seeds, nuts, leaves, twigs, barks, floral and roots. It has been observed that the edible plant materials from the rainforest ecosystem are mostly available at the seasons of the year when the cultivated crops are not yet mature or off seasons (Oni and Gbadamosi, 1998 and Udo, 2016). The edible forest products constitute important and cheap sources of vitamins, minerals, protein, carbohydrate, fat and oil of the diets of the largely rural people. A considerable number of plant species of the rainforest have been identified to contain therapeutic ingredients. The people have for ages been depending on these plant materials for their healthcare needs. Natural forests, particularly tropical rainforest, provide the only medicine available to the largest proportion of the world population of which 90-95% is in the developing world, and the high concentration of different chemicals in some plants serve as raw materials for the production of modern drugs (FAO, 1985; Panayotou and Ashton, 1992; ITTO, 2011). It has been estimated that some 9,000 species of medicinal plants are thus threatened (Burford et al., 2000; Maazou and Wema, 2011). The Nigerian rainforest has been widely destroyed and now generally occurred in scattered patches (Akpan-Ebe, 2015 and Olajide, 2018). Sustainable management of the remaining tracts of rainforest for production of multiple forest goods will be an illusion without sufficient quantitative ecological data on constituent plant species, especially, those producing socio-economically valuable non-timber forest products. Thus, this paper is a report of an assessment of plant species of food and pharmaceutical products in a community-protected lowland rainforest. It is hoped that the information obtained would help sustainable management of the forest and similar other tracts of rainforest for the production of multiple forest goods.

Materials and methods

Study Area

The study was carried out in Abam Itak Forest, Ikono Local Government Area of Akwa Ibom State, Nigeria. The forest is a disturbed lowland tropical rainforest that covers an area of 29.6ha. The area lies between latitudes 5°00' and 5°23'N, and longitude 7°40' and 7°56'E. The mean annual rainfall of the area is 2400mm, while the mean minimum and maximum temperatures are 25°C and 30°C respectively. The mean relative humidity of the area is 83%. The soil type of the area is predominantly silt-loam. The forest had been subjected to timber and other wood resource exploitations in the recent past.

Data Collection

Four 200m belt transects were laid randomly, at 5m away from the major access route, into the forest. Fifty 5m x 5m quadrats were laid alternately at randomly selected points along each belt transect to assess and enumerate permanent undergrowth species. In the case of trees, four 50m x 50m sample plots were laid alternately at randomly selected points along each belt transect. Accordingly, the undergrowth species producing food and pharmaceutical products were identified and enumerated in all the quadrats, while the trees in the 50m x 50m sample plots. The identification of the plants and their food and medicinal products were made on the field with the aid of two forest taxonomists and four resident natives of the community whose ages ranged between 55 and 63 years.

Data Analysis

The enumerated plant species were classified into four life-forms or habits of herb, shrub, climber and tree. The population density per/ha of each species in each of the life-forms was determined from its population in the total area of all the quadrats enumerated, which was 0.5ha, while the population of each tree species was determined from the total area of the enumerated sample plots (4ha). The data were further subjected to descriptive statistic of pie-chart.

RESULTS

Thirty-nine (39) plant species producing various food and pharmaceutical products were encountered. The distribution of the species across the life-forms or habits is as follows: shrubs: 10; herbs: 12; climbers: 6 and trees: 11. Under shrub category, the highest population density of 33 per/ha was recorded by *Microdermis puberula*, while *Araliopsis soyauxii* had the least of 2 per/ha (Table 1). *Nephytytis constrita* had the highest population of 323 per/ha, while *Melastomastrus capitatum* had the least of 4 per/ha under herb life-form (Table 1). Under the climber life-form, *Icacina trichanta* had the highest population density of 35 per/ha, while *Abrus precatorius* had the least of 1 per/ha, and in the category of trees, *Canarium schwinfurthii* had the highest of 42 per/ha, while the least of 2 per/ha apiece was recorded for *Brachystegia nigerica*, *Cola millenii* and *Dacryodes edulis* (Table 1).

Table 1: Population density of plant species producing food and pharmaceutical products in Abam Itak Forest, AkwaIbom State, Nigeria.

	Shrub	**Population density (per/ha)**
1.	*Aralopsis soyauxii*	2
2.	*Genestis ferruginea*	22
3.	*Lasienthra africanum*	21
4.	*Maesobotrya dusenii*	7
5.	*Mallotus oppositifolius*	3
6.	*Microdermis puberula*	33
7.	*Rauvolffia vomitoria*	6
8.	*Rothmania hispida*	29
9.	*Sorindeia mildbrieadii*	16
10.	*Uvaria chamae*	19
	Herb	
1.	*Acanthus montanus*	33
2.	*Afromomum melegueta*	44
3.	*Afromomum sceptrum*	16
4.	*Anchomanes difformis*	56
5.	*Costus afer*	15
6.	*Laportea aestuans*	31
7.	*Marantochloa cuspidate*	30
8.	*Melastomastrus capitatum*	4
9.	*Nephytytis constrita*	323
10.	*Palisota hirsota*	162
11.	*Physalis angulata*	241
12.	*Piper umbrellacum*	84
	Climber	

	Shrub	Population density (per/ha)
1.	*Abrus precatorus*	1
2.	*Gnetunm africanum*	15
3.	*Gongronema latifolium*	8
4.	*Icacina trichanta*	24
5.	*Lonchocarpus cyanescens*	3
6.	*Smilax anceps*	11
	Tree	
1.	*Brachystegia eurycoma*	3
2.	*Brachystegia nigerica*	2
3.	*Canarium schwinfurthii*	42
4.	*Cola millenii*	2
5.	*Coula edulis*	27
6.	*Dacryodes edulis*	2
7.	*Irvingia gabonensis*	3
8.	*Pentaclethra macrophylla*	22
9.	*Petersia africanum*	14
10.	*Pycnanthus angolensis*	3
11.	*Xylopia aethipica*	3

The life-form distribution of the plant species showed that 31% was herb, 28% tree, 26% shrub and 15% climber (Fig. 1). The food and pharmaceutical products from these plants vary from fruits, seeds, nuts, barks, leaves, tubers and root (Table 2).

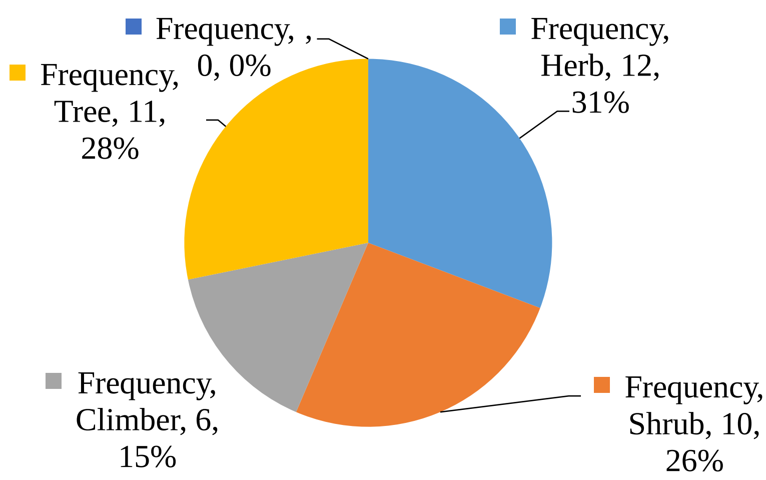

Fig. 1: Distribution of the identified plant species of food and pharmaceutical products into life-form.

Table 2: Food and pharmaceutical products of the plant species

	Shrub	Food and pharmaceutical product
1.	*Aralopsis soyauxii*	Livestock fodder
2.	*Gnestis ferruginea*	Edible fruit
3.	*Lasienthra africanum*	Edible and medicinal leaves
4.	*Maesobotrya dusenii*	Edible and medicinal leaves
5.	*Mallotus oppositifolius*	Livestock fodder
6.	*Microdermis puberula*	Edible leaves and livestock fodder
7.	*Rauvolfia vomitoria*	Livestock fodder
8.	*Rothmania hispida*	Medicinal leaves

9.	*Sorindeia mildbrieadii*	Edible seeds
10.	*Uvaria chamae*	Edible fruit
	Herb	
1.	*Acanthus montanus*	Medicinal leaves
2.	*Afromomum melegueta*	Medicinal leaves
3.	*Afromomum sceptrum*	Edible fruit and pulp, medicinal rhosome
4.	*Anchomanes difformus*	Medicinal leaves
5.	*Costus afer*	Medicinal rhizome
6.	*Laportea aestuans*	Medicinal leaves and root
7.	*Marantochloa cuspidate*	Livestock fodder
8.	*Melastomastrus capitatum*	Edible fruit and medicinal leaves
9.	*Nephytytis constrita*	Medicinal leaves
10.	*Palisota hirsota*	Medicinal leaves and livestock fodder
11.	*Physalis angulate*	Medicinal leaves
12.	*Piper umbrellacum*	Medicinal leaves
	Climber	
1.	*Abrus precatorus*	Medicinal leaves and seeds
2.	*Gnetum africanum*	Edible and medicinal leaves
3.	*Gongronema latifolium*	Edible and medicinal leaves
4.	*Icacina trichanta*	Edible fruit
5.	*Lonchocarpus cynanescans*	Medicinal leaves
6.	*Smilac anceps*	Medicinal leaves
	Tree	
1.	*Brachystegia eurycoma*	Edible seed (soup condiment)
2.	*Brachstegia nigsica*	Edible seed
3.	*Canarium schwinfurthii*	Edible fruit
4.	*Cola millenii*	Medical bark and root
5.	*Coula edulis*	Edible nuts
6.	*Dacryode edulis*	Edible fruit
7.	*Irvingia gabonensis*	Edible fruit and nuts
8.	*Pentadethra macrophylla*	Edible seeds
9.	*Petersia africanum*	Medicinal leaves
10.	*Pycnanthus angolensis*	Medicinal leaves and bark
11.	*Xylopia aethiopica*	Spicy and medicinal fruit

DISCUSSION

The occurrence and stocks density of a plant species in a rainforest ecosystem is a function of availability of its seeds and other propagules (propagation forms), coupledwith the presence of favourable micro-climates for germination and growth. Moreover, the abundance or rarity of a plant species that produces socio-economic product(s) is contingent on the intensity and pattern of its exploitation and general management of the forest. A plant species is deemed abundant in a tropical rainforest ecosystem if its population density is $\geq$10per/ha (Parthasaeathy and Karthikeyan, 1997, Nath *et al*., 2005).Therefore, the high population densities of most herb species indicate that, the study forest is a disturbed rainforest with the micro-climate at the forest floor favourable for their prolific regeneration and growth.This favourable micro-climate is primarily facilitated by canopy gaps occasioned by excessive tree felling, which increase the insolation on the forest floor that induces germination and rapid growth of the undergrowth species particularly herbs. This observation of the higher population densities of most herb species of ethno-botany or socio-economic importance compare to other life-forms had been reported by previous studies on disturbed tropical rainforests (Nath *et al*., 2005; Olajide and Udofia, 2008; Olajide and Udo, 2014; Olajide *et al*., 2019).

The relatively fewer population of most tree species may be ascribed to their over-exploitation for stakes, poles, firewood and timber. Similar observations of very low population densities of timber tree species producing socio-economically valuable non-timber forest products in some rainforest reserves had earlier been reported (Olajide *et al*., 2010; Olajide and Etigale, 2017). Moreover, the collection of most of the trees' seeds for food and medicine might result in gross scarcity of seeds to sustain natural regeneration in the forest.

CONCLUSION

Following the presence and high stock densities of many plant species of food and pharmaceutical in the study rainforest, it therefore, presupposes that sustainable multiple-value management should be applied to the forest to engender sustainable production of diverse forest goods. Indiscriminate felling of trees should be prohibited in the forest to forestall the loss of trees of food and pharmaceutical products. Some of the plant species, particularly trees, should be incorporated to or domesticated in farms to reduce pressures on the forest for extraction of their products.

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COMPATIBILITY EVALUATION AND HISTOLOGICAL OBSERVATION OF GRAFT UNION DEVELOPMENT IN FRUIT SPECIES

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Abstract
Plant grafting is a typical horticultural technique involving combining rootstock and scion to create a new plant. It is among the most common approaches used in agriculture to improve the quality and yield of various crops. Grafting aids in the improvement of plant health, yield, and quality of plant products, hence needs to be studied in details. The growth of callus tissue and the formation of vascular tissues can all be assessed by examining the prepared graft samples. As a result, anatomical evaluation of the compatibility of various rootstock/stock graft combinations is important. On the other hand our understanding of in vitro culture systems has benefited greatly from histological approaches. A good histological investigation based on anatomical and histochemical alterations provides insight into cellular processes and clues that allow for further experimentation to be proposed. In this context, histological analyses of graft sections provide us with preliminary information on the compatibility of combinations in a timely manner. The anatomical technique, on the other hand, is an excellent way to observe the early stages of the grafting process and structural changes at the graft interface, allowing us to observe the formation of fine structures between the scion and rootstock and thus improve our understanding of graft union formation.

Keywords: *Rootstock, Scion, Graft Compatibility, Callus, Histology.*

Introduction

Fruit species have increased more intrigue as of late because of high dietary benefit, phytochemical content and human wellbeing impacts. It has been perceived as a good source of nutrients and minerals, and for their role in preventing nutrient C and nutrient A deficiencies (Kamiloğlu *et al*., 2009; Tosun *et al*., 2009; Zorenc *et al*., 2016)

In many occasions, fruit species fill in as an alternative for nourishment as it promote food security and it likewise improves important nourishment and assorted variety to lessen dullness in human eating regimen. Moreover, these organic products species are edible and are been recognised to contain significant level of nutrient C, proteins, sugar, minerals and so on, therefore assuming a significant role in the nutritional balance of humanity (FAO, 1989).

In addition, these fruits species likewise add to medicinal services conveyance as their barks, natural products, seeds, leaves, roots, and so on could be utilized to fix an assortment of disorder and illnesses (FAO, 1998) and most essentially they additionally add to monetary improvement (Adewusi, 1997). The commitments of these fruits species to human prosperity had been incredibly revealed and should be extraordinarily continued (FAO, 2010). In this manner, Sustainability is fundamental for the consistent stockpile of its assets.

It is important to conserve these hereditary assets in light of the fact of their immediate utilization by man, it likewise assumes a significant role in several ecological functions such as flood and erosion control, maintenance of water quality, and climate amelioration (Jamnadass, *et al*., 2011). For whatever length of time that individuals have lived on the surface of earth, we will even now depend on natural products to support and improve the nature of our lives.

Regularly, these fruit species have various ways where we can raise them either through seeds, or by vegetative propagation. In any case, most time some of these fruit species experience issues in raising them through seeds in light of the fact that their proliferation by seed gives poor outcomes and distinctive seed treatment (scarification and acid treatment) did not essentially improve germination. Might not breed true to type therefore vegetative propagation is sort for.

The aim of this study is to describe, briefly, graft union formation in relation to compatibility/incompatibility growing features among different clonal rootstock and scion

Vegetative propagation

Vegetative recovery is both an artificial and natural procedure (Leakey and Mohammed,, 1985). The artificial procedure is utilized by agriculturist, horticulturists and foresters, to capture and increase individual genotypes, thus producing cultivars and clones (Mudge and Brennan, 1999). It is feasible for multiplication to happen through the arrangement of extrinsic roots and shoots in light of the fact that each cell of the plant contains the hereditary data important to regenerate the entire plant (Amri *et al*., 2010).

Vegetative propagation offers consistent with type and availability of superior individuals in a brief timeframe for huge scope of commercial plantation. It is a key apparatus for plant domestication and breeding with numerous focal points which incorporate fast increase of species that is under threat just as offering a one of a kind chance of maintaining a strategic distance from the issues related with seed viability and recalcitrant seeds prevalent in tropical tree species (Leakey, 1990). It is valuable in the creation of cultivars that are seedless, promising species, which have inadequate stockpile of seeds because of mammalian predation, pest and disease attack. A range of approaches can be used for vegetative propagation yet the significant ones are by cuttings, grafting and micro propagation through in vitro culture to multiply ontogenetically mature shoots that are very difficult to propagate (Amri, 2010). Vegetative propagation of plants is basically the multiplication of plant material from vegetative organs so the posterity will contain the specific qualities of the parent plants with regards to genotypes (Macdonald, 1996). This is possible on the grounds that plants have meristematic, undifferentiated cells that can separate to the different organs important to form an entirely different plant. Therefore a bit of plant shoot, root, or leaf can develop to form another plant that contains the specific hereditary data of its source plant. The vegetative propagation methodology can add value in terms of possible conservation, reduction in fruiting age, quick financial returns and subsequently boosting monetary activities and generation of employment both in the rural and urban areas (Jamnadass *et al*., 2011).

Fruits and nut trees are usually propagated by vegetative methods utilizing grafting techniques (Mmng'omba *et al*., 2008). This technique is utilized to make another plant through the union of an appropriate rootstock and an aerial part of another plant of the desired variety, called a scion.

So far nitty gritty degrees of progress have been made on the grafting of some fruits species which include: *Garcinia kola* (orogbo). Yakubu *et al*. (2014) developed up a proper procedure through grafting and budding of *G. kola* and a high level of accomplishment was recorded. Likewise Yakubu *et al*. (2011) examination had a critical achievement in grafting *I. wombolu*. Sanou *et al.,* (2014). Additionally helped out vegetative propagation through grafting on *Vitellaria paradoxa* and recorded a high achievement pace of combination between the root stock and the scion. Before a degree of graft success can be said to be recorded, there is need to affirm the compatibility between the rootstock and the scion through anatomical procedures.

Appropriate rootstocks/scion must be utilized so as to acquire high quality and yield in various climatic and unfriendly soil conditions, to control the growth vigour of trees, to give early resilience to infestation and resistance against diseases and pests. Consequently, there is a need to recognize and comprehend the essential characteristics for development of the fruits species. The principle factor that decides the achievement of grafting is compatibility status between the rootstock and scion.

Fruit tress compatibility

In regard to this the deciding component for the compatibility of the graft union is the capacity of the rootstock and scion cambia layers to bind together. Henceforth, for the improvement of the graft union there must be a cell to cell association between the rootstock and scion as the endo-hormones assists to trigger shoots development in the scion (Yin *et al*., 2012). The external layers uncovered in the cambium area, in both the scion and the rootstock, produce parenchyma cells that blend and join, forming what is commonly called callus tissue. In this callus tissue, cells that align with the intact cambium and graft rootstock differentiate into new foreign cells, which are a pre-requisite for the successful union of vascular plants (Hartmann *et al.,* 2011). After the vascular tissue of the rootstock and scion interfere the activity of xylem and phloem will function to support the plant growth.

On the other hand, frail development of rootstocks may cause incompatibility during the graft formation. Grafting is a troublesome process and waiting for a long time to observe grafting success can cause money, time and effort loss. Considering prepared graft samples, it gives opportunity to evaluate the improvement of callus tissue, the situation of necrotic layers, cambial differentiation, cambial congruity and the advancement of vascular tissues. On the other hand, irregular anatomical developments identified with developing highlights of graft individuals in graft union can cause incompatibility. The incompatibilities that may emerge after the orchard plantation will cause serious economic losses. It has been recommended that irregular anatomical features are the consequences of inconsistency of the tissues of bud and rootstocks, and these variations from the norm emerge either during the development of the graft union as a response to contact between bud and rootstock or during subsequent growth of the composite tree as a result of physiological or biochemical interactions (Simons 1986). In this regard, anatomical evaluations on graft sections give us first information about compatibility or incompatibility of combinations in a short time (Vachun, 1995; Grzyb *et al*., 1998; Kankaya *et al*., 1999).

Hence, anatomical assessment of the concurrence of various rootstock/stock graft combinations is a rescuer approach. Fruit trees are formed by a combination of the rootstock that gives root framework and the scion that produces the crop. All together for that combination to be effective, an acceptable relationship among scion and rootstock is essential However, graft incompatibility happens as often as possible in combinations (Errea *et al*., 2001). Grafting is a fundamental practice in fruit species tree management to guarantee high plantation yield productivity and high return quality. But, the issue of incapability among rootstock and scion in fruit culture has existed since the time grafting and budding were first utilized (Sitarek, 2006). The term incompatibility with respect to grafted fruit trees is characterized as a premature senescence brought about by physiological and biochemical procedure (Feucht, 1988). A graft union is considered as effective when several functional phloem and xylem connects across the graft surface (Schoning and Kollman, 1997). However, incompatible grafts can grow several years with no outside manifestation of incompatibility, showing presence of functional vascular connection (Mosse, 1962; Errea *et al*., 1994). Some anomalous developments in the structure of the union are found in some anatomical examinations on graft union. These variations such as, poor vascular connections, phloem degeneration and cambial or vascular discontinuity in the association zone can cause mechanical weakness and resulting breakdown of the union (Hartmann *et al*., 1997; Errea *et al*., 2001). Likewise vascular tissues that developed between the rootstock and scion were organized in a whirling pattern, and became necrotic during subsequent development of the plant (Simons and Chu, 1984; Soumelidou *et al*., 1994).

In this manner graft compatibility situations between various rootstocks/stock ought to be assessed by understanding the plant's anatomy systems which will assist breeders with developing a procedure for its further enhancements. Along these lines, rootstocks and scion ought to be controlled by the anatomical perceptions sections prepared from graft zone.
More or less, the point of this exploration is to look at the early biological processes that occur in phases of graft union development in relation to compatibility/through anatomical assessment of the different rootstock/scion combinations.
As part of the investigation concerning the fundamental reasons for limited compatibility and incompatibility, we report the procedure of a histological investigation of various grafts undertaken so as to acquire more data about the sequential arrangement of graft development in compatible and incompatible combinations.

Histology

Plant histology can be characterized essentially the study of the microscopic structure or attributes of cells and their assembly and arrangement into tissue and organs. Histological techniques are broadly utilized in numerous areas of research. Basic investigation is a significant initial phase in the investigation of the association and changes in the plant body, and it is an extremely valuable methodology in the investigation of plant morphogenesis. The development of the tissues is dynamic and changes from moment to moment, investigating the slides give the data with respect to the progressions that occurs during development process. Most histological samples need preparation before microscopic observation; these methods depend on the specimen and method of observation.
This system utilizes microscopic study of plant cell and tissues through staining, sectioning and examing at under a magnifying instrument (electron or light magnifying instrument) (Shostak, 2013). There are different techniques used to study tissue characteristics and microscopic structures of the cells. Histological procedure is a progression of technique undertaken in the readiness of test tissues by utilizing histological stains to aid in the microscope study (Anderson, 2011). This procedure takes five key stages which include; fixation, processing, embedding, sectioning and staining (Titford, 2009).

Fixation

Fixation in histology: Fixation alludes to the utilization of chemicals to preserve the natural tissue structure and maintain the cell structure from degradation. Mostly, 10% neutral buffered formalin or NBF (4% formaldehyde in phosphate buffered saline). Ross and Pawlina 2016). Generally, samples of graft combination of rootstock/scion taken at intervals depending on the type of plant are used for this procedure. The samples are immersed in fixative for 24 hrs. After 24 hours the materials will thoroughly be washed and put away in 70% alcohol. Mostly used when a light microscope is to be used to conduct the study Fixatives enhance the preservation of tissues and cells through an irreversible procedure cross-connecting protein. The fixation stage retains the chemical composition of the tissues, hardens the cells or tissues for sectioning and delays degradation (Titford, 2009). In addition, fixatives changes tissue penetration and influence antigen exposures which might be beneficial or detrimental (Iyiola and Avwioro, 2011). There are various fixatives being used, yet the formaldehyde fixatives are the most usually utilized (Black, 2012). The neutral buffered formalin (NBF) stabilizes amino acids in proteins and offers great tissues and cell structure preservation. Formalin fixation usually prompts degradation of mRNA, miRNA, and DNA as well as denaturation and alteration of proteins in tissues. In any case, extraction and investigation of nucleic acids and proteins from formalin-fixed, paraffin- embedded tissues is possible utilizing appropriate protocols (Weiss *et al.*,2011, Bennike *et al*., 2016).

Embedding

The stored materials in 70% alcohol will then are dehydrated by passing them in ethanol-xylene series.. Samples are transferred through series of progressively more concentrated ethanol baths, up to 100% ethanol to remove remaining traces of water. (Ross and Pawlina 2016). And keeping in mind that lack of hydration, the infiltration will be done by adding paraffin wax to the ethanol-xylene mixture by this procedure the paraffin accumulate into the callus. After saturation the callus were embedded in paraffin wax and blocks will be prepared. These blocks ill at that point be fixed to rider for microtome sectioning. This tissue embedded in paraffin wax assists with providing a mode of support and to permit the cutting of the thin tissue slices (Ross and Pawlina 2016)
In this step, the aim is to expel water from the selected tissues to set them and encourage the cutting of slender segments of slides, more thinly for use in light microscopes and thick for the electron microscope. In general, water should initially be expelled from tissues (dehydration) and replaced with a medium that either hardens directly, or with an intermediary fluid (clearing) that is miscible with the embedding media. For light microscopy, paraffin wax is most frequently utilized embedding material. (Mark, 2019). The procedure is repeated through a hydrophobic clearing substance, for example, xylene to expel the alcohol (Titford, 2009). Once penetrated in paraffin, tissues are situated in molds which are loaded up with wax; once situated, the wax is cooled, it hardening the block and tissue.

Segmenting

The solidified and castened blocks will be utilized for microtomic segments. The blocks are subjected to 15-20 microns segmenting or relying upon the necessary microns. The segments are prepared in ethanol-xylene series and finally stained with toxyline stain. The stained sections were made permanent utilising DPX mountant
For light microscopy, a blade mounted in a microtome is utilized to cut tissue sections which are mounted on a glass microscope slide. (Ross and Pawlina 2016)] In histology, sectioning alludes to the preparation of 'ribbon' like microtomes of a tissue to mount it on a microscope slide for examination (Cai *et al*., 2014). In this case, arrangement of thin sections of tissues of required thickness are sliced and arranged through the paraffin method. After the histological procedures, five basic phases of the graft formation will be analyzed on the samples: ((1) development and positions of necrotic layers, (2) proliferation of callus cells, (3) formation of callus bridge at the graft interface, (4) cambial continuity and (5) formation of vascular tissues.

To this end, some degree of accomplishment had been obtained from grafting through histology procedures and this include and not limited to discoveries of Yildirim *et al*., (2010) who detailed a histological examination on histological investigation on the graft formation in some spur and vigorous apple varieties grafted on Ottawa 3 rootstock and found out that there was a good union formation in the sections prepared from subsequent samples of graft combinations. The grafted seedlings necrotic layers were eliminated in the callus and were transformed to bark. Callus filled the gaps between interface of the stock and the scion. Cambial continuity occurred successfully and vascular tissues were connected. Thus, no evidences for tissue incompatibility were found in the study. Histological observations showed a compatible graft union between the graft partners which have different growing characteristics in relation to tissue formation.

Likewise, in apple rootstocks/scion combinations Dolgun *et al*., (2009) observed a successful level of compatibility between the graftage when observed through a microscopic study. Histological observations showed a compatible graft union in relation to tissue formation between graft members which have different growing features.

Furthermore, a similar kind of result by Farsi *et al*. (2017) was obtained from histological study of grafted seedlings of *Juglans regia* L. cv. Chandler scions (walnut). Cross and longitudinal sections of the graft union were taken for examining different stages of grafting process. The first callus cells were initiated from cambium layer of rootstock thus making a weak connection between the two parts. New vascular connections between rootstock and scion were later observed while vascular connections were increased in central parts of the graft union but later the grafted seedlings were tightly connected to each other and necrotic layer disappeared in most of cross and longitudinal sections. Although there was a weak connection between two parts at the initial stage of development of graft process which after some days the two parts were strongly connected by xylem vessels

Ermel *et al*. (1996) studied the comparative histological study of compatible and incompatible pear/pear and pear/quince grafts. And it was observed there was an adhesion between the two partners along the inner bark tissues (phloem and cambium), while a necrotic layer appeared at the graft interface. The first cell divisions were observed in the inner bark interface and this led to the formation of a junction callus, inside which new cambial strands (neocambia) appeared, starting from the cut edges of the scion and stock cambia, and joining later when they began to produce both phloem and xylem derivatives

Dolgun *et al*. (2009) reported from his histological study conducted in order to observe the graft formation of nectarine varieties Armking, Cherokee, Stark Red Gold and Independence, which were grafted on pixy rootstock. In every combination, callus formation, new cambium differentiating, cambial continuity and vascular tissues formation were noted successfully. All combinations were found compatible in histological observations.

In a study conducted by Özdemir *et al*. (2018), graft compatibility between almond cultivar rootstocks /scion was histologically investigated. The histological analysis of scion/ rootstock combinations was performed and at 30 days after grafting, the callus cells developed but cambial continuity has not occurred between the rootstock and scion tissues in all scion/rootstock combinations. 12 months after grafting, cambial relation was established, vascular differentiation was observed, regular parenchymatic tissue properties and scleroid cells and sclerenchyma bundles were seen in the graft union. There was no problem in terms of rootstock-scion compatibility

Histological studies in herbaceous plants are reported. Take for instance Fan *et al*. (2015) reported in a study of the structural development of graft union formation in tomato plants was examined using Scanning Electron Microscopy (SEM) and a paraffin sectioning technique. The images of the transection revealed that parenchymal cells from the graft union divided and proliferated in most combinations, and these cells could be detected at various stages of development. The SEM images of the scion and rootstock longitudinal sections showed that many interconnecting structures appeared and were followed by a vascular rearrangement that did not connect the scion and rootstock. But as time goes on, vascular bundle bridges appeared connecting the scion and rootstock. The connection of graft union between rootstock and scion is influenced by the plant growth condition.

Graft incompatibility in solanaceous plants by Kawaguchi *et al*., (2008) was investigated using representative cultivars of tomato (*Solanum lycopersicum* L.), eggplant (*Solanum melongena* L.), and pepper (*Capsicum annuum* L.). Evaluations of the extent of graft (in) compatibility were made by examining survival percentages, fruit yields, and fruit quality in grafted plants. Tomato/pepper (scion/rootstock) and pepper/tomato grafts were considered severely incompatible, and the tomato/eggplant and eggplant/tomato grafts were considered moderately incompatible. The anatomy of the graft unions was also observed. Growth inhibition and high mortality in tomato/pepper and pepper/tomato grafts (that is,., severe graft incompatibility) was observed due to discontinuities in the vascular bundles at the graft union, which prevented the translocation of assimilates, mineral nutrients, and water between scions and rootstocks. Plant responses to graft incompatibility varied in solanaceous plants depending on the scion and rootstock combination.

The grafting of two cucumber scions (*Cucumis sativus* L.)—Taiko hybrid and Tsuyoi hybrid— onto a Tropical hybrid pumpkin rootstock (*Cucurbita moschata* L.) was studied by Baron *et al*., (2018). The initial establishment of grafting through anatomical cuts on the region of union graft was evaluated

The results of the anatomical study uncovered that the Taiko cucumber scion grafted onto pumpkin rootstock showed earlier establishment of the graft compared to the Tsuyoi cucumber scion grafted onto pumpkin rootstock. The filling of spaces by parenchyma cells (callus tissue) was more effective on Taiko cucumber scions grafted onto pumpkin rootstock.

Conclusion

To buttress the points about grafting and anatomical studies, there is need to understand fully well that generally, a successful grafting includes the formation of necrotic layer, callus production, first cohesion of stock and scion by the callus junction, subsequent reduction or elimination of necrotic layer in callus, differentiation of some cells to the cambial cells, bridging of cambium tissues of stock and scion, and finally formation and strong connection of vascular tissues. However, the anatomical technique is an excellent way of approach to observe the early stages of the grafting process and the structural changes at the graft interface, which ensured observation of the generation of the fine structures between the scion and rootstock, thus increasing our understanding of the graft union formation.

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VARIATION IN WATER PROPERTIES OF SACHET WATER SAMPLES PRODUCED IN EDE, OSUN STATE

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ABSTRACT
Thirty (30) pieces of sachet water, _each source with three replicate samples produced in Ede and its environs, were randomly purchased from vendors and analyzed for their variation in water properties. Physical and chemical properties of the water samples were determined to ascertain their portability. Analysis of the chemical parameters such as total hardness, pH level and metal ion contents revealed the contents of the sample were below The World Health Organization (WHO) and The National Agency for Food and Drug Administration and Control (NAFDAC) recommended standards. The pH of all the water samples tested were within the standards of 6.5-9.5 with the lowest at 6.74 and the highest of 7.9. Metal ions, Total Dissolved Solids (TDS) and other parameters determined in the samples also complied with the recommended standards. The conformity of these samples to the basic standard required makes them healthy and fit for consumption.

Keywords: Water properties, Sachet water, metal ions, pH

INTRODUCTION
Water is one of the most important and sufficient compounds of the ecosystem. Every living thing on earth needs water for its survival and growth. Presently, planet earth has about 70% water (Patil et al., 2012). Access to safe drinking water is key to sustainable development and essential to food production, quality health and poverty reduction. But due to increased human population, industrialization, fertilizers used in agriculture and human activity, it is highly polluted with different harmful contaminants. Several small-scale industries are packaging and marketing factory-filled sachet drinking water, popularly called "pure water," that many consider a safer source of potable water (Emmanuel and Solomon 2012). Sachet water is any commercially treated water manufactured, packaged and distributed for sale in sealed plastic bags intended for human consumption (Uduma, 2014).

The sachet water industry has been a key player in the Nigerian economy for about three decades now. They came into existence in the 90s as a result of the inability of the government to make available pipe-borne water. The sachet water 'pure water' is potable water inside conserved polythene, usually in 500ml (50cl) sold for N10. Pure water for the world works in remote and underserved regions of developing countries that lack sustainable, clean and safe drinking water (Stoler et al., 2013). The business of packaging water in this form which was aimed at serving the needs of the poor and transient population initially started in transparent flexible plastic bags, which were manually filled usually with untreated water and knotted by hand. This was referred to as "iced" water. Consequently, the demand for "on the go" water extended beyond the initial demography. However, the questionable sources of water and the poor hygiene of vendors posed severe threats to the health of the drinking populace hence the evolution of "Pure water". .

This study determined the purity and safety of different water samples by assessing their properties in tandem with WHO/NAFDAC standard.

MATERIALS AND METHODS
Study design
The experimental study took place in a biotechnology laboratory, Forestry Research Institute of Nigeria, Ibadan where the following parameters, the pH, Total Dissolved Solids (TDS), Total hardness, Ca, Na, K, Cu, Chlorine, lead, iron, were tested.

Study Setting
Ede is a populated place in Osun State, Nigeria with its southwestern region. It is located at an elevation of 269 meters above sea level, total area of over 3,000 km^2 and a population of 159,866.

Study Samples
Only 30 pieces of sachet water, three from each source to serve as replicate samples, were selected at random and were purchased directly from vendors.

Sample size and sampling technique
This study employed a simple random technique. 30 sachets (10 sachets of different samples and 2 replica sachets of each sample) of water produced in Ede and its environs were purchased at random from various sachet water vendors and transported in ice-packed cooler to the biotechnology laboratory in Forestry Research Institute Ibadan for analysis. The physicochemical parameters assessed include the pH, total dissolved solids, hardness, colour, sodium, calcium, potassium, lead, iron, copper, chlorine, odour and taste.
There is need to show the WHO/NAFDAC standards to be used for comparing the present study here. We don't have to wait to see it in the result section only. This will quick understanding of the results and interpretations.

Water testing procedure for each parameter
Determination of pH
The pH was determined with a pH meter equipped with a glass electrode. The pH meter was calibrated using standard buffers, buffer 4 and 7 and de-ionized water. The electrode was cleaned, dried and dipped into the different samples, and the reading was recorded when the reading became stable. After the pH of the first sample was recorded, the electrode was re-washed with distilled water before being dipped into subsequent samples until all were tested.

Determination of chloride
3 drops of 0.1m potassium indicator was added to 10 mL aliquots of each water sample in a flask and titrated with 0.1m silver nitrate.

Determination of Total Dissolved Solids
Total dissolved solids (TDS) for each water sample was determined mathematically as a product of conductivity multiplied by a constant value, 0.6 (APHA, 1985).

$$TDS = \text{conductivity} \times 0.6$$

Determination of Heavy Metals
The following heavy metals; Iron (Fe), Lead (Pb), Copper (Cu), Zinc (Zn), Arsenic (As) and Manganese (Mn), were determined for each water sample using Atomic Absorption Spectrometry AAS (Buck Scientific, VPG 210) procedure as reported by Oyelola et al., 2008 and Olaoluwa et al., 2010. Each sample was digested using 100cm3 and a hollow cathode lamp of the desired metal. This was installed into the AAS instrument, and the wavelength characteristics of that metal were then set. The procedure used flame Atomic absorption spectrophotometry using acetylene/air. Concentrations of the analytes in mg/ml in the digested samples were obtained by extrapolation from the calibration curve prepared by American Public Health Association (APHA, 1985).

Statistical Analysis
The results were statistically analysed using Analysis of variance (ANOVA) operated through SPSS software developed by Microsoft Inc. to determine the variance of the physicochemical parameters of the sachet water samples.

RESULTS AND DISCUSSION
Table 1.0ASSESMENT OF CHEMICAL PARAMETERS

SAMPLES	Na mg/L	K mg/l	Pb mg/l	Fe mg/l	Ca mg/l	Cu mg/l
A	0.16±0.04	3.33±0.4	0.01±0.01	0.05±0.0	23.2±10.2	0.00±0.00
B	0.63±0.09	4.33±1.2	0.01±0.01	0.02±0.00	31.6±6.2	0.00±0.00
C	0.026±0.04	5.00±2.1	0.01±0.01	0.01±0.00	33.3±10.2	0.00±0.00
D	17.46±24.5	6.00±1.4	0.00±0.00	0.01±0.01	38.3±10.2	0.00±0.00
E	0.16±0.12	5.33±2.0	0.00±0.00	0.01±0.01	36.6±6.2	0.00±0.00
F	0.02 ± 0.09	4.66±1.6	0.00±0.01	0.03±0.03	30.0±4.0	0.00±0.00
G	39.35±39.0	5.66±1.2	0.01±0.01	0.02±0.1	42.5±2.5	0.00±0.00
H	0.2 ± 3.4	5.66±2.4	0.01±0.01	0.04±0.02	32.5±2.5	0.00±0.00
I	39.2 ± 39	5.33±2.0	0.00±0.00	0.05±0.04	37.5±2.5	0.00±0.00
J	0.2 ± 0.1	4.33±0.9	0.00±0.00	0.01±0.00	42.5±7.	0.00±0.00

WHO	200	10	0.01	0.3	75	1.0
NAFDAC	200	N/S	0.01	1.0	N/S	0.5

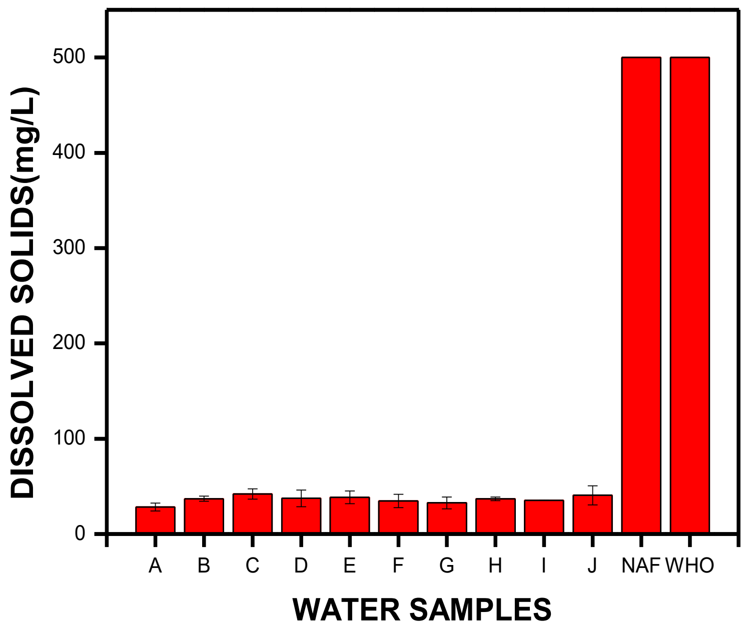

Figure 1: Total Dissolved solids of different sachet water samples produced in Ede compared with WHO and NAFDAC standards.

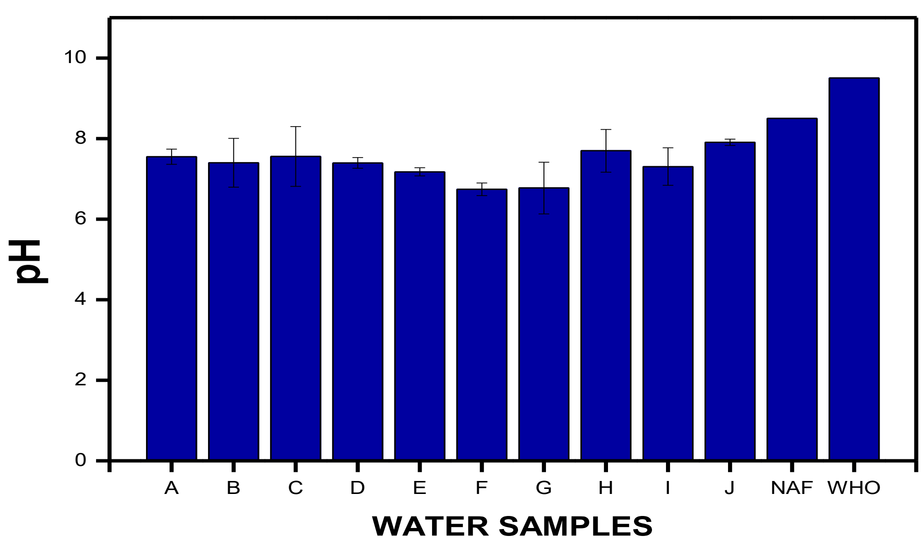

Figure 2. pH level of different sachet water samples produced in Ede compared with WHO and NAFDAC standards.

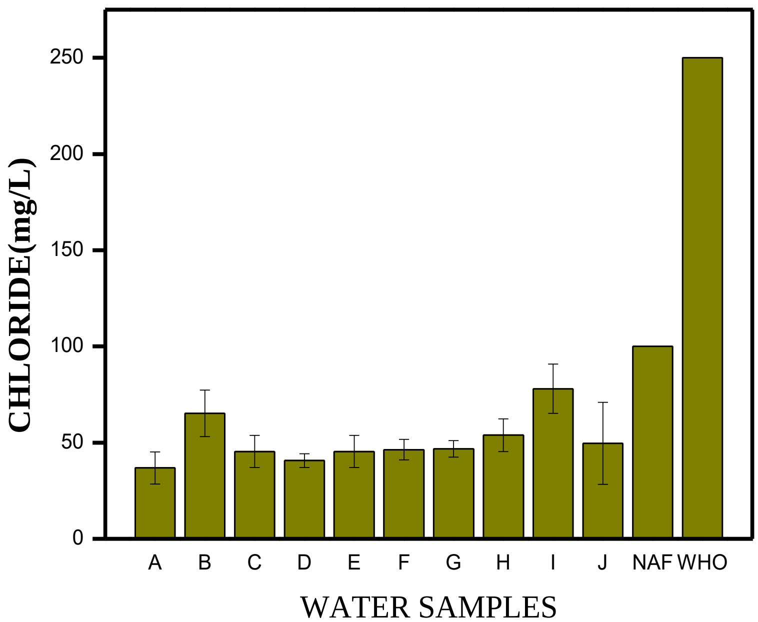

Figure 3.chlorine(mg/L) concentration of different sachet water samples produced in Ede compared with WHO and NAFDAC standards.

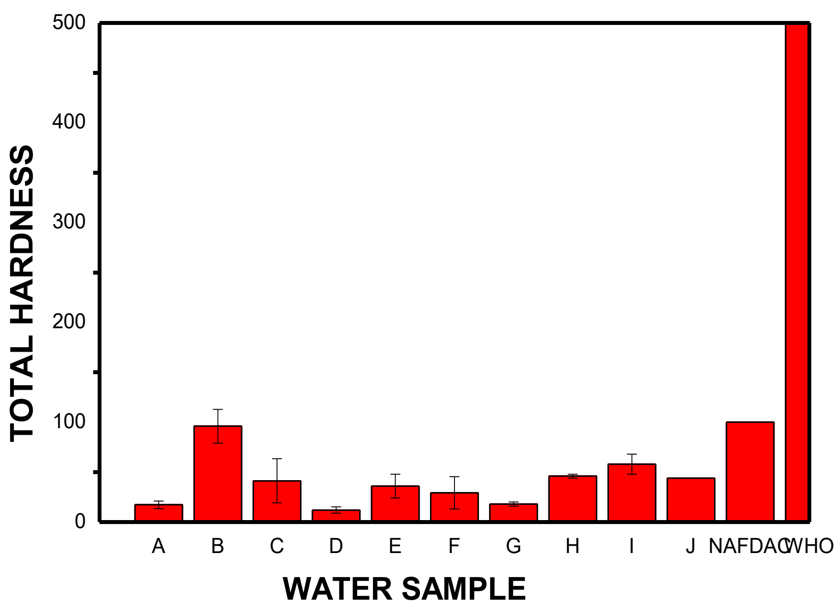

Figure 4. Total hardness (mg/l) concentration of different sachet water samples produced in Ede compared with WHO and NAFDAC standards.

RESULTS AND DISCUSSION

All the chemical parameters analyzed in the sachet water possess acceptable properties of water suitable for consumption and the results obtained are in agreement with a study carried out by Sheshe et al. (2014) on the assessment of the physicochemical quality of sachet water produced in selected local government in Kano, the result of that study revealed that the samples of water tested were odourless, tasteless and their appearance was clear. Water having an odour, taste and unclear appearance has been stated to indicate the presence of potentially harmful substances resulting from pollution or malfunction during water treatment (for instance chlorination) and distribution (Yusuf et al., 2015).

The various chemical parameters analyzed include the total hardness, pH level, chlorine, calcium, total dissolved solids, lead, iron, potassium, sodium, and copper. The total dissolved solids of all the water samples were below the WHO and NAFDAC standards of 500mg/L with the highest value of 41.9 ± 5.4 and the lowest at 32.7 ± 6.2, this can be attributed to the low concentration of other chemicals that make up the total dissolved solids of water (e.g. calcium, potassium, copper) as revealed in the study. This finding is supported by studies carried out by Peter et al. (2015) and Uduma and Uduma (2014) on physicochemical analysis of the quality of sachet water consumed in the Kano metropolis. High TDS can cause a flat, dull taste in drinking water. This was however not the case in this study as the organoleptic assessment of the samples analyzed revealed no insipid taste. This is also revealed in the findings of Magashi and coworkers (2014).

The pH of all the water samples tested was within the WHO and NAFDAC standards of 6.5-9.5 with the lowest pH level of 6.74 and the highest of 7.9 (Figure 2). The result is supported by studies carried out by Martins and Ada (2014) and Ackah et al., (2012). For the total hardness of sachet water, all the samples had low values for total hardness ($12 \pm 3.2 – 58 \pm 10$mg/L) except for sample B (96.0 ± 16.9mg/L) (Figure 4) with a value close to the NAFDAC limit of 100mg/L but was also low for the WHO standard, the values obtained fall within the values reported by Shittu et al., (2008). Hardness of water is usually caused by the presence of compounds of calcium and magnesium at the source of water. The low water hardness recorded in these samples could suggest that the water sources the city has less of salts of calcium and magnesium present in them. This implies that calcium for requirements for bone and teeth development of the people of the area of study would come from other sources. Samples A – J fell within the NAFDAC and WHO standard of 0.3mg/L of iron (Fe) the values fell at 0.00 as reported by Abdul et al (2014) in a research carried out by them on the physicochemical properties of sachet water in the Kumasi metropolis of Ghana and therefore poses no health threats.

The result obtained for the chloride as shown in Figure 3 fell within the NAFDAC recommended standard of 100mg/L but was below the WHO standard of 500mg/L as in contrast to a study carried out by Yusuf et al. (2015) the importance of chlorine cannot be overemphasized as it gives a measure of protection against any contamination in drinking water that may occur. (Yusuf et al., 2015). The result of this study as shown in table 1 indicated that the samples tested are in compliance with the recommended lead standard of NAFDAC and the WHO which is 0.01. This result is in contrast with the result of research carried out by Uduma and Uduma (2014) on the physicochemical analysis of the quality of sachet water consumed in Kano metropolis that the lead value fell below WHO recommended standard, they further said the low loads of lead is due to the treatment of water.

The presence of copper in the water supply can interfere with intended domestic uses of water. It increases the corrosion of galvanized iron and steel fittings. Staining of laundry and sanitary wares occurs at a copper concentration above 1mg/L (Yusuf et al., 2015). All the samples were free from copper with a result of the mean and standard deviation of 0.00 ± 0.00. The concentration of potassium(k), sodium (Na) and calcium (ca) were below the NAFDAC and WHO standards, this is supported by studies carried out by Nagamni (2015) on the physiochemical analysis of water samples, and Uduma and Uduma (2014) on the physicochemical analysis of the quality of sachet water consumed in Kano metropolis that the sachet water was below the WHO and NAFDAC threshold limits of (10mg/L) for potassium, (200mg/L) for sodium and (75mg/L) for calcium.

CONCLUSION AND RECOMMENDATIONS

The study revealed that all sachet water samples analyzed produced in Ede met the recommended chemical assessment. Although the sachet water sample's metal content was below the minimum recommended chemical standard. Inhabitants of the area studied could be advised to rely on other sources of dietary intake of important metal ions that are very low in the water available for their consumption. It is not certain most sachet water-producing companies carry out these tests due to its tedious nature and the high cost it involves. The government should also encourage the companies to carry out this analysis and give water-producing industries supervision more priority.

To reduce the effect of poor quality of sachet water, It is therefore suggested that government agencies like NAFDAC/SON should ensure that packaged water manufacturers comply with good manufacturing practices and standards of the physical parameters

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SUB-THEME 3

USE OF DIGITAL TECHNOLOGIES IN FOREST ASSESSMENT IN THE ERA OF INSECURITY

USE OF DIGITAL TECHNOLOGIES IN FOREST ASSESSMENT IN ERA OF INSECURITY.

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ABSTRACT
Forest are providers of ecosystem services, thus are vital to the national economy and the wellbeing of the people. Monitoring of the forest ecosystem is essential for management, planning, and policy purposes, however, in the face of insecurity in Nigeria and the West African region the need to adopt a safe, secured, and efficiently reliable means of forest monitoring is proposed herein this paper. Moreover, there is also the need to adopt the concept of smart forestry with digital technologies which is the current trend among forestry practitioners worldwide. Accurate and reliable forestry data can be obtained by continuous monitoring of forestry resources using digital technologies. This is a position paper on the application of digital technology in forestry practices which is a paradigm shift from the known practices of inventorying forest resources by the in situ methods. The paper is a call to smart forestry practices and has been sub-divided into three main applications areas: I) Data collection tools; II) Satellite Remote Sensing applications; II) Data science or big data applications which encompass Satellite Remote Sensing and Geographical Information data embedded in server/ web-based interface with machine learning algorithms. The paper further concludes on the need for collaboration between organizations and scientists in Nigeria to meet the need for digital applications in forestry and close the wide gaps in both research, teaching, and management of the Nigerian forests' ecosystem.

Keywords: *Forest, monitoring, Remote sensing, Data Science, Cloud Computing, Artificial Intelligence.*

INTRODUCTION

Forests cover over one-third of the Earth's surface area and are home to more than half of the world's land-based species (FAO and UNEP. 2020). Forest are providers of ecosystem services such as the supply of timber, fiber, and fuel, carbon sequestration, clean water, and air, biodiversity conservation, and aesthetic values, i.e., provision of cultural and spiritual values to communities thus are vital to the national economy and the wellbeing of her people (Millennium & Assessment, 2005). Forests are multifunctional, with an environmental, economic, and social role, providing multiple benefits: ecosystem services related to soil, erosion control, water cycle, clean air, carbon storage, climate regulation, biodiversity protection; provision of recreational and cultural values; and provision of resources, in particular timber, and non-wood products. Forests are thus a source of employment, particularly in rural areas. The entire amount of degraded forest in the tropics which is estimated to be over 500 million hectares store seven times more carbon than humanity emits annually (Putz FE et al 2014). The International Tropical Timber Organization (ITTO 2002) suggests that up to 850 million ha of tropical forest could already be degraded. Forest loss and degradation have slowed or stopped the flow of a wide range of ecosystem products and services, putting billions of people at risk of a variety of negative consequences.

Forest assessment is an age-long practice of inventorying forest resources. Assessing Forest resources with the traditional grand truthing method is time-consuming and costly and results from grand truthing methods are biased and likely to overestimate or underestimate the targeted population. The current widespread insecurity within the West African region has made forest resource assessment through grand truthing almost impossible. There is the need for ''the alternative'' or scaling up of ''the alternatives'' which is a paradigm shift to digital technology applications or smart forest applications to tropical forest resource assessments.

Digital technology and smart forestry?

Digitalization is the use of digital technologies to enhance the day-to-day living of humans(Bespalova, Polyanskaya, Lipinskaya, Gryazkin, & Kazi, 2021). The 21st century is the age of digital-based technologies and digitalization holds great potential for forest resource monitoring, management, and certification. Thus, digitization would help to support decision-making and improve competitiveness (Nitoslawski et al., 2021). Forestry resource assessments are often based on spatial attributes such as inventory or mapping forest areas, therefore the index in forestry data is mainly based on spatial attributes (Zou, Jing, Chen, Lu, & Song, 2019).

There is a paradigm shift in the use of digital technology by ecologists, earth, and conservation scientist toward the novel approach to data collection, storage, and analysis of data. This paper reviews the application of digital smart technologies in forestry practices from data collection, storage, retrieval, and analysis. These tools have metamorphosized into the practice of smart forestry or smart forest resource assessment. The review has been divided into three sections: I) Data collection tools; II) Remote Sensing; II) Data science or big data applications.

Section I: Open-source digital tools for data collections

This section presents a description of the various open-source digital tools for gathering specific knowledge and forestry ecosystem services data and their potential as an effective database support system. There are several open-source tools available for forestry data collections ranging from forest inventory to socioeconomic survey support systems (Table:1). The Open-source digital tools enable the authoring and use of digital survey forms without users needing software development expertise with form design enabling a high degree of customization to be achieved by means of specifying a wide range of data flow control mechanisms (Campus et al., 2020). Collect Earth or Open Foris is an example of Open Source digital tools. It was introduced to Nigeria at the onset of the National Forest Monitoring program by the Food Agriculture Organisation of the United Nation in 2018.

Collect Earth is a free and open source software developed by the Food and Agriculture Organization of the United Nations (FAO) to facilitate the collection, management and analysis of land data (Saah et al., 2019). The open source software enables expert and non-expert users to draw on Google technology to freely access and visually interpret satellite imagery for data collection and it geo-synchronizes the visualization and use of imagery of varying spatial and temporal resolutions, including DigitalGlobe, SPOT, Sentinel 2, Landsat and MODIS imagery within Google Earth, Bing Maps and Google Earth Engine (Saah et al., 2019). Collect Earth differs from previously existing land monitoring tools by offering access to: (a) multiple archives of VHR satellite imagery that can support the assessment of land use and land cover dynamics; (b) graphical representations of inter-annual and intra-annual vegetation indices generated with Landsat and MODIS imagery in Google Earth Engine (GEE), new technology for cloud-based, automated processing of satellite imagery; and (c) built-in data analysis tools through an integration with Saiku Analytics. Collect Earth also differs from previous land monitoring software in that (d) it offers a robust data collection framework that is fully customizable by non-experts; and (e) it streamlines the use of probability sampling statistics. Collect Earth accesses three archives of satellite imagery that have an expansive coverage and collectively enable users to assess any area in the world. However, where supplementary VHR imagery has been acquired, such imagery can be imported into Google Earth (Pro) in numerous formats and immediately used for a land assessment with Collect Earth.

Table 5: Open-source Digital Tools For Data Collections

S/N	Tool	Website
1.	Collect Earth (Open Foris)	https://openforis.org/tools/collect-earth/
2.	Open Data Kit (Android)	https://projectredcap.org/software/mobile-app/
3.	KoboToolbox (Android & Web)	https://www.kobotoolbox.org/
4.	REDcap (Android, iOS & Web)	
5.	Magpi (Android & iOS)	https://www.magpi.com/
6.	Survey CTO (Android & Web)	https://www.surveycto.com/
7.	CommCare (Android & Web)	https://devimpactinstitute.com/courses/mobile-technologies/training-on-mobile-data-collection-and-data-management-using-commcare
8.	Jotforms mobile (Android, iOS &n Web)	https://www.jotform.com/products/mobile-forms/
9.	Team scope (Android, iOS & Web)	https://www.teamscopeapp.com/
10.	Open source Open Data Kit	https://getodk.org/

SECTION II: FOREST ASSESSMENT WITH SATELLITE REMOTE SENSING (SRS).

Tropical forests represent a rare and fragile ecosystem that is under threat in many parts of the world and urgent action is needed to conserve these rich forests, not only because they harbor concentrations of endemic and threatened species but to maintain their vital role in the provision of ecosystem services such as the supply of timber, fiber and fuel, carbon sequestration clean water and air, biodiversity conservation and aesthetic values, i.e., provision of cultural and spiritual values to communities (Bubb, May, Miles. L, & Sayer.J, 2004).

The effects of such loss have both local and global implications on the climate. Efforts at combating such loss of forests and their implications led to the formation of the Essential Biodiversity Variables (EBV) by the United Nations Convention for Biological Diversity (CBD). EBV was established to monitor the progress made by signatories to the CBD on forest ecosystem diversity.

Monitoring EBV such as forest biomass, tree species diversity, forest phenology, and temporal and multi-temporal change detection (forest cover, loss, and gain) are important in determining the progress toward the Convention on Biological Diversity's 2020 Aichi targets (Pereira et al., 2013).

The EBV indicators also provide the foundation for developing scenarios for future biodiversity observations under different policy and management options. For instance, local and regional biomass information is essential for assessing the status and monitoring the dynamics of ecosystem structure. Phenology is also an important EBV that indicates trends, shifts, and structural changes of species traits within an ecosystem. Forest cover, loss and gain mapping, and biomass information are relevant for the CBD target 5, 11, 14, and 15. Information on plant phenology is relevant to the CBD targets 10 and 15 (Pereira et al., 2013).

Satellite Remote Sensing (SRS) offers the possibility of achieving the above targets more accurately and efficiently than the usual extensive ground field campaign often employed by ecologists. The implementation of the CBD's-Essential Biodiversity Variables using field assessments or in situ data gathering method in the tropical forest terrain is costly and time-demanding. SRS data has the capability of constant, repetitive, and cost-effective monitoring of large areas and its application in forest ecosystem monitoring studies is on the increase. Therefore, SRS data can provide precious information nearly impossible to be acquired solely by field assessment.

In other to enhance and broaden biodiversity monitoring in time and space with the EBV classes. The remote sensing-essential biodiversity variables (SRS-EBVs) were introduced as a subset of EBVs and their application relies largely on the use of satellite-based data (Pettorelli et al., 2016). SRS-EBV includes variables whose monitoring relies on the integration of satellite-based data with in situ data. SRS-EBVs can therefore be used as proxies for indicating defined targets for biodiversity conservations (Table 1).

Table 2: SRS-EBV Variables

Examples of SRS-EBV measurable variables			
EBV Class	**EBV Examples**	**Variables meeting SRS-EBV**	**Relevance for CBD Targets**
Genetic composition	Habitat structure	Specific plant genotype	5, 11, 14,15
Species population	Abundance and distribution	Specie occurrence	4,5,6,7,8,9,10,11,12,14,15
Species traits	Phenology	Specie leaf area	10,15
Community composition	Taxonomic diversity	Taxonomic diversity	Targets 10, 15
	Remote sensing of cover	Vegetation height	
Ecosystem structure	(Biomass inclusive) regionally or globally	Aboveground biomass	8,10,14
	Fractional cover	Aboveground biomass	
	Forest cover		
	Land cover		
	Fraction of absorb		
	Leaf area index		
Ecosystem function	Vegetation Phenology		5,8,14

Remote sensing offers the possibility of measuring forest carbon stocks using instruments mounted on satellites or airborne platforms. Optical remote sensing, radar (microwave), and LiDAR data are the three main types of remotely sensed data that are used to extract information for biomass and stand parameters. The passive optical and hyperspectral provides information on tree canopy attributes, leaf area, and tree species types. Optical remote sensing data are mostly used in tropical forest aboveground biomass studies because of the availability in a wide range of spatial and spectral resolutions, affordability(cost), and easy access (Nichol. J. E & .R., 2011).

Forest structural parameters such as the tree heights, canopy height, aboveground biomass, etc have been modeled using optical remote sensing in conjunction with the ground truth measurement and spectral signals such as vegetation indices using the Red and Near Infrared wavelengths (Sarker & Nichol, 2011). Vegetation indices, principal components analysis, minimum noise fractions, tassel cap transformation, spectral mixture analysis, and texture measures are a few of the techniques that are used to produce variables for estimating AGB from optical data (Lu et al., 2016). There are limitations to the use of optical satellite remote sensing for aboveground biomass modeling in tropical forests. The limiting factors include vegetation heterogeneity, canopy shadows, and undulated landscapes that characterized most tropical forest ecosystems. Similarly, the possibilities of data saturation in forests with high forest structural parameters (e.g., AGB) levels have been observed with optical remote satellite images.

The active sensors such as Light Detection and Ranging (LiDAR) and Radar are independent of the sun and the time of the day. LiDAR is known to provide accurate information on the vertical distribution of canopy/ height structure and is useful for three-dimensional (3D) characterization of forest attributes such as the aboveground biomass. LiDAR data was used in mapping forest biomass in French Guiana with an error of 14% and estimates of 340 Mg/ ha. LiDAR use for tropical forest biomass estimations is limited by coverage and the economic cost of procuring the images. Radar data are also independent of the time of the day, and weather and can provide a multi-faceted source of information such as frequency, incidence angle range, polarization, and interferometric baseline. Its advantages also include sensitivity to surface roughness, and imaging possibility from different types of polarised energy (HH, VV, HV, and VH). Forest structural parameters retrieval using radar satellites in the tropical forest has risen significantly in the last few years. The Advanced Land Phased Array Synthetic Aperture Radar (ALOS-PALSAR) data were used in the estimation of the aboveground biomass of the Guinea-Bissau forest and the result obtained from the study (65.17 mg/ha^{-1}) was concurrent with the regional estimate of AGB.

Machine learning methods for aboveground biomass retrieval

In satellite remote sensing applications, the use of retrieval algorithms or machine learning methods has become an essential component of forest structural parameter modeeling or estimation. Retrieval algorithms are crucial to remote sensing-based forest structural parameter modeling and can be grouped into two broad categories: parametric and nonparametric algorithms. In a parametric algorithm, it is assumed that the relationship between dependent variables(eg, volume, canopy height, basal area, AGB) and the independent variables (features derived from SRS data) can be explicitly specified(Lu et al., 2016). Simple or multiple linear regression models are examples of parametric algorithms. Most often, the AGB relationship with satellite remote sensing variables is nonlinear because the relationship between AGB and remote sensing variables is too complex to be captured by parametric algorithms.

Therefore, nonparametric algorithms are flexible and easy to adapt to complicated no-linear biomass models (Lu et al., 2016). Examples of nonparametric include artificial (ANN), K-Nearest

Neighbor (K-NN), support vector machine (SVM), maximum entropy (MaxEnt), and random forest algorithm. Regression-based models are the most common approach to forest structural parameter modelling using SRS data (Lu et al., 2016). A review of retrieval algorithms and their performance in table 4 by Ali et al,. (2015) showed a wide range of excellent performance with various Satellite Remote Sensing images.

Table 4: Examples of Machine Learning Algorithms

Sensor	Resolution	Parameter(s)	Algorithm	Performance (r)	Reference
LiDAR					
ICESat-1		Tree height			
Quick Bird		Height, Biomass, Volume	Support vector regression	0.72	(Huang, Peng, Lang, Yeo, & McCarty, 2014)
Quick Bird		Aboveground Biomass	Random forest	0.8	Adewoye et al, 2015
World view		Biomass	Random forest	0.75	(Mutanga & Skidmore, 2004)
Landsat 5		Aboveground biomass	Random forest	0.943	(Sarker & Nichol, 2011)
Spot		Aboveground biomass	Random forest	0.84	(Thenkabail, Enclona, Ashton, Legg, & De Dieu, 2004)
Landsat-7		Aboveground biomass	Support vector regression	0.75	(Cutler, Boyd, Foody, & Vetrivel, 2012)
MODIS		Aboveground biomass	Random forest	0.82	(Anaya, Chuvieco, & Palacios-Orueta, 2009)
GlAS		Aboveground biomass	Random forest	0.82	(Fatoyinbo & Simard, 2013)
Landsat 8		Canopy height	Random forest		

SECTION III: FOREST ASSESSMENT WITH BIG DATA OR DATA SCIENCE

Data science is the techniques, and processes of gathering, synthesizing, and understanding information through the automated analysis of data. Data science can also be defined as a set of fundamental principles that support the extraction of information and knowledge from data and a closely related concept to data science is data mining which is the extraction of knowledge from data through technics and principles known as algorithms (Provost & Fawcett, 2013). While hundreds of different data-mining algorithms exist, the ultimate goal of data science is to improve decision-making for policy and management (Provost & Fawcett, 2013).

Big data is an emerging frontier discipline, and the main purpose of big data is to quickly learn and acquire knowledge from the data (Zou et al., 2019). In forestry applications, big data is playing an increasingly important role in forest monitoring and forestry decision-making. Big data has ushered in new development opportunities in forestry practice. The availability of large volumes of data in the forestry sector has made data science applications to the gained ground for modeling, prediction, and forecasting. Data science becomes easier on migration to the web or server-based interphase with the major advantages of analysis based on the server, quick and efficient data analysis, and storage and retrieval from the server. Several high precisions modeled data have been generated covering the entire world. The modeled data are gradually replacing the traditional in-situ data. For instance, the High-Resolution Global Maps of 21st-Century Forest Cover Change was produced by the University of Maryland in conjunction with the National Aeronautic Space Agency (NASA) in 2013 and has since been updated yearly with the current version in 2020 (Hansen et al., 2013). The forest cover change map by Hansen et al., 2013 was produced with 30-meter Landsat images with forest cover, forest gain, and forest loss maps for the entire world, Incidentally, the Forest Reference Emission Level (FREL) data submitted in 2018 by the Federal Ministry of Environment to the United Nations Framework Convention on Climate Change program on Reducing Emissions from Deforestations and Forest Degradation in Developing Countries (UNFCC REDD +) used the High-Resolution Global Maps of the 21st Century by Global data (UNFCC, 2018, 2019).

Several big data platforms that support data storage and analysis with machine learning capabilities are freely available. While some of the big data platforms are easy to use, others require programming language skills such as python, java, cc+, etc. For instance, big data platforms such as the System for Earth Observation Data Access, Processing, and Analysis for Land Monitoring (SEPAL. IO) and European Space Agency Sentinel Hub have easy navigation and analysis interphase, while platforms such as Google Earth Engine and pip cloud requires knowledge of python and java programming languages. Platforms for big EO Data Management and Analysis" as computational solutions that provide functionalities for big EO data management, storage, and access; that allow the processing on the server-side without having to download big amounts of EO data sets; and that provide a certain level of data and processing abstractions for EO community users and researchers(Gomes, Queiroz, & Ferreira, 2020). Below are examples of internet-based data science platforms for forestry and environmental monitoring artificial intelligence embedded for analysis.

TABLE 3: Examples of Internet-Based Data Science Platforms

S/N	Data Science Platform	Forestry & Environmental Based Applications	Website
1	System for Earth Observation Data Access, Processing, and Analysis for Land Monitoring (SEPAL)	Forest change detection Near real-time change detection	https://sepal.io/
2	Google Earth Engine	Forest change detection and Climate change studies early warning systems.	https://earthengine.google.com/
3	Earth Blox	Forest change detection Climate change studies early warning system.	https://www.earthblox.io/
4	Sentinel Hub	Forest change detection Near real time change detection	https://www.sentinel-hub.com/
5	Open Data Cube (ODC)	Forest change detection Near real time change detection	https://www.opendatacube.org/

S/N	Data Science Platform	Forestry & Environmental Based Applications	Website
6	JEODPP	Forest change detection Near real time change detection	https://jeodpp.jrc.ec.europa.eu/
7	pipsCloud	Forest change detection Near real time change detection	
8	openEO	Forest change detection Near real time change detection	https://openeo.org/
9	**Earth on AWS**	Forest change detection Climate change studies early warning systems.	https://aws.amazon.com/earth/
10	Microsoft Azure Cloud Services	Forest change detection Climate change studies early warning systems.	https://azure.microsoft.com/en-us/

CONCLUSION

The current technology and strategy of forestry big data can effectively deal with massive forestry data and meet the requirements of real-time queries and analysis for forestry and environmental-based applications. This paper has reviewed the current trends of forest digitization and big data applications from three perspectives: data acquisition, Satellite Remote Sensing, and Big data applications or smart forestry. The use of AI technology has reduced the pressure on data storage and processing, thereby improving the performance of forestry big data and the development of artificial intelligence (AI) related technologies has created enormous value for various fields.

The current trend worldwide is the formation of joint research between organizations. For instance, the Brazilian Environmental Monitoring Project (Map Biomass) and the Swiss Data Cube (SDC) are joint research initiatives between scientific organizations. No organization (Research Institute or University) can do it alone. The need for consortiums of Research Institutes and Universities in Nigeria to come up with the common goals of a joint big data center is necessary. The big data center will form the backbone for data archiving, analysis and dissemination.

Integrating big data or data science applications into the undergraduate and postgraduate curriculum is now a necessity to meet up with the current development in the forestry sector. Some Forestry and Environmental-based departments are ahead in the teaching and analysis of data using the R packages. However, forest digitization requires knowledge of other programming languages such as Python, Java, CC++, etc. Therefore, the University curriculum needs to be updated either through the Nigerian University Commission (NUC) or individual course restructuring as observed with some departments in Nigerian Universities.

Technology is always evolving and humans have learned to adapt to technological developments. The age of smart forestry through big data applications is here, curriculum developments through the National University Commission or individual universities are not enough. Training and re-training of scientists must be accommodated in other to be at the same pace with the current developments and funds for training can be sourced from organizations such as the Tertiary Education Trust Fund (TETFUND), Education Trust Fund (ETF), Ecological Funds and host of other Institutions.

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TREE GROWTH COMPETITION INDICES FOR BIODIVERSITY CONSERVATION IN IITA FOREST IBADAN, NIGERIA

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Abstract
Studies on relative contributions of competition in forest tree growth is essential because it determine forest structure. There is dearth of information on forest growth using Competition Indices (CI) in International Institute of Tropical Agriculture (IITA), Ibadan Forest. Hence, this study assessed CI effects on stand growth in IITA towards improving its structure and biodiversity conservation. Data were collected using four systematic lines transect (270m each) at 200m apart for plot demarcation. Sixteen sample plots of 25m × 25m were alternately laid to collect growth data. Tree growth variable with Diameter at Breast Height (DBH) ≥ 10cm were estimated. Characterizing the joint influence of tree size and competition in each plot, overtopped trees were considered subject trees and 10m search radius was used in identification of competitor's tree for Distance Dependent (DD). Measurement of influence of neighbouring trees for Distance Independent (DI) was based on plot-centered. Eight CI (CI_1-CI_8) were assessed. Competition severity were assessed using Moran Coefficient (MC) and Geary Ratio (GR). Data were analyzed using descriptive statistic and correlation coefficient. The stand comprises of 389 stem ha^{-1}. The mean DBH and tree height were 25.12±1.023cm and 18.548±0.324m, respectively. It was observed that DD CI_6 gave better estimation (50.3021 ± 0.8775) of tree growth competition. Negative value of MC was observed on stand in plot 6, 11 and 15 (-9.52±0.821, -8.07±0.004 and -7.44±0.084, respectively). The GR was least (19.72±1.199) in plot 11 indicating a severe competition. Hence, DD CI assessed the growth predictability well compared to DI indices.

Keywords: Tree growth characteristics, inter-tree-competition, competition severity, IITA biodiversity

Introduction
Nigeria tropical rain forest has a large numbers of species, which are been represented by few tree and their growth pattern and rates varies (Aigbe *et al.,* 2013). Growth is an irreversible process which takes place in all living things. Tree growth simply means the increase in magnitude and quantity of the vegetative structures. As trees grow in the forest, competition sets in for photosynthesis, space and resources. Competition is an interaction between individual for survival for limited resources resulting to decrease for survivorship, reproduction and growth of the competing individual (Ige and Adesoye, 2017). However, it was asserted by Lo and Lin-(2012), that tree height and tree diameter within a forest will be constrained by the pressure of adjacent trees. Competition or growth rate in the forest often determines the shape and the structures of the forest stand (Coomes and Allen, 2007). Competition is also an essential environmental process that plays substantial roles in growth population, survival and replacement of species on forest composition and stand structure (Amiri and Naghdi, 2016; Ige, 2017). However, trees growing in a given population usually exhibit large variation in growth. Coomes and Allen (2007) emphasized on the need for understanding the different variation in growth which is the basis for forest structures and biomass and also noted that tree growth declined with altitude. It was ascertain by Pelemo *et al.* (2011) that some trees grow poorly in the forest not as a result of competition but due to the influence of some other disturbances such as floods, windstorms, fire and human inflicted damages which make the forest to be instable and make the tree less favorable to grow properly. Various attempt of predicting the tree growth as accurate and precisely basically brought out the study of competition on individual tree, two general method are widely used for tree growth competitor indices which are the Distance-independent or Non-Spatial indices and Distance-dependent or Spatial indices (Tome and Burkhart, 1989; Amiri and Naghdi, 2016). Non-spatial indices generally measures and portray the competition status of trees in the stand which requires not the trees coordinate or the relative location of the competitors trees (Tome and Burkhart, 1989; Contreras *et al.,* 2011). Obtaining Non-spatial indices variables are relatively easy and less time taking in terms of data computation and analysis. Spatial indices explain a tree's competitive position based on the direct conditions of their neighbouring tree (Contreras *et al.,* 2011). This generally measures the zones of influence of the neighbouring trees which best improve estimates of individual tree growth (Ige, 2017). In estimating the tree growth competition using Spatial and non-spatial indices, strong positive correlation has been proven to exist between tree growth and basal area. Basal areal basically deals with the average amount of an area occupied by tree stem, thus DBH a good predictors of forest dynamics which also improve the dependability of timber volume, growth and yield models (Brooks *et.al*. 1980; Onyekachi and Osho, 2018). In tropical natural forest, tree growth competition studies are rarely studied. Biodiversity loss in most cases have been linked with indiscriminate harvesting or deforestation without considering possible loss as a result of severe competition in the tropical ecosystem. Hence, this is was set out to provide a baseline information on assessment of tree growth competition using Spatial and Non-Spatial competition index in tropical forest of IITA, Ibadan.

Materials and Method
Study Area
This study was carried out in International Institute of Tropical Agriculture (IITA) Forest (Figure 1). IITA forest is geographically located in Akinyele Local Government Area of Oyo State Nigeria with latitudes of 7° 30' 5.1264" and 7° 28' 55.52" North and longitudes 3° 54' 47.50" and 3° 52' 44.49" East in the city of Ibadan. IITA forest has a humid tropical climate. The wet season starts from March to October and dry season that lasts from November to February, with a mean temperature of about 21°C to 23°C and the maximum temperature ranges from 28°C to 34°C. The forest used to experience bimodal rainfall pattern between 1300 – 1500mm between May and September. The mean daily relative humidity is between 64 -83% (Ariyo *et al*., 2012). The forest reserve has a low lying and gentle undulating topography with an elevation range between 243m to 292m. The parent rock materials of the soil are been formed through the underlying crystalline and gneiss. In the upland areas clay, quartz gravel and sand are

predominant soil types while the bottom of the valley has poorly drained clay and sandy soils (Oluyinka, 2020). Some part of IITA forest has a highly diverse plant species and could be classified as tropical semi-deciduous forest with diverse vegetation types (Osunsina *et al.*, 2012).

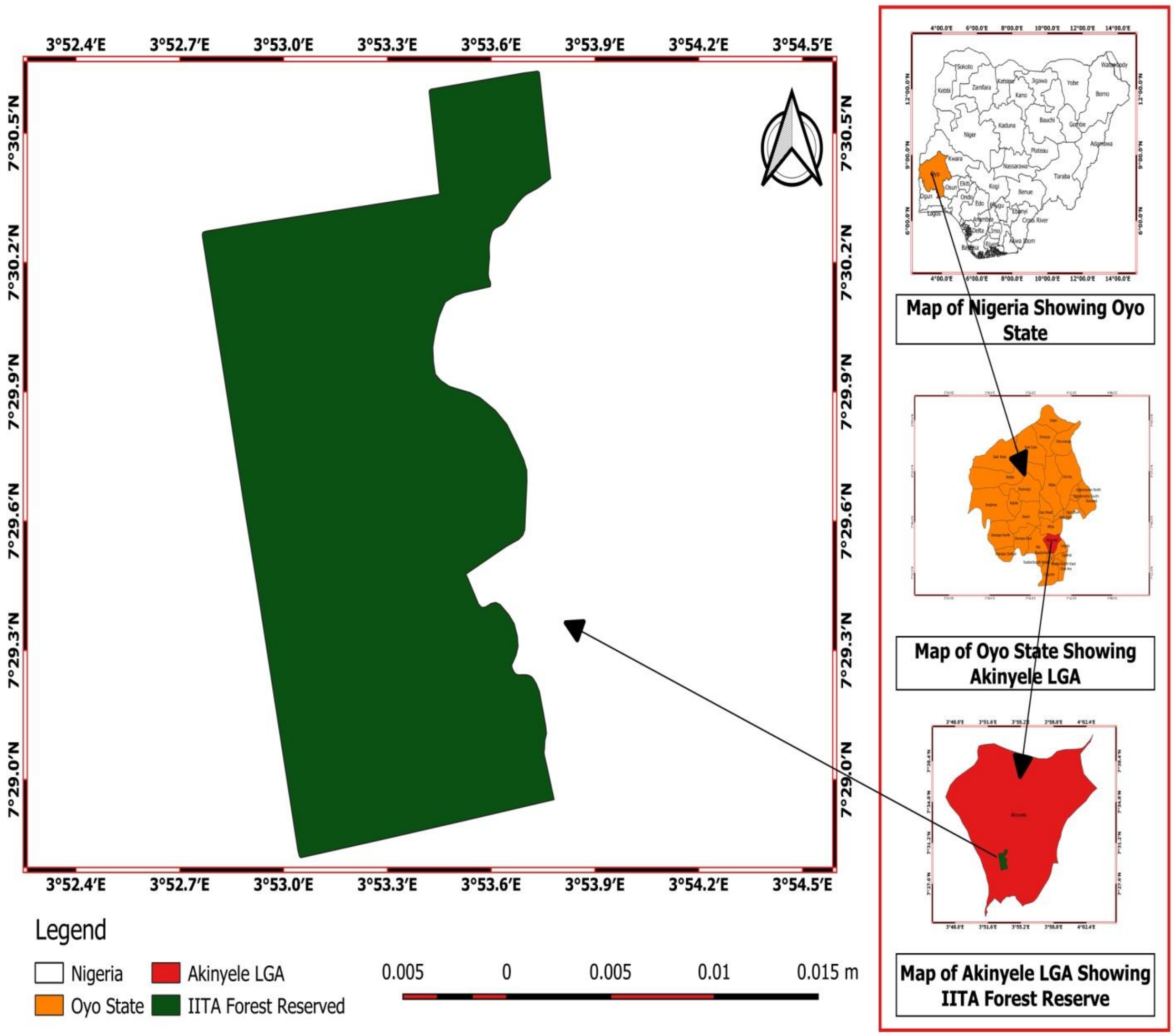

Figure 1: Map of IITA Forest Reserve.

Sampling Techniques and Data Collection

Reconnaissance was carried out so as to assess the forest stand and see the different changes that are currently taken place at the reserve. The survey carried out revealed that there was no evidence of logging in the forest, though the forest is a secondary forest that is currently undergoing reservation phase for biodiversity conservation. The sampling procedure used for the research work was adopted after the visitation to the study area. Simple systematic line transect was adopted for this study for plot laying and data collection. A total of 16 temporary sample plots were used for this research work. In laying of plots for data collection, simple systematic line transect as used by Adekunle *et al.* (2013) was adopted and modified for plot laying, four parallel transects of equal distance (270m) was delineated at 200m apart for this study. A total number of 4 sample plot of equal size (25m x 25m) were laid alternatively on each transect and 50m interval distance offset away from each sample plot was observed so as to decrease replication of tree species. To minimize the edge effect, 20m offset was measured at the beginning of each transect (Figure2).

Data Collection

On each sample plot, trees with DBH ≥ 10cm were identified and measured as done by Adekunle *et al.* (2013). To estimate volume per stand, the diameters at the base, middle and top; the total height of all the tree were measured using Spiegel relaskop Competitors tree was been identified by weighing the dimension of the subject tree and its neighbouring tree. All the relevant information for computational evaluation of the competition indices of each subject tree and its competitors within the search radius of 10 metres were measured and recorded.

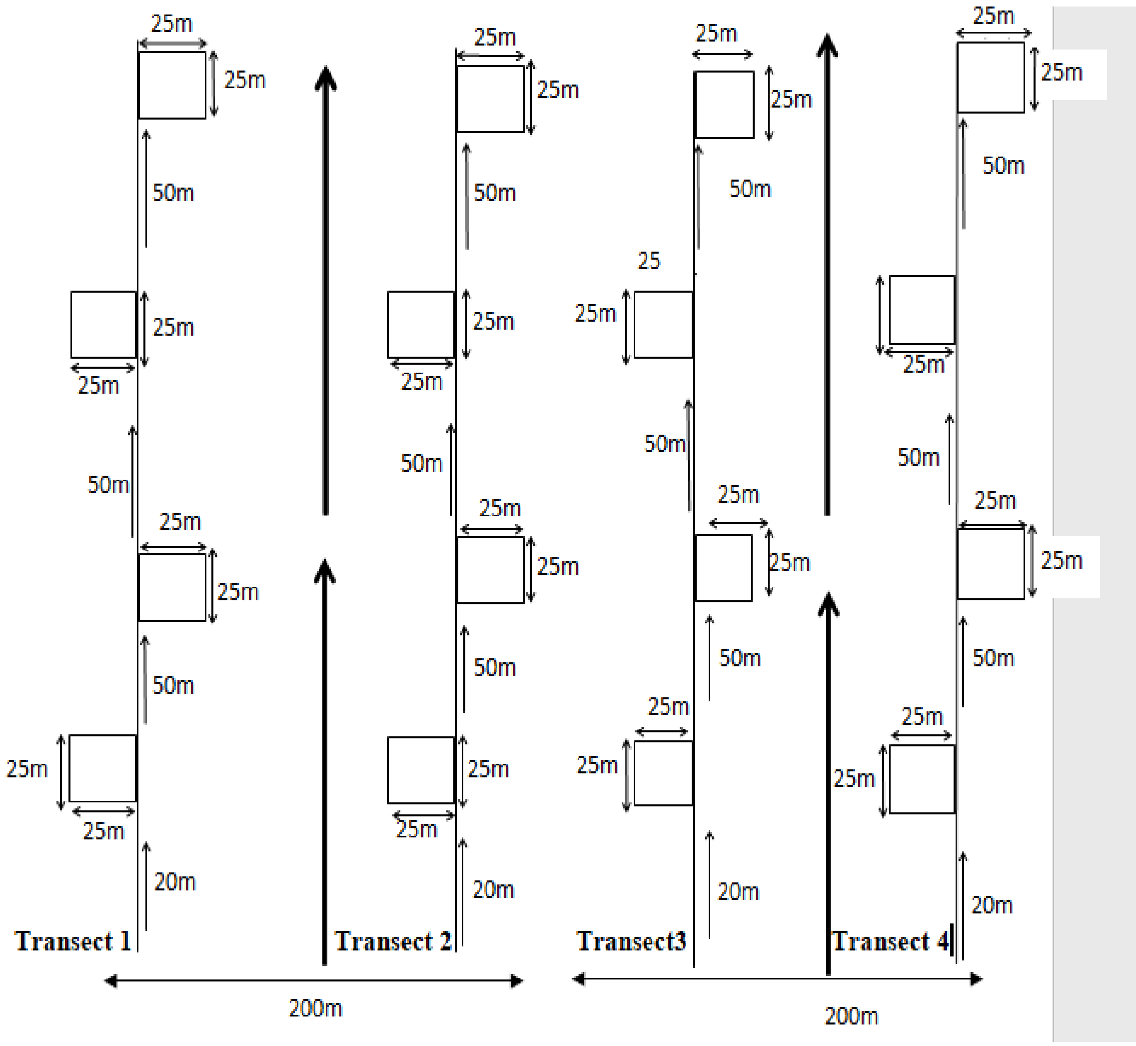

Figure 2: Systematic line transects sampling technique for Plot layout.

Tree Growth Competition Indices

All the tree growth variables were assessed. Spatial and Non-Spatial indices that are generally used were adopted.

Spatial or Distance Dependent Indices

Spatial indices were carried out by spatial location of the affected subject tree for their computations. Diverse method have been adopted to determine the pressure of the possible competitor trees over the subject tree such as crown-influence-zone overlap, DBH angle-gauge, fixed-radius and Height guage method (Ige, 2017). Height guage method was adopted and used. On the sample plot trees that are completely overtopped were considered as the subject tree and radius of 10m was used to measure the dimension of trees considered as neighbour trees ((Figures 2). The coordinates of all trees in the sample plot were been taken using Mapinr Software. The coordinate of the subject trees in each sample plot was been specified in the attribute table for further analysis. The coordinates collected were been transformed to distance as well as buffer of 10 meters created around the subject tree using ArcMap 10.8 software.

Non-Spatial or Distance Independent Indices
Measurements were based at the center of the plot against tree-centered neighborhood data used in spatial competition indices. Competition of each subject tree was quantified using four non-spatial competition indices (CI 1-4) and four Spatial competition indices (CI 5-9) as shown in Table 1 were used respectively for the competition indices. The indices used were carefully chosen from the literature, with the consideration of the availability of tree variables with their simplicity to describe the competition situation for this study.

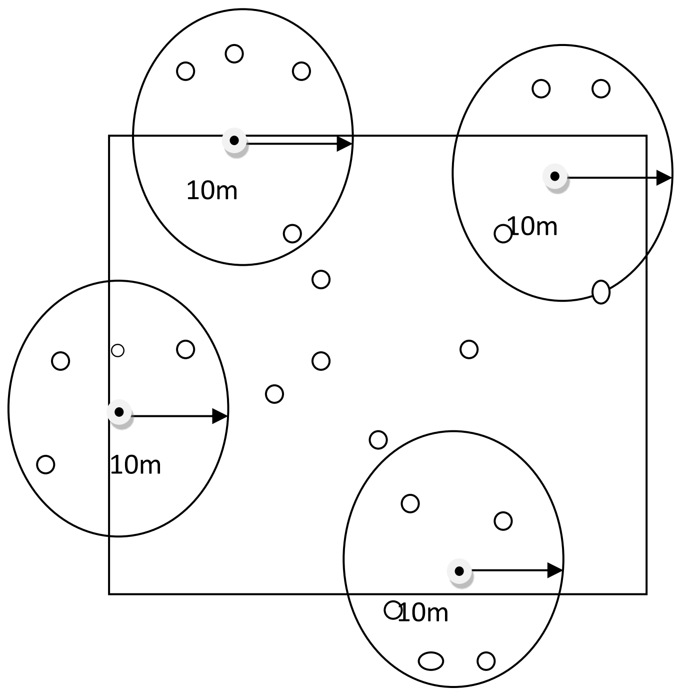

Figure 2: Spatial indices measurement techniques used in a sample plot of four subject trees (Thick dark dots) and competitor trees (open dots) using fixed-radius of 10m.

Table 1: Competition indices evaluated in this study

Equation No	CI	Source
Non-Spatial competition indices		
1	$\frac{\sum_{j=1}^{n} {d_j}^2}{{d_i}^2}$	Corona and Ferrara (1989)
2	$\frac{\left(1-\left[1-\left(\frac{BAL}{G}\right)\right]\right)}{RS}$	Schröder and Gadow (1999)
3	$\frac{\sum_{d_i<j\neq i}^{n}(g_j)}{S}$	Wykoff *et al.* (1982)
4	$\sum_{j\neq i}^{n}\left(g_{j;d_j>d_i}\right)/G$	Daniel *et al.* (1976)
Spatial competition indices		

5	$\sum_{i=1}^{n} h_i \, arctan\left(\frac{d_i}{dist_i}\right)$	Rouvinen and Kuuluvainen (1997)
6	$\sum_{i=1}^{n} h_i \left(\frac{h_j}{dist_i}\right)$	Braathe (1980)
7	$\sum_{i=1}^{n} \mathrm{d}_i \left(\frac{d_j}{dist_i}\right)$	Daniel *et al.* (1976)
8	$\sum_{j=1}^{n} \frac{d_j}{\mathrm{d}_i(\mathrm{l}_{ij}+1)}$	Daniel *et al.* (1976); Ige and Adesoye, (2017)

where n = quantity of neighbours within 10 m radius competition plot; BAL= basal area of neighbour trees larger than the subject tree (m^2h^{-1}); G is total basal area of the trees within plot (m^2h^{-1}); g_j = competitors tree basal area; $dist_i$ is the horizontal distance from ith neighbour tree to the subject tree (m); h_i height of the subject tree (m); h is height of the competitor tree (m); l_{ij}, distance amid subject (i) and competitor (j) tree (m) and, S = plot area.

Evaluation of Competition Severity

The relationships amid individual tree growth and size, and competition indices of trees in severe competition with adjacent trees were modeled using the local forms of Moran coefficient and the Geary ratio (Shi and Zhang, 2003). The Moran coefficient (*MC*) is defined as follows:

$$MC_i = (\mathrm{DBH_i} - \mathrm{meanDBH}) \sum_{j\varepsilon c_i} (DBH_j - \mathrm{meanDBH})$$

where mean*DBH* = plot average *DBH*. Positive *MC* value is an indicator of subject tree is in a cluster of similar size, whereas negative *MC* value indicates subject tree is in cluster of dissimilar size. Lower negative *MC* values indicate that both dominant and suppressed trees are in severe one-sided competition scenario.

The Geary ratio (*GR*) is defined as follows:

$$GR_i = \sum_{j\varepsilon c_i} (DBH_i - \mathrm{DBH_j})^2$$

The *GR* value indicates tree size variance within a cluster; a lower *GR* value means less variance of tree size and more severe competition among similar-sized trees.

Results

Tree Growth Characteristics

Table 2 shows the statistical summary of the growth characteristics obtained. The DBH ranges from 10 cm to 170 cm with mean value of 25.12±1.03 cm. The tree height ranges from 7.70 m to 38.10 m with mean value of 18.55±0.32 m. The numbers of tree per hectare in a sample plot varies from 96 to 704 with mean value of 442. The mean volume and basal area were1.04±0.14 m^3 and 0.08±0.01 m^2 respectively. The crown diameter had a mean value of 5.89±0.08 m with respective minimum and maximum values of 3 and 13.7 m. The crown length and crown ratio had respective mean value of 2.97±0.06 and 0.17±0.004 with their minimum and maximum values of 1 and 7.8m; and 0.05 and 0.51.

Table 2: Statistical summary of the tree growth characteristics

Stand Growth Variable	Mean	MIN	MAX
DBH (cm)	25.123 ± 1.026	10	170
THT (m)	18.548 ± 0.324	7.7	38.1
VOL (m^3)	1.035 ± 0.136	0.003	24.676
BA (m^2)	0.083 ± 0.010	0.007	2.270
CL (m)	2.9688 ± 0.059	1	7.8
CR (m)	0.174 ± 0.004	0.051	0.506
N/ha	442	96	704
CD(m)	5.894 ± 0.083	3	13.7

Where: DBH = Diameter at Breast Height, THT = Tree Total Height, VOL = Volume, BA = Basal Area, CL= Crown Length, CR= Crown Ratio, N/ha= Numbers of Tree per Hectare, CD= Crown Diameter

Table 3 shows correlation matrix amid Basal area and competition indices. There was a strong positive correlation between competition indices 3 (CI_3) and basal area, this was as a result of the similarities in the indices formulation and the association amid the input variables (the basal area in the CI_3) and the sample plot (S). All competition of each subject tree in the study area was quantified using four (4) spatial (dependent) and non-spatial (independent) indices. The results of the competition indices estimated in this study area are presented in table 4. The value of CI_1 ranges from 0.0203 ± 0.0183 to 1.4972±0.0183. Indices estimated with CI_2 ranges from 0.00006±0.0002 to 0.0435 ± 0.0002, CI_3had a value range of 0.1087 ± 0.1575 to 36.3215 ± 0.1575, $CI_4$and CI_5 had a range value 0.55726 ± 0.0058 to 0.9960 ± 0.0058 and 0.110604 ± 0.0044 to 0.4325 ± 0.0044 respectively. There was a change pattern in the estimate of competition indices 6 (CI_6) where the range value was higher compared to other competition indices the range value is between 22.425 ± 0.8775 to 87.7998 ± 0.8775 while CI_7 and CI_8had their values ranges from 0.002 ± 0.0039 to 0.3704 ± 0.0039 and 0.1075 ± 0.0393 to 2.7669 ± 0.0393 respectively. Individual tree growth and size relationship and competition indices of trees facing severe competition with adjacent trees were also assessed (Table 5) using MC and GR as indicators. A negative value of MC was observed on stand in plot 6, 11 and 15 (-9.52±0.821, -8.07±0.004 and -7.44±0.084, respectively) whereas stands in other plots were positive which ranges from 0.09±0.001 to 257.23±2.378. This implies that most of the trees in the negative MC stands are in a cluster of dissimilar sizes. The lower negative MC values is an indicator that both suppressed and the dominant trees are in severe one-sided competition scenario. The GR value indicates tree size variance within a cluster; a lower GR value means less tree size variance and more severe competition among similar-sized trees. Hence, for this study, trees in plot 11 are facing severe competition as its value was the least.

Table 3: Correlation matrix between Basal area increment and various competition indices

	DBH	*THt*	*BA*	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*
DBH	1										
THt	0.595	1									
BA	0.926	0.441	1								
C1	0.108	0.072	0.081	1							
C2	0.826	0.460	0.828	-0.137	1						
C3	0.926	0.4409	1	0.081	0.828	1					
C4	0.210	0.024	0.149	0.510	0.076	0.149	1				
C5	0.139	0.131	0.055	-0.005	0.041	0.055	0.214	1			
C6	0.154	0.181	0.071	0.149	0.066	0.071	0.341	0.356	1		
C7	0.057	0.089	0.0372	-0.042	0.087	0.037	0.238	-0.104	0.553	1	
C8	0.101	0.005	0.075	0.616	-0.033	0.075	0.367	-0.104	0.328	-0.087	1

C1 – C4 are Distance independent competition indices (Non Spatial) while C5-C8 are Distance dependent competition indices (Spatial)

Table 4: Estimated mean for the competition indices

	Mean	Min	Max
CI_1	0.36867 ± 0.0183	0.0203 ± 0.0183	1.4972 ± 0.0183
CI_2	0.0017 ± 0 .0002	0.00006 ± 0 .0002	0.0435 ± 0 .0002
CI_3	1.3266 ± 0.1575	0.1087 ± 0.1575	36.3215 ± 0.1575
CI_4	0.8917 ± 0.0058	0.55726 ± 0.0058	0.9960 ± 0.0058
CI_5	0.2958 ± 0.0044	0.110604 ± 0.0044	0.4325 ± 0.0044
CI_6	50.3021 ± 0.8775	22.425 ± 0.8775	87.7998 ± 0.8775
CI_7	0.0334 ± 0.0039	0.002 ± 0.0039	0.3704 ± 0.0039
CI_8	0.7408 ± 0.0393	0.1075 ± 0.0393	2.7669 ± 0.0393

Where CI = competition indices, ± Standard error

Table 5: Assessment of competition severity

Plot	MC	GR
1	257.23±2.378	598.51±3.192
2	99.24±2.195	194.19±3.991
3	0.09±0.001	351.38±2.182
4	0.09±0.005	185.31±0.320
5	45.73±0.110	188.42±1.882
6	-9.52±0.821	163.57±2.229
7	61.75±1.631	181.06±1.934
8	31.91±1.092	381.46±2.118
9	11.70±0.887	27.91±1.094
10	9.55±0.101	191.07±3.001
11	-8.07±0.004	19.72±1.199
12	10.99±2.550	199.67±0.055
13	15.78±0.991	205.44±2.731
14	19.66±1.831	203.73±1.990
15	-7.44±0.084	212.27±2.992
16	28.99±0.711	210.34±0.921

±Standard deviation

Discussion

Model is now a daily routine used in forestry for predicting growth and yield, modeling diameter distributions, basal area model and tree crown model and many more (Ogana *et al*., 2015; Ureigho and Osho, 2017). Models are simply used for prediction and projection. Tree growth competition model was developed for this study in order to examine the competitive effect on each tree. One well studied Source of variation in individual tree growth is competition for resources. Studies of competitive neighbourhood synergy generally show that large, adjoining neighbours exert higher competitive stress than small distant neighbours (Wagner and Radosevich 1998; D'Amato and Puettmann 2004). Several studies had opined that decision of the management of the forest are often predetermined on information about current and future resources condition. As such, this study has made effort to obtain tree growth competition using spatial and non spatial indices and competition severity. The distance dependent involves spatially location of subject tree to competitors tree while the distance indepent examined the effect of the subject trees in relative to the stand measured at the center of the plot. Studied have shown that adding of competition indices to tree growth improves the predictability of the model due to inclussion of trees variables in the competition indices (Contreras *et al*., 2011; Maleki *et al.,* 2015 and Ige, 2017). For the study area, it was observed that distance dependent competition index C6 gave better estimation of tree growth competition and its effect on the growth of neighbouring trees. This study was in contrast with what was reported by Biging and Dobbertin (1996) that estimation of crown parameter improved the performance of distance dependent indices measure, because competition indices that performed best for this study only uses height and distance in its computational competition index. However, Fraver *et al*. (2014) noted that inter tree competition significantly affect growth rates as observed in better performance of model with competition indices when compared to models with no competition indices. The competition severity was assessed. Shi and Zhang, (2003) suggested that MC with a positive value indicates a subject tree is in a cluster of similar size, whereas MC with a negative value indicates a subject tree is in a cluster of dissimilar size. Hence in this study, a negative MC value was observed at stand plots 6, 11 and 15. This might be due to the topography of the stand which is generally undulating and sloppy with some out crop of rocks and irregular tree sizes. This mainly account for high competition rate in the study plots because trees that are on the same ground level are at the cluster of dissimilar size. Meanwhile, the GR value indicates variance of tree size within a cluster; a lower GR value means less variance of tree size and more severe competition among similar-sized trees. This further confirms the situation at stands in plot 11. Hence, the growth of stands in this plot is highly affected as compared to other plots.

Conclusions and Recommendations

The result of this study revealed the present assessment of stand growth characteristics and evaluation of tree growth competition indices in the study area. The study area has an estimated number of 389 stems per hectare which compares well with what has been observed in tropical forest ecosystem. Tree growth competition indices are not often address in many natural forests. Tree growth competition evaluated for this study involves using eight measures of tree competition index examined in terms of their effectiveness as growth predictor for the study area. This study demonstrated that one of the factors that influence forest processes and structure is competition. The inclusion of Spatial indices described the effects of tree neighbourhood maintained in the complex stand structure compared to distance independent indices in the study area. One major constraint to use of Spatial indices is the need to acquire tree attributes such as location and distance measurement which are time consuming and labour intensive, but with the use of MapinR and ArcMap techniques spatial indices for growth study could be effectively carried out. A positive strong correlation was found between two competition indices and tree growth variables, this is an indicator that competition exists between trees. There was more severe competition among similar-sized trees in plot 11 in the study area.

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ASSESSMENT OF TREES OUTSIDE FOREST (ToF) BENEFITS IN WAMAKKO LOCAL GOVERNMENT AREA OF SOKOTO STATE, NIGERIA

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Abstract

A study on assessment on benefits of Trees Outside Forest (ToF) was carried out at Wamakko Local Government Area, Sokoto State, Nigeria. Multi stage sampling design was used to select three (3) wards based on distribution and abundance of ToF, and one hundred and twenty (120) respondents were selected. Interview schedule were administered to the respondents. Descriptive statistics was used in analyzing the data. The results obtained indicated that 19.28%, 10.48% and 10% of the respondents from Kaura kimba, Gumbi and Dundaye used ToF as their major sources of fuel wood. Forty-two (42) different ToF species were identified. The results further revealed that deforestation was the major management challenge on services and function of ToF. Conclusively, there is no doubt that with continued growth in populations, coupled with the shrinking of forest, ToF is especially utilized for several purposes particularly as source of fuel wood, and these trees are in a very strong position to substantially relieve to the pressure on forest resources. Therefore, efficient utilization of ToF shall be given for promoting sustainable rural livelihood.

Keywords: Trees Outside Forest; Species; Kaura kimba; Gumbi; Dundaye; Fuel Wood

Introduction

Deforestation is now a global problem, due to inappropriate management and lack of appropriate forest policies and legislations (Gibbs *et al.,* 2010). Population growth and agricultural land expansion were today the major cause of deforestation (Foley *et al.,* 2011). Vigorously carry out monitoring and evaluation of forest resources (FAO, 2010), which is important for the multitude services provided by forests. However, there are some trees that grow outside the forest, even if they provide similar services to the forest trees, which are not usually considered by forest monitoring programs, these trees are termed as trees outside forest (ToF) (Pain-Orcet and Bellefontaine., 2004). Trees outside forest (ToF) refers to trees that do not belong to forests and or woodlands, in area of human influence where conditions for tree growth are favorable and are found in spatial patterns and a wide range of situations (FAO, 2010).

Basically, "trees outside forest refers to trees on land not defined as forest and other wooded land" (Bellefontaine *et al.,* 2002). This definition is related to the two FAO categories; forest and other wooded land (Foresta *et al.,* 2013). Forest, other wooded land, trees outside forest and all trees growing in a site were covered in FAO's Global Assessment of Forest and other tree resources (Foresta *et al.,* 2013).

Trees outside forest have increasingly becomes an important feature in the build-up and or agricultural lands (Bellefontaine *et al.,* 2001; Gutzwiller, 2002; Konijnendijk *et al.,* 2005; Forester *et al.,* 2013). Trees outside forest in agricultural landscape are often referred to as scattered, isolated or paddock trees (Manning *et al.,* 2009; Gibbons *et al.,* 1989). All trees in cities and towns planted at back yards, road sides and streets are also known as trees outside forest (Tyrvaienen *et al.,* 2005).

Recently, however, local and international communities have been awakened to the importance of these trees and their increasing importance in scientific, economic and policy discussions (FAO, 2010). Trees outside forest are under threat from logging and agricultural expansion receiving no adequate consideration, thus, neglected. (FAO, 2001). The drivers of trees outside forest spatial distribution either in urbanization or in agricultural landscapes are not much known, because they are often not present in forest inventories (Rossi *et al.,* 2016). It is against the afore-highlighted that the present study is expected to provide answers to: the benefits provided by the ToF and the challenges faced in managing ToF, as well as the species of ToF found in the study area?

Materials and Methods

Study Area

This research was conducted at Wamakko Local Government Area, which lies on a latitude of 13^0 02' 16" N and longitude 5^0 5' 37" E in Sokoto state. Wamakko Local Government Area is located in the Sudan savannah region of Nigeria with scattered trees and shrubs, characterized with a prolong dry season and a short rainy season (with a rainfall distribution of 553.43-628.94mm) and a relative humidity of about 16-55.5% during the dry season and can rise up to 81% during the rainy season (NMA, 2009).

Sampling Procedure and Sampling Size

Reconnaissance survey was done in the study area to observe and assess trees outside forest in the area. Multi stage sampling design was used for this study, Wamakko Local Government constitutes eleven wards (Arkilla, Bado/Kasarawa, Dundaye/Gumburawa, Gidan Yaro, Gidan Hamidu, Gumbi, Gwamatse, Kimba/Gedewa, Kalambaina, Kammata, Wamakko), three (3) of these wards were selected. Similarly, three (3) villages (Dundaye, Kimba and Gumbi) were selected purposively from each of the initially identified wards due to the abundance and distribution of ToF in the areas. Forty (40) respondents were interviewed purposively based on availability and willingness from each of the respective villages to respond to the questionnaire, which makes a total sample size of 120 respondents.

Data Collection

Secondary and Primary data were both used in this study. Secondary data were obtained from relevant literature and research reports specific to the area of study. Questionnaires/scheduled interview were used in the collection of the primary data. Data collected include; species of ToF, information on benefits provided by ToF and challenges faced in managing ToF in the study area.

Data Analysis

The data collected were subjected to descriptive statistics using frequency distribution and percentages to achieve the study objectives.

Results and Discusion

Perceived Benefits Provided by Trees Outside Forest (ToF) in the Area under Study

One important observation in the result from table 1 below was that almost all the respondents from the villages 15.38% of Dundaye, 15.71% of Gumbi, and 13.25% of Kaura kimba used the trees for medicinal and shade by 13.85% of respondents of Dundaye, 13.81% of the respondents from Gumbi, and 16.27% of Kaura kimba, which agreed with Okafor, (1980); Arnold, (1990) findings that ToF provide numerous goods and services that includes fuelwood, herbal medicines, and fibers. Another important observation was that 13.85%, 10.48%, and 19.28% of respondents from the villages major source of fuelwood is from ToF, this result agrees with Arnold *et al.* (2003) who opined that ToF supply majority of fuelwood consumed by rural populace. This is also in conformity with the finding of Food Agricultural Organization (2010) who described ToF products (food, medicine, cooking fuel, animal fodder and construction materials) as critical for the maintaining or supporting hundreds of millions of people.

The table also showed 8.46%, 7.62% 11.45% of the respondents from Dundaye, Gumbi and Kaura kimba villages used the trees for fencing/boundary of their homes and farmland. This is in conformity with Millennium Ecosystem Assessment, (2005) who stated that ToF are used for fencing to protect individual infrastructure from damages. However, 6.15%, 6.19%, and 11.45% of the respondents of the villages said the ToF serve as windbreak, 4.62% of respondents from Dundaye, 9.05% of Gumbi respondents also said the trees on their farmland improves the soil fertility, and 11.54% of the respondents, and 3.61% of respondents said the trees helps in preventing desertification in the area. This agreed with Dantani *et al.*, (2020) who reported that 25.8% farmers in Gaya Local Government area use ToF as wind breaks, and 54.2% of the respondents said ToF improve soil fertility on their farmland, and 5.0% of the respondents said ToF prevent desertification.

The study further revealed that 10.95% of the respondents in Gumbi, and 10.24% of the respondents from Kaura kimba used the trees for aesthetic value to add beauty to their surroundings by adding color to the area for importance. This in conformity with Herzog (2000) who observed that trees outside forest are used on scenic or recreation. The results also showed that 9.23%, 5.71% and 3.61% of the respondent from the villages stated that ToF are source of timber and 7.62% and 4.22% of respondents used the trees for poles. Longi *et al.*, (1999) and Singh *et al.*, (2012) also reported ToF as the main source for forest communities demand on timber and firewood in Terai (plain) Nepal. 6.92% and 9.05% of the respondents from Dundaye and Gumbi said ToF are under agroforestry management and 3.81% of Gumbi and 6.63% of Kaura kimba respondents stated that the trees are in garden; this agreed with Baral *et al.*, (2013) who reported the acceptance of agroforestry system of farming as an important component of rural farming systems in Nepal and mostly considered ToF because of the predominance of agricultural land use.

Table 1: Perceived Benefits Provided by ToF in Dundaye, Gumbi and Kaura kimba

Benefits	**Dundaye**		**Gumbi**		**Kaura Kimba**	
	Frequency	Percentage%	Frequency	Percentage%	Frequency	Percentage%
Medicinal	20	15.38	33	15.71	22	13.25
Agroforestry	9	6.92	19	9.05	-	-
Fencing/Boundary	11	8.46	16	7.62	19	11.45
Aesthetic	13	10.00	23	10.95	17	10.24
Fuelwood	18	13.85	22	10.48	32	19.28
Garden	-	-	8	3.81	11	6.63
Timber	12	9.23	12	5.71	6	3.61
Shade	18	13.85	29	13.81	27	16.27
Serve as windbreak	8	6.15	16	7.62	7	4.22
Improve soil fertility	6	4.62	13	6.19	19	11.45
Prevent desertification	15	11.54	19	9.05	6	3.61
Total	130*	100%	210*	100%	166*	100%

Sources: Field survey 2021 * Multiple responses were observed

Perceived Challenges in Managing Trees Outside Forest (ToF)

Table 2 showed that 51.43% of the respondents from Dundaye,; 29.59% of Gumbi respondents, and 30.61% of Kaura kimba; perceived that deforestation is the major challenge, which is in conformity with (Syaka and Patricia, 2003) who stated that increase in population on limited forest and land resources resulted to a failure of traditional tree-based practices of vegetation cover regeneration. The results also revealed that inadequate knowledge and management skills account for 24.29%, 21.43% and 27.55% of respondents from Dundaye, Gumbi and Kaura kimba respectively. Damage by Pest and Disease account for 14.29%, 9.19% and 5.71% of Gumbi, Kaura kimba, and Dundaye respondents respectively. Limited water account for 32.65%, 22.45% and 10% of respondents from Kaura kimba, Gumbi and Dundaye respectively. Laws and regulation account for 8.57% of the respondents from Dundaye, and 12.24% of respondents from Gumbi ;which agreed with Dogra and Chauhan, (2016) who observed that trees outside forest are not supported by financial institutions and extension services; unavailable improved planting material, no separate laws and regulations for trees outside forests, guided by forest act, and trees are host to insects and birds are part of many constraints to growth and development of trees outside forest.

Table 2: Perceived Challenges in Managing ToF in the Study Area

Challenges	Dundaye		Gumbi		Kaura kimba	
	Frequency	Percentage %	Frequency	Percentage %	Frequency	Percentage %
Limited water	7	10	22	22.45	32	32.65
Deforestation	36	51.43	29	29.59	30	30.61
Inadequate knowledge skills	17	24.29	21	21.43	27	27.55
Pest and Disease	4	5.71	14	14.29	9	9.19
Laws and regulation	6	8.57	12	12.24		
Total	70*	100%	98*	100%	98*	100%

Sources: Field survey 2021 * Multiple responses were observed

Species of Trees Outside Forest (ToF)

Table 3 showed that forty-two (42) different species of ToF were identified in the study area. This is in line with the findings of Dantani *et al.* (2020) who identified *Tamarindus indica, Adansonia digitata, Faidherbia albida, Acacia nicotica, Azadirachta indica* as ToF species in Gaya Local Government Area of Kano State, Nigeria.

Table 3: ToF Species Dominance in the Study Area

S/N	Species name	Common name	Local name	Dundaye	Gumbi	Kaura kimba
1.	*Adansonia digitate*	Baobab	Ichen kuka	✓	✓	✓
2.	*Acacia nilotica*	Gum Arabic	Bagaruwa	✓	✓	✓
3.	*Acacia seyal*	Vachellia seyal	Farar kaya	✓	✓	✗
4.	*Anogeissus leocarpus*	African birch	Marke	✓	✓	✗
5.	*Azadirachta indica*	Neem tree	Dogonyaro	✓	✓	✓
6.	*Bauhinia monandra*	Pink bauhinia	Alkawarii	✓	✓	✗
7.	*Bauhinia rufescens*	Mauritania	Jirga	✓	✓	✓
8.	*Balanites aegyptiaca*	Desert date	Aduwa	✓	✓	✓
9.	*Cassia arereh*	Mishuski	Malga	✓	✓	✓
10.	*Calotropis procera*	Soom apple	Tumfafiya	✓	✓	✓
11.	*Carica papaya*	Pawpaw	Gwanda	✓	✗	✗
12.	*Ceiba pentandra*	Silk cotton tree	Rinin masar	✓	✓	✗
13.	*Citrus lemon*	Lemon	Lemon tsami	✓	✓	✓
14.	*Combretum geitonophylum*	Red bushwillow	Farar taramniya	✗	✓	✓
15.	*Combretum glutinosum*	Bushwillow	Jar taramniya	✓	✓	✓
16.	*Commiphora Africana*	African myrrh	Dashi	✗	✓	✗
17.	*Diospyros mespiliformis*	Jackal berry tree	Kaiwa	✓	✓	✓
18.	*Eucalyptus camaldulensis*	River red gum	Turare	✓	✓	✗

19.	*Faidherbia albida*	Apple ring acacia	Gawo	✓	✓	✓
20.	*Ficus polita*	Heart leaved	Durumi	✓	✓	✓
21.	*Ficus sycomorous*	Sycamore	Baure	✓	✓	✓
22.	*Ficus thonningii*	Chinese banyan	Cediya	✓	✓	✓
23.	*Gmelina arborea*	Gmelina	Mulela	✓	✓	✓
24.	*Guiera senegalensis*	Moshi medicine	Sabara	✓	✓	✓
25.	*Hyphaene thebaica*	Doum palm	Goriba	✓	✓	✓
26.	*Khaya senegalensis*	African mahogany	Madacci	✓	✓	✓
27.	*Mangifera indica*	Mango	Mangoro	✓	✓	✓
28.	*Mimosa pigra*	Giant sensitive tree	Gumbi	✓	✓	✓
29.	*Moringa oleifera*	Drum stick tree	Zogala	✓	✓	✓
30.	*Olea europaea*	Olive tree	Zaitun	✓	✗	✓
31.	*Parkia biglobosa*	African locust bean	Doruwa	✓	✓	✓
32.	*Pilliostigma reticulatum*	Camel foot tree	Kalgo	✓	✓	✓
33.	*Prosopis Africana*	African mesquite	Kirya	✗	✓	✓
34.	*Phoenix dactylifera*	Date palm	Dabino	✓	✓	✗
35.	*Psidium guajava*	Guava	Gwaba	✓	✗	✓
36.	*Sclerocarya birrea*	Jelly plum	Nunu	✓	✓	✓
37.	*Tamarindus indica*	Tamarind	Tsamiya	✓	✓	✓
38.	*Terminalia mantaly*	Madagascar almond	Ichen setlite	✓	✗	✗
39.	*Terminalia catappa*	Indian almond	Fruits, Umbrela	✓	✓	✓
40.	*Vitex doniana*	Black plum	Dunya	✗	✓	✓
41.	Ziziphus *mauritiana*	Indian jujube	Magarya	✓	✓	✓
42.	*Ziziphus spina-christi*	Christ's thorn jujube	Kurna	✓	✓	✓

Sources: Field survey 2021 ✓ Identified ✗ not identified

Conclusion and Recommendations

The present study focused on trees outside forests, which play very important roles in the nutritional and economic life of the people. There is no doubt that with continued growth in populations, coupled with shrinking forests, and degraded ecosystems, trees outside forest are bound to play a much greater local and global role in meeting the challenges of resource sustainability, poverty reduction and in contributing to food security. The findings of this research revealed that, these trees are in a very relevant position to substantially relieve the pressure on forest resources, conserve farmlands, and boost agricultural productivity.

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Monitoring Termite's Activities In Built-Up Environment Using Geographic Information System (GIS) Based Approach. (A Review)

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Abstract
Termites' attacks to building has been a major concern to builders, home owners and Government Agencies desiring solution due to cost of constant replacement of affected wooden parts. Termites control can be more efficient when information on the current status of its prevalence and severity in a given area is available. This review paper focused on monitoring termite's activities in built-up environment using GIS based information. Available literature revealed that there are little information available on the destructive termites' attacks to build-up environment in Nigeria. This review was therefore carried out with a view to providing baseline information on prevalence of activities of termites and the use of GIS in the survey of termites severity in guiding builders, home owners and Government agencies in taking informed decision before, during and after construction also ensuring building safety.

Keywords: Termites, Geographic Information System (GIS), Termite Probability Map, Built-environment

Introduction.

Termites are social ecosystem engineers which play a major role in the ecosystem across the world especially in the tropics (Jouquet *et al*., 2006 and Rahman *et al.,* 2013). They help in the recycling of cellulosic material and aeration of the soil. However, when it comes to building and other wooden structure they are enormous menace. They destroy wooden materials and a lot of money is been spent annually by home owners for repair and replacement of damage parts (Owoyemi *et al*, 2017). The annual estimated cost of global damage by termites are in billions of dollar (Su, 2002; Rust and Su, 2012). In the recent times, there is the need for builders to take adequate precautionary measure before construction. This is done by ensuring that building are sited in a safe environment, which is free from termites or any other biodeteriorating agent. One way of doing this, is by carrying out preconstruction investigation to ascertain termites prevalence and severity level in order to adopt appropriate construction technology which will guarantee the safety of the building to prevent loss as most of the buildings are constructed on mortgage. In the United States of America, Florida for example, the building code contain regulation on termites control for pest control company and building owners on the need for continued protection of building from termite unlike country like Nigeria (Florida building code, 2010). The Certificate of Protective Treatment for Prevention of Termites must be provided prior to the issuance of the Certificate of Occupancy as per Section 104.2.6 of the code of Florida. This certificate is needed when home owners want to sell their properties or accessing loan facility from bank as the buyer and bank will want to be sure that the building is safe from termite infestation (Florida building code, 2010; Anonymous 2022 and Freedom mortgage 2019). This review is therefore aimed at providing information on monitoring termite's activities in built environment using Geographic Information System which will serve as a guide to homeowners, developers and pest control companies in taking informed decision during planning and execution of projects.

Termite activities.

Termites are social insect living in colonies. They live in self-constructed mounds called termitaria. A termite colony is very organized and has castes that are morphologically and functionally distinct. (Lee and Wood, 1971; Richards and Davies, 1977). Termite belongs to the Order Isoptera (Grimaldi and Engel, 2005). Termites have different group comprising of over 2600 species in 280 genera worldwide, 80 termite species were considered serious pests and subterranean termites accounted for 38 species (Lee and Chung, 2003; Ahmed *et al*. 2011; Rust and Su, 2012). Subterranean termites, especially those from the subfamily Macrotermitinae (Odontotermes spp. and Macrotermes spp.) and Rhinotermitinae (Coptotermes spp.) are seriously attacking building and *Coptotermes* spp genus has the largest number of species (Sornnuwat *et al*., 1996; Kirton and Azmi, 2005; Rust and Su, 2012). Termites occur in most tropical countries and are also found to a limited extent in some semi-temperate climate including North America and several European countries (Fig. 1) (Berry, 1994; Owoyemi, 2008). The estimated number of termite species distribution worldwide for Africa, North America, South America, Europe, Australia are 435, 1000, 50, 400, 10 and 360 respectively (Meyer *et al.,* 1999 and UNEP 2015). Also the rate of its destructive activities is a function of the species of termites, soil properties and climatic condition of the area (Owoyemi *et al*, 2017). The attack of termite to building mostly originated from their nest on the ground to the building (Fig. 2). The galleries are usually constructed in the top 300mm of soil but may be deeper (Owoyemi *et al*, 2008). It access the building through galleries built on any material (Ghaly and Edwards, 2011). Owoyemi *et al*, (2013) reported that termites have become very prominent and of great economic importance among other wood destroying agents as a result of its destructive nature. Worldwide estimate of losses incur due to termite attack are in billions of US dollars annually (Eko *et al.,* 2015) However, in some Africa countries like Nigeria, are unable to give the right account of losses incurred due to termite attack to building (Ye, Jones, & Ammar, 2004), this could be the difficulty in collecting such kind of data. There is little information on the cost of termite control to building in Nigeria annually unlike records found (Table 1) for countries like USA, Indonesia, Malaysia, Japan, China, Hong Kong, Taiwan and Philippines (Eko *et al.,* 2015). Despite the allocation of thirty million naira for termite control in a school in Ekiti state by the state government, there was no indication that anything was done to eradicate the destructive activities of termites which threaten to ruin the school after four year intervention (Iretomiwa, 2021).

Table 1 Country estimated economic losses due to termites attack to building annually

SN	Country	Economic losses due termite attacks per year
1	Indonesia	IDR 90 billion
2	Malaysia	USD 10-12 million.
3	*Japan*	US $ 1 billion
4	China	RMB 1700-2000 million
5	*India*	280 millions rupee
6	Taiwan	4 million US dollars
7	*USA*	$1.5 billion

Source. (Eko *et al*. 2015) and Su Nan-yao and Rudolfh. Scheffrahn. (2000)

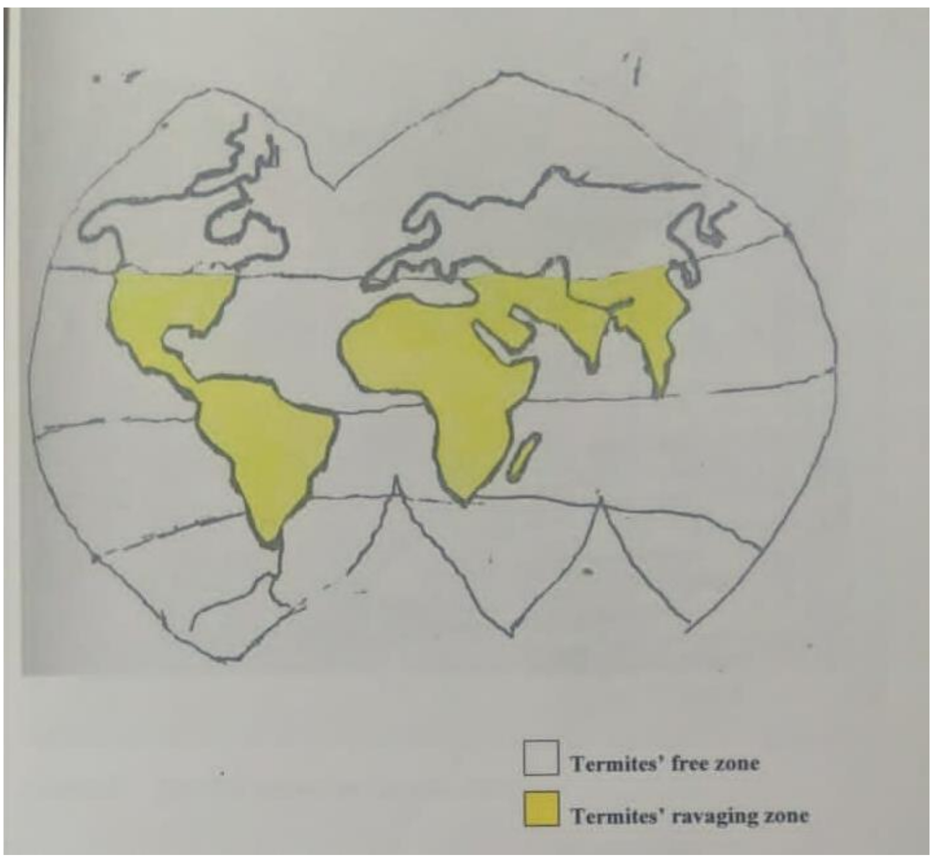

Figure 3: World Distribution of Termites. Source: Berry (1994)

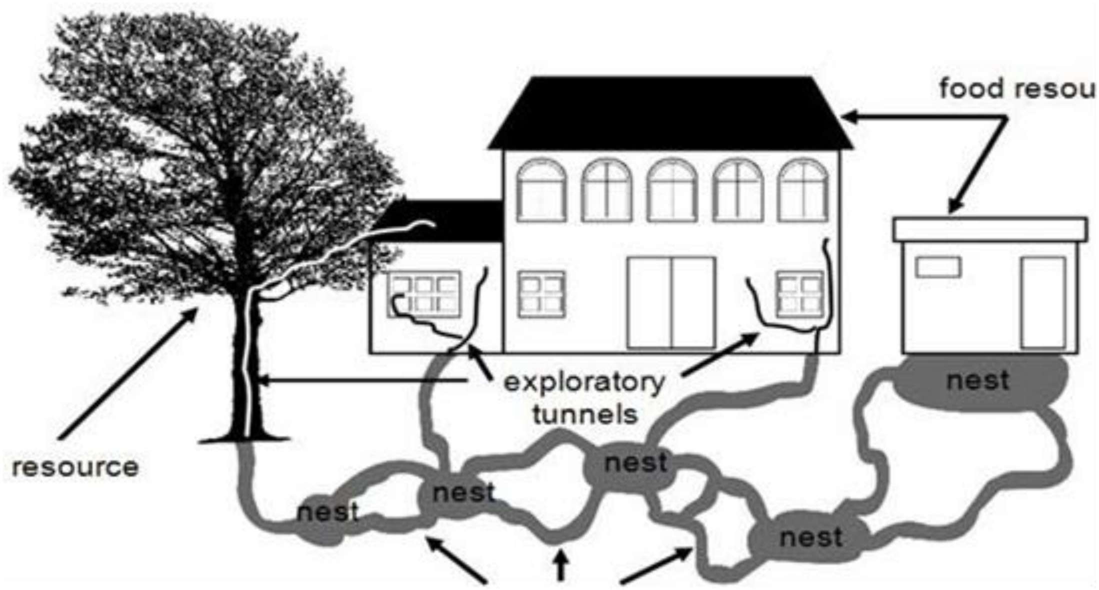

Figure 2: Typical Termites activities in building. (Eko *et al*. 2015).

Monitoring termite's activities

Monitoring of termites activities is important in managing its destructive activities to structures. This could be expensive and time-consuming; it involves establishment of termite monitoring station around the outside perimeter of the building's foundation at about 3 to 6 meters intervals. The monitoring station composed of plastic holder and a cellulosic materials. The station housing is a hollow green plastic cylinder, about 225 mm long by 50 mm wide, with slits along the sides for termites to enter. Initially, each station contains two untreated pieces of wood, intended as monitoring devices for the presence of termites in the area. (http://www2.ca.uky.edu/agcomm/pubs/ent/ent65/ent65.pdf). Also developing termite's probability map for documenting activities of termite for an area is important reference tools for planning and siting structures. It is a rigorous activities, well plan, time consuming and costly (Sónia *et al,* 2016, Su and Scheffrahn 2000). According to Owoyemi *et al*, (2021), the process of developing termites probability map for an area include digitizing the study area and then converted from the ArcGIS shape file format (.shp) to Google earth-compatible format (.kml). The digitized boundary of the shaped file will then be opened on the Google earth interface to extract the Google earth images that fall within the study area boundary. Other known features, such as the roads, river, and buildings, from the acquired images will be obtained without further need for georeferencing. The data will then be loaded on QGIS software where the plot sampling followed a systematic sampling technique using the "Research tools" on QGIS by dividing the georeferenced study area map into rectangular grids populated with serially regular numbered points. Sampling locations will be randomly selected among the regular points spread across the gridded area with the help of a randomization device.

The coordinates of the selected points will be exported to Google earth to ascertain their exact locations on the study area location, where a selected location falls on a structure or other facilities, the nearest suitable location besides it will be selected. Finally, a reconnaissance survey (ground truthing) will be carried out to assess the ground locations of the selected points and subsequently establish the timber graveyard at these selected locations.

Defect free less durable wood will then be used as termite's bait at the timber graveyard in the selected locations processed into standard sample sizes of 35 × 35 × 450 mm according to ASTM D3345-17 (2017). All the samples will be labeled for easy identification and their initial wet weight obtained using a weighing balance, after which they will be oven-dried weight at a constant temperature of 103 ± 2 °C for twenty-four (24) hours until a constant weight is obtained. The oven-dried weights of each sample will also be noted, and this will served as the starting (i.e., initial) weight of each of the samples with respect to weight loss assessment. Wood samples will be buried to a depth of 225 mm below the ground surface and at the spacing of 1000 × 1000 mm from each other in each of the selected locations. The samples will be subsequently inspected weekly for between twelve weeks to one year which will be revalidated every five years since termites migrate from one place to another due to noise and anthropogenic activities of man and climate change (Owoyemi, 2008; Grzegorz and Cloe, 2017) .Termites species will also be collected in each of the area of study for proper identification because of the numerous species of termite known worldwide over 2600 species as the rate of attack differ from each other.

Furthermore, soil sample from each of the location will also will be taken to determine some physical properties like bulk density, particle size and percentage moisture content. At the end of the assessment period, data obtained from the weight loss assessment and soil properties tests will be used to prepare a termite probability map using QGIS print composer.
The map will be colour coded following United States Forest Service codes for subterranean termite's probability map (Table 2) according to ASTM D3345-17 (Peterson *et al,* 2006):

Table 2: United States Forest Service codes for subterranean termite's probability map

ASTM Rating	Description	Colour
10	None to slight attack	White
9	Slight attack	Green
7	Moderate attack	Yellow
4 and 0	Heavy attack	Red

A depiction of the steps taken from the acquisition of the location boundary map to the preparation of the termite severity probability map is shown in Fig 3

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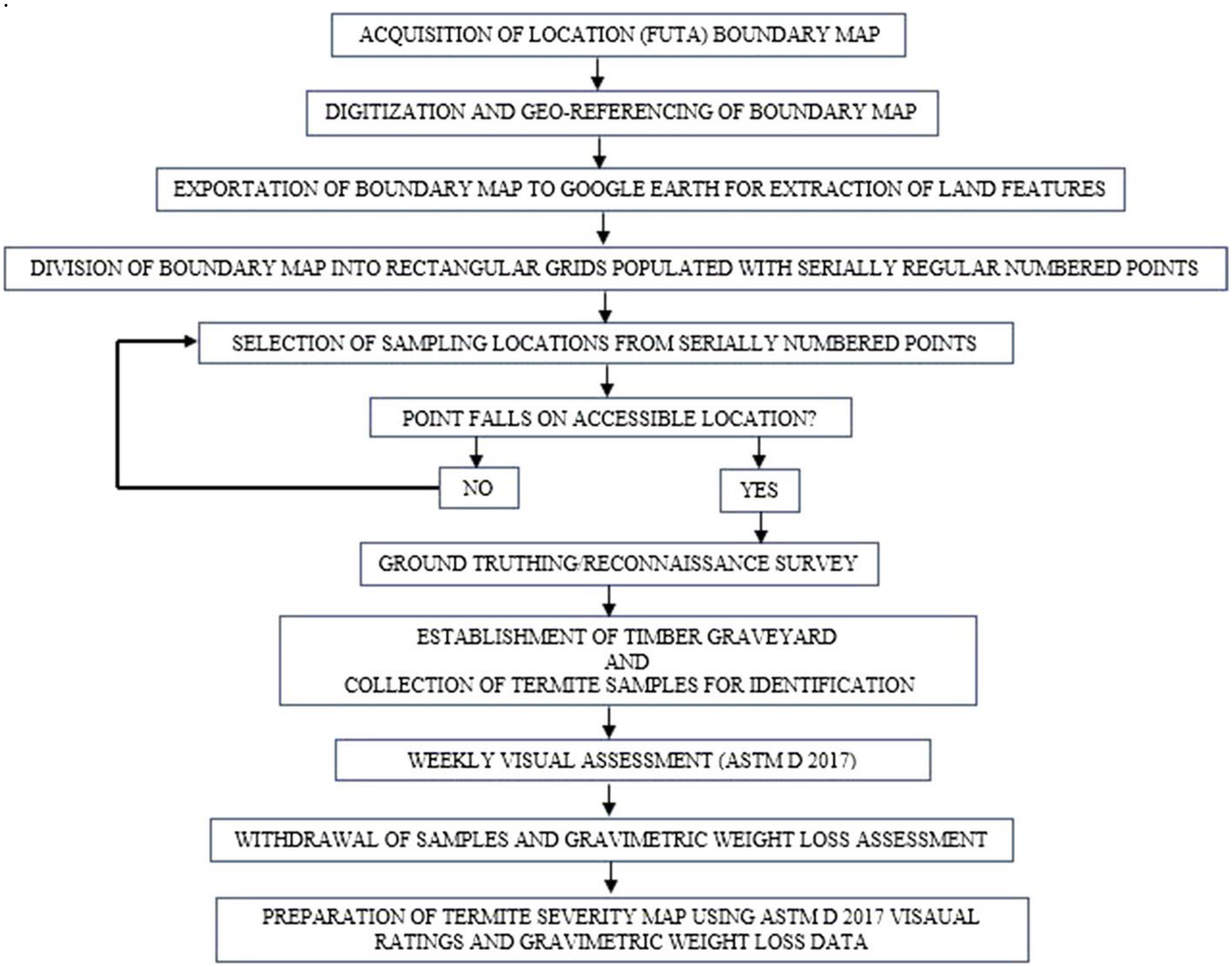

Figure 3: Flowchart depicting the steps followed in the preparation of the termite severity probability map. Source (Owoyemi et al, 2021)

Application of Geographical Information System (GIS) in monitoring termite's activities

A Geographical Information System (GIS) is a set of hardware, software, and methods for managing, manipulating, analyzing, modeling, representing, and displaying geo-referenced data in order to solve complex problems in resource planning and management (Ranjan and Vinayak, 2020). Its data are flexible, precise, and accessible for meeting operational and other software requirements (Acharya *et al.,* 2018). It uses georeferenced data, that is, having unique location information, such as postal addresses, or point coordinates. Geovisualization is used to explore, analyze, and present spatial data, however, a GIS mapping system also supports on-screen digitizing of spatial features on top of background maps. Point, line, and polygon object features are often displayed over a base map, e.g. a satellite image, which can be provided through a Web mapping service within the GIS (fig. 4) (Hochmair *et al*, 2013).

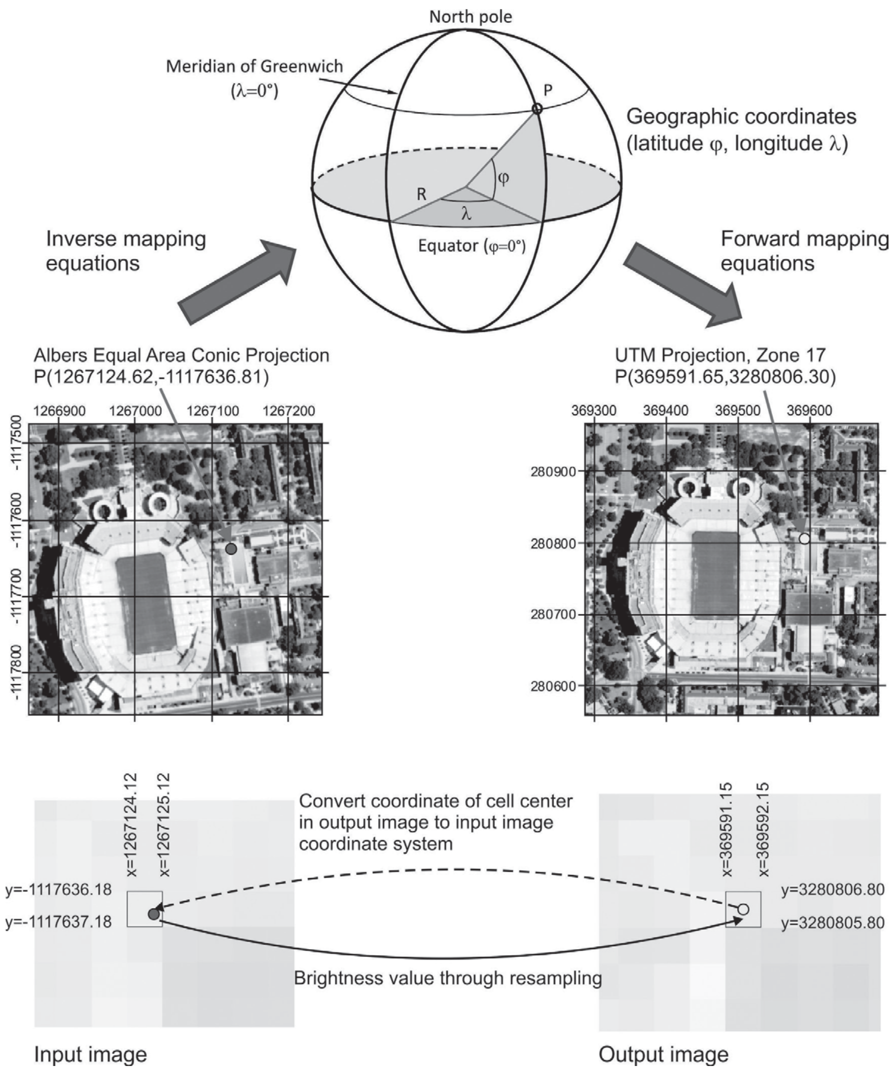

Figure 4: Re-projection of a 1-m resolution aerial image between Albers Equal Area Conic projection and UTM Projection (Zone 17) using geographic coordinates as an intermediate step. Resampling is used to fill pixel values in the output image through pixel values derived from the input image. Sources: (Hochmair *et al*, 2013).

GIS output maps with clear captions and varied groupings of colouring and patterns make it simple to visualize even with inexperienced GIS users to feel at ease (Paramasivam, 2019). With GIS we can produce maps to monitor termites hazard (Fig 5, 6 and 7) and tell where and why the populations are higher and lower in any through relating, comparing, analyzing the information more precisely via graphical representation in a map for better decision making approaches. The knowledge of GIS can also be applied in precision building technology construction together with remote sensing. GIS system helps in analyzing past records or databases with reference to the geographical maps by producing various models for building technology construction, and in entomology these technologies have great potential and offer many new opportunities and methods for studying and managing insect pests (Dminić *et al*., 2010).

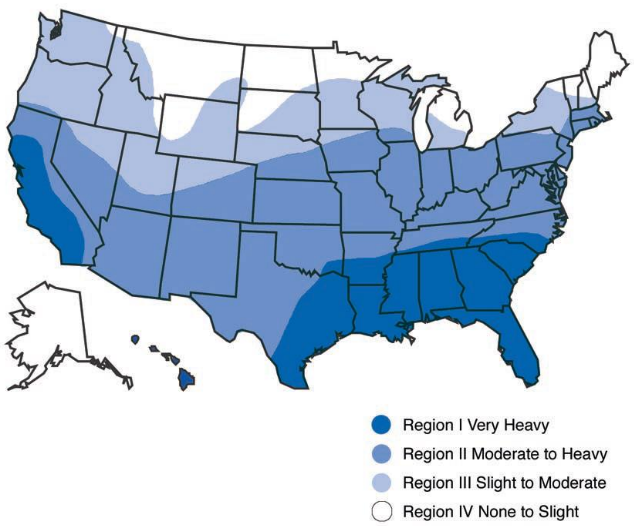

Figure 5 Relative hazard of subterranean termite infestations in the United States. *(*Source. Peterson *et al*., 2006*)*

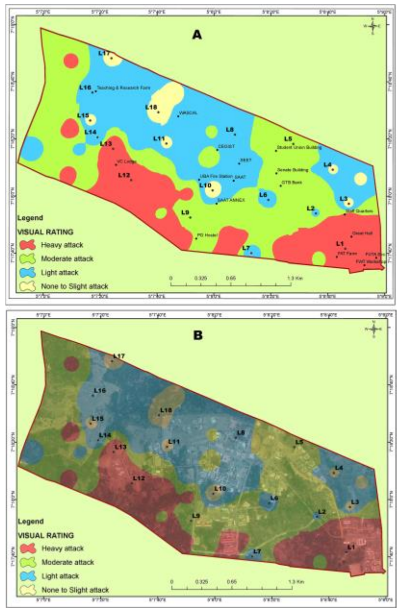

Figure 6: Termite severity probability map of FUTA campus area showing the severity of termite attack as determined by the averaged ASTM D3345-17 visual ratings of the 18 locations across the campus with key academic and administrative buildings that fall within the study area boundary. **B** Map showing extracted
Google earth images of the campus that fall within each severity class. Source *(*Owoyemi *et al*, 2021*)*

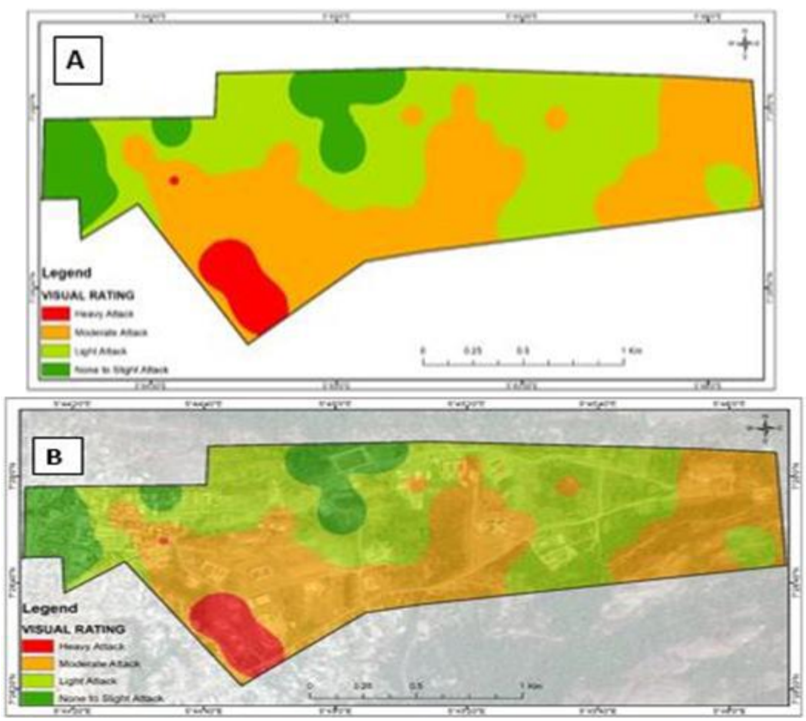

Figure 7: Termite Infestation Probability Map of AAUA campus; A: Map showing the termite severity on the campus-based on the visual ratings of the selected locations, B: Termite severity of the AAUA campus superimposed on the extracted Google earth imagery showing other known features that fall within the campus boundary.(Owoyemi *et al*, 2022)

Benefit of GIS in termites monitoring

GIS as a tools can create a data concepts to describe the real-world life systematically classifying features into a series of thematic layers. To produce layers, GIS can incorporate geo referenced data like termite's species and abundant, severity of it attack, soil type and climatic condition. Each layer can be evaluated independently or features between two or more layers can be analyzed together. Single kind of theme or data can compose a map layer and a complete database can combine themes representing similar areas. For the analysis of interaction between and within different themes GIS works as a tool. And without GIS, it would be impossible to manage and analyze these vast databases (Duarte et al., 2015, Saifatul et al, 2022). Also, GIS can be used to create and visualize dynamic simulation models. The simulation shows the evolution of the phenomenon of interest through time and may involve multiple sub processes. Dynamic modeling allows scientists to experiment with policy options and what-if scenarios. It also allows them to implement ideas about the behavior to the world (Longley et al. 2011, Hochmair *et al*, 2013).The ability to manage geospatial data has made GIS an important tool for a wide range of applications over the past decades, including management of natural resources, analysis of wildlife movement, ecological niche modeling, or land records management **(**Hochmair *et al*, 2013). Termite's probability maps produced with the aid of GIS serve as baseline data for builders, home owners and government on the destructive activities of termites. It serves as easy reference tool in guiding builders on the right constructional technology to employ during construction. Cost effectiveness is ensured as frequent replacement of wood in service is avoided and also contribute to the sustainable forest management.

Conclusion

The aggressive and destructive activities of termites to structures in recent time call for concerted effort in managing the activities of termites. Baseline information on the activities of termites in an area where a structure is to be constructed is required in planning before construction. Regular termites mapping of environment using GIS has therefore become a potent tool in planning and erecting building structures in built-environment.

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Adaptation of Geometric Functions for Calculating Tree Volume and Biomass in One Step

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Abstract
Stem volume and biomass are important variables frequently measured in forestry. Their direct measurements are impossible on standing trees and impracticable on felled logs. Consequently, stem volume and biomass are commonly estimated using selected established relationships between them and some directly measurable tree dimensions, such as diameter and height. One way of estimating them on standing trees and logs is by determination of their values, directly from detailed measurements of the trees or logs in question, using geometric formulae. The conventional way of using the geometric formulae involves at least two computational steps to calculate volume and at least four steps to calculate biomass. But, with some modifications, it is possible to calculate volume and biomass with these formulae in just one step of computation. The modifications involve building the necessary conversion factors; cross-sectional area formula and specific wood density into the various geometric formulae to enable them calculate the required stem content in a single step. The adapted formulae yield the same results as one would obtain by using the geometric formulae in the conventional way. By reducing the process to just one step, they save time, energy and space, reduce computational errors and avoid conversion from one unit of measurement to another and some approximations between steps that may affect the final result.

Key words: Huber's formula, Smalian's formula, Newton's formula, Conoid formula.

Introduction

Trees are the main focus of all forest inventories for timber and carbon; and tree stem content constitutes a very important quantity of interest in such forest assessments in view of its importance in forest management and utilization. Its quantification in cubic volume (m^3 or ft^3) or weight (kg) is always given serious attention because of the value of its products (Kauffman and Donato, 2012). Tree stem produces wood, which is the most prominent forest product in the world, given its numerous applications (Olajide and Eniang, 2000; Fuwape, 2005; Olajide and Udo, 2005) and its immense contributions to the national economies of many countries of the world. In fact, timber has been a primary source of capital for forested nations such as Canada, India, Indonesia, Italy, Malaysia, Norway, Sweden, the Russian Federation, Thailand and United States of America, among other countries, which have relied on their forests for sources of revenue, foreign exchange and equity for loans to get the necessary capital for building their industrial and agricultural capacities (Duerr, 1993; Durning, 1994). Even in modern economy, wood plays a part in more activities than does any other commodity, since there is hardly any industry that does not use wood or wood products somewhere in its manufacturing and marketing processes (Cunningham and Cunningham, 2004).
Stem volume estimation is very useful for both research and practical purposes in forestry and contributes to the sustainable management of timber resources (Barrio-Anta, *et al*., 2007). Information on the quantity, quality and value of timber in the forest is always desired for timber management, sales and purchases. Generally, information on wood volume is very important for forest valuation, planning of sustained yield of timber harvest, monitoring and evaluation of management effects on forests, measuring the effect of experimental treatments on tree growth and developing growth and yield models for predicting sustained yield levels (Higman *et al.,* 2000; Panwar and Bhardwaj, 2012).
Monitoring and evaluation of forest biomass is becoming more important because of the vital roles played by forest ecosystems in regulating global carbon balance and mitigating global climate change (Tomppo *et al*., 2010). Biomass measurements have become crucial for determining the amount of carbon sequestered in vegetation and understanding the impacts of land-cover changes on carbon fluxes (Cole and Ewel, 2006; Heryati *et al*., 2011; Addo-Fordjour and Rahmad, 2013). This is because carbon mass in vegetation is a fractional part of biomass and can easily be calculated from it (Losi *et al*., 2003; Montagu *et al*., 2005; Kauffman and Donato 2012; Yuen *et al*., 2016). Generally, study of forest biomass is important in the study of ecosystem productivity, energy and nutrient flows, standing tree carbon and the effect of forest land dynamics on the global carbon cycle (Parresol, 1999; Yuen *et al*., 2016).
In estimating aboveground biomass and carbon stock of forest ecosystems, it is essential to measured trees thoroughly and accurately since they dominate the aboveground carbon pool and are an obvious indicator of land-use change and ecological condition (Santa and Tarazona, 2001; Kauffman and Donato, 2012). Additionally, trees have been identified as principal sinks of CO_2 among the forest species, (Sukhdev, 2010; ITTO, 2011). Estimation of tree stem biomass is very essential in quantifying total tree biomass. This is because the stem constitutes the highest proportion of total tree biomass (Ecometrica, 2011; Feliciano *et al*., 2014) and is more accessible and easier to measure than any other part of the tree. Sometimes the biomasses of other parts of the tree are estimated from stem biomass using known relationships between stem biomass and the biomasses of other parts of the tree (Ecometrica, 2011), especially when non-destructive method is used in estimating total tree biomass.
Stem volume and biomass are variables frequently measured in forestry, but are impossible to measure directly on standing trees. Even on fell trees, the direct measurement of these variables is impracticable due to the bulky nature of the stem, which requires large capacity and highly expensive instruments to handle. Aside from that, such exercise is very tedious and time consuming. Consequently, stem volume and biomass are commonly estimated using selected established relationships between them and other directly measurable tree dimensions, such as diameter and height. One way of estimating these

variables on standing trees and logs is by determination of their values directly from detailed field measurements of the trees or logs in question using geometric formulae.
The conventional method of direct estimation of stem content from diameter and height measurements using geometric formulae involves: (i) converting diameter measurements from centimetres to metres, since tree diameters are always measured in centimetres (cm) and volume in cubic metre (m^3), (ii) calculating cross sectional areas of the stem or log at the various points of diameter measurements, (iii) calculating volume using any of the geometric formulae and (iv) if biomass is required, converting volume to biomass by multiplying it by the wood density of the tree species. Wood density is usually expressed in gram per cubic centimetre (g/cm^3) and needs to be converted to kilogram per cubic metre (kg/m^3) before it can be used, since biomass is expressed in kilogram (kg). Thus, even if one bypasses the step for calculating cross sectional areas, it takes at least two computational steps to calculate volume and at least four steps to calculate biomass. But it is possible to calculate volume and biomass using these geometric formulae in just one step of computation, thus saving time and energy and avoiding conversion from one unit of measurement to another, computational errors and some approximations between steps that may affect the final result. The objective of this study was to build all the necessary conversion factors and the formula for calculating cross sectional area into the frequently used geometric formulae to facilitate their usage in calculating stem contents, even with the use of manual calculators.

Frequently used Geometric Formulae for Volume Estimation
The following are geometric formulae frequently used in forestry for calculating the volume of a stem or log:

Huber's formula: $V = \mathrm{h}(A_m)$ …………………….. (1)

Smalian's formula: $V = \frac{h}{2}(A_b + A_t)$ …………………….…….................................... (2)

Newton's formula: $V = \frac{h}{6}(A_b + 4A_m + A_t)$ ……….. (3)

Conoid formula: $V = \frac{1}{3}A_b h$ .... (4)

Where; A_b = Cross sectional area at the base (m^2),
A_m = Cross sectional area at middle (m^2),
A_t = Cross sectional area at the top (m^2),
V = Cubic volume (m^3),
h = Height or length (m),
(Avery and Burkhart, 2002; Husch *et al*. 2003).
The Conoid formula is used for calculating the volume of the upper part of the tree stem, since upper logs usually approach the form of conoids (Clutter *et al*., 1983; Avery and Burkhart, 2002). Using the formulae as stated in equations (1) to (4) requires that the cross-sectional areas at the various points of measurements are calculated first, before the values are substituted into the geometric formulae. The cross-section of the stems of most trees approximates a circle, thus, its area is usually computed with the standard formula for calculating the area of a circle, stated as follows:

$A = \pi r^2 = \frac{\pi d^2}{4}$ ………………………………………………………………. (5)

Where; A = Cross-sectional area (m^2),
r = Radius (m),
d = Diameter (m) and
π = Constant
(Avery and Burkhart, 2002; Husch *et al*. 2003).
In forestry, since diameter instead of radius is the dimension of the stem usually measured, the derivative or modified version ($\frac{\pi d^2}{4}$) of the standard formula for calculating the area of a circle is normally adopted for calculating cross-sectional area of the stem.

Modification of the Formulae for Calculating Cross-Sectional Area and Volume
When cross-sectional area is only required for volume computation, the two steps for calculating cross-sectional area and volume can be accomplished in just one step if the formula for calculating cross-sectional area is built into the required geometric formulae for calculating volume as follows:

Huber's formula: $V = \mathrm{h}(A_m) = h\left(\frac{\pi d_m^2}{4}\right) = \frac{\pi d_m^2}{4}h$ ……….. (6)

Smalian's formula: $V = \frac{h}{2}(A_b + A_t) = \frac{h}{2}\left(\frac{\pi d_b^2}{4} + \frac{\pi d_t^2}{4}\right) = \frac{\pi h}{8}\left(d_b^2 + d_t^2\right)$ .... (7)

Newton's formula $V = \frac{h}{6}(A_b + 4A_m + A_t) = \frac{h}{6}\left(\frac{\pi d_b^2}{4} + 4\frac{\pi d_m^2}{4} + \frac{\pi d_t^2}{4}\right) = \frac{\pi h}{24}(d_b^2 + 4d_m^2 + d_t^2)$ .... (8)

Conoid formula $V = \frac{1}{3}A_b h = \frac{1}{3} \times \frac{\pi d_t^2}{4} h = \frac{\pi d_t^2 h}{12}$ .... (9)

Where; d_b = Diameter at the base (m),
d_m = Diameter at the middle (m),
d_t = Top diameter measured at crown point (m),
V = Cubic volume (m^3)
h = Height or length (m)
π = Constant.

These modified versions of these geometric formulae have been used by some authors (Hamilton, 1988; Picard *et al*., 2012; Shamaki and Akindele, 2013). Using these geometric formulae as expressed in equations (6) to (9) for calculating volume, requires the conversion of diameter measurements from centimetre (cm) to metre (m) by dividing each diameter value by 100 before they are used in calculating volume to obtain the result in cubic metre if not, after the calculation the result must be divided by 10000 to have it in cubic metre. However, converting diameter measurements from centimetre to metre and calculating cross-sectional area can be accomplished in one step by building the conversion factor (100) into the formula for calculating cross-sectional areas as shown in equation (10).

$A = \frac{\pi d^2}{4} = \frac{\pi}{4} \times \frac{d}{100} \times \frac{d}{100} = \frac{\pi d^2}{40000}$ …....……………….. (10)

Where; A = Cross-sectional area (m^2),
d = Diameter (cm) and
π = Constant

When the actual value of pi (π) is substituted into the equation, equation (10) can be simplified to:

$A = 0.00007854\mathrm{d}^2.$ ……………………………………………………………………. (11)

But the constant 0.00007854 is an approximation. The cross-sectional area formula with inbuilt conversion factor as expressed in equations (10) and (11) have been used by many authors for calculating cross-sectional areas (Avery and Burkhart, 2002; Husch *et al*. 2003; Laar and Akca, 2007; Etigale *et al*., 2014; Etigale *et al*., 2021).

When equation (10) is built into the various geometric formulae, they can be used to calculate volume directly from field measurements in just a single step and obtain results in cubic metres without converting from one unit to another as follows:

Huber's formula: $V = \mathrm{h}(A_m) = h\left(\frac{\pi d_m^2}{4}\right) = h\left(\frac{\pi d_m^2}{4 \times 100 \times 100}\right) = \frac{\pi d_m^2}{40000}\mathrm{h}$ ……....................... (12)

Smalian's formula $V = \frac{h}{2}(A_b + A_t) = \frac{h}{2}\left(\frac{\pi d_b^2}{40000} + \frac{\pi d_t^2}{40000}\right) = \frac{\pi h}{80000}\left(d_b^2 + d_t^2\right)$ .... (13)

Newton's formula $V = \frac{h}{6}(A_b + 4A_m + A_t) = \frac{h}{6}\left(\frac{\pi d_b^2}{40000} + 4\frac{\pi d_m^2}{40000} + \frac{\pi d_t^2}{40000}\right)$
$= \frac{\pi h}{240000}(d_b^2 + 4d_m^2 + d_t^2)$ .... (14)

Conoid formula $V = \frac{1}{3}A_t h = \frac{1}{3} \times \frac{\pi d_t^2}{40000} h = \frac{\pi d_t^2}{120000}\mathrm{h}$ .... (15)

Where; V = Cubic volume (m^3)
h = Height or length (m)
d_b = Diameter at the base (cm),
d_m = Diameter at the middle (cm),
d_t = Top diameter measured at crown point (cm).

Modification of the Formulae for Calculating Biomass

Biomass can also be calculated directly from field measurements in just a single step using these geometric formulae without going through the rigours of converting values from one unit to another and calculating cross-sectional area and volume. This can be accomplished by modifying the various geometric formulae and incorporating specific wood density term into the formulae as shown in equations (16) and (20). Note that specific wood density is expressed in g/cm^3 and the factor for converting it to kg/m^3 (1000) is also built into the formulae.

Huber's formula: $\boldsymbol{B = h(A_m) = h\left(\frac{\pi d_m^2}{40000}\right) \times 1000\rho = \frac{1000\pi h_1 \rho}{40000}\left(d_m^2\right) = \frac{\pi h \rho}{40}\left(d_m^2\right)}$ .... (16)

Smalian's formula: $\boldsymbol{B = \frac{h}{2}(A_b + A_t) = \frac{h}{2}\left(\frac{\pi d_b^2}{40000} + \frac{\pi d_t^2}{40000}\right) \times 1000\rho}$

$= \frac{\mathbf{1000\pi h\rho}}{\mathbf{80000}}\left(\boldsymbol{d_b^2} + \boldsymbol{d_t^2}\right) = \frac{\boldsymbol{\pi h\rho}}{\mathbf{80}}\left(\boldsymbol{d_b^2} + \boldsymbol{d_t^2}\right)$ .... (17)

Newton's formula $B = \frac{h}{6}(A_b + (4 \times A_m) + A_t) = \frac{h}{6}\left(\frac{\pi d_b^2}{40000} + \left(4 \times \frac{\pi d_m^2}{40000}\right) + \frac{\pi d_t^2}{40000}\right) \times 1000\rho$

$= \frac{1000\pi h\rho}{240000}(d_b^2 + 4d_m^2 + d_t^2) = \frac{\pi h\rho}{240}(d_b^2 + 4d_m^2 + d_t^2)$ .... (18)

Cnooid formula: $B = \frac{1}{3}A_t h = \frac{1}{3} \times \frac{\pi d_t^2}{40000} h \times 1000\rho = \frac{1000\pi h\rho}{120000} d_t^2 = \frac{\pi d_t^2 h\rho}{120}$ .... (19)

The total stem biomass of a standing tree can also be estimated in one simple step after the tree has been scaled from the base to the top. This can be done with the adapted Newton's (equation 18) and Conoid (equation 19) formulae. Equation (18) calculates biomass from the base of the tree to the Crown Point, while equation (19) takes care of the upper part of the tree, since upper logs usually approach the form of conoids. Adding the two equations together and simplifying the resulting equation as shown in equation (20), it produces a simple formula for calculating total main stem biomass of a standing tree (Etigale *et al*., 2021).

$$B = \frac{\pi h\rho(d_b^2 + 4d_m^2 + d_t^2)}{240} + \frac{\pi d_t^2 l\rho}{120} = \frac{\pi\rho(h(d_b^2 + 4d_m^2 + d_t^2) + 2ld_t^2)}{240}$$

$= \frac{\pi\rho}{240}(h(d_b^2 + 4d_m^2 + d_t^2) + 2ld_t^2)$ …………………………… (20)

Where; B = Biomass (kg)

h = Bole height or length (m)

d_b = Diameter at the base (cm),

d_m = Diameter at the middle (cm),

d_t = Top diameter measured at crown point (cm),

P = Wood density (g/cm^3),

l = Crown length (m).

The adapted formulae yield the same results, to the last decimal place, as one would obtain by using the geometric formulae in the conventional way (following all the computational steps and converting values from one unit to another) for calculating stem contents.

The adapted geometric formulae have some advantages over the long method of using the geometric formulae in the conventional way. The adapted geometric formulae provide the short cut for estimating stem contents directly from detailed measurements of stems of individual trees or sections of logs. The formulae do not require conversion of diameter measurements from cm to m and specific wood density values from g/cm^3 to kg/m^3 before they are used in estimating volume or biomass. The process of going through some computational steps before obtaining volume and biomass are reduced to just one step by adapting the geometric formulae to accomplish all conversions and computations at once. They are easy to use both with manual calculator and computer, as all the necessary values are keyed into the device at once. They save time, energy and space in using manual calculator or computer. Their use simplifies the use of geometric formulae for estimation of stem contents directly from detailed measurements of stems of standing trees or logs. No approximation is required before the final result, unlike the long procedure where at times some values with many digits need to be approximated before they are used for calculation in the next step.

Conclusion

The adapted formulae are derived from the normal geometric formulae for calculating volume. They are the same geometric formulae frequently used, the only difference is that the adapted formulae are enhanced by the various components, such as the necessary conversion factors, cross-sectional formula and specific wood density that have been built into them to enable them calculate the required stem content without going through the rigours involved in the conventional way of using the geometric formulae. The adapted formulae yield the same results as one would obtain by using the geometric formulae in the conventional way for calculating stem contents.

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CHALLENGES AND PROSPECTS OF REMOTE SENSING AND GIS TECHNOLOGY FOR FOREST RESOURCES MANAGEMENT IN NIGERIA

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Abstract
Forest resources are indispensable to man because of the number of essential goods and services they provide. Forest management is becoming more complex because of the paradigm shift in the way the forest is managed in recent time. Effective and sustainable management therefore requires accurate, reliable and up-to-date information. However, in Nigeria, one of the notable problems of forest management is paucity of data on forest resources and this has negatively impact forest management planning and monitoring. Insecurity and insurgency have further heightened the problem, making it difficult to collect field data directly from the forest. This article highlighted some of opportunities remote sensing (RS) and Geographic Information System (GIS) technology present in overcoming this challenge. Remote sensing and GIS provide tools for capturing, storing, analysing and displaying spatial data on forest resources. Some of the contributions of RS/GIS technology to sustainable forest management were highlighted. They included land use and land cover classification, GIS map production, development of forest management information system and spatial analysis. Some challenges hampering the adoption RS/GIS technology were discussed and recommendations were made on how to address them.

Keywords: Forest data, Forest management, Forest resources, Geographic Information System (GIS), Remote sensing

Introduction

Forest ecosystems play a vital role in the survival of humans because of the number of essential goods and services they provide (Njana *et al*., 2016; Sabogal *et al*., 2013; Usman *et al.*, 2020). Some of these include recreation, timber production, biodiversity conservation, habitat for some wildlife species, water production, soil protection, carbon sequestration, oxygen production, *etc.* (BGCI, 2021; Sabogal *et al*., 2013). Sustainable and effective management of forests are very key to ensure the continuous production of these goods and services (Bhandari and Lamichhane, 2020). The forests are sometimes managed for a single purpose and at other times for multiple purposes depending on the management objective. Meanwhile, traditional forest management planning has shifted from sustainable timber management to ecosystem-based multipurpose forest management (Sheppard *et al.*, 2020). Sonti (2015) noted that with increasing demand for forest products and services, forest management is becoming very complex.

Effective and sustainable forest management therefore requires a sound knowledge of the structure, composition and dynamics of the forest as well as deployment of the right strategy and plan using reliable data and tools (Cillis *et al*., 2021). This is important because some forest management decisions when taken might be irreversible (Abildtrup *et al.*, 2012). Therefore, tools that can help a forest manager foresee and predict consequences of planned actions are indispensable in forest management. Several tools have been employed in recent time in ensuring sustainable management of the forest, among which are Remote Sensing (RS) and Geographic Information System (GIS) technology.

Remote sensing in this context is defined as the "science of acquiring information about the earth using instruments which are remote to the earth's surface, usually from aircraft or satellites" (Lwin, 2018). Data can be collected on relatively large geographic area very quickly using remote sensing technology. Geographic Information System on the other hand is a "powerful set of tools used for collecting, storing, retrieving, analysing and displaying spatial data from the real world" (Burrough and McDonnell, 1998). These capabilities, when properly harnessed, helps forest managers make well-informed decision on the forest they are managing. These tools have been used in many parts of the world and have been proven to be very effective (Bolstad, 2016; Bratu, 2017; Cillis *et al*., 2021; Picchio *et al*., 2019; Sonti, 2015).

In Nigeria, despite several research studies illustrating the effectiveness of GIS technology in monitoring and managing forests, its benefit is yet to be harness for the management of most public forests (Abiodun, 2018; Adedeji *et al*., 2015; Akinola and Akindele, 2020; Njungbwen and Mbakwe, 2013; Oke *et al*., 2020; Suleiman *et al*., 2017). Sustainable forest management in Nigeria has been faced with a lot of challenges, some of which are poor management, inadequate funds, outdated forest management plans, inadequate manpower, and outdated information on the size and extent of forest estate in Nigeria (Edu *et al*., 2011; Ogbodo *et al*., 2017; Olukwu-Kalu *et al*., 2022). Some of these can be solved by adopting RS and GIS technology. However, there seems to be a gap between research findings, recommendations and actual implementation. This article therefore seeks to review the importance of RS and GIS technology in solving some forest management problems and likely challenges encountered in the adoption of such technology in public forest management in Nigeria.

Sustainable Forest Management and GIS/Remote Sensing Technology

Forest management is defined as "the process of planning and implementing practices for the stewardship and use of forests to meet specific environmental, cultural, social, and economic objectives" (FAO, 2020a). It is "the art and science of making decisions with regard to the use, organization, and conservation of forests and related resources" (Buongiorno and Giless, 2003). The focus of forest management has shifted from just timber to include other goods and services (both tangible and intangible). The unending demand for forest goods and services has brought the forest under intense pressure necessitating the concept of sustainable management. Sustainable forest management was defined as "the management of forests to achieve optimum yield and continuous flow of desired forest products and services, enhancing forest productivity and maintaining economic, social and environmental values of forests" (Bhandari and Lamichhane, 2020).

Sustainable forest management focuses on ensuring that the present use of forest does not hamper the future benefit. For a forest entity to be sustainably managed, sound knowledge on the available resources as well as adequate planning is required. Accurate and up-to-date information is an essential part of management (Alo *et al*., 2014; Oke *et al*., 2020). Information about forests is traditionally obtained through forest inventories. Forest inventory is an activity purposefully designed for data collection to generate information base on size, shape, as well as qualitative and/or quantitative information on the growing stock of the forest resource within an area of interest (Asrat and Tesfaye, 2013). It provides qualitative and quantitative information on the extent, state and use of forests (Dau *et al*., 2015).

Traditional method of forest inventory involves actual field work where data are collected by direct field measurement. A field team will often visit the forest with relevant equipment for data collection. Obtaining information about the forest using traditional measures can be challenging and cumbersome because of the vastness of the forest, difficulties in accessibility, insecurity problems, *etc.* (Shuaibu and Dagba, 2013). Field work for collection of data cannot be completely jettisoned in forest inventory, however, GIS and remote sensing technologies help in mitigating some of these challenges encountered and provide more information in a relatively shorter period of time. In other words, GIS enhances more effective forest inventory.

Geographic Information System and remote sensing technology have helped foresters by providing detailed information about vast areas of forest without necessarily having physical contact with the forest. They have helped in facilitating the management, analysis, manipulation, modelling, representation and display of geo-referenced data to solve complex problems regarding planning and management of forest resources (Cillis *et al*., 2021; ESRI, 2006; McKendry and Eastman, 2002). Raw and analysed data obtained through remote sensing and GIS provides important tools for forest resources assessment, inventory and monitoring. It has also helped in modelling and forecasting to support planning and decision geared towards sustainable forest management. Some of the advantages of GIS include its ability to produce thematic and interactive maps while at the same time integrating data from different sources (Bolstad, 2016; ITC, 2009). GIS and remote sensing technology has proven useful in forest management because they help provide relevant data and information to answer the questions regarding the location of forest resources, their condition, as well as established trends and patterns, which can help in predicting and planning for the future.

Prospects of GIS/Remote Sensing Technology for Sustainable Forest Management in Nigeria

There are several areas GIS/Remote Sensing technology had been aiding sustainable forest management, some of which are listed below.

Land Use and Land Cover (LULC)

Land use and Land cover (LULC) refers to the classification or categorization of human activities and natural elements on the landscape within a specific time frame based on established scientific and statistical methods of analysis of appropriate source materials (Singh, 2017). It helps in land cover identification which provides baseline information for activities such as change detection analysis and thematic mapping. GIS and remote sensing technology makes it possible to monitor and quantify changes in forest cover over time by comparing multi-temporal images. Remotely sensed satellite imagery can help provide information on forest type, extent of the spatial cover and the biophysical properties of the forest. Examples of satellite imagery that have been used for LULC include Landsat Thematic Mapper (TM), Landsat Enhanced Thematic Mapper plus (ETM+), ALOS ANVIR-2, Sentinel -2 (S2) and Landsat 8 series (Fonji and Taff, 2014; Lwin, 2018; Nasiri *et al*., 2022). These satellite imageries are major source data used by GIS for detailed analysis.

A number of studies has been carried out using remote sensed data and GIS software such as IDRIS, ArcView, ArcGIS for LULC of forest reserves in Nigeria (Adedeji *et al*., 2015; Akinola and Akindele, 2020; Olokeogun *et al*., 2014; Suleiman *et al*., 2017; Wachiye *et al*., 2013). The first large-scale remote sensing application to forestry in Nigeria was the Nigeria Radar (NIRAD) project commissioned by the Federal Government of Nigeria in 1976 to procure Side Looking Airborne Radar (SLAR) images for Nigeria (Akindele, *et al.*, 2022). The images were used to produce the first comprehensive wall-to-wall vegetation and land cover maps for Nigeria in 1978. In 1994, the Federal Government of Nigeria commissioned a second project tagged Land Use and Vegetation (LUV) project to carry out an assessment of Vegetation and Land Use changes in Nigeria between 1978 and 1993. The maps produced formed the basis for land use planning in many states of the country. They were also the basis for planning the national Forest Resources Study (FRS), which involved a large-scale inventory of Nigeria's high forests and plantations covering 28 States. In a recent FAO REDD+ study on carbon stock assessment in Nigeria, remote sensing and GIS techniques were used to identify field clusters for data collection and determine the extent of the various land use and land cover classes (FAO, 2020b, FAO, 2020c). In addition to all these applications of remote sensing techniques in forestry in Nigeria, QGIS software is being used to calculate forest cover, forest loss, and gain from derived data obtained from Google Earth Engine platform. This is done by research scientists in the Remote Sensing laboratory of the Forestry Research Institute of Nigeria (Akindele, *et al.,* 2022).

Forest Management Information System

Accurate and up-to-date information is key to achieving sustainable forest management *(Alo et al.*, 2014). In Nigeria, paucity of data on forest resources is a major challenge facing forest management. Available information in most cases are in paper format and they are in multiple files and platforms, which in most cases are not properly integrated or accessible. Updating these information poses another challenge. Forest Management Information System (FMIS) are management information system designed specifically for forestry applications to support planning, analysis and reporting map design (Oke *et al*., 2020). Information systems helps to generate accurate, timely and organized information so managers and other users can make decisions, solve problems, supervise activities, and track progress (Hasan, 2018). It is an integrated system which will be used to support the planning, monitoring and implementation of multi-objective forest management activities (Robak and Murty, 2009). Forest management information systems can incorporate both spatial and non-spatial data from varied sources for easy assessment, monitoring, reporting activities (Wellving, 2010). Some FMIS are designed solely based GIS Software like ArcGIS while others work with other software such as SQL and Microsoft Assess as done in study by Alo *et al.* (2014) and Oke *et al*. (2020). At the national level in Nigeria, a Forest Information System (FIS) was designed and set up as part of the deliverables of the Forest Resources Study in 1999. It was warehoused in the Remote Sensing laboratory at the Federal Department of Forestry, Abuja. It has all the spatial and non-spatial data collected during the Forest Resources Study. The spatial data were in ArcView and Landsat formats while the database was set up in Oracle. PowerBuilder was used to design the frontend, and training was conducted for selected staff of the Federal Department of Forestry to manage the system. Unfortunately, the system could not be maintained because the civil service in Nigeria is not set up for such services. Within a few years of no maintenance, the system broke down and became abandoned. If the system had been warehoused within a University, it would have survived and experienced several updates.

Map production

Geospatially accurate maps showing different forest type and their spatial distribution are essential to forest management. Traditional maps used for the management of public forest in Nigeria are sometimes obsolete, inaccurate and do not contain the necessary information required for management. GIS software help produce intelligent maps that are suitable for planning and management purpose using remote sensed imagery. A major advantage of GIS maps is their ability to combine both spatial data and their non-spatial attribute of geographic data. Each feature on the map has a unique value which helps to differentiate it from other features. The maps are usually interactive and the user has the ability to zoom in and out to highlight the specific feature of interest (ESRI, 2006). GIS software can also help store and organize information as a collection of thematic layer with each layer containing features of similar attribute like roads, houses and street that are located within the same geographic extent. The dataset can then be managed as a layer and combined graphically using overlay analysis operators available in the software (ESRI, 2018). This makes it possible to produce maps showing all the features on a single map or produce the map of each of the feature as separate maps depending on the data layer included, depending on the desire objective (ESRI, 2021a). Working with these layers helps the forest manager to explore critically important management questions and find answers to those questions (ESRI, 2018). A major advantage of GIS technology is its ability to work with different types of data to produce maps and to update them easily. Snow *et al.* (2008) describes GIS as a highly effective information and communication technology due to its ability to graphically convey knowledge through the universal language of maps.

In Nigeria, GIS technology has been used to produce series of maps for various purposes. The Land Use and Vegetation maps of the LUV project in the 1990s were produced with GIS technology. Similarly, the field maps used during the forest inventory exercise under the Forest Resources Study were produced with ArcView, a prominent GIS software in the 1990s. In recent times, several individuals and groups have used GIS software such as ArcGIS, QGIS, etc. to produce forest thematic maps used for various purposes. Examples include Alo (2018), Oke, et al., (2020) and Akinola and Akindele (2020).

Spatial Analysis

One of the major attribute that set GIS apart is its ability to perform certain types of spatial analysis. Spatial analysis is defined as a process in which problems are modelled geographically, results derived by computer processing, and the results explore and examined (ESRI, 2018). Spatial analysis can help find best locations and paths, determine relationship and make predictions. It works by combining information from many independent sources to derive new set of information using sophisticated set of spatial operators (ESRI, 2021a). Spatial analysis helps in determining the suitability of a site for a planned activity. Site suitability models are very critical in forest management planning. This is done by identifying certain criteria that suit a planned activity, after which available dataset are analysed in GIS environment to determine the best location that meets such criteria (Felicısimo *et al*., 2002). This ensures that forest and related resources are optimally used. Suitability of certain site/location for specific purposes can be evaluated using spatial analysis features such as proximity, network analysis and density analysis. Proximity analysis examines the relationship between features in terms of nearness or connectivity while network analysis examines connectivity of linear features and how easily resources flow through them (Bhutani, 2020; ESRI, 2021b). Important hidden patterns can be detected, interpreted and the outcome predicted. Quantum GIS (QGIS), ArcGIS, SAGA are examples of GIS software that can be used for such analysis as used in the study by Alo (2018).

Challenges hindering the adoption RS/GIS technology for Forest Management in Nigeria
In spite of the several advantages of using remote sensing and GIS technology in forestry, and the past efforts of the Federal Government in this direction, there are still some challenges as enumerated below:

Inadequate skilled manpower and expert in RS/GIS technology : In Nigeria, one of the major problems hampering sustainable management of the forest is inadequate manpower (Shuaibu and Dagba, 2013). Government are not recruiting enough skilled manpower to manage the country's forest estate (Olaitan and Nosiru, 2022). Most forest reserves and national parks in Nigeria do not have remote sensing/GIS units and most still rely on crude tools to manage the forest, which are generally not effective, especially with the issue of insecurity and insurgency.

Poor Funding: Investment in RS and GIS technology requires a lot of funding. Funding available for the running of most forest reserves in Nigeria is grossly inadequate (Ogbodo *et al*., 2017). Most department managing the country's forest estate cannot afford to purchase Information and Communication Technology (ICT) equipment that support RS and GIS. Budget, in most cases, is only able to cater for salaries of staff and no other major project needs (Olaitan and Nosiru, 2022).

Lack of willingness of forest managers to embrace new technologies: A number of forestry staff are not open to adopt new technology for the management of the forest. Most will rather stick to the old conventional method they are familiar with, even when there is opportunity to be trained. According to Innes (2009), most difficult step in any innovation process is the actual implementation on the ground. In some cases, there are concerns that new technology would lead to loss of traditional jobs, especially for those involve in manual labour (Morrison-métois and Lundgren, 2016).

Obsolete and non-functioning Information Communication Technology (ICT) Department: In most forestry department in Nigeria, there are no modern ICT equipment that can be used for forest management and planning purpose. Most available equipment are either damaged or obsolete. In few departments where there are modern equipment, available staff lack the technical know-how to do any meaningful spatial analysis to solve forest management problems.

Knowledge gap between research institutions and public forest management institutions: A lot of research work is done in various forest-related educational and research institute but the findings, results and recommendations are not being implemented in the management of public forests. There seems not to be integration and proper communication of research findings within different forest institutions (Universities, Government research Institutes, NGOs), between forest research groups and among other research institutes (Byron and Sayer, 1999).

Conclusion and Recommendations
Sustainable forest management requires that a manager is well-equipped with the right data and tools to make well-informed decisions about scarce forest resources. Remote sensing and GIS technology provides resources and tool which can help achieve the ultimate goal of sustainable forest management. Many countries (both developing and developed) are already taking advantage of these tools and Nigeria should not be left out. In this era of growing insecurity and insurgency in the nation, remote sensing and GIS technology should be harnessed for forest stand inventory, monitoring, planning and decision making. In view of this, Government and forestry staff should be properly sensitized on the importance of remote sensing and GIS technology to forest management and planning. More so, there must be a forum where research findings by the various academic, research and Government institutions are properly communicated and integrated for the advancement of sustainable forest management in Nigeria.

In addition, adoption and implementation of new technology should take the bottom-top approach rather that the top-bottom approach, that is, there should be adequate consultation from the grassroots. Focus group discussions that focus on the identification of areas of need and proposed actions should be organised for all stakeholders. In addition, other stakeholders should put more pressure on the Government to properly fund forest management in Nigeria. Training and re-training opportunities should be explored by all forest stakeholders. Free and open source land monitoring tool like System for Earth Observation Data Access, Processing and Analysis for Land Monitoring (SEPAL), Google Earth, Quantum GIS (QGIS)and other relevant software should be explored for management of public forest.

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Non-Linear Models for Individual Tree Volume and Aboveground Biomass Estimation in Okpon River Forest Reserve, Cross River State, Nigeria

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Abstract:
Two transects of 1500m in length with a distance of 500m between the two parallel transects were used for this study. Sample plots of 50m X 50m in size were laid in alternate along each transect at 100m interval and thus, summing up to 10 sample plots per 1500m transect and a total of 20 sample plots in the study area. A total of 1100 individual tree species spread across 65 species belonging to 21 different tree families were measured for diameter at breast height, diameters at the base, middle and top and tree total height. The mean diameter at breast height (dbh) and total height of 28.8cm and 18.6m respectively were obtained while10.36 m^3 and 76.31 kg were obtained for average tree volume and biomass respectively. At stand level, mean basal area of 50.29 m^2ha^{-1} was obtained with a mean volume of 271.249 m^3 $ha^{-1}$and mean green biomass was460.867ton $ha^{-1}$with a dry biomass of 334.128ton ha^{-1}. Curve Expert software was used for models development. Logistic model had the least AIC and standard error (SE) values for tree volume and aboveground biomass and therefore recommended as the best fit models for individual tree volume and aboveground biomass estimation in the study area.

Keywords: Non-linear, Carbon-trading, Models, Systematic sampling, Transect and Sustainable management.

Introduction

Vanclay (1994) defines models as abstractions of the natural dynamics of a forest stand, which may encompass growth, mortality and other changes in stand composition and structure. Therefore, forest models can be used as very successful research and management tools. The development of effective and accurate models to predict forest volume and biomass is essential for forest managers and planners. Growth and yield models, which rely on functions to measurement data from a sample of the forest population of interests, are the tools that have mainly been used to provide decision support information that meets basic operational needs for evaluating various forest management scenarios (Avery and Burkhart, 2002). Foresters need to know every detail about the forest they are managing in terms of location, size, quantity and quality of forest resources available and how these resources are changing over time. This information can be obtained through proper resource modeling. Models are used for operational and strategic planning in nations that own and manage forest lands.

The substantial focus has been given to forestry for the development of estimation schemes to predict volume at the individual tree and stand-level due to the ecosystem's economic impact. Periodic inventories are often needed by forest industries and other organization as it helps to determine the quantity of wood utilization. Forest inventory were majorly conducted in plantation or in natural forest with the aim of estimating the timber volume of the plot obtainable in the entire stand. Estimating tree volume is important for forest management due to its effectiveness in the assessment of growing stock, timber valuation, distribution of area allocated for harvest and decision-making process involving the use and management of the forest.

The tropical rainforest is the most diverse of all terrestrial ecosystems, containing more plant and animal species than any other biome. Biomass assessment is important for national development planning as well as for scientific studies of forest ecosystem productivity, carbon budgets, etc. (Pandey *et al.,* 2010). Biomass analysis is an important element in the carbon cycle especially, carbon sequestration. Recently, biomass is increasingly used to help quantify pools and fluxes of greenhouse gases (GHG) from terrestrial biosphere associated with land use and land cover changes (Cairns *et al.,* 2003). The importance of terrestrial vegetation and soil as significant sinks of atmospheric CO_2 and its other derivatives is highlighted under Kyoto Protocol (Wani *et al*. 2010). Vegetation especially, forest ecosystems store carbon in the biomass through photosynthetic process, thereby sequestering carbon dioxide that would otherwise be present in the atmosphere. An estimate indicates that tropical forests account for 247metric tons vegetation carbon, of which 193 billion tons is stored above ground (Saatchi *et al*., 2011).

Though, large numbers of stem volume and tree biomass equations exist in literatures; but it is really more difficult to decide which model form is most appropriate for a particular forest type and very often, it is unknown how many trees of what species were used and how they were selected for the development of models. The unclear description of the existing equations regarding the range of DBH, cover type, geographical location and the management systems for which they are applicable makes their use and estimate uncertain. It is within these backgrounds that this research explored the feasibility of developing non-linear models for the estimation of tree volume and aboveground biomass in Okpon River Forest Reserve of Cross River State.

Methodology

Study Area

The research was conducted in the Okpon River Forest Reserve located within Obubra, Etung and Yakurr Local Government Areas in Cross River State, Nigeria (Latitudes 5° 40' 30" and 5° 57' 30"N; Longitudes 8° 12' 00"and 8° 32' 00"E). The reserve has a total area of thirty-one thousand, three hundred hectares (31,300 ha.) (NASDRA and FAO, 2014). The elevation of the study areas ranged between 14 m and 87 m above mean sea level. The mean annual rainfall ranges from 2,500mm in January to 4,000mm in August. The rain is fairly distributed through-out the months of April to October. Mean annual temperature range from 27.6⁰ C in August to 33.1⁰ C in February. The Strong winds usually accompany the onset of dry season, which is caused by hot and dry North East wind. The mean relative humidity ranges from 71% in February to 90% in August (Ajayi *et al.,* 2006).

Sampling Procedure and Data Collection

Systematic line transect was employed in the laying of sample plots. Two transects of 1500m in length with a distance of at least 500m between the two parallel transects were used in the study site. Sample plots of 50m x 50m in size were laid in alternate along each transect at 100m interval and thus summing up to 10 sample plots per 1500m transect and a total of 20 sample plots in the forest reserves.

In each plot, all living trees with dbh ≥10cm were identified and measured. Spiegel relascope was used for individual tree DBH and other diameters (diameter at the base, diameter at the middle and diameter at the top) and tree height measurement. For trees growing on a slope, the dbh was measured from the uphill side. Buttresses were considered to be non-commercial. So, when buttresses extending more than 1.30 m above ground surface were encountered, the equivalent of dbh was measured at a height of 20 cm above the upper limit of the buttresses. When knots or localized deformations occurred at breast-height point, a more representative dbh point either above or below the breast-height point was chosen as recommended by Adekunle *et al.*, (2010).

Data Analysis

Basal Area Estimation

The diameter at breast height was used to calculate the basal area.

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

Where: D = diameter at breast height (m), $\pi = 3.14$ and BA = Basal Area (m^2).

The total Basal Area (BA) for each plot was obtained by adding all trees basal area in the plot while mean basal area for the plot was calculated with the formula:

$$\overline{BA_p} = \frac{\Sigma BA}{n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots.2$$

where; $\overline{\mathrm{BA_p}} = \text{Mean basal area per plot } = \text{Total number all possible sample plot plot}$

Stem Volume Estimation

Individual tree volume was calculated using the Newton's formula of Husch *et al.,* (2003) given as:

$$V = \frac{h}{6}[A_b + 4A_m + A_t] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots.3$$

Where: V= Volume (m^3), A_b = Basal area at the base (m^2), A_m = Mid basal area (m^2) and A_t = Basal area at the top (m^2)

The plot volumes were obtained by adding the volume of all the trees in the plot while mean plot volume was obtained by dividing the total plot volume by number of sample plots. The volume of trees per hectare (V_{ha}) was subsequently estimated by multiplying the mean per plot by the number of sampling units in a hectare (Adekunle, 2010).

Biomass and Carbon Stock Estimation

To estimate the above-ground live biomass, the equation of Brown (1997) for tropical wet climate zone was adopted. The equation is given as

$$Y = 21.297 - 6.952(D) + 0.740(D^2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

Where; Y = biomass per tree in kg and D = diameter at breast height (dbh) in cm.

Estimation of the above-ground live biomass was also carried out by multiplying the volume of each tree with its respective wood density. Below ground biomass was estimated as 15% of the above ground biomass (MacDicken, 1997).

Aboveground Live Green Biomass Estimation per Hectare

The summation of the biomass that was calculated for all trees in a sample produced the total plot biomass (AGBplot). This per plot estimate of aboveground (in kg) was divided by 1000 to express it in metric tons. This was then converted to per hectare estimate (AGBha) by using the equation:

$$AGBper\ ha = \left(\frac{Ah}{Ap}\right) \times AGBplot \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5$$

Where: AGBha= aboveground biomass (metric tons per hectare)
Ah= area of one hectare in m^2, Ap= area of the plot (m^2)(Brown, 1997).

Aboveground Dry Biomass Estimation

Aboveground dry biomass estimation was calculated from:

$$W = \frac{AGBh \times 0.725}{1000} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

Where: W= aboveground dry biomass (metric tons)
AGB_h = aboveground green biomass (kg ha^{-1}) expressed metric ton
(Chaven and Rasal*et al*., (2012)

Determination of Carbon Sequestration

$$Sc = Wx\ 0.5 \qquad .\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 7$$

Where: Sc = sequestered carbon (tha^{-1})

Construction of the Non-linear Regression Models for Tree Volume and Biomass Estimation

Volume and biomass equations are mathematical expressions which relate tree volume and biomass to tree's measurable attributes such as diameter at breast and/or height. They are used to estimate volume and biomass contents for standing trees of various sizes and species. The non- linear regression models for volume and biomass in tables 1 and 2 respectively were generated using Curve Expert Professional software.

Table 1: **Non-linear Regression Models for Tree Volume**

MODEL	MODEL FUNCTION
Logistic Power	V = a/(1+(x/b)**c)
Gompertz Relation	V = a*exp(-exp(b-c*x))
MMF	V = (a*b + c*x^d)/(b + x^d)
Weibull	V = a - b*exp(-c*x^d)
Logistic	V = a/(1 + b*e^(-cx))
Ratkowsky model	V = a / (1+exp(b-c*x))

a, b, c and d are parameters to be estimated, V is Tree Volume in (m^3), x is the Dbh (cm) while exp. is the exponential.

Table 2: **Non-linear Regression Models for Tree Biomass**

MODEL	MODEL FUNCTION
Logistic Power	Y = a/(1+(x/b)**c)
Gompertz Relation	Y = a*exp(-exp(b-c*x))
MMF	Y = (a*b + c*x^d)/(b + x^d)
Weibull	Y = a - b*exp(-c*x^d)
Logistic	Y = a/(1 + b*e^(-cx))

Ratkowsky model	Y = a / (1+exp(b-c*x))

a, b, c and d are parameters to be estimated, Y is Tree biomass in (Kg), x is the Dbh (cm) while exp. is the exponential.

Criteria for Volume and Biomass Models Selection

Models were assessed with the Standard error of estimate (SEE) and Akaike Information Criterion (AIC) as follows:

Standard Error of Estimate (SEE):

It is the square root of the average squared error of prediction and it is used as a measure of the accuracy of prediction. SEE is expressed as:

$$SSE = \sqrt{\frac{\Sigma[y_i - \overline{y_i}]^2}{n-p}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 8$$

Where $y_i =$ Actual tree volume

$\overline{y_i}$ = Predicted tree volume

n = Number of observations

p = Number of parameters in the volume models.

The value must be small to be judged a good model.

Akaike's Information Criteria (AIC)

The idea of AIC (Akaike, 1973) is to select the model that minimizes the negative likelihood penalized by the number of parameters as specified in the equation below:

$$AIC = 2Logp\ (L) + p \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 9$$

Where *L* refers to the likelihood under the fitted model and *p* is the number of parameters in the model.

Results

Summary of Characteristics data for Okpon River Forest Reserve

Results in table 3 below show that a total of 1100 individual trees spread across 65 species belonging to 21 different tree families were measured for diameter at breast height, diameters at the base, middle and top and tree total height. The mean diameter at breast height (dbh) and total height of 28.8cm and 18.6m respectively were obtained while10.36 m^3 and 76.31 kg were obtained for average tree volume and biomass respectively. Mean basal area of 50.29 m^2 ha^{-1} was estimated with a mean volume of 271.249 m^3 ha^{-1} and mean green biomass was 460.867ton $ha^{-1}$with a mean dry biomass of 334.128ton ha^{-1}.

Non-Linear Tree Volume Models and their Assessment Criteria

The non-linear models considered were Logistics, Gompertz Relation, Logistic Power, Ratkowsky models, Richards, MMF, and Weibull models. The results in Table 4 show the best models for non-linear models generated for the stand level volume estimation in the Okpon River Forest Reserve of Cross River State. . Recommendation was done based on the model with the lowest AIC and standard error values. Logistic model was best fit model and very closely followed by Ratkowsky, and Logistic Power, Gompertz Relation, Weibull and MMF models. Furthermore, Figure 1 shows three best non-linear tree volume models for the reserve; meanwhile Figure 2 shows the residual plots of the selected three best nonlinear volume models. It indicates an even spread of above and below the zero line with no systematic trend implying that the selected model is fit for tree volume estimations.

Table 3: Summary of Characteristics data for Okpon River Forest Reserve

S/N	Parameters	Mean	Min.	Max.	Std. Error	Std. Deviation	Skewness	Kurtosis
1	No. of sample plots measured	20						
2	No of trees measured				1100			
3	DBH(cm)	38.47	3.00	193.80	0.7883	26.03	3.11	12.27
4	Height (m)	18.6	11.40	46.20	0.55	19.14	2.72	6.84
5	Basal area. (m^2 ha^{-1})	50.29	32.05	60.25	0.88	30.21	2.53	13.4
6	Tree volume (m^3)	10.36	7.65	14.89	0.34	15.51	1.75	8.34

7	Tree green biomass (kg)	76.31	55.75	102.12	0.85	33.45	3.54	11.83
8	Stand volume (Ha^{-3})	271.25	87.23	234.10	0.53	73.51	2.41	7.12
9	Stand green biomass (ton ha^{-1})	867	305.77	965.49	17.745	79.35	-512	-992
10	Stand dry biomass (ton ha^{-1})	334.128	188.29	409.98	12.865	56.54	-512	-992

Table 4: Non-Linear Tree Volume Models and their Assessment Criteria

Forest Reserves	Models	Parameter Estimates				AIC	Std Error
		a	B	c	d		
Okpon	Gompertz Relation	28.10	2.81	0.09		1989.59	2.48
	Logistic Power	25.33	31.10	-5.01		1984.43	2.46
	Weibull	36.83	36.97	0.00	3.63	2012.44	2.5
	MMF	-3.67	285.93	55.48	1.27	2324.63	2.89
	Ratkowsky	21.01	6.67	0.22		1977.58	2.47
	Logistic	21.01	785.33	0.23		1977.58	2.45

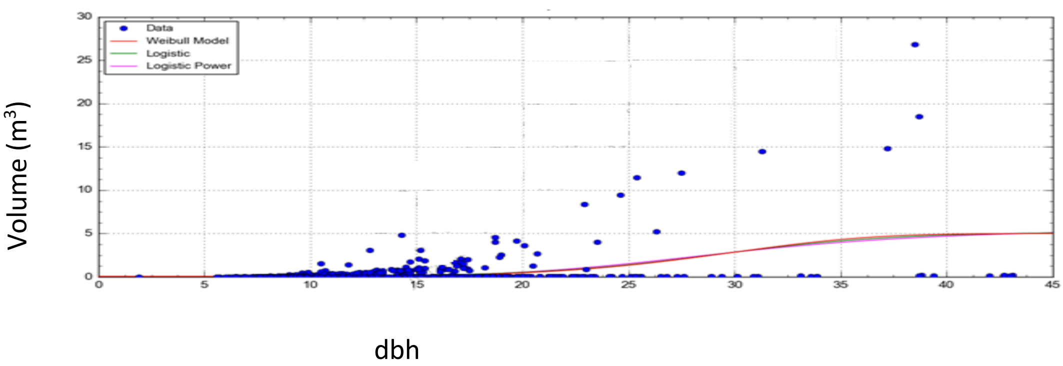
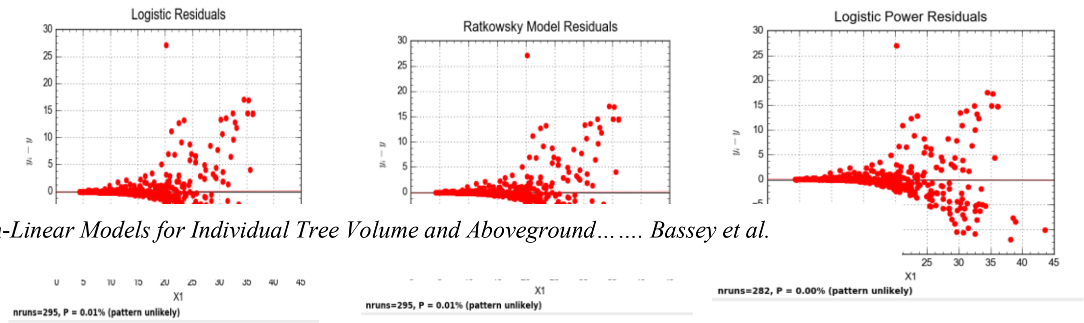


Figure 1: Graph Showing the Results for the best Non-Linear Stand Volume Models

Developed for Okpon Forest Reserve, Cross River State, Nigeria



Non-Linear Models for Individual Tree Volume and Aboveground……. Bassey et al.

Figure 2: Residual plots for Best three Selected Volume Models

Non-Linear Aboveground Tree Biomass Models and their Assessment Criteria

The non-linear aboveground tree biomass models considered were Logistics, Gompertz Relation, Logistic Power, Ratkowsky models, Richards, MMF, and Weibull models. The results in Table 4 show the best models for non-linear models generated for the stand level aboveground biomass estimation in the Okpon rainforest reserve of Cross River State. Recommendation was done based on the model with the lowest AIC and standard error values. Logistic model was best fit model and followed by MMF, Logistic Power and Gompertz Relation models. Ratkowsky and Weibull models could not fit the biomass –diameter data. Figure 3 shows three best non-linear tree aboveground biomass models for the reserve while Figure 4 Presents the residual plots of the selected three best nonlinear aboveground biomass models. It indicates an even spread of above and below the zero line with no systematic trend implying that the selected model is fit for tree biomass estimations.

Table 5: Non-Linear Aboveground Tree Biomass Models and their Assessment Criteria

Forest Reserves	Models	Parameter Estimates				AIC	Std Error
		a	B	c	d		
Okpon	Gompertz Relation	21.61	2286.08	333.97		2437.98	3.04
	Logistic Power	49.35	14750.40	-0.04		2377.96	2.96
	Weibull						
	MMF	21.04	188.06	26.55	0.95	2374.77	2.95
	Ratkowsky						
	Logistic	413.29	18.52	0.00		2371.24	2.95

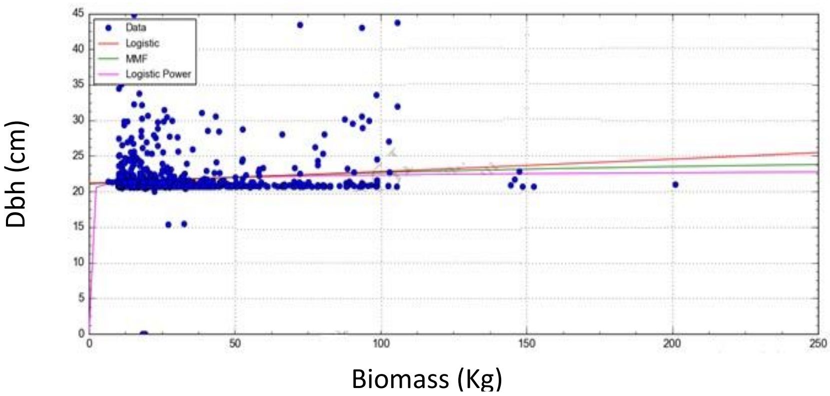
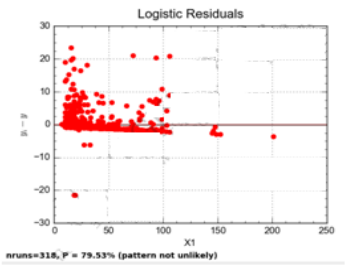
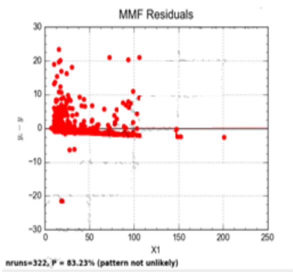
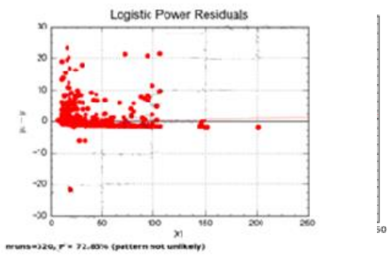


Figure 3: Graph Showing the Results for the Best Non-Linear Tree Aboveground Biomass Models Developed for Okpon River Forest Reserve.



plots





Discussion

The study tested the efficacy of nonlinear models for tree volume and aboveground biomass estimation in the Okpon River Forest Reserve of Cross River State. Logistic Power, Logistic, Ratkowsky, MMF, Gompertz Relation, and Weibull models were considered suitable for describing the volume-diameter relationship in the study areas. This is in agreement with the findings made by Adesuyi *et al.*, (2020) that Logistic Power, Logistic, Gompertz Relation, Ratkowsky, MMF, and Weibull model were suitable for describing the volume-diameter relationship in strict nature reserve, South-West, Nigeria. However, Logistic model was the most flexible for volume estimation based on the assessment criteria (least AIC and standard error). Similarly Logistic, MMF, Logistic Power Ratkowsky, and Gompertz Relation models were considered suitable for describing the aboveground-diameter relationship in the study area. Logistic model had the least AIC and SE values and therefore recommended as the best fit model for the estimation of the aboveground biomass in the Okpon River Forest Reserve. This result further revalidated the claims earlier made by previous authors (Nelson *et al.*, 2020). Therefore, the non-linear models generated and validated for both volume and biomass can fitly be used to estimate tree volume and aboveground biomass in the study area.

Conclusion and Recommendations

Conclusion

The effectiveness of sustainably managing the reserve depends greatly on the formulation of accurate, and up-to-date and location specific models. This research study therefore generated and tested the efficacy of nonlinear models for tree volume and aboveground estimation in Okpon River Forest Reserve of Cross River State. Logistic model was the most appropriate for the estimation of tree volume and aboveground tree biomass in the Forest Reserve.

Recommendations

Permanent sample plots should be established by the Cross River Forestry Commission in the study area to enhance and promote accurate data collection, and the development of models for informed management decisions. Models developed in this study were discovered to be very adequate for yield estimation and are recommended for tree volume and aboveground biomass estimation in the tropical natural forest ecosystem of Cross River State and in any similar ones.

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Accuracy Assessment of Two Mobile Applications Used for Tree Diameter and Height Measurements

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Abstract
Tree measurement is a very important aspect of forest assessment. Readings from such measurements are used to compute estimates of growth and yield which are required in sustainable forest management. There are several conventional instruments used for measuring diameter and height of trees. These range from relatively simple ones to more sophisticated tools. With the current advancement in technology, mobile applications for measuring tree diameter and height have been developed for smartphones. These applications are relatively easy to use and many of them are free. They can be downloaded from Google Play Store and installed on smartphones for field use. In this paper, the accuracy of two of these mobile applications were assessed. These are *Bole Diameter Measurement* for diameter measurement and *Trees* for height measurement. Fifty observations of diameter and height were measured from twelve trees using the applications. At the exact point of measurement with the mobile applications, girth-diameter tape and linear tape were used to measure the true diameter and height of the trees, respectively. The data were subjected to paired t-test analysis to test for significant difference between the values obtained through the mobile applications and the actual values from tape measurements. Scatter plots were also prepared to compare the two sets of data. The results show that the *Bole Diameter Measurement* app generally over-estimated tree diameter while the *Trees* app slightly under-estimated tree height. Analysis of the absolute and relative errors indicates that the errors associated with using the mobile apps for diameter and height measurement were not normally distributed. Simple linear regression with zero intercept was fitted to the data to produce an adjustment factor to correct the readings from the mobile applications.

Key Words: tree measurements, mobile applications, accuracy, diameter, height, smartphones.

Introduction

Forest assessment is one of the important bedrocks of sustainable forest management. It involves several activities including establishment of field plots, tree measurements, and computation of estimates of the growing stock. It provides qualitative and quantitative information on timber and nontimber forest resources of an area and the land on which they are growing. Based on the results of forest assessment, the forest manager can decide on what silvicultural treatments to adopt for different areas of the forest. Such results are also used in taking decisions on logging and valuation of various products from the forest.

Foresters rely on a variety of basic instruments and equipment to measure individual trees and forests (Nix, 2019). These range from instruments for forest land survey such as ranging poles, compass, linear tapes, Gunter chains, flagging tapes, *etc.* to instruments used for tree measurement such as calipers, diameter tapes, clinometers, Haga altimeter, Spiegel relaskop, Vertex, Criterion Laser, *etc.* (Hassani, 2018a, Hassani, 2018b, Williams, *et al.*, 1994). Some of these instruments require intensive training and technical know-how in order to use them correctly. The use of these tools provides information that can be used to compute reliable and precise estimates of the forest growth and yield. With advances in technology, new tools based on smartphone technology have been developed. These tools are mobile applications and they are designed and developed to run on iPhones, smartphones, tablets and many other mobile devices (Rajput, 2015).

In recent years, the use of smartphones has gained traction among the populace. According to Sasu (2022), the number of Internet users in Nigeria is around 104 million people. A particular aspect of this Internet usage is the remarkably high proportion of mobile Internet users who account for over 70% of Internet traffic in Nigeria (Sasu, 2022). These users can easily access Google Play Store on Android phones or Apple App Store on iPhones to download mobile applications for various purposes. At the beginning of this year 2022, Apple App Store has 1.96 million apps available for download, while 2.87 million apps were available for download on Google Play Store (BUILDFIRE, 2022). This advancement in information and communications technology is a very important enabler of innovation and development (Akindele, *et al.,* 2022). Many mobile apps have been developed for use in forest assessment. The key ones are those capable of providing estimates of tree diameter and height. Their use is not yet prominent in Nigeria where many foresters still rely on the conventional instruments such as tapes and Haga altimeter for tree measurements. Due to the scarcity of these conventional instruments, foresters will begin to use the mobile apps for tree measurements. For the apps to be acceptable, there is the need to assess their accuracy. Accuracy refers to the closeness of a measured value to a standard or known value. In this study, the values obtained by direct measurement using measuring tapes are regarded as the standard. This study will examine how close the values obtained by using the apps are to the standard or actual values. It is hoped that the findings will facilitate the correct use of the mobile apps for tree measurements.

Some common mobile apps for forest assessment

Several mobile apps are available for forest assessment but it is not the aim of this paper to review all of them. In this section, only a few common ones are highlighted.

Mobile App for obtaining GPS Coordinates

In forest assessment, there is the need to correctly locate sample plots to be enumerated. To accomplish this, we often go with field maps, hand-held Global Positioning System (GPS) unit, and a compass. With the availability of smartphones, all these are now available in a single mobile application called *Polaris Navigation GPS*, which can be downloaded from Google Play Store on Android smartphones. *Polaris Navigation GPS* is a free and very versatile mobile app with many functionalities. Primarily, it provides geographic coordinates of locations in terms of latitude and longitude. It also provides information on altitude (elevation above sea level). The app can also be used as a compass because it provides information on true bearing and magnetic bearing. Other features of the app include odometer which measures and displays speed and distance traveled, and clock which displays current time in analog and digital formats. The map feature of the app can be activated by downloading vector map and a series of raster maps for the country of interest.

Mobile App for Plant and Tree Identification

PlantSnap is the most high-tech, comprehensive and accurate plant identification app ever created. It has a searchable database of over 650,000 plants and can be used to identify over 90% of all known species of plants and trees. The app works anywhere on Earth and is translated into 37 languages. To identify a plant, the user takes a snapshot of the plant with his smartphone, and the app gives the name of the plant within a few seconds. *PlantSnap* was developed by PlantSnap Inc., a company based in Telluride, Colorado, USA and has over 42 million total downloads so far. At present, it has been used to identify over 475 million images of plants and trees, based on Machine Learning technology and Artificial Intelligence. The app can be downloaded from Google Play Store and subscription can be made on monthly, yearly or lifetime basis.

Mobile App for Distance Measurement

Distance measurement between two or more points on the Earth surface is a common feature in forest assessment. For this purpose, a chain or tape is normally used. The basic procedure for measuring distance with either chains or tapes requires two people, traditionally referred to as the head chainman and the rear chainman (Husch, *et al.*, 2003). With the current advancement in technology, we now have various mobile apps on smartphones which can be used for distance measurement. These include *Distance Meter, Smart Distance, Distance Measurement,* and *Distance and Area Measurement*. Using any of the distance measurement apps to measure distance requires only one user. Once the starting point is marked, the user moves forward following the desired compass bearing to the end point.

Mobile App for Land Area Measurement

In forest assessment, it is often necessary to determine the size of the forest area being assessed. Sometimes, the forest is divided into strata and there is the need to obtain an estimate of the area of each stratum. The conventional way of doing this on the field is to have a survey crew consisting of compass man, poles men, chain men and labourers. In addition, instruments such as ranging poles, compass and linear tapes are required. Foresters involved in forest assessment are often called upon to retrace old lines, locate compartment boundaries, and measure land areas (Avery and Burkhart, 1994). Mobile apps for land area measurement have made things much easier such that a single person can carry out the land area measurement and obtain reliable results in less time. Although there are many apps available for this, one of the best is *GPS Fields Area Measure* developed by FARMIS. This is an easy-to-use app for area, distance and perimeter measurement. It has over 10 million downloads, indicating that it is widely used in different parts of the world. The app basically uses GPS data to measure distance and area.

Mobile App for Tree Diameter Measurement

Tree diameter, a measure of tree size, is the commonest attribute measured during forest assessment. It is commonly measured using calipers and diameter tapes. When the point of measurement is beyond reach, a Spiegel relaskop or a laser caliper such as Haglöf Mantax Black Calipers with Gator Eyes can be used to measure tree diameter. Two mobile applications for measuring the diameter of standing trees are available on Android operating system. These are *AgriMeter* released on February 16, 2020, and *Bole Diameter Measurement* released on March 15, 2021. Both of these apps can be used to measure the diameter of tree trunks at any height.

Mobile App for Tree Height Measurement

Tree heights are often out of reach for the use of linear tapes for measurement. Instead, optical instruments such as clinometer, Haga altimeter and Spiegel relaskop are normally used. These instruments are very expensive and often beyond the budget of most forestry departments in the developing countries. While the analog model of a clinometer costs US$195, the digital model is US$425. These are base prices and will attract taxes and shipping fees. The base price for Haga altimeter is US$575 while a Spiegel relaskop sells for US$2,400. Going by the number of students undergoing forestry training in various tertiary institutions across Nigeria, most departments are ill-equipped. The availability of mobile apps for tree height measurement is certainly a welcomed development. The apps include *Trees, Tree Height Measurement, Arboreal, Measure Height, Tree Height, etc.* Many of these apps are free and can be downloaded from Google Play Store on Android smartphones.

Methodology

Two popular mobile apps were selected for this study. These are *Bole Diameter Measurement* for measuring stem diameter, and *Trees* for measuring tree height. Their selection was based on ease of use when compared to other apps. Twelve trees were marked out in the forestry plantation site of the Federal University of Technology, Akure. For test of accuracy, the measurement obtained with the app must be compared with the actual measurement obtained with a measuring tape. In the absence of a tree bicycle, it was not possible to get to the top of each tree to be able to measure diameter and height with measuring tape. Actual measurement with tape can only be up to the point that human hands can reach along the stem height. In order to increase this reach, a ladder was used. At the top of the ladder, a flagging tape was tied to the tree stem. A girth-diameter tape was then used to measure stem diameter at this point while a linear tape was used to measure stem height from the ground to the point marked by the flagging tape. Descending from the ladder top to the ground, three other points were marked on each tree. The diameter and height at these points were measured and recorded. On two of the trees, an additional point was marked in order to avoid tree knots at the breast height position. A total of 50 diameters and 50 heights were measured with the tape as well as with the selected mobile apps.

The data were subjected to graphical analysis using scatterplots with a trendline. Separate plots were made for the diameter data and the height data. Intercept of the trendline was set to zero since the readings from the tape and the app were paired. A simple linear regression equation (with zero intercept) was fitted to the trendline. Paired t-test was carried out to test for any significant differences between the readings obtained with the tapes and the apps. At each data point, the actual value was subtracted from the value obtained with the app to check whether the app under-or over-estimated the variable. A positive value indicates over-estimation while a negative value indicates under-estimation. For each stem diameter and stem height measurement, the absolute and relative errors as well as the root mean square error (RMSE) were calculated with the following formulas (Bijak and Sarzynski, 2015):

$$Absolute\ Error = X_{app} - X_{tape} \quad \ldots (1)$$

$$Relative\ Error = \frac{X_{app} - X_{tape}}{X_{tape}} \times 100\% \quad \ldots (2)$$

where,
X_{app} = stem diameter or height measured with the mobile app
X_{tape} = actual stem diameter or height measured with tape.

Basic statistics were calculated to describe these errors for diameter and height measurements. The hypothesis about the normal distribution of the errors was tested using the Shapiro-Wilk normality test. The analysis was done with R statistical software.

Results and Discussion

A summary of the data obtained in the study is presented in Table 1 below. The table shows that the diameters assessed in this study ranged from 15.8 cm to 65.0 cm, while the height measurements ranged from 0.1 m to 3.83 m. The data showed that mean diameter obtained with the mobile app was greater than the actual mean diameter measured with the girth-diameter tape. On the other hand, the mean height measured with the mobile app was slightly less than the actual mean height. When the values obtained with the mobile apps were compared with the actual diameter measurements, 28% of the cases were under-estimated while 68% were over-estimated, as shown in Table 2. The table also shows that 56% of the height readings were under-estimated while 16% were over-estimated. Generally, the mobile app for height measurement performed better than the mobile app for diameter measurement. Twenty-eight per cent of the height readings with the mobile app were exactly the same as the actual measurements while only 4% of the diameter readings were accurate (Table 2).

The results of the analysis of errors associated with using the apps are summarized in Table 3 below. The table shows that the errors are higher with diameter measurements than with height measurements. The Shapiro-Wilk normality test shows that the errors are not normally distributed, suggesting skewed distribution of the analysed errors. Similar results were obtained by Bijak and Sarzyhski (2015) in their accuracy assessment of smartphone applications in field measurement of tree height.

Table 1: Summary Statistics for the field data

	Diameter (cm)		Height (m)	
Parameter	Tape	Mobile App	Tape	Mobile App
Mean	30.68	34.12	2.04	1.98
Minimum	15.8	14.9	0.1	0.1
Maximum	65.0	73.3	3.83	3.80
Standard Deviation	10.50	12.79	1.38	1.32
Variance	110.20	163.55	1.89	1.73
Standard Error	1.48	1.81	0.19	0.19
No. of observations	50	50	50	50

Table 2: Accuracy assessment of the mobile apps for diameter and height measurements

	Diameter		**Height**	
Status	**Frequency**	**%**	**Frequency**	**%**
Under-estimation	14	28.0	28	56.0
Exact estimation	2	4.0	14	28.0
Over-estimation	34	68.0	8	16.0
Total	50	100.0	50	100.0

Table 3: Errors associated with using the mobile apps for diameter and height measurements

	Diameter Measurements		Height Measurements	
	Absolute Error (cm)	Relative Error (%)	Absolute Error (m)	Relative Error (%)
Minimum	-5.10	-22.12	-0.40	-54.55
Maximum	22.80	89.76	0.11	66.67
Mean	3.44	12.17	-0.06	-0.64
Median	1.60	5.13	-0.02	-1.03
Standard Error	0.82	3.47	0.02	2.42
Shapiro-Wilk statistic	0.91	0.8028	0.8689	0.6906
p(normal)*	<0.01	<0.01	<0.01	<0.01

* p-value in Shapiro-Wilk normality test.

Fig.1 depicts the relationship between stem diameter measured with girth-diameter tape and with the *Bole Diameter Measurement* app. The correlation coefficient (r) is 0.9877, indicating very strong positive linear relationship between the readings from both measuring tools. However, most of the points are not on the trendline, suggesting considerable deviation from the actual values. For height measurements, Fig. 2 indicates that the linear relationship between measurements with linear tape and *Trees* mobile app is very strong (r = 0.9992). The data points are very close to the trendline, which means that the deviations from the actual values were minimal.

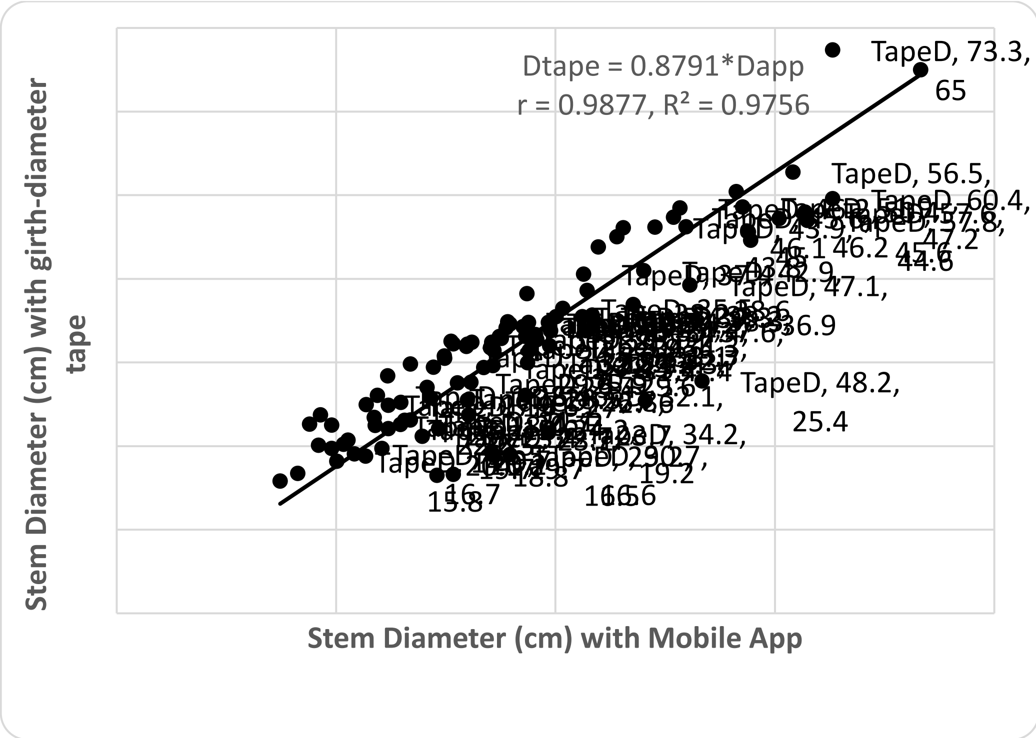

Fig. 1: Scatter plot for the diameter measurements

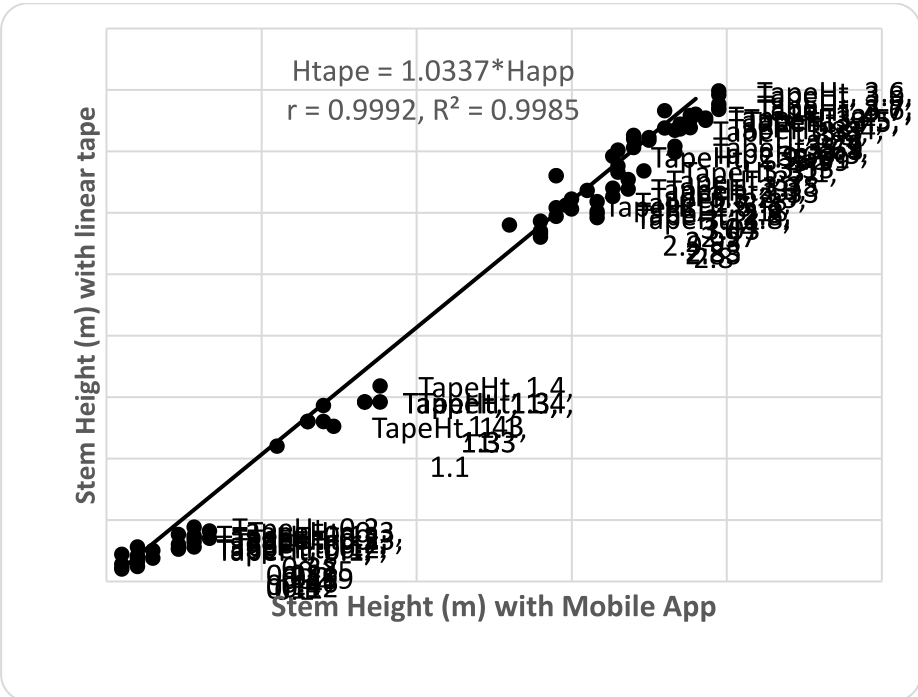

Fig. 2: Scatter plot for the height measurements

The results of the paired t-test carried out to test for significant differences between the measurements done with the tapes and those done with the mobile apps indicate that there are presented in Table 3. The results indicate that the diameter readings obtained with the app were significantly higher than the actual values measured with the girth-diameter tape; $t(49) = 4.19$, $p < 0.05$. For height measurements, the app readings were significantly lower than the actual values measured with the linear tape; $t(49) = 3.72$, $p < 0.05$. Bijak and Sarzynski (2015) also reported that the two height measurement mobile apps they tested for accuracy (*Measure Height* and *Smart Measure*) significantly under-estimated tree height regardless of the distance of the measurement. The results obtained show that the apps tested in this study did not produce accurate readings for diameter and height. This is in agreement with the remarks by Arceo (2022) that even the best apps may not be quite as accurate as the measuring tape. Similarly, Piccinini, *et al.* (2020) reported that smartphone applications provide inaccurate measurements in long-term analysis. Similar results has been found by Villasante and Fernandez (2014) who reported that the errors associated with the use of smartphones for forest measurements are unacceptable if precise estimates are needed. The inaccuracy in the readings of the mobile apps could be due to the sensitivity of the apps to small deviations in the inclination of the smartphone during measurements. To tackle this challenge, adjustments of the apps readings are required. The appropriate factor to use for the adjustments are the slope coefficients of the regression equations. The two regression equations are as follows:

$$D_{tape} = 0.8791*D_{app} \quad \ldots (3)$$

$$H_{tape} = 1.0337*H_{app} \quad \ldots (4)$$

To obtain accurate estimate of diameters using the *Bole Diameter Measurement* mobile app, each app reading should be multiplied by 0.8791. Similarly, each height reading obtained with the *Trees* mobile app should be multiplied by 1.0337 to make it accurate. In their research on measurement errors in the use of smartphones as low-cost forestry hypsometers, Villasante and Fernandez (2014) reported that smartphone results indicate that a prior calibration is required to correctly transform the data from the accelerometer into angle or height measurements. Multiplying the apps readings by a constant is similar to the calibration referred to by Villasante and Fernandez (2014). The adjusted values were compared with the actual readings using a paired t-test. The results show that the adjusted app readings were not significantly different from the actual measurements ($p > 0.05$).

Conclusion

This study found that there were significant differences between the apps readings and the actual diameter and height measurements. The deviations from the actual values were more pronounced with the diameter app. The inaccuracies can be corrected if each of the values obtained from the mobile apps is adjusted by multiplying them with the appropriate factor recommended in this study. To minimize errors when using the mobile apps, care must be taken to ensure steady and correct sighting of the app to the point of taking each measurement. As follow-up to this study, research should be conducted to compare the mobile apps with optical instruments such as Haga altimeter and Spiegel relaskop. Mobile apps on smartphones are very promising tools for tree measurements; nevertheless, they require improvement so that they can be very accurate.

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GEOSPATIAL MODELING OF AKURE FOREST RESERVE IN ONDO STATE, NIGERIA

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Abstract
Land Use Land Cover (LULC) changes is one of the significant factors that determines the interaction between humans and its environment in the tropics. In Nigeria, the effect of these anthropogenic activities has led to deforestation and consequent degradation. However, there is dearth of information on the dynamics of many forests cover in Southwestern Nigeria, especially in Akure Forest Reserve. Therefore, this study aimed at assessing the LULC change of Akure forest reserve. Landsat imageries (5 TM of 1984, 7 ETM+ of 2000, and 8 OLI/TIRs of 2016 and 2021were obtained and processed. The processed imageries were analyzed using supervised Maximum Likelihood Classification algorithm to determine LULC classes of Akure forest reserve. The LULC classification followed Anderson darling categorization. Five LULC classes were used: Dense Forest (DF), Less Dense Forest (LDF), Built-Up (BU), Bare Land (BL) and Water Bodies. Normalized difference Vegetation Index (NDVI) was used to determine the greenness of the reserve. Dense Forest has drastically reduced from 82.6% observed in 1984 to 26.41% in 2021, indicating high level of forest deforestation and degradation, while an upsurge was observed in LDF from 1984 (14.19%) to (55.03%) in year 2021. Erratic increment was observed in the BU from (0.51%) in 1984 to (3.16%) in 2021. The highest (0.4) and lowest (0.3) NDVI were recorded in 2016 and 2000. Dense forest cover in Akure Forest Reserve has been converted to agricultural activities. Therefore, there is need for conservation of the forest resources to preclude depletion.

Keywords: Forest cover, Image classification, Land use, Akure Forest Reserve.

Introduction

Forests are vital renewable natural resources that play an important part in environment preservation which also make available a safe anchorage for diverse lifeforms (Singh et al., 2016). Forest is a vegetal community with a tree canopy covering over 10% (0.5 hectares) of the land area (FA0 2020; Singh et al., 2006). In Nigeria, natural forest occupied 349,278 km^2, accounting for nearly 35% of the land mass of the country of 997,936 km^2 (Nweze, 2003). Forest cover of 14.9 million hectares in 1960, drastically reduced with a net loss of 4.8 million hectares between 1960 to 1980 and even reduced more between 1990 to 1996, reducing to 9.5 million hectares (Gbiri and Adeoye 2019). According to Joshi et al. (2016), Land use land cover (LULC) process deals with the examination of the disparity in properties of the physical land surface of an area, as it changes from one LULC with the way the biological and physical features of the land are being used (Turner et al., 1995). It was asserted by Alo et al. (2020) that formulating policies and decision-making is by understanding the forest cover dynamics. Diverse land cover changes pattern is produced in a highly dynamic manner by distinct scales (Kpienbaareh et al., 2022). Persistence of this shift in LULC, thus requires conversion measures in promoting the benefit of sustainable agroforestry with a view to dipping the jeopardies caused by climate change. However, communication between LULC and Climate change is a result of various human activities (Mahmood et al. 2010), the LULC induces changes in climate due to various decisions taken by a man in meeting various needs and aspirations (Akintuyi, et al., 2021). The use of Geographical information systems and remote sensing (RS) for LULC assessment has shown to be tremendously promising over time (Walker et al., 2021) as the Rs technology has evolved into a critical tool for stakeholders to assess and anticipate LULC as they extend over time. Advances in RS technologies is helping developing cities with limited resources to significantly improve their environmental resource monitoring as reported by (Aliyu and Botai, 2018). Sustainable forest resource management has long been a priority due to its potential impact on biological variety and relevance in maintaining global ecological functioning. This sustainability can also be achieved by consistent examination of changes in LULC changes assessment for potential adjustment or development (Lambin et al, 2001). Land has been used for several purposes such as construction and agricultural purposes (Shiferaw and Singh 2011). Inadequate documentation of this LULC of many forests has resulted in poor planning and management decision. The rate of forest cover lost is at an alarming rate which directly affects regional climate (Pielke et al, 2011) and global warming (Lambin et al, 2003). Therefore, this study focused on the dynamic changes between 1984 to 2021 LULC dynamics in the Strict Nature Reserve of Akure.

Materials and Method

The Study Area

Akure forest reserve is geographically situated in a humid rainforest zone of Akure south local government area of Ondo State, Nigeria. It is located between the latitudes of 7°16'40" - 7°18'38"N and the longitudes of 5°9'11" - 5°11'39" (Figure 1). It was gazetted in 1936 with a land area of 66km^2. The forest reserve is bounded by Osun State in the northeast. Five Local government areas in Ondo State shares boundary with the forest, which includes: Oke-Igbo, Ifedore, Akure South, Ile-Oluji, Idanre and Ondo East. The forest is bordered by a river on one side. Mean daily temperatures range from 210°C to 290°C, and the annual rainfall averages 2000mm in the south and 1500mm in the north, with a relative humidity of 80-85% (Gbiri and Adeoye, 2019).

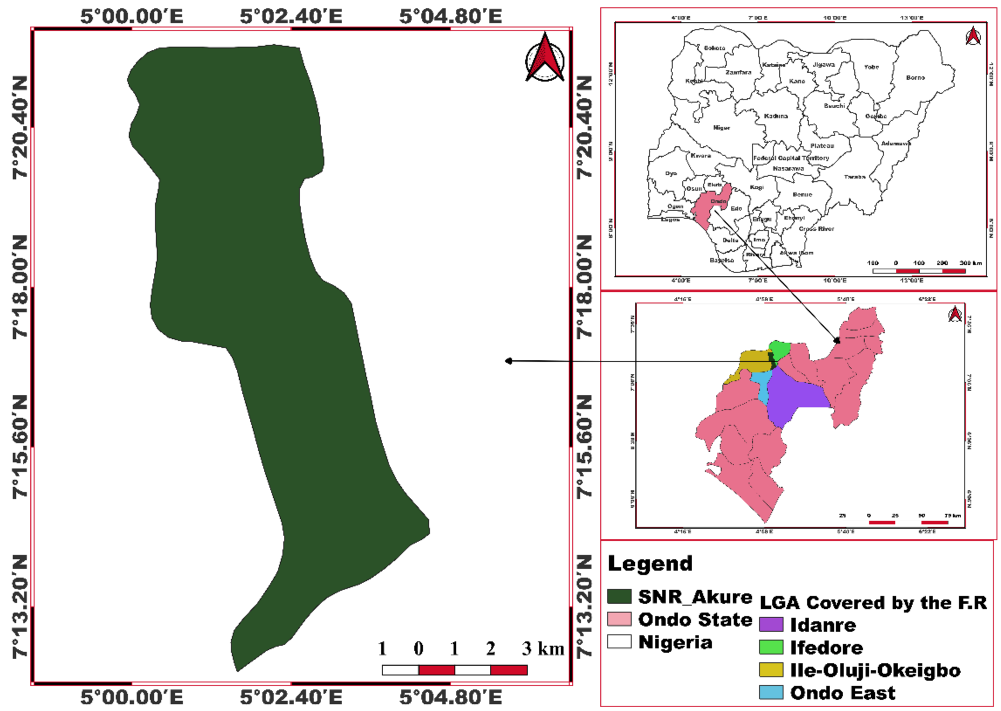


Figure 1: Map of Strict Nature Reserve (SNR) Akure (Source: Author 2022)

Data Collection

The data collected for this research work was secondary. Landsat satellite imageries of 1984, 2000, 2016 and 2021 (making use of sixteen years interval between 1984 to 2016) and 2021 was downloaded to make the analysis up-to-date. Data was gotten from United States Geological Survey website' (earthexplorer.usgs.gov). The year selected was based on Landsat pictures that were available without any form of cloud. The summary of the Landsat data downloaded is presented below in table 1.

Table 1: Summary details of the Satellite Imagery acquired

Satellites	Year	Sensor Identify	Path/Row	Spatial Resolution
Landsat 5	1984	T/M	190/55	30m
Landsat 7	2000	ETM	190/55	30m
Landsat 8	2016	OLI/TIR	190/55	30m
Landsat 8	2021	OLI/TIR	190/55	30m

Where: (TM, ETM and OLI/TIR) are 'Thematic Mapper'; 'Enhanced Thematic Mapper; 'Operational Land Imager/Thermal Infrared Radiation'.

Methods of Data Analysis

The data acquired were analysed using Quantum GIS (QGIS) 3.24.1 software and ArcGis 10.8 software. Image masking was carried out on the imageries of the year 2000 and 2010 respectively on QGIS using the fill no data tool. The classification for this study uses Anderson's (1976) image classification scheme of land cover techniques which classifies entire pixel of the image or themes as shown in Table 2.

Table 2: Anderson et al. (1976) image classification categorization

LULC Classes	**Description**
Dense Forest	Mixed forest
Less Dense Forest	Agricultural land, Nurseries
Built Up	Residential, Industrial area, Commercial areas and transportation
Bare Land	Barely exposed rock, sandy areas, transitional area and open land
Water Bodies	Streams, Lakes, Dam, Pool and Reservoir

In classifying the imageries, the image was exported into the ARCGIS 10.8 using the add data tools. Landsat TM and ETM band combination of 2, 3 and 4 were used while for Landsat OLI/TIRS imagery, bands combination of 3, 4 and 5 was used by applying false colour composite (FCC) to select the region of interest for the land cover category. The maximum likelihood classification

(MLC) method of the supervised algorithm was used in assigning pixel to the class with the highest likelihood by a normal distribution from the training sample.

Change Detention Analysis

Change detention examination was carried out to determine the rate of changes over the years assessed for the study area. The percentage change for each year and the rate of change between the years were all calculated using the formula below.

$\Delta = Y_2 - Y_1$

Average rate of change was computed using this formula $= \frac{Y_2 - Y_1}{T_2 - T_1}$

$\%\Delta/\text{yr.} = \frac{Y_2 - Y_1}{Y_1} \times 100$

Where Δ represents change; Y_2 and Y_1 are the area sizes in the initial year T_1 and final year T_2 respectively

Normalize Difference Vegetation Index (NDVI)

NDVI was used in determining the concentration of the greenness of the study area. The range value of NDVI ranges between +1 and -1. NDVI higher value refers to healthy and dense vegetation while the lower value shows scant vegetation. NDVI was computed following Rouse et al.1974

$$(\text{NDVI}) = \frac{NIR - Red}{NIR + Red}$$

Accuracy Assessment

Accuracy Assessment was computed using the following equations

$$\text{Users Accuracy} = \frac{Total\ Number\ of\ correctly\ Classified\ Pixels\ in\ each\ category}{Total\ Number\ of\ Classified\ \ Pixels\ in\ that\ category\ (Row\ Total)} \times 100$$

$$\text{Producer Accuracy} = \frac{Total\ Number\ of\ correctly\ Classified\ Pixels}{Total\ Number\ of\ Reference\ Pixels\ in\ that\ Category} \times 100$$

$$\text{Overall Accuracy} = \frac{Total\ Number\ of\ correctly\ Classified\ Pixels\ (Diagonal)}{Total\ Number\ of\ Reference\ Pixels} \times 100$$

$$\text{Kappa Coefficient (T)} = \frac{(TS \times TCS) - \sum(Column\ Total \times Row\ Total\ )}{TS^2 - \sum(Column\ Total \times Row\ Total\ )} \times 100$$

Results

Figure 2 to figure 5 presents the pattern of LULC of 1984, 2000, 2016 and 2021 for the study area. It was observed that more vegetation was more seen in 1984 compared to 2000, 2016 and 2021. The entire study area covered a land area of approximately 66km^2. The dense forest was assigned using deep dark green, less dense forest was assigned using light green while built-ups, bare land and water bodies were assigned using red, light orange and blue colours respectively. Table 3 shows the area and the percentages of all the LULC of the forest reserve for the year assessed. In 1984, the area occupied by dense forest was 82.6% while the less dense forest accounted for 14.9% of the forest land. The built-ups and bare land in 1984 were 0.51% and 2.66% respectively. However, there was a reduction in the area occupied by the dense forest from 82.6% observed in the year 1984 to 47.8% in the year 2000, this accounts for about 34.8% of the dense forest cover loss between the period of sixteen (16) years. Between the period of 5 years, 5.6% of the forest cover was lost as the percentage of dense forest in 2016 and 2021 accounted for 40.6% and 26.4% respectively. This was a result of an increment observed in the percentage of less dense forests from 1984 to 2021. The area covered by the built-up keeps increasing. The percentage of built-ups in 1984, 2000, 2016 and 2021 was 0.5%, 0.72%, 1.23% and 3.2% The bare land also increased from 1986 to 2000 but decreased from 36.6% in 2000 to 6.5% in 2016 while a surge increase was observed in the year 2016 to 2021 as the percentage of bare land was 13.9%. In the year 2016 and 2021 water bodies were found in the imagery and the classification indicated that the water bodies covered an area of 1.47% and 1.5% in the year 2016 and 2021. A validation check using Google Earth historical imagery ascertained the presence of the water bodies in the two imageries.

Table 3: Land Cover Classification for the Study Area (1984, 2000, 2016 and 2021)

	1984		2000		2016		2021	
LULC	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)
Built-Ups	0.33	0.51	0.48	0.72	0.81	1.23	2.08	3.16
Bare Land	1.76	2.66	24.13	36.62	4.28	6.50	9.16	13.90
Less Dense Forest	9.36	14.19	9.77	14.83	33.05	50.17	36.25	55.03
Dense Forest	54.51	82.64	31.53	47.83	26.77	40.64	17.40	26.41
Water bodies					0.97	1.47	0.99	1.50

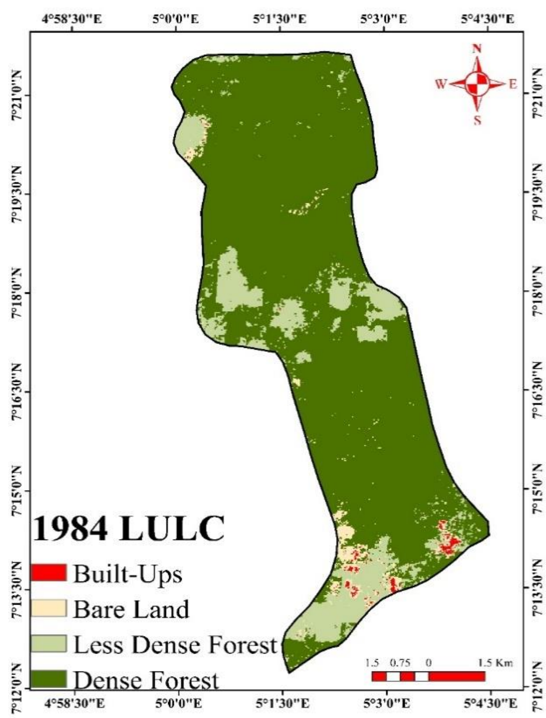


Figure 2: LULCC for 1984

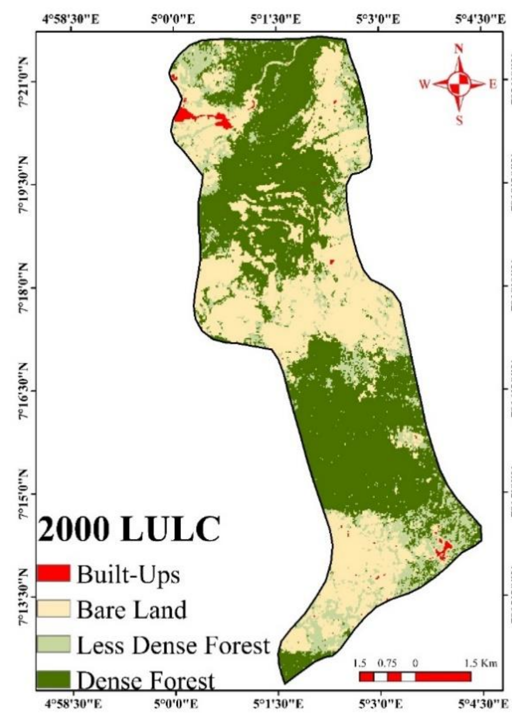


Figure 3: LULCC for 2000

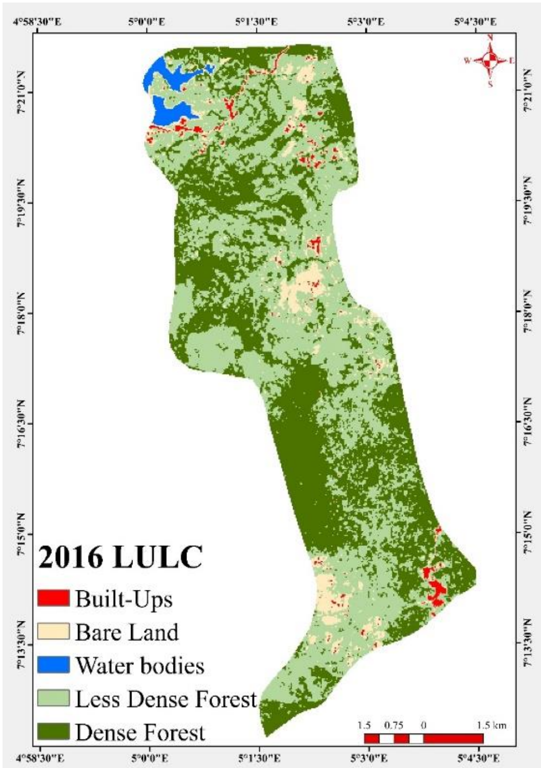


Figure 4: LULCC for 2016

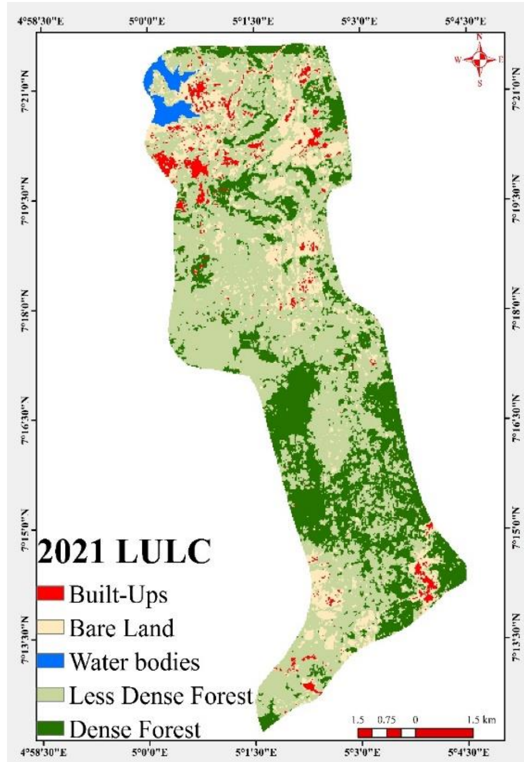


Figure 5: LULCC for 2021

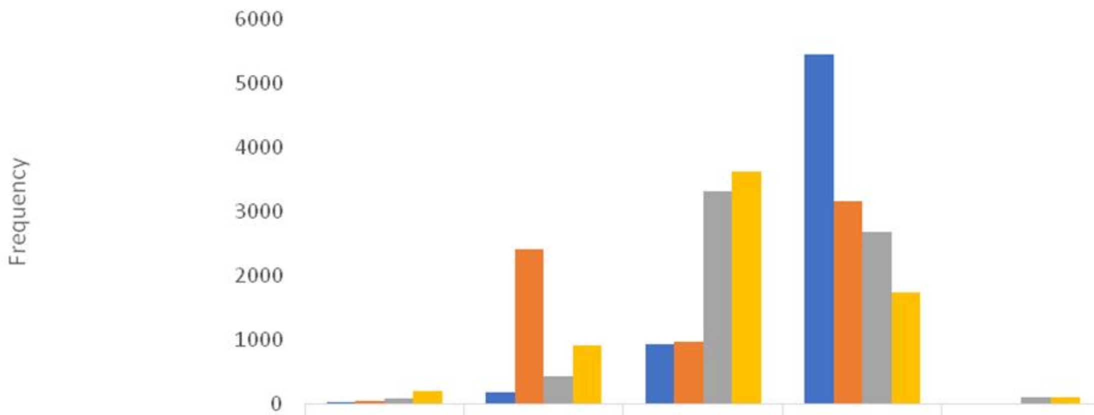
Figure 6 presents the quantity of land use categories for 1984, 2000, 2016 and 2021 in distinct multiple charts. It is fundamental to compare between green cover areas and areas subjected to changes in per hectare proportions. Dense forest decreases as the year increases. It decreased with a net loss of 2298 hectares between 1984 to 2000. A further decrease was observed between the year 2000 to 2016 accounting for a dense forest cover loss of about 476 hectares within 16 years. A surged decrease was observed between the year 2016 and the year 2021, this amount to about 937 hectares of loss in the area covered by the dense forest within 5 years. However, the built-up increases throughout the year assessed for this study with an erratic increment observed in the year 2016 to 2021 with a positive change value of 127 hectares while water bodies in the year 2016 and 2021 accounted for 97 hectares and 99 hectares.

Land Use Land Cover Change trend

Table 4 shows the result of the change detection analysis for the study area. The trend of change from 1984 to 2000 shows that the dense forest had a negative change with a decrease of -1.44km^2/yr. Less dense forest had an increase of 0.03km^2/yr, while the built-up and bare land had an increase of 0.01km^2/yr and 1.40km^2/yr respectively as shown in figure 7. The trend of change from 1984 to 2016, the dense forest had a negative change with a decrease of -0.87km^2/yr while less dense forest, bare land and built-ups had an increase of 0.74km^2, 0.08km^2/yr and 0.02km^2/yr respectively (figure 8). The trend of change from 1984 to 2021 shows that the dense forest had a negative change with a decrease of -1.00km^2/yr while the less dense forest, bare land and built-ups had an increase of 0.73km^2/yr, 0.20km^2/yr and 0.05km^2/yr respectively (Figure 9). The land cover change trend observed from 2000 to 2016 indicates that the dense forest and the bare land decreased with a negative value of -0.30km^2/yr and -1.24km^2/yr while less dense, built-up and water bodies increase 1.46km^2/yr, 0.02km^2/yr and 0.06km^2/yr respectively (Figure 10). Figure 11 shows the trend of change for the year 2000 to 2021. It was observed that the dense forest and bare land had a negative value of -0.67 km^2/yr and -0.71km^2/yr while less dense forest, built-up and water bodies increased by 1.26km^2/yr, 0.08km^2/yr and 0.05km^2/yr. The built-ups, bare land and water bodies increase by 0.25km^2, 0.98km^2/yr and 0.00km^2/yr respectively in the year 2016 to 2021(figure 12).

Normalized Difference Vegetation Index (NDVI)

Figure 13 to 16 shows the NDVI for all the years examined in this study. The NDVI has been frequently utilized to examine the relationship between spectral variability and vegetation growth rate changes which has been generally accepted as a standardised way of measuring healthy vegetation for precision farming and use in measuring biomass. The highest NDVI was observed in the year 2016 followed by 2021 with a value of 0.409 and 0.401respectively (Figures 15 and 16). The lowest NDVI value was observed in the year 2000 (Figure 14)



	Built-Ups	Bare Land	Less Dense Forest	Dense Forest	Water Bodies
Area Hectare (1984)	33	176	936	5451	0
Area Hectare (2000)	48	2413	977	3153	0
Area Hectare (2016)	81	428	3305	2677	97
Area Hectare (2021)	208	916	3625	1740	99

Figure 6: Land use categories of 1984, 2000, 2016 and 2021in hectares using distinct multiple charts.

Table 4: Change detection analysis for the study area

Where LULC= Land use land cover; Δ = Change in (Km^2)

LULC	Δ 2000-1984	Rate of Δ 2000-1984	Δ 2016 -1984	Rate of Δ 2016 -1984	Δ 2021 -1984	Rate of Δ 2021-1984	Δ 2016-2000	Rate of Δ 2016-2000	Δ 2021-2000	Rate of Δ 2021 -2000	Δ 2021 -2016	Rate of Δ 2021 -2016
Built-Ups	0.15	0.01	0.48	0.02	1.75	0.05	0.33	0.02	1.60	0.08	1.27	0.25
Bare Land	22.37	1.40	2.52	0.08	7.40	0.20	-19.85	-1.24	-14.97	-0.71	4.88	0.98
Less Dense Forest	0.41	0.03	23.69	0.74	26.89	0.73	23.28	1.46	26.48	1.26	3.20	0.64
Dense Forest	-22.98	-1.44	-27.74	-0.87	-37.11	-1.00	-4.76	-0.30	-14.13	-0.67	-9.37	-1.87
Water Bodies	0.00	0.00	0.97	0.03	0.99	0.03	0.97	0.06	0.99	0.05	0.02	0.00

Table 5: Forest cover change and percentage rate of change per year in Akure Forest Reserve

LULC	Δ 2000-1984	2000-1984 %Δ/yr.	Δ 2016 -1984	2016 -1984 %Δ/yr.	Δ 2021 -1984	2021 -1984 %Δ/yr.	Δ 2016-2000	2016 -2000 %Δ/yr.	Δ 2021-2000	2021 -2000 %Δ/yr.	Δ 2021 -2016	2021 -2016 %Δ/yr.
Built-Ups	0.15	45.45	0.48	145.45	1.75	530	0.33	68.75	1.60	333.33	1.27	156.79
Bare Land	22.37	1271.02	2.52	143.18	7.40	420	-19.85	-82.26	-14.97	-62.04	4.88	114.02
Less Dense Forest	0.41	4.38	23.69	253.10	26.89	287.29	23.28	238.28	26.48	271.03	3.20	9.68
Dense Forest	-22.98	-42.16	-27.74	-50.89	-37.11	-68.08	-4.76	-15.09	-14.13	-44.81	-9.37	-35
Water bodies	-	-	0.97	-	0.99	-	0.97	-	0.99	-	0.02	2.06

Where Δ = change in year ($Y_2 - Y_1$), %Δ/yr. = Percentage change/Year $\left(\frac{Y_2-Y_1}{Y_1}\times 100\right)$ (Km^2)

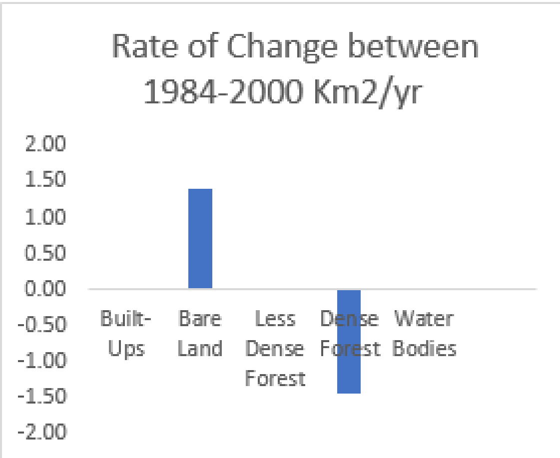


Figure 7: Land Cover trend between 1984 and 2000

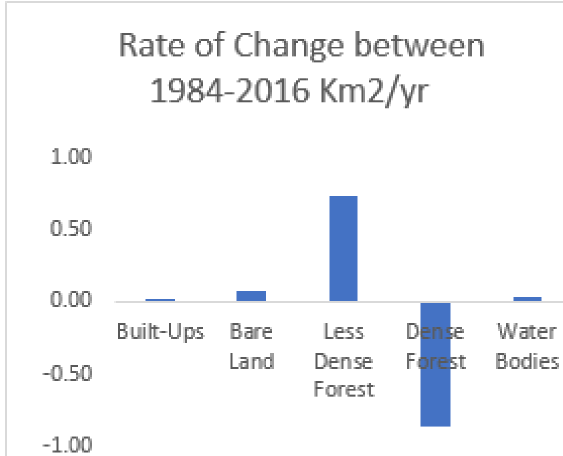


Figure 8: Land cover trend between 1984 and 2016

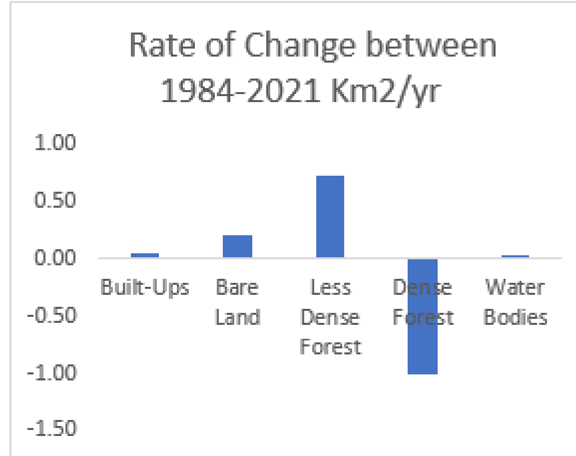


Figure 9: Land cover trend between 1984 and 2021

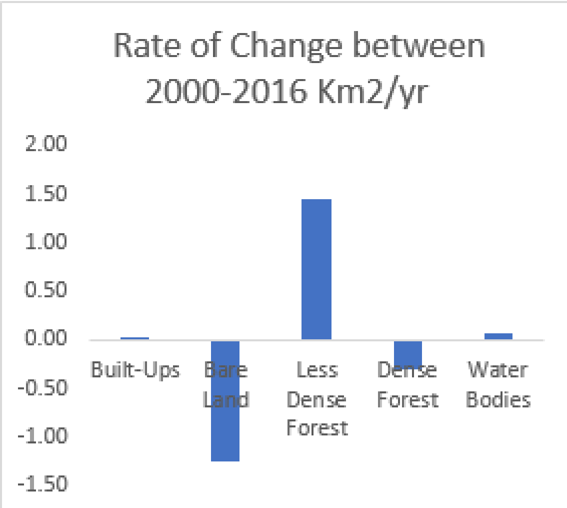


Figure 10: Land cover trend between 2000 and 2016

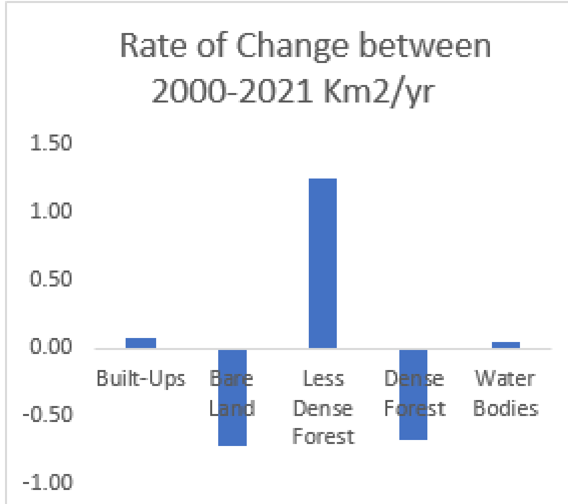


Figure 11: Land cover trend between 2000 and 2021

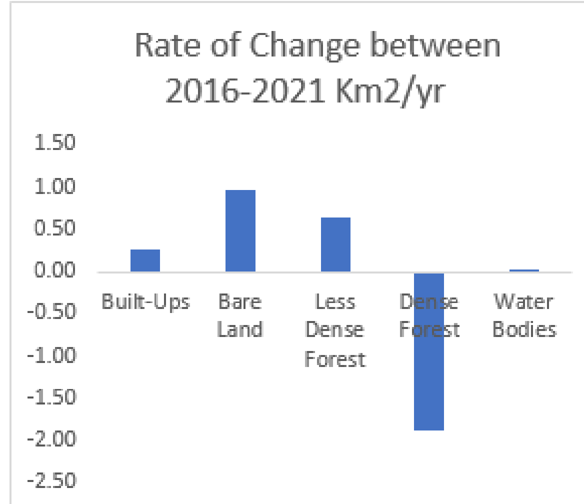


Figure 12: Land cover trend between 2016 and 2021

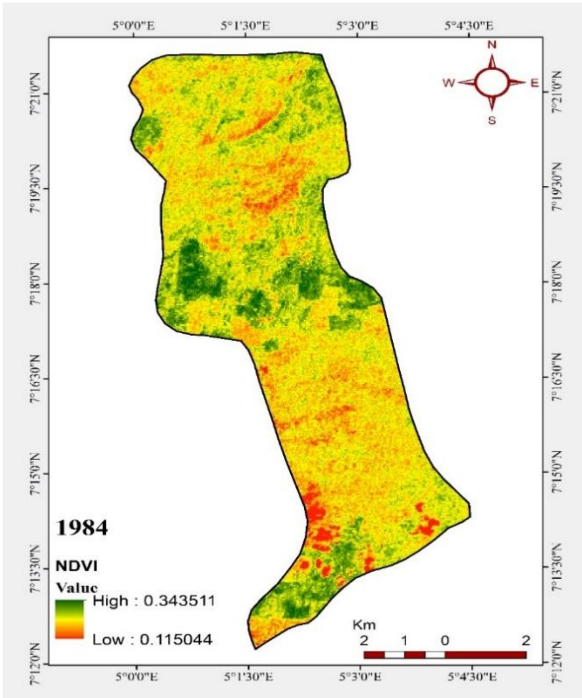


Figure 13: NDVI for 1984

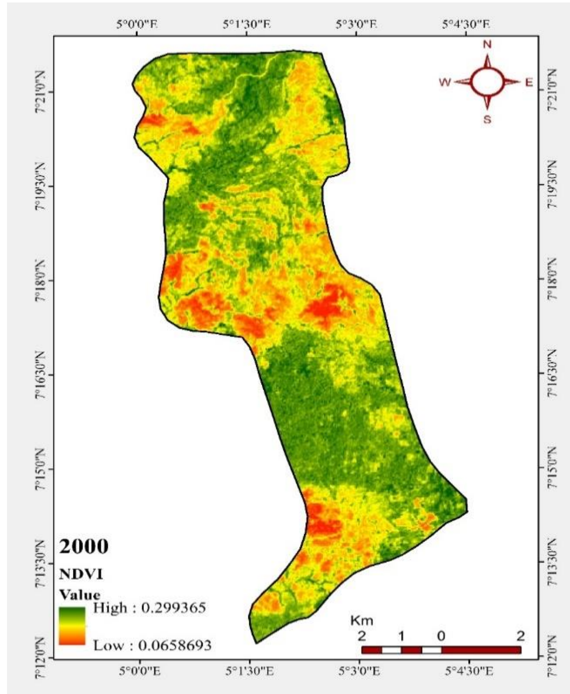


Figure 14: NDVI for 2000

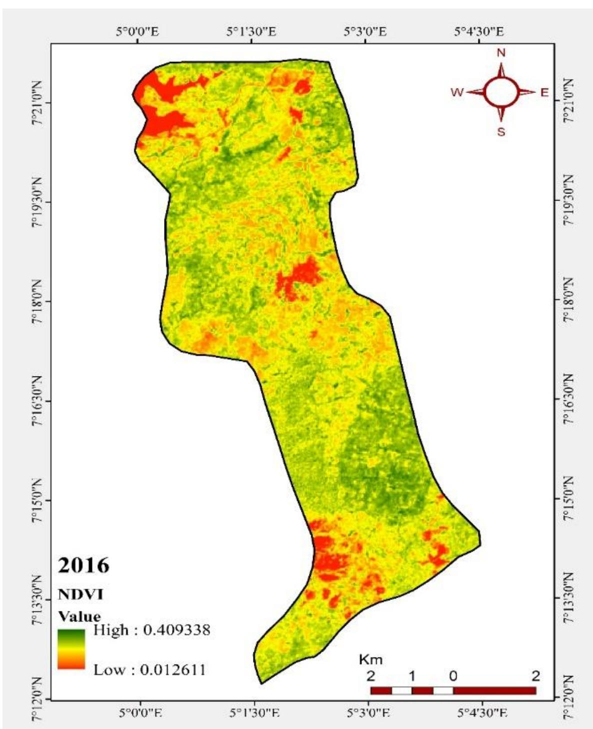


Figure 15: NDVI for 2016

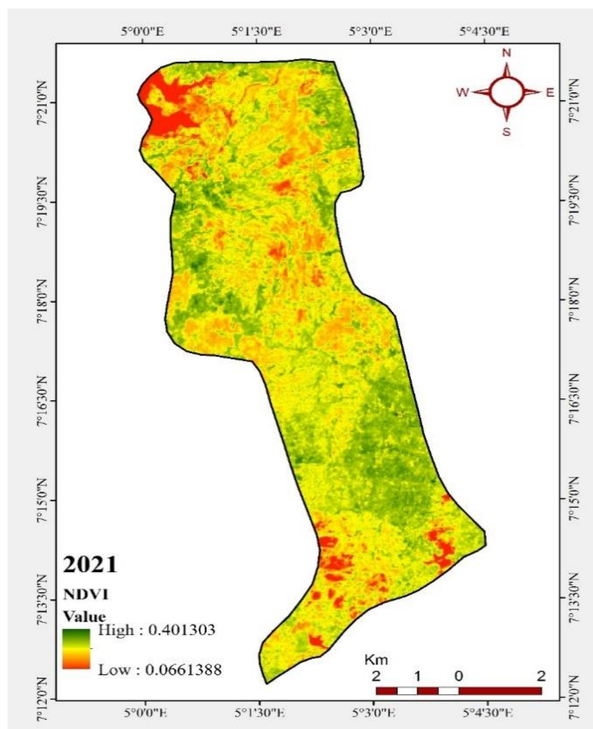


Figure 16: NDVI for 2021

Accuracy Assessment of the Images

The error matrix is summarized in table 6. The error matrix was carried out by linking the land cover classification result to geospatial data that are assumed to be true. The (user's, producer and overall) accuracy with kappa statistic (k) for the year examined was computed as shown in table 6 below. The overall accuracy for year 1984, 2000, 2016 and 2021 were 92.1%, 89.3%, 85.9% and 83% respectively. The kappa statistic for year 1984, 2000, 2016 and 2021 was 89 %, 86%, 82% and 79%.

Table 6: 1984, 2000, 2016 and 2021 error matrix

	1984			2000			2016			2021		
LULC	UA	PA	OA	UA	PA	OA	UA	PA	OA	UA	PA	OA
Dense Forest	95	100	92	95	91	89	100	91	86	100	79	83
Less Dense Forest	100	95		100	83		95	76		93	74	
Built-Ups	71	100		75	100		60	100		55	100	
Bare Land	100	79		84	89		80	76		80	60	
Water Bodies	-	-		-	-		100	100		100	100	
Kappa statistic	89			86			82			79		

UA: User Accuracy, PA: Producer Accuracy, OA: Overall Accuracy

Discussion

Knowing the key consequences of unregulated use of the forest with a means of evaluating this high loss of forest cover, biodiversity reduction, decline of environmental quality and wetland destruction is by examining and understanding LULC. Analyzing land use has been extensively researched with the aid of acquiring satellite imagery data, processed and achieved greatly either using supervised or unsupervised classification method (Alo et al., 2020; Gbiri and Adesoye, 2019). For this study, a supervised method of image classification was adopted and used for analyzing changes in the LULC. The depletion and disappearance of the forest cover and reduction in the floristic components of the forest reserves are as a result of the alteration of the forest to other land use. This also agrees with the findings of Alo et al. (2020) that most forest reserves in this country experience a high rate of anthropogenic disturbances due to the increase in the human population. Increasing rate of Build-ups in the forest is a pointer to unregulated entry of people into the forest reserve. The reduction in dense forest from 1984 to 2021 in this study area was in agreement with Gbiri and Adesoye (2019) who observed that the undisturbed forest in 1986 was higher as compared to year 2002. The rapid increase in less dense forests and continuous decrease in the dense forest is a pointer to the continuous movement of people into the forest for diverse agricultural activities. This was also in concord with Olayode (2019) findings in Osho forest reserve, indicating a gradual decline in the natural forested area into farmland and plantation. Ojo et al. (2019) findings also noted that classification of landsat imagery of year 2018 shows that, light vegetation occupies larger percentage of the land area. Chukwuka et al. (2020) in geospatial modelling of forest assessment in Ikere also reported that forested area decrease annually. The increase in built-up area from 1984 to 2021 is inimical to the forest reserve. Alo et al. (2020) in the dynamics of LULCC in Enugu State where also observed an increase in the area occupied with built-up across the year examined. The presence of water bodies in the year 2016 and 2021 reduce dense forest which was not found in imageries of the year 1984 and 2000. However, a validation check was carried out by backdating Google Earth historical imagery. The presence of water bodies in the two imageries was in concord with Gbiri and Adesoye (2019) findings that the presence of water bodies was a result of dredged Owena river for dam construction. The Normalize Difference Vegetation Index (NDVI) was used in comparing greenness levels of the spatial change patterns derived from the Landsat. The NDVI 1984 was higher compared to what was observed in the year 2000. However, the result gotten for this was in agreement with Singh et al., (2016) findings, where they observed a significant decrease in NDVI values across the year examined. Veritable evidence from this study highlighted the significant reduction in the area occupied by forests due to the role of the human in various LULC types at the expense of forest land.

Conclusion and Recommendation

Landsat photos were used to successfully assess forest vegetation features and spatial pattern changes in the Akure forest reserve between the year 1984 to 2021. According to the result, the forest had lost almost all its vegetative cover within 37 years. The changing forests turning to less dense forests such as agricultural land, cocoa plantation and farmland is highly significant in the study area which will continue to increase if the rate of anthropogenic disturbances in the forest is not checked. The need for constant monitoring of the forest reserves should be put in place, this could be greatly achieved through the use of higher resolution satellite imagery and using Unmanned Aerial Vehicle to detect any unpermitted encroachment and disturbance to the ecosystems. Also, the need for proper planning of the land use of this forest reserve must be of utmost priority by the government to checkmate the rate of forest loss by reviewing law and policy for proper monitoring of the forest. This study,, recommends quick intervention from authorities in charge to take their responsibility in addressing problems related to forest conversions and implementation of forest policy plans to provide quick answers to some of the intermediate and underpinning causes of forest conversion in the reserve.

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TREE SLENDERNESS COEFFICIENT AND ITS RELATIONSHIP TO DIAMETER AT BREAST HEIGHT FOR *Azadirachta indica* STAND IN SANYINNA COMMUNITY PLANTATION, SOKOTO STATE, NIGERIA

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Abstract
The study was aimed at establishing relationship between tree slenderness coefficient (TSC) and diameter at breast height (Dbh) at Sanyinna Community Neem Plantation. Simple random sampling technique was adopted in selecting three (3) temporary plots from each hectare (15 plots in total) for measurement of tree heights, diameter at different positions of the tree (base, middle, breast height, and top). The TSC was computed using ratio of tree height to Dbh (both measured in meter). Trees were classified based on their TSC as high (TSC>80), moderate (TSC: 70-80) and low (TSC<70). Data were summarized using both frequency table and charts. Pearson correlation analysis was used to establish relationship between TSC and tree growth characteristics. Regression (linear and nonlinear) analysis was used to generate models for predicting TSC from Dbh. The functional models were evaluated with the least values of standard error of the estimates (SEE), Akaike information criterion (AIC), Bayesian information criterion (BIC) as well as the highest values of the coefficient of determination (R^2). The significance of the estimated parameters was verified with plot of residuals against predicted to ascertain the goodness of fit of the best models. The results of TSC classification showed that 52.2% of the measured trees in the area had low slenderness coefficient, 27.8% recorded high TSC and 20% shows moderate TSC, which implies low to moderate susceptibility to windthrow and damage. For the Neem stand, the relationship between TSC and Dbh was best predicted with Exponential model and is therefore recommended for predicting TSC of Neem stand.

Keywords: Trees slenderness coefficient; Dbh; Growth characteristics; *Azadirachta indica*

Introduction
Forests provide habitat for plants and animals, clean water, places for outdoor recreation, and many other benefits. Irrespective of these benefits, they are subjected to multiple threats which can jeopardize their health, ecology, biodiversity, and resources. Such threats can be natural or anthropogenic. Natural disturbances include wildfire, catastrophic wind events, drought, insect infestation, fungal/pathogen outbreaks, and invasive plants. Anthropogenic disturbances include pollution, forest fragmentation, and urbanization. The stability of a stand is mainly affected by biological and physical factors (Nivert, 2001). Neem tree (*Azardirachta indica*) is a tropical evergreen tree native to Indian sub-continent (Roxburgh, 1874). The tree grows naturally in areas where the rainfall is in the range of 450 to 1,200 mm. However, it has been introduced successfully even in areas where the rainfall is as low as 150 to 250 mm. Neem grows on altitudes up to 1,500 m (Jattan *et al.,* 1995; Chari, 1996). It can grow well in wide temperature range of 0 to 49°C (Hegde, 1995). It cannot withstand water-logged areas and poorly drained soils. The pH range for the growth of neem tree lies in between 4 to 10. Neem trees have the ability to neutralize acidic soils by a unique property of calcium mining (Hegde, 1995). It has been used in Ayurvedic medicine for more than 4,000 years due to its medicinal properties. Most of the plant parts such as fruits, seeds, leaves, bark and roots contain compounds with proven antiseptic, antiviral, antipyretic, anti-inflammatory, antiulcer and antifungal uses. It has great potential in the fields of pest management, environment protection and medicine. Neem is a natural source of eco-friendly insecticides, pesticides and agrochemicals (Brahmachari, 2004). Neem is considered to be a part of India's genetic diversity (Sateesh, 1998). It is the most researched tree in the world and is said to be the most promising tree of 21st century. The tree has adaptability to a wide range of climatic, topographic and edaphic factors. It thrives well in dry, stony shallow soils and even on soils having hard clay pan, at a shallow depth. Neem tree requires little water and plenty of sunlight (Sateesh, 1998).

Trees show considerably variation and flexibility in their shape and size of crowns, height and trunk diameters (Givnish, 2002). These are governed by an inherited developmental tendency, which may in turn be modified by the environment where the tree grows. The size of a tree canopy and its height above the ground is significant to a tree in that it determines the total amount of light that the tree intercepts for photosynthesis (Midgley, 2003). The physical factors are mainly related to the wind components, the topography, and the site properties while the biological factors include the species characteristics. Wind is a natural phenomenon in all forest landscapes and some amount of wind damage to forest stands is normal. Wind damage, sometimes referred to as blow down and is defined as the breaking or uprooting of live trees due to strong winds (Navratil, 1996). Vulnerability of individual trees and stands to wind is based on a combination of tree attributes (species, age, health, total height, crown size, rooting characteristics), stand conditions (species, density, and structure of surrounding stands), local topography, soils (texture, depth, soil moisture level), and predominant wind patterns (Ruel, 2000). The adaptive significance of tree height has been through a mathematical model that the higher a tree is, the more light it intercepts during the course of the day (Jahnke and Lawrence, 1965). The tree trunk size also has its own adaptive significance to a tree. It must be strong enough to withstand the forces that act on it and the force exerted on it by the wind. These forces are the weight of the tree and the drag exerted on it by the wind, as demonstrated by Fraser (1962). Experimentally, wind has been found to be much more important than weight in determining what thickness of trunk is necessary for a tree (Alexander, 1968).
The most promising approaches for determining tree and stand stability to wind throw are those which integrate tree stability characteristics (e.g., slenderness coefficient) with local stand (e.g., average tree height), site, topography, and windiness

features (Navratil *et al.*,1994*).* Wang *et al.* (1998) stated that susceptibility of a tree to wind damage is principally influenced by the slenderness coefficient or taper of the tree. Slenderness coefficient of a tree is defined as the ratio of total height (H) to diameter outside bark at 1.3 m above ground (DBH) when both H and DBH are measured in the same unit (Wang *et al.*, 1998*).* This coefficient is related to tree taper and is the inverse of the DBH/H ratio that is often used to measure tree taper over the entire main stem of the tree. A straight relationship exists between the slenderness coefficient of the stands and the risk of stem breakage or tree fall due to abiotic factors such as the wind. Due to tree slenderness coefficient importance for indexing tree resistance to wind throw, it is, therefore, important to get to know slenderness of trees, considered to be a measure of their stability as well as developing models that can predict these values.

In Silvicultural studies, the tree slenderness coefficient often serves as an index of tree stability, or the resistance to wind throws (Navratil 1995). The likelihood of wind throw of a tree may be influenced by many factors interacting with each other. These factors include tree attributes (e.g., tree height, taper or form, the size and shape of crown, and the size and shape of root system), site condition (e.g., soil characteristics), and local wind characteristics (e.g., average wind speed, frequency of wind gusts). A low slenderness coefficient value usually indicates a longer crown, lower centre of gravity, and a better developed root system. Therefore, trees with higher slenderness coefficient values (that is slender trees) are much more susceptible to wind damage. Actions improving the stability of trees and stands could considerably limit these damages. Tree slenderness coefficient has been variously described as a dimensionless value based on the ratio of tree diameter at breast height (Dbh) and total height and computed as the tree total height divided by the Dbh (Moravčík, 2007; Harja *et al.*, 2012; Magruder *et al.,* 2012; Budeanu and Sofletea, 2013). Greater values indicate taller and narrower trees, and trees with values over a threshold of 80 are prone to wind-throw as well as wind induced breakage (Rudnicki *et al.*, 2004). It has been observed that slenderness ratio of trees is an excellent indicator of their long-term exposure to wind before harvesting (e.g., Mattheck and Breloer, 1994; Harris *et al.,* 1999; Rudnicki *et al.,* 2001). A very tall, slender, plantation-grown tree would respond dynamically like a pole or chimney, which is the approximation used by Kerzenmacher and Gardiner (1998) when modelling tree behaviour with slenderness ratio of 75. James (2010) and Šebeň *et al.* (2013) noted that slenderness coefficients above 100 generally indicate low stability and the affected tree is likely to buckle under its own weight. For forest trees, slenderness coefficient below 80 indicates excellent stability (Smudla, 2004; Slodicak and Novak, 2006; Kontogianni *et al.*, 2011). For trees in urban areas, lower slenderness ratios of 50:1 have been proposed by Mattheck *et al.,* (2003). This study, therefore, intends to establish relationship between SC and tree characteristics (H and DBH) as well as to develop equations for predicting SC from tree DBH and H for Neem stand at Sanyinna Community Plantation.

METHODOLOGY

The Study Area

The research was conducted in Sanyinna Community Neem Plantation in Sokoto State, Nigeria. The area lies in the Northwestern region of Nigeria, and it is geographically geo-referenced on coordinates lines of 12.709°N and 4.8572°E. The plantation was established in the year 2016 by the British American Tobacco Nigeria Foundation and is being managed by the community. The plantation is about 5 ha with a spacing of 3 x 3 m. The vegetation of the area consists of very short grasses and shrubs with dominant plant species which include *Azadiractha indica* (Neem tree) and the annual rainfall ranges from 500 to 1,300 mm per annum.

Sampling and Data Collection

A total of 15 temporary sample plots (three plots/ha) of 25 x 25 m were randomly laid within the plantation. All trees within the selected plots were enumerated. Diameters at breast height (Dbh), bases (Db) middle (Dm) and top (Dt) were measured in centimeters. Db, Dbh, and Dm were measured using diameter tape, while Dt was obtained with the aid of Spiegel Relaskop. Total height, which is the height from the ground through the stem to the tip of the tree, was measured using Spiegel Relaskop in meters.

Data Analysis

The data collected were analyzed using descriptive statistics, correlation analysis, and regression analysis. Pearson's correlation was considered in order to establish relationship between TSC and other measured tree variables, while regression analysis was used in generating models that predict TSC (dependent variable) from Dbh (independent variable). Tree volume and TSC were computed using appropriate procedures as follows:

- Volume estimation

The volume of individual trees was estimated using Newton's equation developed for trees volume estimation (Husch *et al.*, 2003)

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

Where:
V = Tree volume (m^3)
H = Tree height (m)
D_b = Diameter at base (cm)
D_m = Diameter at middle (cm)
D_t = Diameter at top (cm)

- Slenderness coefficient (TSC)

$$TSC = \frac{THT}{Dbh}$$

Where:
TSC = Tree slenderness coefficient
THT = Total tree height (m)
Dbh = Diameter at breast height (m)

Model Fitting and Evaluation
Five different model forms (Table 1) were considered as candidate models for prediction of TSC for Neem tree stands at Sanyinna Community Plantation as adopted from Oladoye *et al.* (2020).

Table 1: Selected regression models to be fitted

Model No	Model type	Model expression
1	Simple linear	$TSC = a + bD$
2	Exponential	$TSC = ae^{bD}$
4	Logarithmic	$LnTSC = a + b \ln(D)$
5	Quadratic	$TSC = a + bD + cD^2$

RESULTS
Summary Statistics of the Field data
The statistical summary for the dataset collected and computed is presented in Table 2. The table shows the mean, the standard error, the standard deviation, minimum and maximum values of the tree variables obtained. Figure 1 presents the summary of the TSC classes as low, moderate, and high. The result reveals that more than 50% of the neem trees within the Sanyinna Community Plantation fall under low slenderness coefficient class, even though the average size of the tress is still small but have the potentials of growing bigger under sustained management practices.

Table 2: Summary Statistics

Variables	Dbh (cm)	THT(m)	BA (m^2)	Volume (m^3)	SLC
Mean	9.27	7.02	0.0069	0.0348	77.52
Minimum	6.78	6.00	0.0036	0.0170	51.64
Maximum	12.20	8.60	0.0117	0.0643	110.62
Standard Deviation	1.423	0.720	0.0021	0.0105	14.137
Standard Error	0.150	0.076	0.0002	0.0011	1.490

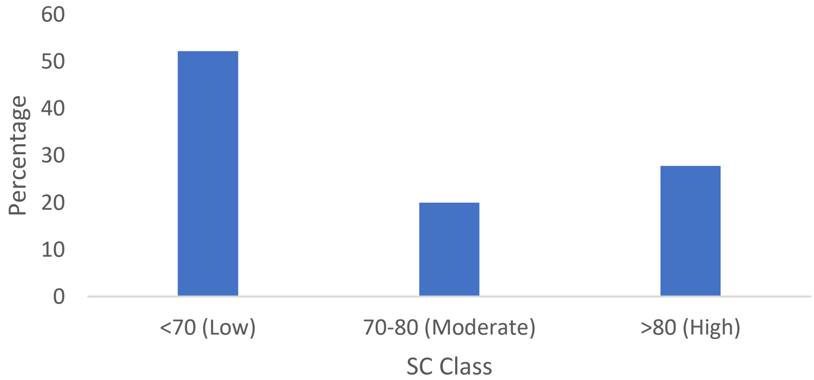

Figure 1: Distribution of Tree Slenderness Coefficient within the Plantation

Correlation Coefficients
Correlation analysis was used in order to investigate the relationship between tree slenderness coefficient and each measured and/or calculated tree variable (Table 3). The approximate correlation coefficients between TSC and all other variables (Db, Dm, Dbh, Dt, BA, Vol) were negative except the correlation between TSC and tree height. This result is an indication that the larger the tree the less slenderness and taller trees tend to have higher slenderness coefficient values (slender trees). It also, indicates that tree diameters are better predictors of TSC than tree height, hence the choice of Dbh for model calibration.

Table 3: Correlation Analysis between tree slenderness coefficient and tree variables

	Db	Dm	Dt	Dbh	THT	BA	Vol	TSC
Db	1							
Dm	0.35	1						
Dt	0.40	0.16	1					
Dbh	0.91	0.47	0.43	1				
THT	-0.18	0.30	-0.11	-0.07	1			
BA	0.92	0.45	0.43	0.99	-0.08	1		
Vol	0.50	0.93	0.23	0.61	0.50	0.59	1	
TSC	-0.81	-0.24	-0.38	-0.83	0.59	-0.83	-0.24	1

Db: diameter at the base, Dbh: diameter at breast height, Dm: diameter at the middle, Dt: diameter at the top, THT: total tree height, BA: basal area, Vol: tree volume, TSC: slenderness coefficient

Regression Models

Linear and nonlinear regression models (Table 1) were developed and tested in this study for tree slenderness coefficient (TSC) prediction using Dbh as independent variable and the results are presented in Table 4. The tree slenderness coefficient models are formulated to express slenderness coefficient as a function of tree growth characteristics. Model evaluation criteria adopted was based on the highest values of the coefficient of determination (R^2), the least values of the standard error of the estimate (SEE), the least values of Akaike information criterion (AIC), and least values of Bayesian information criterion (BIC). The four (4) fitted models were all significant ($p<0.05$) and based on the stated selection criteria, the Exponential model appeared to be the best model for estimating the TSC from Dbh.

Table 4: Developed models for predicting SC from Dbh

Model Name	Parameters			R^2	SEE	Sig.	AIC	BIC
	a	b_1	b_2					
Simple linear	146.48	-7.759		0.77	6.660	0.000	482.6	489.3
Logarithmic	236.54	-73.185		0.77	6.679	0.000	482.1	488.8
Quadratic	150.99	-8.724	0.050	0.77	6.697	0.000	483.6	490.3
Exponential	200.96	-0.109		0.80	0.087	0.000	482.3	488.9

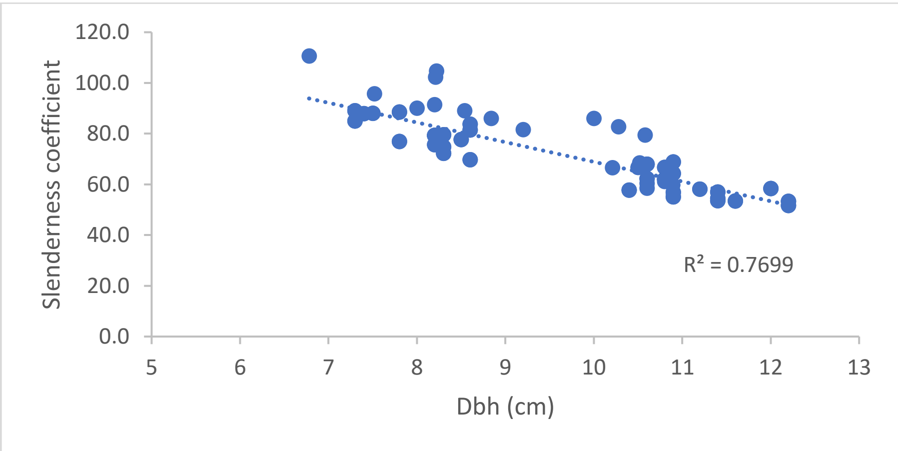

Fig 1: Relationship between SLC and Diameter at breast height

Discussion

The results of tree slenderness coefficient classification showed that over 50% of the measured trees in the area had low slenderness coefficient, 20% has moderate slenderness coefficient and about 28% of the trees fall under high slenderness coefficient class, which implies that the trees have low susceptibility to wind-throw and damage. The result is in agreement with Rudnicki *et al*. (2004) who reported that trees with values over a threshold of 80 are prone to wind-induced breakage. For forest trees, slenderness coefficient below 80 indicate excellent stability (Smudla, 2004; Slodicak and Novak, 2006; Kontogianni *et al*., 2011). The low occurrence of trees with high slenderness coefficients may be a result of plantation age and other climatic factors. Hence, it can be said that trees in the study area have been experiencing stress free growth, a situation pleasant to sustainable forestry. Trees with low slenderness coefficient are less susceptible to breakage than those with high slenderness coefficients which agrees with the findings of Eguakun and Oyebade (2015). Lower slenderness coefficient can be an indicator of larger crowns, lower centre of gravity and a better developed root system. The desirable height/dbh ratios for adequate wind resistance vary according to species and regions (Ige, 2017). In general, trees with a higher slenderness coefficient (low taper) are much more susceptible to damage than trees with low slenderness coefficient (high taper). Since smaller slenderness coefficient is usually indicating a higher resistance to wind throw, the relationships confirmed suggest that silvicultural treatments, such as producing long crowned trees, and maintaining appropriate stand density through spacing, thinning, or gradually harvesting overstory trees, can be helpful in reducing the risk of wind throw (Wang *et al*., 1998; Eguakun and Oyebade, 2015). As noted by Liu *et al*. (2003), when tree slenderness coefficient becomes very low, there is no possibility of exposure of such trees to bending stress, leading to reaction wood, which may affect wood properties as well as the ultimate usage to which the wood can be put. Negative correlation coefficient values were observed between TSC and all other tree variables except Tree Height, with Dbh, Db, and BA recording significantly ($p<0.05$) strong negative correlation, implying that the bigger the size of the trees the lower the TSC. This result indicates that the tree slenderness coefficient values tend to decrease for larger trees, and the largest slenderness coefficient values occur for the trees with small Dbh which is in accordance with the result of Onyekwelu (2001) and Onyekwelu *et al*. (2003).

Dbh and TSC data were first fitted in a scatter plot in order to have an idea of the kind of relationship that exist between the two variables for easy selection of candidate models. Based on the pattern of the relationship from the scatter chart, five (5) candidate models were selected to predict TSC (dependent variable) from Dbh as a major predictor due to the fact that it has the highest correlation coefficient and practically, Dbh is the easiest and commonest variable to measure in many forest inventories. All the models showed strong fit to the tree slenderness coefficient data. Hence, least values of AIC, BIC and SEE were used to select the best model that explains the relationship. Based on this criterion, Exponential model was adjudged the best among the candidate models. Hence, this model is therefore recommended for predicting slenderness coefficient in the stand.

CONCLUSION

It is concluded that the growth characteristics (Dbh, Height, BA, Volume) of the Neem stand at Sanyinna Community Plantation follows a regular growth pattern. Majority of the tee stands fall under low TSC which is an indicative of low vulnerability of trees to fell off due to windthrow. There was significant strong negative correlation between TSC and some tree characteristics (Db, Dbh, BA, Volume) which is an indication that the bigger the size of a tree the more the ability to withstand windthrow within the *Azardirachta indica* stand of Sanyinna Community Plantation, Nigeria. The study has projected that there is little possibility of occurrence of wind throw among this specie in Sanyinna plantation and advances the need for continuous silvicultural treatment and avoiding other environmental degradation within the plantations in Nigeria. Diameter at breast height (Dbh) was considered as the common useful independent variable used in all selected candidate models for the study. Both linear and nonlinear model forms were calibrated and evaluated for predicting TSC (dependent variable) from Dbh (independent variable) and based on the selection criteria adopted the Exponential Model was selected as the best model for predicting TSC. Based on the findings of the study it is recommended that there should continuous sustainable management of the plantation for healthy, productive, and stable stands with appropriate silvicultural treatment such as thinning and weeding to avoid competition.

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SUB-THEME 4

SUSTAINABLE UTILISATION OF WOOD AND NON-WOOD FOREST PRODUCTS FOR CLIMATE CHANGE MITIGATION

SUSTAINABLE UTILISATION OF WOOD AND NON-WOOD FOREST PRODUCTS FOR CLIMATE CHANGE MITIGATION

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Abstract
Climate menace as it affects world environment has become a global discussion especially at the United Nations. At the Climate Action Summit in September 2019, 65 countries and major sub-national economies, such as California, committed to cut greenhouse gas emissions to net zero by 2050, while 70 countries also agreed to boost their national action plans by 2020 in order to meet the deadline. Greenhouse gases in the atmosphere play a critical role in shaping the global climate and human activities have significantly modified the concentrations of many of these gases. Harvesting and utilization of wood and non-wood products are major contributors to these changes. While harvesting and utilization should continue because of the global needs, sustainable use of these products will not only reduce the scourge of climate change but assist in sustaining the resources for the unborn generation. Understanding the effects of human activities on global climate requires identification and quantification of these greenhouse gas flows and how it could be curtailed. Strategies for an enduring management of these forest resources, within the context of exploring forest resources gains through carbon budget management was discussed, as mitigation measures for climate change.

Keywords:

Introduction

The forest is dominated by wood and other non-wood products which are vital to survival of mankind. Utilization of wood has over the years supported the entire world in terms of domestic uses as well as industrial applications. As a dominant product of forests, it is used for many purposes, such as wood fuel in form of firewood, charcoal and other products derived from wood biomass. the finished structural materials used for the construction of buildings, or as a raw material, in the form of wood pulp, that is used in the production of paper. All other non-wood products derived from forest resources, comprising a broad variety of other forest products, are collectively described as non-timber forest products (NTFP); (Belcher 2005, Ticktin 2004, Belcher and Schreckenberg 2007).

The world has a total forest area of 4.06 billion hectares (ha), which is 31 percent of the total land area (FAO 2020). Globally, about 1.15 billion ha of forest is managed primarily for the production of wood and non-wood forest products. In addition, 749 million ha is designated for multiple use, which often includes production. Wood and other forest products, such as bamboo, are renewable and highly versatile natural resources for production of structural and composite materials. Reports on global wood products market indicated that wood is increasingly being used as a building material due to the numerous advantages of wood buildings over concrete buildings, thus driving the market for wood products. Increasing global demand for various wood products with the consequent high rate of over exploitation of forests has contributed adversely to climate change. Currently, the building industry is causing 25% of greenhouse gas emissions globally and therefore the concept of green building construction has evolved, which is expected to reduce CO2 emissions and store carbon. In addition, constructing buildings with wood produces less waste and allows for quicker construction when compared to a concrete building. For instance, The University of British Columbia inaugurated an 18-storey wooden hybrid building, which was built four months faster than similar non-wooden buildings take, reducing construction time by almost 20%. Wooden building construction has increased the demand for mass timber components such as cross-laminated timber (CLT) and laminated veneer lumber (LVL). Timber is rapidly becoming the building material of the future and therefore needs to meet the increasing demand from construction industries. According to the Central Statistical Office, the number of wooden buildings in Poland in 2020 almost doubled over the last five years. Countries such as the US, Japan and China are also witnessing an increase in wood construction due to its economic and environmental benefits. Although, this trend is still very low in the developing countries, particularly in the sub-Saharan Africa, there are indications that use of wood for construction purposes would increase due to high level of urbanisation which requires high input of tropical wood. The rapidly growing urban population is expected to increase the demand for new residential and commercial buildings and furniture, thus further driving the demand for wood products.

According to World Bank, Asia Pacific was the largest region in the wood product market, accounting for 38.7% of the total in 2020. It was followed by North America, and then the other regions. Going forward, the fastest-growing regions in the wood products market will be the Middle East and Asia Pacific, where growth will be at Compound Annual Growth Rates (CAGRs) of

11.0% and 10.4% respectively. These will be followed by Africa, and South America, where the markets are expected to grow at CAGRs of 9.31% and 9.32% respectively.

The forest industries in Nigeria have over the years contributed immensely to industrial employment, manpower development and human welfare. After trees are harvested, they provide wood products which continue to store carbon in materials we use in our everyday lives. Wood-based industrial operations in Nigeria include timber logging, sawmilling, wood-based panel products manufacturing (i.e. plywood, veneer and particleboard), furniture making, paper making, match making, wood seasoning and the manufacture of various wooden items such as tool handles and wooden trays and other marketable wooden souvenirs. Items such as paper and packaging, building materials, furniture and musical instruments have a complete lifecycle which retains the carbon sequestered from the atmosphere by the trees they are derived from. The amount of wood waste generated from forest industries has become a problem to the local environment despite the fact that some are used for household cooking and in bread making industries yet a large part of the waste such as barks, slabs, lumber edges and sawdust remain unused in the factory and is either burnt or used in several locations in Nigeria as landfills or burnt to further pollute the atmosphere.
Harvesting timber can cause environmental problem. One of the greatest environmental concerns of twentieth century worldwide is deforestation, particularly the destruction of the tropical rain forests of Africa. Asia, and Central and South America by forest industry through unsustainable logging practices. Consequently, the environmentalists call for boycotts of tropical timber products that are not certified as derived from well-managed forests. Expert Group meeting held in Kyoto, Japan to discuss “Clean Development Mechanism and Sustainable Industrial Development” (UNIDO, 2000) suggested that African Industries should build institutional and infrastructural capacity to take full advantage of opportunities available in world trade by adopting environmental friendly technologies. Hence, it is important to assess the forest industry sector of Nigeria particularly the influence of the wood wastes factors on the long-term sustainability of the operating environment, in order to suggest recommendations for improvement. There is need to align the forest industry in the developing countries with the realities of the modern global forest products trade and the institutional requirements for the smooth running of the industry in line with the concept of sustainability. Developing countries should realise that wood harvesting per se is no longer a problem, rather the manner of harvest in relation to global best practices.

Forest Industry, Global Warming and Climate change mitigation

Climate change can be defined as fluctuations in the pattern of climate over a long period, it manifests by temperature increase as a result of increase in atmospheric concentration of $C0_2$, CH, and other gases. Greenhouse gasses cause warming of the atmosphere because they absorb outgoing long wave radiation and therefore less radiation is lost. Forest industry can be classified into two categories: primary activities and secondary activities. Primary activities, which typically use logs as raw material, include sawmills, veneer mills, and pulp mills. They are located near the source of raw materials and hence located in rural communities or country sides. Secondary activities on the other hand involves conversion of products such as lumber, plywood, and particleboard into finished goods, such as mass timber products like LVL, OSB, furniture, doors, boats, and packaging. They are located close to major transportation routes and population centres that serve as markets. Activities of these industries contribute to global warming. There has however been an increasing concern in the last two decades over the operational status of wood transformation industries and their consistency with the contemporary drive towards sustainable forest management. Total dependence on the natural forest in the and excessive commercial logging have caused wood scarcity and untold impact on the forest ecosystem in many timber producing countries. Increasing concerns of global warming and climate change have significantly shifted consumer preferences towards eco-friendly furniture, which has enabled manufacturers to develop furniture using eco-friendly materials. This helps wooden furniture manufacturers to gain a competitive edge in the market. Along with the environmental concerns, consumer demand for modular and elegant furniture is also driving the demand for wooden furniture across rural and urban areas: therefore, benefiting the wood processing market’s growth.

Sustainable Utilisation of wood and non-wood products

The concept of sustainability stipulates that resources should be used in such a manner will allow generation yet unborn to have access to the same quality of use if not better. In the language of the current dispensation, it is called responsible utilisation and consumption. In order to ensure responsible consumption and utilisation, forest products should be exploited in line with the provisions of the pillars of sustainability, figure 1. It ensures ensure that products are used in a manner that is economically viable, socially acceptable and environmentally compatible.

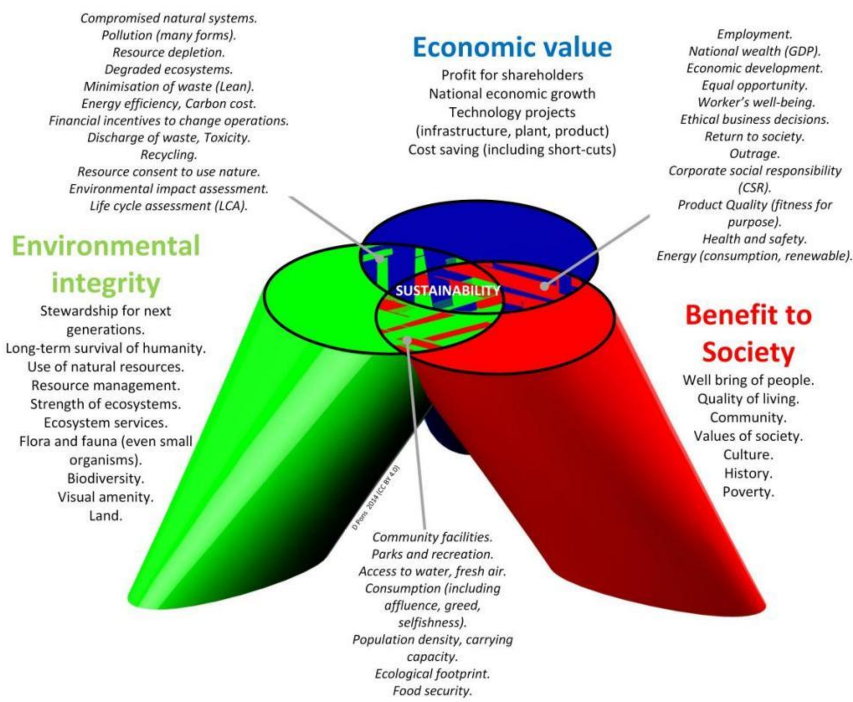

Figure 1: Model showing the pillars of sustainability

Natural resource utilisation is a social process in which different interest groups, with diverse and often conflicting intentions, confront each other at local, regional, national, and global levels. The social relations of resource utilisation are historically and politically constructed, and the concepts change over time and between different social and cultural actors. It is important to determine the most influential actors who mobilise development in the direction of their own interests in terms of the utilization of nature resource utilisation. As a natural resource, wood has been used in various industries for centuries. In this regard, wood resource utilisation has complex stakeholders and interests according to the social structural and cultural construction. The supply of and demand for wood in each country have thus affected sustainable wood resource utilisation, since the pattern of supply and demand of wood resources varies according to the industrial composition of wood products by country. Wood supply is affected by factors, such as harvestable trees in the forests, accidental felling, wood stock from previous periods, ownership structure, own consumption, wood price, price of production factors, and legislation. In contrast, wood demand depends on the number and structure of the processing industry, the energy industry, wood stock from previous periods, economic development, demand of related industries, supporting programs and activities for wood promotion, wood and wood products prices, traditions, and consumer preferences. Primary wood products require different raw materials. The quality of sawn wood and plywood depends on specific round wood conditions, such as the species and size, which leads to a difference in the quality and price of the sawn wood produced. On the other hand, fiberboards, such as medium-density fiberboard and particle boards, are produced using round wood as well as recycled wood, wood chips, and wood by-products as raw materials. All these social and economic considerations should stay within the framework of ecological compatibility, such that a web of relationships among economic consideration, social well-being, cultural and spiritual beliefs as well as ecosystem services and functions are established in a manner that is consistent with internal best practices.

Mitigating Climate Change through Sustainable Wood and Non-wood Utilisation

1. **Regulating Forest Products use through Global products market**

In order to ensure sustainable utilisation of wood and non-wood products, the Forest Stewardship Council (FSC) and other related Organisation such as Forest Law Enforcement, Governance and Trade Action Plan FLEGT have instituted Forest Certification procedure, which will ensure that forest products generated from sources other than a sustainably managed forest will be

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countries who are willing to follow standard global practices in timber and timber products trade through a thoroughly verified

procedure. This approach to sustainable forest utilisation on the long run regulate harvesting and prevent practices that are normally aggravating climate adversities.

2. Sustainable Utilization of Lesser Known and Lesser-Used Tree Species

Increased demand for traditional timber species has led to the depletion of large areas of Nigeria's forest cover. Sustainable forest management requires that measures are put in place to minimize forest depletion through the utilization of lesser-known species, reforestation, setting margins for annual allowable cut, banning export of round logs, conservation of biological diversity and promotion of efficient wood-based industry. In a study conducted by Ewudzie *et al* (2018), Greater part of the population prefers species like *Milicia excelsa* (iroko), *Nesogordonia papaverifera* (Danta), *Pipadeniastrum Africana* (Dahoma) and *Ficus benghalensis* (Denyan), for roofing while *Khaya senegalensis* (mahogany), *Tieghemella heckelii* (Makore), among others are used for furniture. The perception is that when the traditional species are used for either roofing or furniture they last longer.

3. Sustainable Utilization of Non-wood Forest Products

A lot of works have been carried out on the technical suitability of some non-timber products such as bamboo as substitutes for woods to optimize its utilization potential. Ogunsanwo *et al* ((2015) found an average density of 700 kg/m3 which was a prerequisite for high mechanical strength. The moduli of elasticity were high and exceeded 14 kN/mm^2 for bamboo boards and 13 kN/mm2 for finger joints. Comparing *Bambusa vulgaris* with selected topical hardwoods, Adebayo (2020) observed higher specific strength of glulam *Bambusa vulgaris* boards. The specific gravity for MOR was 10.36Nmm^2 which was higher compared to *Sterculia rhinopetala* (1.67Nmm^2) and *Mansonia altisima* (2.08 Nmm^2). Utilisation of Bamboo, a product with far lower gestation period, as substitute for wood will offer greater opportunity to sustainable forest products utilisation.

4. Sustainable Utilisation of Residues of Forest Products for Energy Generation

Wood remains the largest biomass energy source (Urban and Mitchell 2011). The principal uses of mill residues for energy are as domestic fuel, as reed stock for charcoal production, and as industrial fuel to produce process heat, electric power, or both. In a research carried out by Egbewole *et al* (2009) on potential use of wood residues for briquette production; *Anogeissus leiocarpa* had the highest heat of combustion value of 5211.28 323 Kcal/kg, followed by *Antiaris toxicaria* with 5035.61 543 Kcal/kg, while the mixture of *Anogeissus leiocarpa* (Ayin) and *Albizia adianthifolia* had the least heat of combustion value of 4874.80 326 Kcal/kg. In Developing countries, particularly in sub-saharan Africa, the wood processing industry lacks facilities to process sawmill wood residue into green products. This makes it very inefficient in terms of wood conversion (Ogunsanwo (2010). In the past, these items

kept at homes as carbon in stock for several years.

Plate 1: Wooden souvenirs produced from some tropical hardwoods

5. Harvested wood products (HWPs) in climate change mitigation

Greenhouse gas (GHG) reduction by conserving carbon stocks in forests and increasing carbon uptake through improved forest management and reforestation are important tools for mitigating climate change. According to Jang and Youn, (2021), Harvested wood products (HWPs) have been recognised for their contribution to the reduction in GHGs by storing carbon dioxide from the atmosphere in trees before decaying and combustion . When trees are harvested from forests, a significant amount of carbon is released, but will be continually stored in wooden products (e.g., in wood products as a building material, furniture, and paper). HWP, therefore, contributes to sequestering carbon dioxide over a period of time, rather than being immediately released into the atmosphere after harvesting.

HWPs as a carbon pool in the second Kyoto implementation period were ratified by the parties of the United Nations Framework Convention on Climate Change (UNFCCC) during the 17th Conference of the Parties (COP) in 2011. As a result, the parties were able to account for carbon stored in HWPs as a means to reduce GHG emissions and include them in their national carbon inventory. Harvested wood products are good sources of stored carbon which are gradually being incorporated into national and international carbon budgeting. At the present, there are challenges arising from socio-economic differences among states, efforts are however being intensified to provide needed information towards acceptable and enduring harvested wood carbon pools.

6. Green Building as climate change mitigators

Wood as store of carbon is being exploited in the building industry. It is a sustainable, high-value building material which has potential to contribute immensely to decreasing the fossil carbon footprints in the construction sector and possible direct and indirect benefits from wood use can contribute to the achievement of multiple Sustainable Development Goals. A typical Hotel constructed in Australia for instance has the capacity to store 1,500 tonnes of CO_2. This trend is growing all over the world and indeed attracting

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carbon calculations in its regulations for buildings. These requirements turn the spotlight on timber, due to its lower embodied carbon and its ability to act as a carbon sink.

From January 2022, Sweden requires developers to submit embodied carbon calculations for the whole lifecycle of a new building in order to receive planning permission. France also brought in new regulations at the beginning of 2022: its RE2020 regulations require embodied carbon analysis over the lifecycle of residential buildings, a requirement that will extend to other building types from 2023. RE2020 also introduces embodied carbon limit values which will tighten in stages over the years. In order to expand the scope of green building concept, France also has goals for using bio-sourced materials, such as timber, in its public buildings. Currently its legislation calls for bio-sourced materials to be used in at least 25% of major refurbishment or new build public projects from 2030. The new direction is clearly indicating that timber harvest in a sustainable manner will contribute positively to climate change mitigation while expanding the frontiers of global wood and wood products utilization.

Plate 2: A typical Timber structure in Australia

Conclusion

Global demand for wood and wood products will continue to increase due to population increase and the need to produce green products of wood origin. The trend has the ability to aggravate the climate change adversities due to loss of carbon sink and other related ecological problems. Sustainable utilization of wood and wood products through adherence to standard global practices has great potentials to stem the tides of climate adversities arising from unsustainable practices. To date, several practices have been proposed to expand the efficiency of wood products utilization through sustainable practices. One practice that has recently caught the attention of forestry experts is the cascading concept. The concept of cascading use has been resented for the sustainable use of wood resources and consists of a method to increase the usage time of wood resources and efficiently increase the carbon stock in Harvested Wood Products. It uses wood resources sequentially: (1) by producing raw wood as sawn wood, (2) using sawn wood as a building structural material, (3) recycling sawn wood into wood-based panel materials, and (4) using wood as fuel at the end of its life. Using wood products for as long as possible is a way to trap carbon in the HWPs in use and delay carbon dioxide emissions into the atmosphere, thereby contributing to greenhouse gas reduction.

Recommendations

1. There is need for an aggressive afforestation programme through private plantation development initiative.
2. There is need for all Countries to embrace timber legality standardization in order to stem unsustainable wood utilization practices.
3. Scope of wood should be expanded by utilization of lesser-used species and non-wood products like bamboo.
4. Residues generated from wood processing should be used to generate green products that are compatible with the principle of responsible consumption and utilization.
5. Harvested Wood Products (HWPs) are enormous store of carbon all over the world, technologies and strategies for their incorporation into the Country's carbon balance should be encouraged.

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BIOLOGICAL CONVERSION OF LIGNIN FOR CHEMICAL PRODUCTION

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Abstract
Lignin, a derivative of wood is one of the abundant aromatic polymers, and a cell wall component which provides mechanical support for wood fibres, regulates the transport of water through the cell wall xylem and protects plant against destructive attacks from insects and enzymes by building an impenetrable membrane surrounding the inner polysaccharides components. Lignin has high energy content due to its complex polymer structure and thus makes it a potential renewable resource for chemicals and fuels. The biological conversion of lignin is achieved chemically, physically or biologically. The biological conversion is of utmost importance and this article takes a critical look at the methods used for its conversion and the products obtainable from lignin.

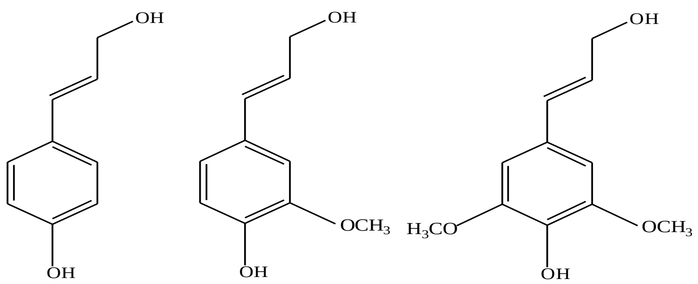
Keyword: Lignin, biochemical, biological conversion, renewable resources

Introduction

Lignin is compound name given to a vast group of aromatic polymers. The word lignin is derived from the Latin term lignum, which means wood (Sarkanen et al., 1971). Lignin is a derivative of wood and one of the most abundant aromatic polymers on earth (Lora and Glasser 2002; Kudanga and Rose-Hill 2014). It is one of the three major components of plant materials: lignin, cellulose and hemicellulose. In plants, it is predominantly a cell wall component and makes up between 15-25 % of woody plant materials representing a large amount of the world non-fossil carbon reserve (Kudanga and Rose-Hill 2014). Its presence in plant play lots of roles such as provision of mechanical support for wood fibres, regulation of water transport through the cell wall xylem and protection of plant against destructive attacks from insects and enzymes by building an impenetrable surrounding the inner polysaccharides components (Sjostrom, 1993; Sammond et al 2014). Although it is abundant, it is underutilized as less than 5% lignin have been put into productive use (Kudanga and Rose-Hill, 2014; Kleinert and Barth, 2008). Lignin contains high energy content due to its complex polymer structure and this makes it a potential renewable resource for chemicals and fuels (Liu et al., 2014). The use of lignin as a renewable source of energy is highly encouraging due to the current instability in the demand and prices of petroleum and products (Liu et al., 2014). It is also a means of sustainable energy source as it has less hazardous effect on environment compared to first generation fossil fuels (Clark and Deswarte 2015). Lignin is majorly generated as effluent of paper and pulp industries, while its intended production runs to about 50 million tons/year (Suhas et al., 2007). Due to the economic importance of this polymer, International Lignin Institute, Switzerland was established to promote technologies for conversion of lignin to environmentally friendly products (www.ili-lignin.com).

Biosynthesis of lignin

Lignin structure is extensively complex, heterogeneous, dimensional, irregular, branched and an optically inactive organic polymer. The three main components (monolignols) of lignin structural units are p-coumaryl alcohol [4-hydroxycinnamyl alcohol or its 3- and/or 3, 5-methoxylated derivatives], coniferyl and sinapyl alcohol (Roberts, 2006) (Fig. 1). Upon their final incorporation into the lignin moiety, these monolignols become p-hydroxyphenyl (H), guaiacyl (G) and syringyl (S).



A B C

Figure 1. Lignin precursors (monolignols): A - p-coumaryl alcohol, B – coniferyl alcohol, C - sinapyl alcohol (Liu, 2012).

The overall biosynthesis of lignin is a complex process which can be categorized into three discreet but concerted cellular processes. These processes involves the synthesis of monolignols within the cytosol, the transport of monomeric precursors across plasma membrane and the oxidative polymerization of monolignols to form macromolecules within the cell wall (Liu, 2012).

Synthesis of the monolignols

The first stage of the synthesis proceeds in the cytosol by the synthesis of the monolignols from a single precursor, L-phenylanine (Fig. 2). The synthesis begins with the series of reactions leading to the glycosylation of the amino acid. This process renders the amino acids water soluble and less toxic due to the glucose molecules attached to them (Boerjan et al., 2003).

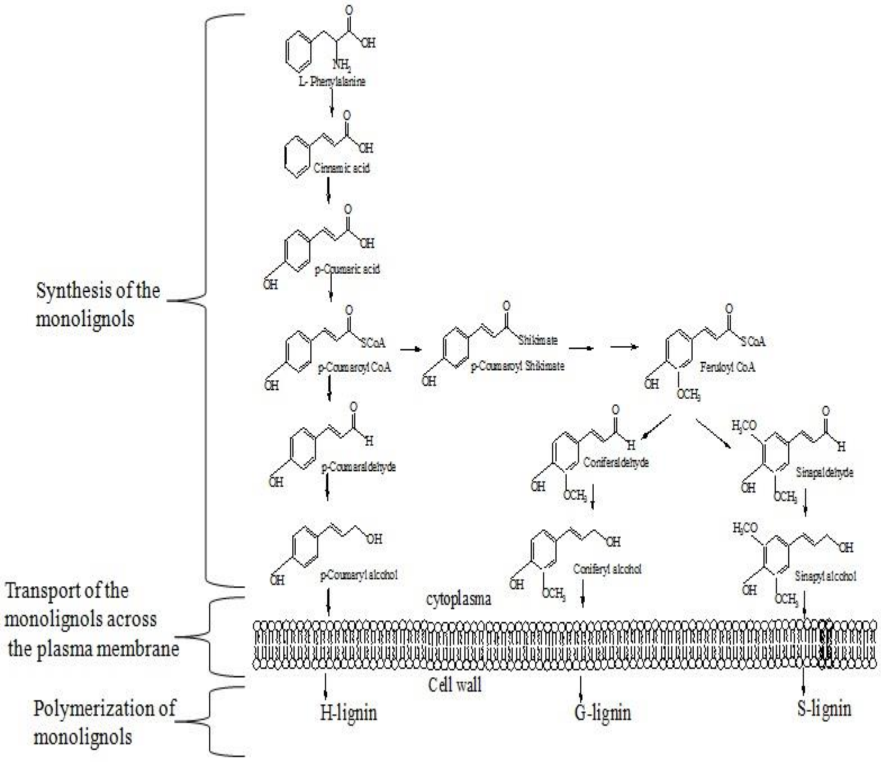


Figure 2. The phenylpropanoid-lignin biosynthesis pathway (Liu et al. 2014).

The linear pathway of this phase of the synthesis ends at a critical branching step where an intermediate precoursor, *p*-coumaric CoA, is subject to two fates. This intermediate could either form *p*-coumaryl shikimate by the action of enzyme: hydroxycinnamoyl-CoA:shikimate/ quinate hydroxycinnamoyl transferase (HCT) or continued in the linear pathway to produce *p*-coumaric aldehyde by the action of CCR, cinnamoyl-CoA reductase (Humphreys and Chapple, 2002). This step is critical in that it coordinates the subsequent direction of the carbon flux precursor to the synthesis of guaiacyl and syringyl lignin precursors in the phenylpropanoid pathway (Niggeweg et al., 2004).

Transport of monomeric precursors across plasma membrane

Upon the complete synthesis of the monolignols in the cytosol, they are exported across the plasma membrane and deposited into the cell wall (Fig. 2). The entrance of the monolignols into the accompanied by the dissociation of the attached glucose unit and polymerization of the units follows (Samuels et al., 2002).

Although, the intrinsic mechanism of the translocation of the monolignols is yet unclear, transcriptomics, proteomics and modern auto radiographic studies have suggested the involvement of ATP-binding cassette (ABC) transporters in plant lignification (Nilsson, et al., 2010; Smith et al.,2013).

Oxidative Polymerization of Monolignols

The polymerization is initiated by oxidation/dehydrogenation of the phenolic hydroxyl groups to form radicals. This step is supposed to be catalysed by oxidative enzymes: laccase and peroxidise present on the plant cell wall (Ralph et al., 2004). The radicals formed are stabilized in a series of radical-radical coupling to one another in positions of the unpaired electron.

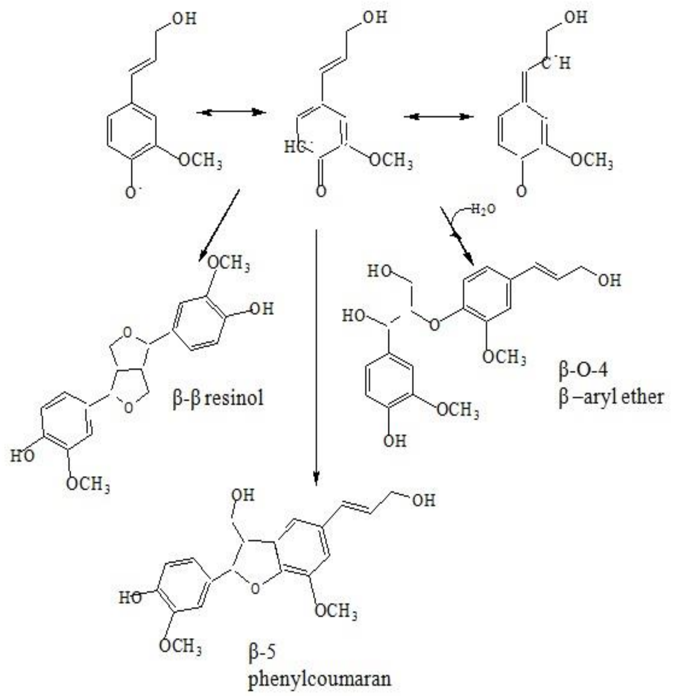


Figure 3. Dimerization of two dehydrogenated coniferyl alcohol monomers (Adler, 1977).

The combination of monomeric radicals through only β-O-4, α-O-4 and β-5 coupling would lead to the formation of a dilignol. The dilignols could subsequently undergo further endwise polymerization with one another or a new oxidized monolignol.

Structure of lignin

Due to the complex nature of lignin, its chemical structure remains unresolved after many years of study. However, advances in crystallography and structural elucidation studies have improved the identification of lignin molecules (Liu, 2012). Lignin structure is heterogeneous, dimensional and irregular. Its structure is branched and optically inactive organic polymer.

The lignin molecule is a product of high number of polymerization reactions and this yield a highly-branched, interlocking networked polymer. Figure 4 is a schematic representation of a softwood lignin proposed by Adler (1977).

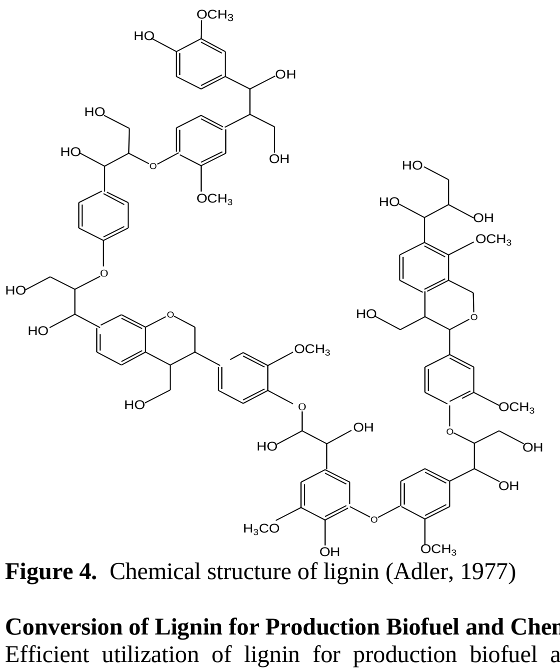


Figure 4. Chemical structure of lignin (Adler, 1977)

Conversion of Lignin for Production Biofuel and Chemicals

Efficient utilization of lignin for production biofuel and chemicals is greatly hampered by its recalcitrance (Roberts, 2006). Depolymerisation of lignin can generally be categorized into three broad spectrums: physical, chemical and biological depolymerisation for chemical production (Figure 5). The physical deploymerisation process involves: pyrolysis, hydrolysis, hydrogenolysis and gasification (Clark and Deswarte, 2015). Generally, chemical depolymerization of lignin can be carried out according to different chemicals applied in the depolymerization process, which includes: acid/base-catalyzed, metallic catalyzed, ionic liquids-assisted and supercritical fluids-assisted lignin depolymerizations (Ralph and Baucher, 2003)

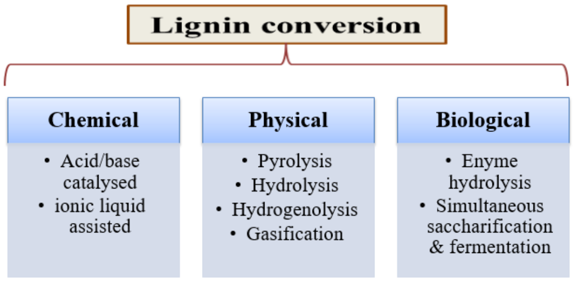


Figure 5. Methods for lignin conversion

According to The International Lignin Institute, Switzerland, there are four broad categories in which the applications and products derivable from lignin can be classified: multi-polarity products, Agriculture applications, high-purity value products and materials (www.ili-lignin.com). Table 1 shows a summary of products and the applications of lignin under the above mentioned categories.

Table 1: Applications and Products derivable form lignin (www.ili-lignin.com)

Multi-polarity	Agriculture	High-purity value	Materials
Ceramics	Soil rehabilitation	Antioxidants	Polyurethanes
Tiles	Granulation	Antibiotics	Particle boards
Dyes	Fertilizer	HIV Inhibitors	Epoxides
Electrolytes	Soil stabilization	Growth stimulators	Polyesters
Wax	Pelletizing	Biofuels	Carbon fibres
Grinding aids	Insecticide	Foam stabilizer	Biodegradables
Cements	Manure treatment	Binder	Activated carbons
Water softening	Soil stabilization	Tanning agents	Paper bounding
Dust control	Artificial fertilizer	Enzymes	Phenolic resins
Metal cleaners	Controlled fertilizer release	Absorbent	Carbon sieves

Bioconversion of Lignin

The biological conversion of lignin involves the utilization of living organisms or enzymes to catalyze the conversion of biomass into specialty and commodity chemicals (Fig. 6).

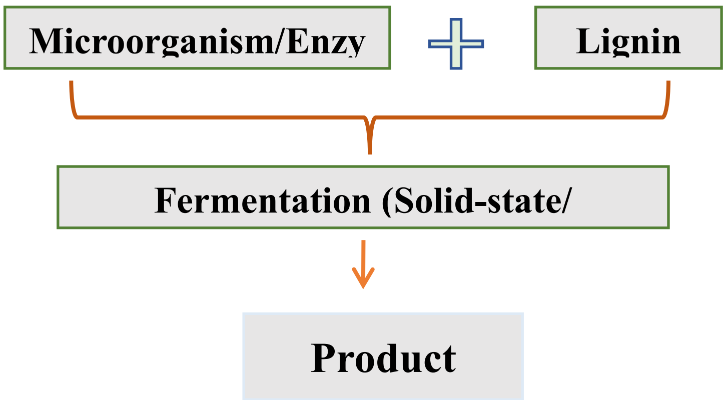


Figure 6. Schematic representation of lignin biological conversion

Bioconversion has a unique advantage due to its flexibility when compared to other methods of conversion. It also provides the pathway to obtaining numerous industrial products. (Dale, 2003). The utilization of physical and chemical processes for lignin conversion involves high temperatures and pressures, whereas, biological conversion operates under mild conditions. The advantages of this conversion over other techniques include: low energy input, mild operation conditions, high yield of products, cheap starting materials and cost-effective production.

Fermentation is one of the primordial methods of food transformation and chemical production. This technique has advanced with biotechnology for biological transformation of bio-materials. Fermentation has been in use for centuries in preserving and processing food and beverages. It is only in the last several decades ago due to current advancements in biotechnology, that it has been used to bring to market a wide variety of fermentation-based obtainable from agricultural waste and materials include industrial chemicals, organic acids and enzymes, biofuels and biogas, and pharmaceuticals.

Some commercial bulk chemicals, such as ethanol, lactic acid, citric acid, acetone, and butanol, have been produced via yeast, fungal and bacterial fermentation processes (Dhillon et al., 2011; Chen, 2013 and Mitchell et al., 2000). Advances in utilization of biocatalysts has enabled the transformation of renewable bioresources into biochemicals. However, not much of desired chemicals could be produced via fermentation as a result of specificity in microorganism metabolic pathways. (Danner and Braun, 1999). With advances in genetic engineering, modification of microorganisms to perform specified metabolic functions is now possible (Zha et al 2004). Recombinant DNA technology, also provides for genetic manipulations of organisms to be cloned for specialized biochemical production (Danner and Braun, 1999). Therefore, it is important to explore these technological advances to produce recombinant strains that can efficiently utilize all components of lignocellulosic biomass (Chen and He, 2012). Currently, research efforts are ongoing to isolate, identify, characterise, and even tailor microorganisms and enzymes in order to better utilize renewable resources to produce structurally diverse and complex chemicals. However, problems such as capital cost, pretreatment, low yield of products in innate organism and downstream recovery of the products still bedevils the biotransformation process (Danner and Braun, 1999). Further research and considerable investment is required to make biotransformation processes highly efficient and rewarding (Dodds and Gross, 2007). Pretreatments can be carried out by various means to breakdown the recalcitrant lignocellulosic structures to obtain maximum efficiency (Chen 2013; Chen and He, 2012; Brodeur et al, 2011). The well-arranged three-dimensional structure of lignocellulosic wastes serves as an impediment to its efficient hydrolysis and subsequent conversion of sugar derived to various important products. This also depends upon various other factors, such as crystalline structure of cellulose, amount and nature of lignin present, and production of various inhibitory compounds during hydrolysis (Chen and He, 2012; Brodeur et al., 2011; Dodds and Gross, 2007; Chen and Liying, 2007). Lignin residues obtained from such hydrolyisis often serve as fuel in some combustion engines thereby reducing the effects of greenhouse gas emissions from fossil fuels (Kaur et al., 2013).

High-Value Chemical Derivatives from Lignin Bioconversion

Currently, research efforts are ongoing to isolate, identify, characterise, and even tailor microorganisms and enzymes in order to better utilize renewable resources to produce structurally diverse and complex chemicals. Although bioconversion provides avenue for production of biochemical, the biotransformation technologies still suffers some impediment in upstream and downstream processes. The capital costs related to energy requirements, such as pretreatment, sterilisation, production, agitation, aeration, temperature control, and finally recovery of target products from aqueous systems with low product concentration, result in high-cost processes (Dodds and Gross.2007). Further, considerable investment is required to make processes highly efficient and continuous (Danner Braun, 1999). The drive to develop bio-based economy from the conversion of lignin provides lots of research opportunities whose results could lead to production of important biochemicals. Biological conversion also known as biotransformation is well defined process with fermentation and anaerobic digestion as the key methods utilized for converting lingo-cellulosic materials. The lignin residues could be used as fuel for the energy required and even providing surplus energy, resulting in significantly improved energy balances and resulting potential reductions in greenhouse gas emissions. Generally, the production of high-value biochemicals from lignin derivatives are regarded as safe products and even their uses in food and beverages (Xu et al., 2007). Converting lignocellulosic materials provides ample opportunity to generate lots of raw materials and make them cheaply available for production of various industrial chemicals and products.

Other few examples of chemicals obtainable from lignin conversion include, Biofuels (Liu and Cheng 2010; Wang and Liu, 2009), Industrial chemicals and enzymes such as; cellulose (Vu et al.,2011), Succinic acid (Lee et al., 2022), Lactic acid (Huang et al., 2005), Lignolytic enzymes (Szabo et al., 2015), Antibiotics, (Asagbra et al., 2005; Barrios-Gonzalez and Mejia, 1996) and Antioxidants (Knoblich et al., 2005; Ajila et al., 2011).

Conclusion

The current problem faced by production of most high-value chemicals from fossil fuels poses a major challenge due to climate change and fossil-resource depletion. Thus, there is an increasing demand for sustainable production of bio-based platform chemicals using lignin contained biomass as substrates for fermentation by microorganisms. From time immemorial, microbes have shown great potentials for a broad range of chemical products with high market value. Improved molecular biology and genetics have likewise contributed immensely into the development of microbial strains with higher ability to produce desired chemicals. The ability of researchers to manipulate the genetic systems and re-engineering metabolic pathways provide an ever-growing design space for the production of chemicals of interest. Likewise, the development of numerous pretreatment technologies has greatly encouraged the efficiency of the downstream process of microbial production of high-value chemical and improved output. All these put together could act as impetus to the use of renewable, inexpensive, and most readily lignin and lignocellulosic wastes thus reducing the production cost of biopolymer production process and will attract more the industries.

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ANTIFUNGAL POTENTIALS OF STEM EXTRACTS OF *EUPHORBIA HIRTA* AGAINST WHITE ROT FUNGI IN CEIBA *PENTANDRA* WOOD

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Abstract
The susceptibility of wood to deterioration from different organisms and longtime effects on global economic is enormous. One important aspect of alternative preservatives is bio-preservatives plants in which locally available plants or its parts can be used which are economically viable and environmentally friendly. This research was undertaken to establish the potency of the extracts from *Euphorbia hirta* species on strains of white rot fungi (*Pleurotus ostreatus*) on *Ceiba pentandra* wood for percentage weight loss. The test samples then inoculated using white rot fungi (*pleurotus ostreatus*), then, it was exposed to a susceptibility test for 12 weeks using three extraction duration (8, 16 and 24 hours) of aqueous extracts of stems that were individually steeped in (boiled, un-boiled, and ethanol) extract of *Euphorbia hirta.* A 3×3×6 factorial in a *complete randomised block design* was adopted for the experiment. The *obtained data were subjected to analysis of variance (ANOVA). DMRT was used to determine the significance of the treatment means at* α 0.05. *The findings indicated that* Un-boiled *aqueous extract* had the highest retention (2.71 kg/m^3), and lowest weight loss (2.32%), It also, *exhibited the highest inhibitory potency against white rot fungi,* followed by boiled extract (1.18 kg/m^3) and ethanol extract (1.30 kg/m^3) after the six weeks of inoculation. Therefore, the study has established that the stem extract of *Euphorbia hirta* has antifungal activities against white rot fungi isolates and could be a suitable bio-preservative for the control of fungi attack in wood.

Keywords: *Ceiba pentandra,* white rot fungi, *Euphorbia hirta*, weight loss, *Pleurotus ostreatus*

Introduction

Wood is the hard, fibrous biological substance found beneath bark in the stems and branches of trees and shrubs which is renewable and biodegradable. Wood is a renewable natural resource. It is widely used in our daily lives and economy, in wood-frame homes and furniture, newspapers, books, and magazines, railroad ties, fences, posts, and poles, textile textiles, and organic compounds. (Bandana and Bhupender, 2018). Approximately 50% of wood's elements are carbon, 6% are hydrogen, 44% are oxygen, and numerous metal ions are in trace quantities (Rowell, 2013). Wood as biological materials, proned to attacked by bio-deteriorating agents such as bacteria, fungi and termites is pronounced. Wood extractive have been found to be effective against fungi and insect damage (Schultz and Nicholas, 2002, Teaca *et al*, 2019). Due to the high extractive content in the heartwood and presence of phenolic compounds, most of the attack on wood is usually limited to the sapwood. As such, heartwood has greater deteriorating resistance than sapwood (Bandana and Bhupender, 2018). The hemicelluloses are principally in charge of moisture sorption, but the available cellulose, noncrystalline cellulose, lignin, as well as surface of crystalline cellulose are also important (Rowell *et al.,* 2008). Fungal attack on wood mainly pronounced in outdoor wooden structures. It reduces wood physical, mechanical and aesthetic properties and expressively reduces its service life (Magdalena, 2020). Unfriendly ecosystem substances used as chemical preservatives have been prohibited due to environmental restrictions and thus, there is a search for alternative techniques which can extend wood service life, and at the same time less harmful to the environment and man (Faruwa *et al.,* 2015).

Euphorbia hirta *commonly known as asthma weed or milk weed is widely distributed in the temperate or tropical parts of India, Asia, Australia, and Africa. It grows in dry and wet land, and mainly found in lowland, rice paddy fields, refuse places, most gardens and often in the roadsides (Ghosh,* et.al. *2018, 2019,* Manorma, et.al.*2011 and* Abdul et. al. *2007). According to Essiett* et al. *(2013); Asha* et al. *(2014), (2015), the phytochemical analysis of leaf extract from E. hirta reveals the presence of carbohydrates, reducing sugars, terpenoids, alkaloids, steroids, tannins, proteins, fats, oils, mucilages, glycoside, saponin, coumarin, and anthroquinones. These substances were also isolated from the aerial parts of the plants. Again, according to (Huang* et al. *2012, Shih* et al. *2012, Kausar* et al. *2016; Chen, 1991 and Pioro* et al. *2011), these plants also include alkaloids, saponins, protein, amino acids, and minerals.*

Ethanol extract of Euphorbia hirta also showed marked anti-microbial properties against the growth of Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa, and Bacillus subtilis. Based on the studies that compared the antibacterial capability of the methanol, hexane, and water extract in Escherichia coli, Klebsiella pneumoniae by (Akinrinmade,*et.al* 2010, Michael, *et.al.*, 2010 and Ogbulie, *et.al.*, 2007). Meanwhile, it was found that aqueous decoctions provided more anti-microbial properties than organic solvent decoctions and the leaves extract was found to regulate the growth of all examined microbes with large proportion of inhibition. Okanlawon and Olaoye (2020) also reported the successful utilization of biological products for preserving wood against bio-deteriorating agents. Hence, plant extracts are found to be economical, environmentally friendly, and very effective against organisms that degrade wood. Therefore, this study was carried out to authenticate the anti-fungal potency of *Euphorbia hirta* extracts as potentials preservative in perishable wood species (*Ceiba pentadra).*

Materials and Methods

Aqueous Extractions procedure of *Euphorbia hirta:* The stems of *E. hirta* harvested within the University of Ibadan, Nigeria and identified at the Botany Department of the University were used for this study. The crude extraction process was done through mechanical extraction process. The stems were weighed, cut into smaller sizes and macerated following the procedure by (Adedapo *et al.,* 2004). The macerated materials were subsequently shaken and filtered using Whatman filter paper (0.037mm) directly placed on top of funnel to obtain the aqueous crude extract, and it was later measured using a measuring cylinder to obtain the volume. The total volume of the total aqueous crude extract obtained for the plant was divided into three equals portions where one portion served as the un-boiled extract, another portion was boiled at 100 ^{O}C for 2 hours so as to be used for the boiled extract of *E hirta* and the third portion was used for the ethanol extract.

$$\%\, stem\, extract = \frac{volume\ collected}{weight\ of\ initial\ material} \times 100\% \qquad \text{………………………………………. (1)}$$

Ethanol extractions procedure of *Euphorbia hirta:* One hundred gram (100g) of *Euphorbia hirta* was dissolved into 500ml of 80% ethanol and was kept for 72 hours at room temperature and shaken to get a better extraction. Then the extract was filtered with cotton wool. The preparations of dilutions of crude extract for anti-fungal assay was adopted following Akujobi *et al*. (2004) and Esimone *et al*. (1998) methods.

Preparation of wood test sample: *Ceiba pentandrapentandra* wood (was chosen because it has been classified as a perishable timber) was selected for this study and because of it is susceptible to biodeterioration. *Ceiba pentandrapentandra* tree was harvested from Amina way within the premises of University of Ibadan campus, and were converted into planks. A cntre plank was obtained and further converted into square block sizes of (2.0 × 2.0 × 2.0) cm following the method of Faruwa *et al*. (2015). Prepared samples were oven dried at 103 ^{O}C until they attained a constant weight. The weights obtained were recorded as initial dry weight for each of the test sample. The 24 block of wood samples were then arranged into different jars based on the three different soaking periods 8, 16 and 24 hours and extract type (fresh extract, boiled extract and extract prepared with ethanol given total block samples, respectively.

Treatment of test block: Soaking of the wooden blocks using a non-pressure method was adopted. The wooden blocks of 2.0 cm × 2.0 cm × 2.0 cm prepared were soaked in the crude extract of un-boiled, boiled and ethanol-made *Euphorbia hirta* for 8, 16 and 24 hours respectively. After the treatment, the blocks were then conditioned for 72 hours and then reweighed to determine the retention of the extract.

$$Retention\ (Kg/m^3) = \frac{10^6 \times weight\ of\ preservative\ absorbed}{1000\ \times volume\ of\ wood \times 100} \qquad \text{………………………….(2)}$$

Procedures for culturing fungi: Cultured white rot fungus was obtained from pathology section of Forestry Research Institute of Nigeria. The wood samples were then inoculated with the fungus (*Pleurotus osteatus)* at room temperature (27± 2 ^{O}C) in the laboratory.

Infestation of test sample: The block samples placed in the bottle were inoculated with fungi. Inoculation was made such that the entire wooden blocks in different jars were in contact with the mycelium of the test fungus and not in contact with the medium. This is done to prevent some preservatives escaping or leaching out. The bottles were then incubated at 27 ± 2 ^{O}C for 2, 4, 6, 8, 10 and 12 weeks. After incubation, the block samples were removed from the bottles for cleaning of mycelium that may adhere to its surface and weighed to determine the weight gain or moisture absorbed. The weighed samples were thereafter oven dried for 18 hours at 103 ^{O}C to constant dry weight (Sarker *et al.,* 2006).

Moisture content after incubation:

At the conclusion of each incubation period, the moisture absorbed by each wood sample was determined using weighing balance. The blocks were measured for their wet weight before being dried in an oven for 18 hours at 103 ^{O}C. Final weighing of the test wood block was done after test samples were allowed to properly cool.The moisture content was calculated thus:

$$\%\, Moisture\ content = \frac{Wet\ weight - Oven\ Dried\ Weight}{Oven\ Dried\ Weight} \text{………….} (3)$$

Weight Loss Determination: At the end of each incubation period, wood test sample was carefully removed from each bottle, oven dried and reweighed to determine weight loss after 2-week interval for 12 weeks. Weight loss method was used to evaluate the decay resistance of the wood species against *Pleurotus ostreatus.*

$$\%\, weight\ loss = \frac{initial\ dry\ weight - final\ dry\ weight}{initial\ weight} \qquad \text{……….(4)}$$

Statistical analysis

The data obtained were analyzed using the analysis of variance (ANOVA) and a 3×3×6 factorial in a *complete randomized block design* was adopted. DMRT was used to determine the separation of means at *α0.05*.

Where; = test blocks (*Ceiba pentandrapentandra)* and fungi (*Pleurotus ostreatus)*

Factor A: 3 = extract types (boiled, unboiled, and ethanol)

Factor B: 3 = period of soaking (8, 16 and 24 hours)

Factor C: 6 = weeks of inoculation (2, 4, 6, 8, 10 and 12).

Results and Discussion

Retention Rate of Extracts in *C. pentandrapentandra* wood

The descriptive analysis of extract type retention is presented in Table 1. The un-boiled extracts of *Euphorbia hirta* showed the highest retention in *Ceiba pentandrapentandra* wood samples after a 24-hour soaking period, with a mean value of 2.7128kg/m^3. It was followed by the boiling extracts after a 16-hour soaking time with a mean value of 1.4310 kg/m^3. The ethanol extract had mean (1.1572 kg/m^3) and the boiling extract had a mean (1.1371 kg/m^3), hence, both had the lowest retention after an 8-hour soaking time.

Table 1: Descriptive analysis of retention rate of *Euphorbia hirta* extract by *Ceiba pentandra*

Treatment	Time (Hours)	Mean (kg/m^3)
Boiled	8	1.1371±0.6^b
	16	1.4123±0.8^a
	24	1.1845±0.1^b
Un-boiled	8	1.1612±0.1^b
	16	1.4310±0.8^b
	24	2.7128±0.6^a
Ethanol extract	8	1.1572±0.1^b
	16	1.1880±0.6^b
	24	1.3030±0.7^a

*means with the same alphabet are not significantly different from each other ($p < 0.05$).

Table 2 shows the ANOVA for the retention of boiled extract and it reveals that there was no significant difference ($p > 0.05$) in the retention of boiled and ethanol extract of *Euphorbia hirta* after subjecting it to different soaking period (8, 16 and 24 hours) and this indicates that at 8 hours soaking period, *Ceiba pentandra* wood samples would still retain sufficient preservative chemical of the extract as much as that of 16 and 24 hours soaking period. But for un-boiled extract, there was significant difference ($p < 0.05$) with respect to the different soaking period.

Table 2: Analysis of variance of retention rate of *Euphorbia hirta* extract by *Ceiba pentandra*

Source of variation	Sum of square	Df	Mean square	F	Sig
Soaking period (Boiled Extract)	1.039	2	0.519	1.572	0.215^{ns}
Error	22.792	69	0.330		
Total	23.831	71			
Soaking period (Un-boiled extract)	32.98	2	16.492	48.890	0.215*
Error	23.276	69	0.337		
Total	56.260	71			
Soaking Period (Ethanol)	0.283	2	0.142	0.434	0.650^{ns}
Error	22.558	69	0.327		
Total	22.842	71			

Note: ^{ns} insignificant, * significant

Percentage Weight Loss: The effect of extract types of *Euphorbia hirta* on weight loss of *Ceiba pentandra* after exposure to the fungi (*Pleurotus ostreatus)* is presented in Table 3. The lowest weight loss was observed in un-boiled extract (2.3%), followed by boiled extract (3.6%) and ethanol extract (3.8%) while the highest weight loss was observed in the control having (7.4%)

Table3: Potency of extraction type on the percentage weight loss

Types of extract	Mean value (%)
Boiled	3.6146
Un-boiled	2.3181
Ethanol	3.8190

Control	7.4376

Note: means with the same alphabets are not significantly different from each other

The result presented in Table 4 showed that, there was a significant difference ($p < 0.05$) in the percentage weight loss after 12 weeks of exposure of *Ceiba pentandra* wood samples to *Pleurotus ostreatus* (white rot basidiomycetes) as well as type of extract used. Also, boiled, un-boiled and ethanol extract of *Euphorbia hirta* has a significant effect on *Pleurotus ostreatus* with reference to weight loss on wood sample when compared to control after 12 weeks of exposure. Significant differences also exist with respect to the soaking period; 8, 16, and 24 hours. But, no significant difference ($p > 0.05$) in weight loss was obtained among the interaction effect weeks and extract types, weeks and soaking periods, Extract types and Soaking period as well as Weeks, Extract and Soaking period.

Table 4: Analysis of variance for treatment effects on percentage weight loss of samples

Source	Sum of square	df	MSS	F	Sig
Inoculation Weeks	45.233	6	14.564	5.491	0.02*
Soaking Period	0.311	2	0.155	8.990	0.000*
Extract Type	0.145	3	0.048	2.789	0.041*
Extract type * Soaking Period	0.270	6	0.045	2.606	0.018*
Extract type* i inoculation Weeks	88.565	10	8.857	1.230	0.275^{ns}
Weeks* Soaking period	74.278	5	14.250	1.246	0.107^{ns}
Extract type* inoculation Weeks* Soaking period	69.458	10	16.393	2.276	0.702^{ns}
Total	5.496	287			

*significant ($p>0.05$), ns- not significant ($p>0.05$)

The result of the overall weight loss difference after 12weeks of exposure of both the treated and untreated *Ceiba pentandra* wood samples to fungi infestation was presented in Table 5. At 6th week, wood samples of *Ceiba pentandra* had the lowest percentage weight loss with (2.3%) after inoculation while the 2nd week with (6.4%) has the highest percentage weight loss. More so there was no significance difference in the percentage weight loss (4.82% and 4.64%) for 8th and 12th week respectively.

Table 5: Follow up test on period of exposure (Duncan) for white rot fungi (*Pleurotus ostreatus*)

Weeks	Mean value
2	6.4942^{d}
4	6.1249^{d}
6	2.3180^{a}
8	4.8286^{b}
10	5.3140^{c}
12	4.6429^{b}

**means with the same alphabets are not significantly different from each other*

The quality of wood impregnation is being demonstrated by the quantity of the preservative that is retained in the wood. (Dong, *et al.*, 2020). The concentrations of preservatives as well as the condition under which the treatment is done such as type of preservatives as well as the duration are the primary determinant of retention. The result obtained from this study shows that the degree of retention of *Euphorbia hirta extract by Ceiba pentandra* is directly proportional to period of soaking irrespective of the extract type. But then, from the result of the analysis of variance, there is no significance difference in the period of soaking of boiled and ethanol extract on the retention by *Ceiba pentandra*. The woods that were soaked for 24 hours in each of the extract have the highest retention rate similar to what Areo *et al.* (2016) reported for *T. grandis* wood.

According to (Salami *et al.*, 2019), opine that the retention level of an extract is a function of the plant from which the extract was gotten as well as the degree of viscosity and chemical constituent of extracts with respect to their genetic make ups. Retention value can be impacted by a lot of factors which include texture, density as well as wood porosity. Penetration efficiency rate on the other hand can be determined by the particle size of the extractive (*Gupta et al., 2021)*.

The highest and lowest weight loss after 2 and 6 week inoculation respectively is similar to those reported of Adegeye *et al* (2009) and Okon-Akan *et al,* (2019) on the effect of two white rot fungi weight loss of wood samples. This may be as a result of the reduction in the quantity of the fungi due to the potency of the extract. Meanwhile, the untreated wood (control) had the highest weight loss. This is in accordance with the report of Okon-Akan *et al.* (2019), Okanlawon and Olaoye, (2020) and Ogutuga *et al*. (2020). This shows that *Euphorbia hirta* extract is potent in protecting the wood against the attack of the fungi. In another research, Salami *et al*. (2019), and Yayaha *et al.* (2021) observed that plant extract has been recorded to have success as an alternative for wood preservatives to chemical preservatives which are harmful to human and the environment.

Conclusion

Based on the findings of this research, both boiled, un-boiled and ethanol extract of *Euphorbia hirta* has a significant effect on *Pleurotus ostreatus* with reference to weight loss on wood sample when compared with control after 12 weeks of exposure. This shows that the extract of *Euphorbia hirta* has a great potential to be used as a preservative for wood against fungi attack. Hence, it is recommended that more research should still be carried out by scientist on other plants as well as other natural source of preservatives in other to harness the potential of this eco-friendly resource. This will help in reducing the adverse effect of chemical preservatives and thereby makes the world more habitable for both fauna and flora.

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PROSPECT OF SAWMILL WOOD WASTES UTILIZATION AS HOUSEHOLD ENERGY SOURCE IN ISHIAGU, IVO LOCAL GOVERNMENT AREA OF EBONYI STATE.

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ABSTRACT

Prospects of Sawmill wood wastes utilization as household energy source in Ishiagu, Ebonyi State, Nigeria was undertaken in the year 2021 with a view to identify the importance of sawmill wood wastes utilization to rural livelihood. Data were collected through the use of structured questionnaires supplemented with oral interview and observation via on-the-spot assessment. A multi-stage sampling technique was employed for this research, the first stage was the purposive selection of Ishiagu Town. The second stage involved total selection of all the communities in the town while the third stage was random selection of twenty (20) households from each community. The A total of 200 Questionnaires were randomly administered on in the study area. Data generated was analyzed using descriptive statistics. The result showed that 56% and 23.5% of the respondent use sawmill wood wastes for cooking and for processing of farm produce respectively. It was observed in the study that 37.5 % of the household spend an average of ₦450 on sawmill wood wastes utilization weekly while 4.5% of them spend above ₦600 within the same period. The significance of the results found in this study is that effective usage of the sawmill wood residues should be encouraged so as to reduce wastage. This may also boost the local economy of the rural dwellers.

Key words: *Household energy, Ishiagu, Sawmill, Wood utilization, Wood wastes.*

INTRODUCTION

Forest plays integral role in supporting rural livelihoods especially in developing countries because it is blessed with wide range of resources. The performance of the forest industry in Nigeria has been evaluated by various authors, among which are Kukogho *et al* (2011), Ogunwusi *et al* (2013), Larinde (2010) and Ogunsanwo (2010). From the different analyses carried out, it can be deduced that the forest industry has contributed significantly to local and international trade. The wood industry can be divided into formal and informal sectors, both have witnessed serious anomalies dictated by sub-optimal deployment of raw materials. The formal sector includes the organized wood-based industries such as the pulp and paper mills, sawmills, plymills, particles board mills and furniture factories. The informal enterprises are the small wood-based enterprises operating without formal corporate entity and include enterprises that engaged in production of firewood, charcoal, chewing sticks, sculptured wood and in some cases, artisanal cabinet markers and lumber converters. The informal sector which is often downplayed in reporting activities in the wood industry dominate the industry in terms of number, and is involved in activities which directly and indirectly influenced trade volume in the formal sector (Ogunsanwo, 2010).

Sawmill wood wastes are residues from log conversions and lumber processing. They include saw dusts, slabs, flakes, off cuts, barks, wanes, planner shavings, and wood rejects. Wood wastes have been broadly classified into avoidable and unavoidable wastes (Aina, 2006). While the latter (unavoidable waste) are majorly residues from sawmills, the former (avoidable waste) results from lack of precision in harvesting and processing of logs. Other causes of waste may be related to the conditions of the band mill used. Wood wastes are often used in making briquette, poultry beds, and charcoal. This represents a relatively insignificant utilization of generated waste (Omoniyi et al., 2013). Better utilization of our forest resources is inevitable because of decreasing quality timber on a declining land base (Omoniyi et al., 2013). The enormous waste generated during processing can be utilized in wood-based composites industries, or harnessed towards the co-generation of power and heat. In contemporary civil engineering, mortar/concrete can be reinforced with wood waste to enhance the properties of the basic material (Babalola *et al.* 2011).

Large volumes of wood waste are generated annually from timber processing industries in Nigeria. It *was* estimated that about 1.72million m^3 of wood waste generated in Nigeria in 1988 and 3.87 million m^3 in 1993 (Badejo, 2001). Dosunmu and Ajayi (2002) reported that about 294,798 tons of wood waste is generated yearly in Lagos. Aina (2006) estimated that about 2288 m^3 is generated daily in Abeokuta. However, as generated *wood waste increases beyond its present utilization, it therefore becomes important to find safer means of reducing and disposing wood waste. These means should conform to environmental regulations and one of the best ways of reducing wood waste is improved utilization of avoidable wood waste.* The continued increase in the global consumption of industrial wood products would deplete forest and woodland resources and experts are concerned about the additional pressure this will put on the world's forests. (FAO 2010). This additional pressure on the world's forests calls for sustainable utilization and efficient usage of wood in its production. Sustainable development is a key issue for governmental bodies, industries, and other stakeholders, particularly in the timber production sector in improving the efficiency of primary wood utilization, which could help to reduce the rate of harvesting and hence a reduction in the annual allowable cut and to meet the increasing demand for wood without further impacting the world's forests. Better recovery also provides a high volume of secondary resources (offcuts, broken timber, and slabs) for recycling into new advanced materials (Asamoah, *et al*., 2020). This will further enhance the environmental profile of wood.

MATERIALS AND METHODS

Study Area

This project was carried out at Ishiagu, Ivo Local Government of Ebonyi State in 2020. Ishiagu is located at longitude $07^0 46$'E and Latitude $05^0 45$'N with a mean annual temperature of 29^0C and mean annual rainfall of 1350mm. The area lies within derived savannah vegetation zone of South Eastern Nigeria with grassland and shrub tree combined together. There are two reported distinct seasons, the dry season which spans November to March, a times extend to April and the rainy season which spans April to October (Nwite *et al*., 2008). It is made up of ten (10) autonomous communities: Amaeke, Amaeze, Amagu, Amata, Ihie, Okue, Amaonye, Amaokwe, Ngwogwo, Ogwor. All the communities were selected for this research work.

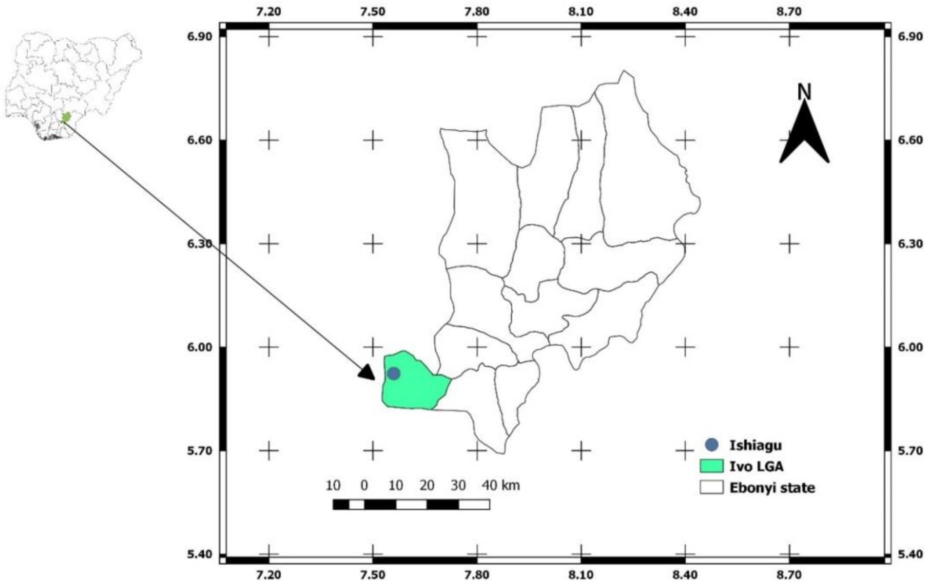

Figure 1: Map of Ishiagu community

Data Collection and Analysis

A multi-stage sampling technique was employed in the selection of the respondents for this study. The first stage is the purposive selection of Ishiagu town. The second stage involved total selection of all the communities in the town. The third stage was random selection of twenty (20) households from each community. In all, a total of 200 respondents were therefore sampled and used for the analysis. This study employed descriptive statistics such as percentages and frequency distribution. The parameters surveyed include demographic size of the household, household usage of sawmill wood wastes, weekly expense, choices and types of sawmill wood wastes used by household in Ishiagu, Ivo local Government area of Ebonyi state.

RESULTS AND DISCUSSION

Demographic Data of Respondents

The results of the demographic data of respondents are presented in Table 1. Most of the respondents are in their active ages, as 43.5% are between the ages of 45- 60 years, while 37% are between the ages of 31-45 years. In terms of household size, the average family sizes of the respondents was found to be six persons (47%) within the communities. Respondent’s literacy level revealed that 1.5% as having had tertiary education, 50.5% had secondary school certification while 30.5% of the respondents had primary school leaving certificate and 17.5% had no formal education. Also, 61.5% of the respondents were female while 38.5% were males, an indication that majority of those using sawmill wood waste as household energy were females. Marital status distribution showed that 22.5% of were single, 67% married, 6 % divorced while 4.5% were widowed.

Table 1: Demographic Data of the Respondents

Ages	Frequency	Percentage
18-30	31	15.5
31-45	74	37
45-60	87	43.5
60 and Above	8	4
Total	200	100
Family Sizes		
1-4 persons	27	13.5

5-8 persons	68	34
9-12 persons	94	47
12 and Above	11	5.5
Total	200	100
Level of Education		
Non-formal	35	17.5
Primary Education	61	30.5
Secondary Education	101	50.5
Tertiary Education	3	1.5
Total	200	100
Sex		
Female	123	61.5
Male	77	38.5
Total	200	100
Marital Status		
Single	45	22.5
Married	134	67
Divorced	12	6
Widowed	9	4.5
Total	200	100

Utilization of major types of Sawmill wood waste

The results showed that timber offcuts were the most common and frequently used sawmill wood wastes as attested to by 42.5% of the respondents. This was followed by wood slabs 21.5%. The utilization of the sawdust was 16.5% of the respondent while wood barks was used by 14.5% of them. The least utilized sawmill wood wastes were the planner shavings by 5.0% of the respondent. Table 2. The high preference of the timber offcuts and wood slabs by households could be traced to its relatively large size and thus its economic use. It also has a relative high combustion rate and provides satisfactory heat energy to its users

Table 2: Major types of sawmill wood wastes utilized.

Variables	Frequency	Percentage
Sawdust	33	16.5
Slabs	43	21.5
Offcut	85	42.5
Barks	29	14.5
Planner shavings	10	5
Total	200	100

Table 3: Reasons for choices of Sawmill wood wastes by the Respondent.

Variables	Frequency	Percentage
Readily available	74	37.0
Relative cheap	63	31.5
User-Friendly	39	19.5
Economics of use	24	12.0
Total	200	100

The respondents also gave reasons for the high preference of sawmill wood wastes to other sources of household energy Table 3 to include that it was readily available (37.0%), relative cheapness (31.50%), user-friendly (19.5%), economics of use (12.0%).

Uses and Quantity of sawmill wood wastes for energy utilization

Majority of the respondent (56%) use sawmill wood wastes for cooking, 23.5% for processing of farm produce, 16.0% for processing forest fruits while 4.5% uses it to cure tobacco as presented in Table 4. This is an indication that a high percentage of sawmill wood wastes is utilized for cooking purposes. This result agrees with the earlier submission of Sodimu *et al* (2003), who observed that majority of households in Nigeria especially among the rural dwellers, depends greatly on fuelwood as their main source of cooking energy.

Table 4: Household usage of Sawmill wood wastes.

Uses of Sawmill Wood Wastes	Frequency	Percentage
Cooking	112	56
Processing of Farm produces	47	23.5
Processing of Forest fruits	32	16
Curing of tobacco	9	4.5
Total	**200**	**100**

Table 5: Weekly usage of Sawmill wood wastes.

Quantity (Kg)	Frequency	Percentage (%)
1 - 6	19	9.5
7 - 12	48	24
13-18	93	46.5
19-24	24	12
> 24	16	8
Total	**200**	**100**

Weekly expense on Sawmill wood wastes utilization.

The weekly expense on sawmill wood wastes utilization (Table 6) showed that some of the respondent 37.5% spend between ₦400 and ₦500 on sawmill wood wastes utilization weekly, 27.5% spend between ₦500-₦600, 18.5% spend between ₦300 - ₦400 while 12% spend between ₦200 - ₦300 weekly. However, 4.5% of the respondent spend above ₦600 weekly through sawmill wood wastes utilization. The variations recorded in the amount spent on sawmill wood waste utilization depends on some socio-economic variables which includes size of the household, level of income, category of food consumed and reason for usage.

The result presented in Table 5 showed the weekly usage range in the study area. 46.5% of the respondent use between 13-18kg, 24% use 7-12kg, 12% use 19-24kg while about 9.5% utilizes 1-6kg of sawmill wood wastes weekly. However, a small percent of them (8%) use above 24kg of sawmill wood wastes weekly in meeting their household energy commitment. The high percentage of the respondents utilizing 13-18kg of sawmill wood waste weekly is due to the number of persons per household, since majority of the products are utilized as domestic energy source for cooking purposes. This observation agrees with the earlier report by Izekor and Osayimwen (2010) that most household depends largely on firewood as their main source of energy for cooking and other domestic energy needs.

Table 6: Weekly expense on Sawmill wood wastes.

Amount (Naira)	Frequency	Percentage
200- 300	24	12
300-400	37	18.5
400-500	75	37.5
500-600	55	27.5
>600	9	4.5
Total	**200**	**100**

CONCLUSION

The result of the study has shown that the usage of sawmill wood wastes adds considerably to household energy needs of people of Ishiagu. The study also revealed the different types of wood wastes produced from sawmills and its mode of utilization in meeting their various domestic energy needs. The amount of sawmill wood wastes utilized by household size, level of income and reason for usage are due to the widespread socio–economic characteristics of the sampled respondents in the study area. It is therefore imperative for member of the forestry professional and other relevant government agencies to promote policies and strategies aimed at increasing the usage of sawmill wood wastes in the provision of energy for both household and industrial use. Utilization of sawmill woodwastes will reduce pressure on the forest for fuelwood and thereby improve conservation.

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BREAKING SEED COAT DORMANCY OF *Terminalia mantaly* H. Perrier SEEDS

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ABSTRACT
Terminalia mantaly is a popular amenity tree that is commonly used to beautify the environment and provide shade. The seeds exhibit seed coat dormancy especially when it is allowed to dry before sowing thereby hindering rapid and synchronous germination. To break the seed coat dormancy, the seeds were subjected to biological treatment using termites as the biological agent. Viable seeds of Terminalia mantaly were subjected to 4 treatments, namely: Termite digestion for 5 days (T1), 7 days (T2), 9 days (T3), 12 days (T4) and control (undigested seeds) (T5). Fifty (50) seeds were collected from each treatment and sown in germination trays that were filled with sterilized river sharp sands. The experiment was arranged in a completely randomized design (CRD) and replicated 4 times. The germination trays were watered twice daily (morning and evening) while the experiment lasted. The results show that the duration (days) of termite digestion significantly affects germination percentage and germination speed. Seeds that were digested for 7 days (T2) recorded the highest germination percentage (82.5%), while the lowest germination percentage (13.75±4.79) was recorded by undigested seeds (control). Seeds digested for 5 days (T1) had a faster germination speed (7.15±0.09), while the control had the lowest (0.51±0.05). Termites' digestion successfully breaks seed coat dormancy of Terminalia mantaly, however, for a high germination rate, digestion for 7 days is recommended.

Keywords: *Terminalia mantaly, Madagascar almond, seed coat dormancy, germination percentage, termites.*

INTRODUCTION

Germination is the most critical stage of seed-bearing plants (Foley and Fennimore 1998). Seeds germinate after being subjected to favourable environmental factors such as water, light, temperature and oxygen. However, when seeds failed to germinate after being subjected to these favourable environmental conditions, they are regarded as dormant (Baskin and Baskin, 2000). Many seeds plants exhibit some form of dormancy, according to Baskin and Baskin (2000), except for tropical rainforest and tropical semi-evergreen forest plants, most seed plants are dormant at maturity. Several pretreatment methods such as chemical, mechanical, biological, hormone, water etc have been used to break dormancy in seeds. These methods performed one or more of the following: stimulate embryo metabolism, increase the permeability of seeds to water and oxygen and/or reduce the mechanical resistance to the growth of the embryo (Kozlowski and Pallardy 1997).

The use of biological agents in breaking seed dormancy is not popular possibly because of the challenge faced in controlling the processes. However, this method is successful in breaking dormancy in some plant seeds. For example, seeds coat dormancy of *Acacia senegal* and *ceratonia siligua* were broken after passing through the digestive tract of goats (Goor and Barney 1976). Termite digestion has been reported to successfully break the seed coat dormancy of *Tectonia grandis* (Bryndum 1966; Sompherm 1975) and *Pterocarpus angolensis* (Groome *et al*., 1957). However, Vijayalakshmi and Renganayaki (2011) observed no significant difference between seeds of *Pterocarpus santalinus* sown without treatments (Control) and those sown after being subjected to termite digestion. The lack of significant effects between termites' digestion and undigested seeds of *Pterocarpus santalinus* seeds could be due to the high phenol content in the seeds which could inhibit termites' activities as opined by Vijayalakshmi and Renganayaki (2011).

Terminalia mantaly formerly known as *Terminalia radii is* commonly called Madagascar almond in English and it is from the family of Combretaceae. The tree is native to Madagascar, but it is now distributed in Djibouti, Eritrea, Ethiopia, Kenya, Senegal, Somalia, Tanzania, and Uganda (Orwa *et al*., 2009). In Nigeria, it is commonly called a "satellite tree" because of its crown shape and branching pattern which are in layers. It is one of the popular amenity tree species in Nigeria, it is found adorning streets and beautifying houses in many towns and cities in Nigeria. It has received wide acceptability because of its fast growth rate and beauty. *Terminalia mantaly* trees provide shade and improve the micro-climatic condition.

Freshly collected seeds of *Terminalia mantaly* germinate easily when sown; however, after storage its exhibit seed coat dormancy. This could largely be attributed to the drying of the seeds during storage thereby resulting in a hard seed coat which prevents water permeability. The duration of time it takes for the seeds to germinate when sown poses a serious challenge for its propagation sexually. Breaking the dormancy of *Terminalia mantaly* seeds will reduce the time, resources and effort used thereby promoting rapid and synchronous germination which is vital for raising seedlings in the nursery. However, there is scanty information about breaking seeds coat dormancy of the species. Although Kiamba (2011) reported enhanced germination of *Terminalia mantaly* seeds when subjected to nipping in comparison to other treatments (boiled seeds, nipped seeds, cold water soaking and sulphuric acid scarification), experience is required to be able to carry out nipping.

In this study, we explored the possibility of breaking seeds coat dormancy of *Terminalia mantaly* using biological methods. Termites were used as biological agents. This method is safe, cheap and environmentally friendly in comparison to the use of chemicals.

Figure 1. Plantation of *Terminalia mantaly* at University of Ibadan

MATERIAL AND METHODS

Experimental site

The study was carried out at the Seedlings Nursery of the Department of Forestry and Wildlife Management, Federal University Gashua, Yobe State, Nigeria. Gashua town is located between Latitude 12°51'.723"- 12°54'.723" N and longitude 11°00'.024" - 11°03'.475" E. The climate is divided into wet (June – September) and dry seasons (end of September – May). Average annual rainfall ranged between 500 to 1000 mm. The minimum temperature ranged from 23 to 28°C, while the maximum temperature ranges from 38 to 40°C (Wakawa and Suleiman 2022).

Experimental design and treatments

Matured and healthy seeds of *Terminalia mantaly* were collected beneath mother trees within the town of Gashua, Yobe State, Nigeria. The seeds were subjected to a viability test to ascertain their viability. The seeds were then divided into 5 batches of 500 seeds each, representing five treatments, namely: Termite digestion for 5 days (T1), 7 days (T2), 9 days (T3), 12 days (T4) and control (undigested seeds). Each batch of seeds was placed on a sheet of paper; this was done to stimulate easy initiation of the seeds by termite. The seeds were then placed on a termite mould located within the Federal University Gashua, Yobe State, Nigeria and allowed to stay for 5 days (T1), 7 days (T2), 9 days (T3) and 12 days (T4). The seeds were collected after being subjected to the various treatment methods and washed to remove soil particles. Fifty (50) seeds were then randomly selected from each batch and sown in a germination tray filled with sterilized river sharp sand, this was replicated 4 times. The last batch of seed was sown without termite digestion to serve as a control (T5). The experiment was arranged in a completely randomized design (CRD). The germination trays were watered twice daily (Morning and Evening) while the experiment lasted. The seeds were considered to have germinated when the plumule emerges. The experiment was terminated after germination, this was after two weeks for all the treatment. The experiment lasted for 5 weeks.

a. Termite mound b. **seeds of Terminalia during termites initiation**

Figure 2. Termite mould and seeds of Terminalia during initiation

Germination characteristics assessed

Germination percentage (GP %): GP was calculated using the formulae described below:

$$GP = \frac{Number\ of\ germinated\ seeds}{Total\ number\ of\ seeds\ sown} \times 100$$

Germination speed (GS): Maguire's (1962) equation was used to calculate GS as shown below:

$$GS = \frac{No. of\ seeds\ germinated}{Days\ of\ first\ count} + - - + \frac{No. of\ seeds\ germinated}{days\ of\ final\ count}$$

Data analysis

Germination percentage data were transformed using arcsine before being subjected to analysis of variances (ANOVA). STATISTICA version 12 package was used for the analysis of variance (P ≤0.05). Fisher's least significant difference (LSD) was used to separate means.

a. *Terminalia mantaly* seeds **b. Seedlings of *Terminalia mantaly* after germination**

Figure 3. Seeds and seedlings of *Terminalia mantaly* after germination

RESULTS AND DISCUSSION

Germination percentage

A significant difference in germination percentage was observed among treatments. Digestion of *Terminalia mantaly* seeds by termites for 7 days gave the highest germination percentage (82.5), while termite digestion for 5 days recorded 71.25 germination percentages (Table 1). This implies that termite digestion for 5 and 7 days significantly enhanced the germination percentage of *Terminalia mantaly*. The least germination percentage (13.75±4.79) was recorded by seeds sown without termite digestion (control). Our result was in agreement with that of Omokhua and Alex (2015) who observed a significant improvement in mean germination of *Tectona grandi*s seeds after termites' digestion. However, Vijayalakshmi and Renganayaki (2011) result contradicts our findings, they reported a lack of significant difference among seeds of *Pterocarpus santalinus* digested by termites and those sown without termite digestion. This contradiction may be attributed to the differences in species. Various species exhibit a different form of dormancy as such their behaviour would be expected to vary. The presence of chemical substances such as phenols in large quantity could also hinder the effects of termites on the seeds as opined by Vijayalakshmi and Renganayaki (2011) Germination percentage reduces as the days increase as can be seen from the results (Table 1). Seeds digested for 9 days recorded 43.75%, while those digested for 12 days had 15% germination. This is probably due to the damage of endosperm by the termites because of prolonged exposure. Seeds sown without termite digestion (control) had the least germination percentage. The poor germination rate recorded by undigested seeds could be an indication of dormancy thereby confirming our earlier assumption on the dormancy status of the seed.

Table 1. Germination percentage of *Terminalia mantaly* seeds subjected to termite's scarification

Treatments	GP (%)
Termites' scarification for 5 days	71.25±19.74^{a}
Termites' scarification for 7 days	82.5±14.43^{a}
Termites' scarification for 9 days	43.75±17.5^{b}
Termites' scarification for 12 days	15±4.08^{c}

Breaking seed coat dormancy of *Terminalia mantaly* H. Perrier seeds …………Wakawa *et al.*

Means carrying the same alphabet did not differ significantly p≤ 0.05 (values presented are Mean± Standard deviation)

Germination speed

The duration of termite digestion of *Terminalia mantaly* seeds significantly affected the germination speed of *Terminalia mantaly*. *Terminalia mantaly* seeds digested for 5 days germinated faster and differed significantly from all the other treatments (Table 2). This implies that digestion of *Terminalia mantaly* seeds by termites for 5 days would lead to faster germination. *Terminalia mantaly* seeds digested for 7 days had a germination speed of 3.58±0.16 and did not differ significantly with seeds digested for 9 days which recorded a germination speed of 3.44±0.06 (Table 2). Germination speed is used in combination with germination percentage to assess seedling vigour after treatments (Wakawa and Akinyele, 2017) and give us an indication of how well the seeds will perform under field conditions (Schmidt, 2000). Therefore, seeds of Terminalia mantaly digested by termites' for 5 days which had the highest germination speed would be expected to be of high vigour and do well when transplanted to the field.

Table 2. Germination speed of *Terminalia mantaly* seeds subjected to termite's scarification

Treatments	GS
Termites' scarification for 5 days	7.15±0.09[a]
Termites' scarification for 7 days	3.58±0.16[b]
Termites' scarification for 9 days	3.44±0.06[b]
Termites' scarification for 12 days	1.44±0.02[c]
No scarification (Control)	0.51±0.05[d]

Note: GS = Germination speed
Means carrying the same alphabet did not differ significantly p≤ 0.05 (values presented are Mean± Standard deviation)

CONCLUSION AND RECOMMENDATION

Termite digestion successfully breaks the seed coat dormancy of *Terminalia mantaly* in this study. Termite digestion for 7 days gave the optimum germination percentage (82.5±14.43), while Termite digestion for 5 days resulted in the fastest germination rate (7.15±0.09). Termite digestion of *Terminalia mantaly* seeds for 5 or 7 days is recommended. Scientists should consider exploring the same method in breaking the seed coat dormancy of other species of trees. However, constant monitoring is required when using termites to break seat coat dormancy. This is because prolonged exposure can damage the endosperm, hence, affect germination as evidenced from this study.

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EFFECT OF WOOD-DEGRADING FUNGI ON MECHANICAL PROPERTIES OF *Boscia angustifolia* (A. RICH) WOOD

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ABSTRACT
Lesser-used wood species are gradually becoming commercially important due to an economic loss resulting from wood degrading fungi and thus reducing quality of grade of timber. This study therefore investigated the influence of wood-degrading fungi on mechanical properties of lesser-used wood of Boscia angustifolia. The weight loss and mechanical properties of the B. angustifolia wood after exposure to brown and white rot fungi (Sclerotium rolfsil and Pleurotus ostreatus) respectively for 16 weeks were measured. Data collected were subjected to analysis of variance at $_{0.05}$. The results revealed that B. anguistifolia could be classified as non-durable wood since its average weight loss was 16.47% and 14.16 % for brown and white fungus respectively. The pooled mean for the initial MOE and MOR of the wood samples were 6291.33 Nmm^2 and 46.44 Nmm^2 respectively while the MOE after exposure to Sclerotium rolfsil and Pleurotus ostreatus was 617.08 and 627.78 Nmm^2 and MOR of 24.47 and 19.54 Nmm^2 respectively. The results indicated that the bending strength properties of B. anguistifolia wood reduced significantly ($P<0.05$) due to activities of the fungi when compared with initial MOE and MOR of the wood before inoculation. Consequently, there is a need to preserve B. anguistifolia wood using suitable preservatives against wood-decaying fungi.

Keywords: *Boscia anguistifolia, Sclerotium rolfsil, Pleurotus ostreatus, modulus of rupture, modulus of elasticity, weight loss*

INTRODUCTION

Wood is a heterogeneous material and its composition and structure differs depending on the species, individual, and location in the tree (Young and Rowell, 1986). The wood used as a raw material in structural work originates usually from either softwood or hardwood trees. the diversity of wood structure is high, it always consists mainly of cellulose, hemicelluloses and lignin together with extractives. The hemicelluloses and lignin which form the main strength of wood. The lignin component is associated with compressive strength of wood and it plays the role of binding other components together while cellulose is linked with the tensile and bending strength of wood acting like a building block acts like sand and rubble (Gabrelli, 2000; Bon and Ferrara, 2007). According to Barnett and Jeronimidis (2003), any change that affects lignin and cellulose contents affect both chemical and mechanical properties of wood. Reduction of wood strength occurred when degradation of hemicelluloses component such as arabinose and galactose occurred (Winandy and Morrell, 1993; Curling, *et al.*, 2002a).

Wood-degrading fungi often belong to the *Basidiomycetes* class and they destroy cell wall components; including cellulose, hemicellulose, and lignin, that make up the woody portion of a tree (Malakani, *et al.*, 2014). Depending on the organism, decay fungi can destroy the living (sapwood) or the central core (heartwood) part of the tree. White rots fungi break down lignin and cellulose, and commonly cause rotted wood to feel moist, soft, spongy, or stringy and appear white or yellow. The brown rots fungi primarily decay the cellulose and hemicellulose (carbohydrates) in wood, leaving behind the brownish lignin (Downer and Perry, 2019). Scholars such as Malakani, *et al.* (2014); Bari, *et al.(*2015) reported effect of different fungi on the mechanical properties including compression strength parallel to the grain, Brinell hardness perpendicular to tangential and radial surfaces among others.

Consequently, many lesser-used wood species are becoming commercially important due to an economic loss resulting from wood decay which actually brings about reduction in the quality of grade of timber.

Boscia angustifolia is a small evergreen tree of 10 –15m tall that is found in Nigeria and in deciduous wood bush land in West Africa countries like southern Mauritania, Senegal and Gambia eastward to Somalia and southward to northern South Africa. It usually grows in sites such as hills, laterite outcrops and cliffs and sometimes dry riverbeds (Hassan *et al*., 2007). The wood is hard and used for charcoal production for gun powder. Also, it is used in carpentry and for making vessels for water storage (Orwa *et al*., 2009). Being a lesser used wood, there is shortage of information on the durability of the wood against wood decaying fungi. It is therefore important to investigate the durability of *Boscia angustifolia* against fungi before choosing it as a replacement for other known wood species for structural applications.

MATERIALS AND METHODS

Materials source and preparation of test samples

Two trees of *Boscia angustifolia* were harvested from Onigambari Forest Reserve, Oyo state, Nigeria. Taking into account stem straightness and absence of obvious decay, they were selected based on defect-free, clear, and normally grown (without zone lines, reaction wood, decay and insect damage, or fungal infection).

The method for the preparation of test samples followed the work of Ogunsanwo and Onilude (2002) as described by Adebawo, *et al.* (2019). The trees were felled and converted to three bolts from 50cm in length from the base. The three bolts were collected from the top (90%), middle (50%) and base (10%) of the merchantable lengths of the trees. The bolts were partitioned into three equal zones, namely inner wood, middle wood and outer wood along the radial planes. The test samples were converted to standard sizes of 20 mm X 20 mm X 300 mm and 20 mm X 20 mm X 60 mm in the wood workshop of Department of Wood and Paper Technology, Federal College of Forestry, Ibadan according to the British Standard BS373 (1989).

Accelerated Decay Test (BS EN 350)

The white rot fungi (*Pleurotus ostreatus*) and brown rot (*Sclerotium rolfsil*) were obtained from Pathology Department, Forestry Research Institute of Nigeria, Ibadan Oyo State Nigeria. The fungi were cultured using Potato Dextrose Agar as the culturing medium. 40ml of PDA was poured into McCartney bottles and sterilized by autoclaving at 0.1N/mm^2 (120 °C) for a period of 20 minutes. The medium was inoculated with the test fungi within 6 days after preparation of the bottles (Sarker, *et.al.*, 2006).

The wood specimen was infected by placing them in the bottles in which there were actively growing cultures of the test fungi and then incubated at room temperature (27±2^{0}C) in the laboratory for 16 weeks. At the end of incubation period, the blocks were removed from the culture bottles, cleaned and oven dried at 103±2^{0}C to constant weight (Sarker, *et. al*, 2006).

Percentage weight loss of each sample was calculated using equation 1.

$\%\text{ Weight Loss} = \frac{T_3 - T_4}{T_3} X\, 100$ %Weight loss = …………………………… (1)

T_3 =weight of test block after treatment.

T_4 = weight of test block after exposure to fungi attack.

According to Findlay, (1985) as described by Olfat, *et al.* (2007) and Malakani, *et al.* (2014), the classification was used for natural durability. This was considered in order to classify and determine the durability of wood. However, the natural durability of wood species was grouped according to the weight loss (Table 1).

Table 1: Typical service life criteria for the evaluation of durability on wood species and mass loss criteria of laboratory durability test (wood blocks)

Natural durability or decay resistance class	Laboratory tests mass loss (%)
1. Very durable	0, or negligible
2. Durable	<5
3. Moderately durable	6-10
4. Non-durable	11-30
5. Perishable	>30

Source: Findlay (1985)

Mechanical Test

The mechanical properties (static bending) of *Boscia angustifolia* wood after exposure to fungi decay were carried out at Forest Products Development and Utilization (FPD&U), Forestry Research institute of Nigeria (FRIN). The tests were performed on the wood samples at 12 % MC using universal testing machine - manufactured by Jinan Hensgrand Instrument Co., Ltd. Jinan, China with model number WDW-50. The measurement accuracy was ±0.01 mm for position, ±0.1 % for speed and ±0.5 % for loading. The properties measured were Modulus of rupture (MOR) and Modulus of Elasticity (MOE).

STATISTICAL ANALYSIS

The statistically significant differences that exist in the mean weight loss values of *B. anguistifolia* wood against brown and white-rot fungus and mechanical (static bending – MOR and MOE) were tested using the analysis of variance. All comparisons were made using Duncan Multiple Range Test (DMRT) at statistical levels of $\alpha_{0.05}$

RESULTS AND DISCUSSION

The weight loss of *Boscia anguistifolia* wood after exposure to *Sclerotium rolfsil* and *Pleurotus ostreatus* for 16 weeks is presented in Table 2. The percentage weight loss of *B. anguistifolia* ranged from 11.68 % - 17.92 % and 11.37 – 16.07% for *S. rolfsil* and *P. ostreatus* fungi respectively along the axial position with a decreasing pattern observed from top(16.47±1.67) and (14.16±0.35) to base (14.74±1.59) and (13.33±0.82) and for *S. rolfsil* and *P. ostreatus* respectively along the bole of the tree as presented in Table 2. The top of the sampling height of the *B. anguistifolia* wood species has the highest weight loss with pooled mean of 16.47 and 14.16 % for *S. rolfsil* and *P. ostreatus* fungi respectively. The base portion of the wood has the lowest weight loss values 13.32 % and 12.52 % for *B. anguistifolia* as caused by brown and white fungi. All portion of the wood (top-middle, inner-wood, middle-wood and outer-wood) also had a weight loss. Meanwhile, the results of the analysis of variance indicated that the *S. rolfsil* and *P. ostreatus* fungi had a significant effect on the weight loss of the *B. anguistifolia* wood (P< 0.05) as presented in Table 2.

However, since the pooled mean weight loss of decayed *B. anguistifolia* wood caused *S. rolfsil* and *P. ostreatus* was 14.74 % and 13.33 % respectively as presented in Table 2, *B. anguistifolia* wood is placed into non-durable wood class as indicated in Table 1 (Messner *et al.,* 2003). Although, Adebawo *et al*., (2019) reported that *B. angusitifolia* is moderately durable by other deteriorating agents such ad termite during graveyard test. The proportion of heartwood to sapwood of *B. anguistifolia* wood might made it more resistance to decay. In that the toxic extractives in the heartwood of *B. anguistifolia* have a slight effect on natural durability against the brown and white fungus. Olfat *et al.* (2007) reported that the weight loss of *Fagus orientalis* wood samples was of 42.20 % after incubation with *Coriolus versicolor* fungus for 16 weeks. Malakani *et al.,* 2014, reported that highest weight loss of 36.08% was observed for sapwood samples of *Fagus orientalis* and the heartwood samples *Fagus orientalis* had the lowest value of 32.98% when exposed to white rot fungus.

Table 2: Weight loss of *B. anguistifolia* wood due to fungi attack

Sampling Height	Radial Position	Basidiomycete fungi	
		Sclerotium rolfsil **(%)**	***Pleurotus ostreatus*** **(%)**
Top	Core	17.89±0.36^{c}	14.06±0.92^{b}
	Middle	16.88±0.56^{b}	14.55±2.18^{b}
	Outer	14.63±2.39^{a}	13.88±4.42^{ab}
	Mean	**16.47±1.67**	**14.16±0.35**
Middle	Core	11.68±0.86^{a}	11.37±0.81^{a}
	Middle	17.92±9.61^{c}	16.07±1.51^{c}
	Outer	13.48±0.14^{b}	12.53±1.05^{ab}
	Mean	**14.33±3.23**	**13.32±2.45**
Base	Core	12.09±2.15^{a}	12.05±0.45^{b}
	Middle	13.74±1.15^{ab}	11.85±0.93^{a}
	Outer	14.12±4.65^{bc}	13.65±0.01^{bc}
	Mean	**13.32±1.08**	**12.52±0.99**
Pooled Mean		**14.74±1.59**	**13.33±0.82**

Mean Value ± Standard Error; Number carry different letter in column are significantly different from each other (P≤0.05)

Mechanical Test

The initial static bending - Modulus of elasticity (MOE) and Modulus of rupture (MOR) of the *B. anguistifolia* wood before inoculation were presented in Table 3 and 4, respectively, to compare the level of degradation that occurred. The pooled mean MOE and MOR was estimated to be 617.08 Nmm^2 and 627.78 Nmm^2 and 24.47 Nmm^2 and 23.55 Nmm^2 for *S. rolfsil* and *P. ostreatus* fungi respectively as presented in Table 3 compared with initial MOE and MOR estimated to be 6291.33 Nmm^2 and 46.44 Nmm^2 respectively as presented in Table 4. However, it was also found that the rates of deterioration by fungus are inconsistent in radial positioning (core wood, middlewood and outerwood) whereas at the top of sampling height experienced an increase from top to base and also a decrease from top to base for *Boscia* wood before and after inoculation respectively. The highest MOE and MOR of degraded *B. anguistifolia* were 673.13Nmm^2 and 729.84Nmm^2; 33.07Nmm^2 and 25.94 Nmm^2 as caused by *S. rolfsil* and *P. ostreatus* fungi respectively while the base of the sampling height had the lowest MOE and MOR 588.65 Nmm^2 and 551.32Nmm^2; 14.45Nmm^2 and 12.09 Nmm^2 (Table 3 and 4). There were significance differences between initial MOE and MOR of *B. anguistifolia* when compared with the degraded *Boscia* wood as caused by the fungi likewise also at the sampling height and radial. This implies that the activities of fungi differ in term of deterioration. The exposure of *B. anguistifolia* wood samples to *S. rolfsil* and *P. ostreatus* fungi caused weight loss and reduction in strength properties of the wood after 16 weeks. Fungal degradation alters the microstructure (Bader *et al.,* 2012) and, thus, causes changes in the mechanical properties (Wilcox, 1978; Curling, *et al*., 2001 Curling *et al.,* 2002b; Clausen and Kartal, 2003).

According to Winandy and Rowell, (2005) that changes in temperature, pressure, humidity, pH, chemical adsorption from the environment, UV radiation, fire, and biological degradation (fungi) can have significant effects on the strength of wood. Similarly, Hashemi *et al.,* (2010) reported a decrease in the mechanical properties of poplar wood samples. In the same vein, Malakani *et al.,* (2014) and Bari *et al.,* (2015) also reported deteriorating effects on the mechanical properties and chemical composition as that caused by *Coriolus versicolor* and *Trametes versicolor* respectively.

Table 3: Modulus of Elasticity (MOE) of *B. anguistifolia* wood exposed to fungi attack

		MOE (Nmm^2)		
Sampling Height	**Radial Position**	**Initial MOE (Before Inoculation)**	***Sclerotium rolfsil***	***Pleurotus ostreatus***
Top	Core	4204.91±807.00^c	476.31±197.60^a	607.91±178.79^b
	Middle	5939.64±3489.04^c	707.68±512.77^{ab}	708.84±230.82^b
	Outer	3502.45±678.48^c	835.40±198.99^a	872.78±125.91^b
Mean		**4549.00±1254.50**	**673.13±148.61**	**729.84±109.15**
	Core	6102.03±2543.14^c	539.80±215.32^c	674.69±57.33^b
	Middle	5027.66±0.00^c	453.32±30.80^b	355.33±101.42^c
Middle	Outer	5070.513±097.67^b	775.29±179.67^a	775.29±179.66^a
Mean		**5400.07±608.30**	**589.47±141.93**	**601.77±112.80**
	Core	9867.84±1667.19^c	730.11±311.48^b	502.51±116.48^a
	Middle	8889.29±200.96^c	465.96±50.66^a	494.20±91.86^b
Base	Outer	8019.05±4965.19^c	569.89±254.64^a	657.22±76.13^b
Mean		**8925.39±2277.78**	**588.65±205.59**	**551.31±74.97**
Pooled Mean		**6291.33±1380.19**	**617.08±148.61**	**627.78±109.15**

Mean Value ± Standard Error; Number carry different letter in row are significantly different from each other (P≤0.05)

Table 4: Modulus of Rupture (MOR) of *B. anguistifolia* wood exposed to fungi attack

Sampling Height	Radial Position	MOR (Nmm^2)		
		Initial MOR (Before Inoculation)	*Sclerotium rolfsil*	*Pleurotus ostreatus*
Top	Core	50.351±1.52[c]	27.79±2.34[b]	20.79±1.74[a]
	Middle	54.09±3.60[c]	30.98±4.56[b]	23.89±2.54[a]
	Outer	65.23±0.00[c]	40.45±5.10[b]	33.14±3.56[a]
Mean		**56.56±1.71**	**33.07±3.24**	**25.94±6.42**
6Middle	Core	49.76±0.00[c]	27.29±2.34[b]	21.30±2.85[a]
	Middle	45.84±0.00[c]	23.96±2.16[b]	17.05±1.56[a]
	Outer	48.75±6.73[c]	26.43±2.67[ab]	23.46±2.37[a]
Mean		**48.12±2.03**	**25.89±1.73**	**20.60±1.23**
Base	Core	35.34±5.64[c]	15.04±1.20[ab]	12.33±0.97[a]
	Middle	32.26±0.00[c]	12.42±1.05[ab]	10.77±1.68[a]
	Outer	36.34±0.00[c]	15.89±1.65[ab]	13.16±1.67[a]
Mean		**34.65±2.13**	**14.45±1.80**	**12.09±1.76**
Pooled Mean		**46.44±1.96**	**24.47±2.25**	**19.54±3.16**

Mean Value ± Standard Error; Number carry different letter in row are significantly different from each other ($P \leq 0.05$)

CONCLUSION

This study evaluated the effect of wood-degrading fungi on *B. anguistifolia*, a lesser used wood species using weight loss and their selected mechanical properties. It is evident that from the study that *S. rolfsil* and *P. ostreatus* fungi had a significant effect on the weight loss of the *B. anguistifolia***,** the wood species is placed into non-durable wood class based on mass loss criteria of laboratory durability test. The selected mechanical properties of *B. anguistifolia* wood using MOE and MOR also reduced significantly after exposure to brown and white fungi when compared with initial values of MOE and MOR of the wood. Thus, confirming the degradation effect of the fungi on the wood species.

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ANALYSIS OF THE CONTENT OF THE HEARTWOOD EXTRACTIVES OF THREE DURABLE NIGERIAN GUNINEA SAVANNAH TIMBERS

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ABSTRACT

Resistance of most wood depend on the toxicity rather than the concentration of the heartwood extractive. However, most studies are not examining the contents of heartwood which are responsible for the resistance of most durable timbers to biological attacks. In this study, the heartwood of Prosopis africana, Burkea africana and Vitellaria paradoxa were extracted with distiled water and absolute ethanol and the extracts were subjected to phytochemical screening. The results showed that B. africana heartwood revealed 42 and 24 bioactive compounds for the ethanolic and aqueous extract. Hexadecanoic acid, methyl ester accounted for 34.82% and 17.38% of the total phyto-constituents in both ethanolic and aqueous extracts respectively. Other compounds occured in trace quantity. P. africana heartwood ethanolic (PHE) extract revealed 11 phyto-constituents while the aqueous (PHA) revealed 24 constituents. 83.36% of PHE was made up of two constitutes; 7,7-Dimethyl-1-oxo-2,3,4,5,6,7-hexahydro-1I (which accounted for 50.16% of the total constituents) and 1,4-methanophthalazine, 1,4,4a,5,6,7,8,8a-oct (33.20%) while the PHA revealed 7 compounds which were in fairly large amount. The major compound in V. paradoxa was (S)-(+)-1,2-Propanediol which accounted for 73.51% out of the 30 compounds revealed in the ethanolic heartwood extract. The aqueous heartwood extract of V. paradoxa however revealed 22 compounds with 7 of the compounds fairly large in proportion. The result showed that extraction medium had influence on the type of bioactive compounds extracted. However, some compounds were similar irrespective of the extraction medium. Extractives from these species could be isolated and utilized to increase the durability of non-durable and non-refractory wood species.

***Keywords**: Phytochemicals; Biocides; Termites, Fungi, (S)-(+)-1,2-Propanediol, Hexadecanoic acid methyl ester*

INTRODUCTION

The destructive effects of insects and decay fungi to structural timbers are enormous. Several efforts is continually being made to complement previous reseraches to control these biodeteroriating organisms. To protect wood and wood-based products against biological agent, preservative treatments is required. However, most conventional preservatives are synthetic and they pose threats to the environment and negatively affect living organisms (Tascioglu et al.,2012). Due to this, attention has been shifted to the use of eco-friendly biocides in the control of wood destructive agents. Wood extractives are a major contributory factor in the natural durability of wood (Roszaini, 2017). Natural durability is undoubtedly derived from and affected by the extractive components (Hillis, 1987; Hon & Minemura 2001). Bioactivity of different parts of wood species against different biological agents of degradation have been reported (Alireza, 2012; Adedeji et al., 2018; Prayitno et al., 2021). Extractives either from the bark, stem or heartwood of most tropical trees are known to possess some bioactivity against varieties of biological agents of degradation. These extractives are of considerable interest for wood protection because of their indigenously known biocidal properties (Ademola et al. 2004, Agbedahunsi et al. 2004).

Many studies have been carried out on the feasibility of using heartwood extractives in preserving wood. Reports of these studies have shown promising results. Adedeji et al. (2018) reported the termicidal activity of *K. ivorensis* stem bark extractives impregnated into *Triplochiton scleroxylon* and *Vitex doniana* against wood-degrading agents under field conditions. Roszaini (2017) reported the toxic effects of selected Malaysian timber heartwood extracts against *Coptotermes gestroi* and *Coptotermes curvignathus* which are two aggressive Asian subterranean termites species. Bald cypress (*Taxodium distichum*) heartwood extract (Scheffrahn et al. 1988), southern catalpa (*Catalpa bibnonioides*) heartwood extract (McDaniel 1992), red louro (*Sextonia rubra*) wood extract (Rodrigues et al. 2011) have all been reportedly utilized to increase natural durability of inferior wood species to biological attack. Tascioglu et al. (2012) concluded that resistance of wood varies depending on many factors including natural durability, density and extractive types and quantities. Of all these factors, the quantity of the extractives and their chemical composition play an important role on wood durability (Anda et al., 2019). Therefore, the durability characteristics of most timbers may be attributed to the toxic content of the extractives rather than the concentration of the total extractive content. Some wood may possess non toxic extractives which may confer little or no level of durability to the wood while some woods may have very toxic extractable materials that were accumulated during the formation of heartwood which are thus responsible for their resistance against different biological agents of degradation.

Wood extractives have shown to have different structures as well as belong to different classes such as flavonoids, steroidal compounds, glycosides, quinones and phenolic acids (Alabi and Oyeku, 2017). Quite a number of bio-compounds in wood extractives are known to inhibit the activities of biological agents. Phenolic compounds, terpenes, carbohydrates, long-chain fatty acids, waxes and other substances, including steryl esters and sterols are among the main chemical compounds in heartwood extractives (Fengel and Wegener 1989). Ji et al. (2014) reported the bioactivity of limonoids from *K. ivorensis* seed, fruit and stem bark as anti-feeding, anti-fungal, anti-bacterial, anti-trypanosomal and anti-tumor. Sesquiterpenes are known to play a role in plant defense mechanisms against insects and fungi (Fraga, 2003, Wu et al., 2005). Pinosylvin and pinosylvin-monomethyl-ether reported to be toxic to fungi (Hillis and Inoue 1968) as well as quinones (e.g in *Prosopis africana* and *T. grandis*) toxic to termites (Alabi and Oyeku, 2017). Naphthoquinones and anthraquinones have been reported to show remarkable anti-fungal and anti-termitic effects (Guerrero-Vásquez, 2013). Likewise, Bis(2-ethylhexyl)phthalate has also been reported to be toxic to agents of wood degraration (Alabi and Oyeku, 2017).

Although, many studies have been carried out on the anti-termitic and anti-fungal activities of heartwood of many timber species, however, most studies did not examine the content of the heartwood which are responsible for the resistance of most durable timbers to attack by biological agents. According to Tascioglu et al. (2012), extractives isolated from naturally resistant heartwood in some plant species may provide alternatives in pest control because of their bioactive chemicals if their compositions are known to be toxic to biological agents of degradation. In this study, the content of the heartwood extractives of three important and durable timbers species (name them) which are native to the Nigerian Guinea Savannah region were evaluated to know the contents which are likely to be responsible for the enhanced durability of these timbers species. These timber species are some of the prominent timbers of economic value in this region. They have been reported to have high load bearing applications, greater resistance to shock as well as higher resistance to attack by biological agents of degradation by local wood workers. However, to the best of our knowledge, little or no report of the chemical content of the heartwood of these species exists in scientific literature. The present study was with the intent that the extractives from these species could be isolated and utilized to increase the durability of non-durable and non-refractory wood species.

MATERIALS AND METHODS

Collection of Plant Materials

Prosopis africana, *Burkea africana* and *Vitellaria paradoxa* trees were harvested from the natural plantation of the Department of Forest Resources Management, University of Ilorin. Ilorin is located in the transitional zone between the deciduous woodland of the South and dry savannah of North Nigeria (Jimoh 2003) and on latitude 8º 24' N and 83º 6' N and longitude 4º10' E and 4º 36' E. The climate of Ilorin is characterized by both wet and dry seasons. The rainy season begins towards the end of April and last till October while the dry season begins in November and ends in April. The temperature of Ilorin ranges from 33º C to 35º C from November to January while from February to April; the value ranges between 34º C to 37º C. Days are very hot during the dry season. The total annual rainfall in the area ranges from 990.3mm to 1318mm. The rainfall in Ilorin city exhibits the double maximal pattern and greater variability both temporarily and spatially. The relative humidity ranges from 75% to 88% from May to October, while in the dry season it ranges from 35% to 80% (Ajibade and Ojelola 2004). The marchantable lenght of each of the trees were divided into three equal parts. Thereafter, the billets were laterally sawn to separate the heartwood from the sapwood regions. Each of the heartwood portion of the timbers were ground to fine powder. The sawdust were air dried (to avoid the possibility of extracts degradation) to constant weight. They were then sieved using 250 mesh sieve and kept in polythene bags prior to extraction. All reagents used were analytical grades.

Extraction and isolation of Extractives

About 1000 g of sawdust from each of the wood was extracted with de-ionised water and absolute ethanol (EtOH) for 48 hours on an orbital shaker (Gallenkamp, UK). Thereafter, the extracts were concentrated under pressure at 45ºC, using a rotary evaporator (EYELA, SB-651, Rikakikai Co. Ltd. Tokyo, Japan). After extract concentration, the extracts were stored in glass vials and refrigerated at a temperature of -4ºC prior to analyses.

Gas Chromatography Mass Spectra Analysis

The bioactive compounds analysis of the heartwood extracts of the three timber species was done by GC-MS analysis of the aqueous and ethanolic extracts. Breifly, the extracts were subjected to GC-MS analysis to identify the various bioactive compounds present. Each of the samples was analyzed in Perkin Elmer-Clarus-600 instrument using software Turbomass 5.2 version. Capillary standard non-polar column (30 m x 0.25 mm, 0.25 mm film thickness) was used. The volume of injected specimen was 1 L of ethanol extract, injector temperature (temp.) of. 220°C with a split ratio of 25:1 Carrier gas Helium, Solvent Delay=3.00 min, source Temp=180°C, oven temperature program initial temp. of 60°C for 5 min, ramp7°C/min to 300°C, hold 15 min, Scan: 50 to 600Da, ionization energy 70 eV, in the electronic ionization mode.

Identification of Compounds

The identification of compounds was done using computer matching of mass spectra with those of standards (NIST library). The spectrum of the unknown component was compared with the spectrum of the known components stored in the NIST library. The Name, Molecular weight and structure of the components of the test materials were ascertained. The test was run in triplicate.

RESULT

Bioactive Compounds in *Burkea africana* Heartwood

B. africana Heartwood Ethanolic Extract revealed 42 phyto-constituents. The constituents which occured in fairly large amount was hexadecanoic acid, and methyl acid. This accounted for 34.82% of the total phyto-constituents. Others include Dibutyl phthalate (5.38%), 9-Octadecenoic acid, methyl ester (E)- (9.01%); Methyl stearate 7.6% and Squalene (4.86%) (Table 1). However, aqeouos extract revealed 24 constituents which included 6 compounds which occured in fairly large amount, like the ethanolic extract, Hexadecanoic acid, and methyl ester were the major constutuent in *B. africana* aqeuous extract accounting for 17.38% of the total phytochemicals present. Other constituents included; 1H-Pyrido [3,4-b]indole 2,3,4,9-tetrahydro-1-1 (11.46%); 9-Octadecenoic acid (Z)- methyl ester (6.97%); Stigmasterol (14.38%); Resorcinol (6.98%) and Campesterol (7.51%) (Table 2). The remaining 18 were in minute quantities.

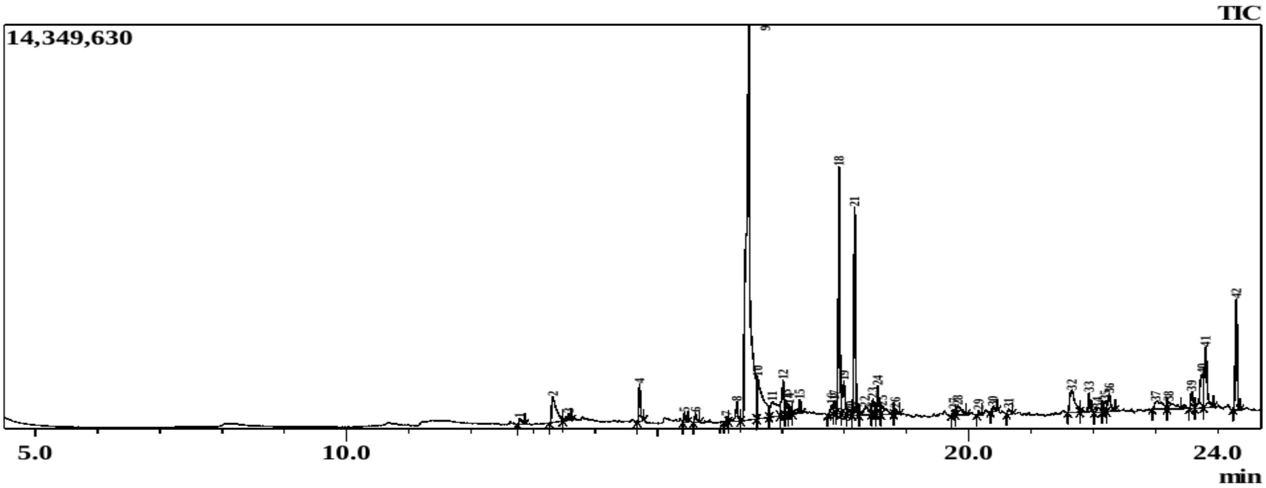

Figure 1: Chromatogram of *B. africana* Heartwood Ethanolic Extract

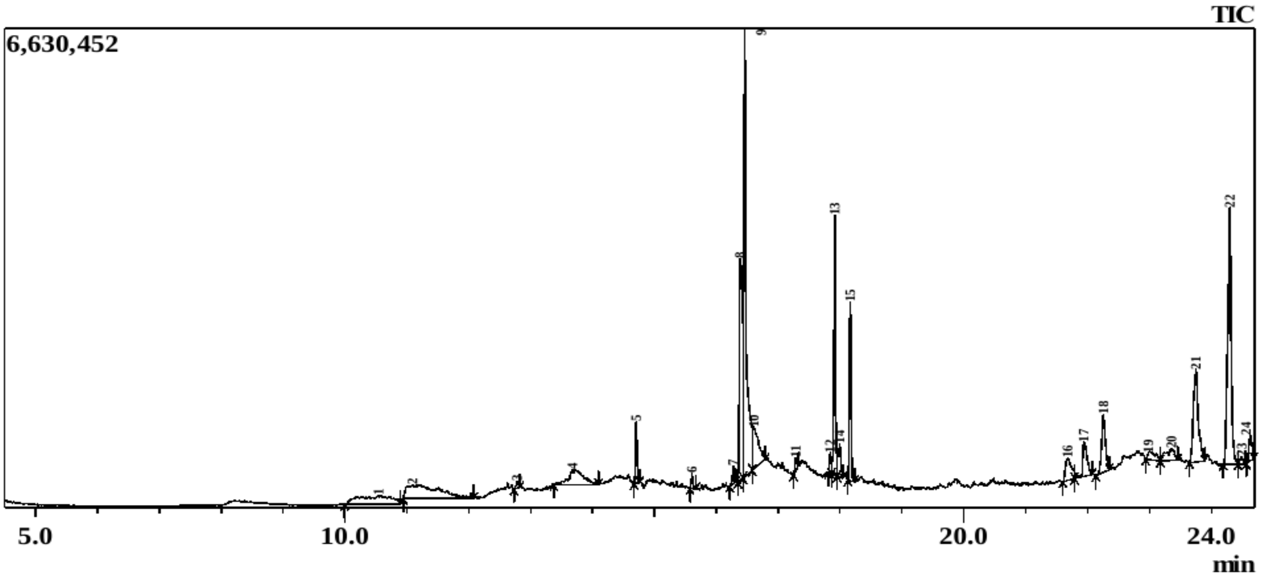

Figure 2: Chromatogram of *B. africana* Heartwood Aqueous Extract

Although, extraction medium had great influence on the type as well as the concentration of bioactive compounds extracted from *B. africana*, 8 compounds were similarly revealed in both extracts. The compounds were Methyl tetradecanoate, Pentadecanoic acid methyl ester, Hexadecanoic acid methyl ester, 9-12-Octadecadienioc acid methyl ester, 9-Octadecenoic acid methyl ester, Methyl stearate, 1,4-Di-O-acetyl-2,3,5-tri-O-methylribitol and Bis(2-ethylhexyl) phthalate (Table 1 and 2). *B. africana* could be a source for the extraction of hexadecanoic acid, methyl ester, because this compound occured in large amount representing 34.82% of the total constituents while others occured in fairly large to minute quantities.

Table 1: Biochemical Compounds in *B. africana* Ethanolic extract

Peak No.	R_{time}	Area (%)	Compound
1	12.781	0.33	Dodecanoic acid, methyl ester
2	13.317	2.79	Diethyl Phthalate
3	13.568	0.40	1-Hexadecanol
4	14.708	1.40	Methyl tetradecanoate
5	15.433	0.35	9-Eicosene, (E)-
6	15.609	0.39	Pentadecanoic acid, methyl ester
7	16.108	0.22	n-Nonadecanol-1
8	16.274	1.08	7-Hexadecanoic acid, methyl ester, (Z)
9	16.463	34.82	Hexadecanoic acid, methyl ester
10	16.608	5.38	Dibutyl phthalate
11	16.842	2.59	8-Methyl-6-nonenamide
12	17.02	1.80	Hexadecanoic acid, methyl ester
13	17.06	0.75	Tetradecanoic acid, 12-methyl-, methyl ester
14	17.12	0.46	1-Heneicosanol
15	17.28	0.58	Hexadecanoic acid, 14-methyl-, methyl ester
16	17.8	0.5	n-Pentadecanol
17	17.84	0.48	9,12-Octadecadienoic acid, methyl
18	17.92	9.01	9-Octadecenoic acid, methyl ester, (E)
19	17.99	1.86	11-Octadecenoic acid, methyl ester
20	18.1	0.42	Trans-2,3-Epoxynonane
21	18.17	7.80	Methyl stearate
22	18.33	0.97	2,8,9-Trioxa-5-aza-1-silabicyclo[3.3.3]undeca
23	18.46	0.7	Ethyl 9,12-hexadecadienoate
24	18.54	1.31	(E)-9_Octadecenoic acid ethyl ester
25	18.61	0.92	Decanamide-
26	18.82	0.31	Octadecanoic acid, 17-methyl-, methyl ester
27	19.76	0.29	Octadecanoic acid, 2,3-dihydroxypropyl ester
28	19.83	0.94	1,4-Di-O-acetyl-2,3,5-tri-O-methylribitol
29	20.16	0.18	Methyl 18-methylnonadecanoate
30	20.39	0.26	9-Octadecenamide
31	20.64	0.36	Tetradecanamide
32	21.66	2.62	Hexadecanoic acid, trimethylsilyl ester
33	21.93	0.88	Bis(2-ethylhexyl) Phthalate
34	22.07	0.49	Tetracosanoic acid, methyl ester
35	22.19	0.73	6,8-Dioxapentadecane
36	22.26	1.07	Octane, 1,1'-oxybis-

Peak No.	R_{time}	Area (%)	Compound
37	23.01	1.43	Cis, 6-Octadecenoic acid, trimethylsilyl ester
38	23.21	1.12	1,4-Di-O-acetyl-2,3,5-tri-O-methylribitol
39	23.58	0.93	1,3-Benzenedicarboxylic acid, bis(2-ethylhexy)
40	23.75	2.97	Hexanoic acid, 2-ethyl-, nonyl ester
41	23.81	3.48	Oxalic acid, decyl neopentyl ester
42	24.3	4.86	Squalene

Table 2: Biochemical Compounds in *B. africana* Aqeous extract

Peak No.	R_{time}	Area (%)	Compound
1	10.543	4.76	1-Oxaspiro[3.5]nona-5,8-dien-7-one, 3-methyl
2	11.090	6.98	Resorcinol
3	12.781	0.23	Undecanoic acid, 10-methyl-, methyl ester
4	13.679	3.56	Hydrazinecarboxylic acid, butylidene-, methyl
5	14.704	1.64	Methyl tetradecanoate
6	15.608	0.37	Pentadecanoic acid, methyl ester
7	16.274	0.52	13-Methyltetradec-9-enoic acid methyl ester
8	16.388	11.46	1H-Pyrido[3,4-b]indole, 2,3,4,9-tetrahydro-1-
9	16.460	17.83	Hexadecanoic acid, methyl ester
10	16.608	3.91	2-(Heptyloxycarbonyl)benzoic acid
11	17.286	0.38	Hexadecanoic acid, methyl ester
12	17.840	0.57	9,12-Octadecadienoic acid, methyl ester
13	17.915	6.97	9-Octadecenoic acid (Z)-, methyl ester
14	17.994	1.47	9-Octadecenoic acid (Z)-, methyl ester
15	18.165	4.69	Methyl stearate
16	21.678	2.14	1,4-Di-O-acetyl-2,3,5-tri-O-methylribitol
17	21.940	2.47	Bis(2-ethylhexyl) Phthalate
18	22.255	3.54	Vitamin E
19	22.983	1.07	Ocadecane, 1-isocyanato-
20	23.355	1.72	3-Methoxy-D-homoesta-1,3.5(10)-trien-14-.b
21	23.751	7.51	Campesterol
22	24.298	14.38	Stigmasterol
23	24.492	0.45	Cholestan-3-one, 4,4-dimethyl-,(5.alpha)-
24	24.627	1.37	Campesterol

Bioactive Compounds in *Prosopis africana* Heartwood

P. africana Heartwood Ethanolic Extract revealed 11 phyto-constituents. The most prevailing compounds in the ethanolic extract of *P. africana* were two namely; (7,7-Dimethyl-1-oxo-2,3,4,5,6,7-hexahydro-1) (50.16%) which accounted for more than half of the total constituents contained in *P. africana* and 1,4-Methanophthalazine, 1,4,4a,5,6,7,8,8a-oct with peak area of 33.20% (Table 3). The two compounds represented 83.36% of the total phytochamicals in ethanolic extract of *P. africana*. *P. africana* aqeuous extract had 5 constituents which occured in fairly large quantities, however, 14.alpha.-Methyl-5.alpha.-ergosta-8,24(28)-di was the major constituent with peak area of 17.95%

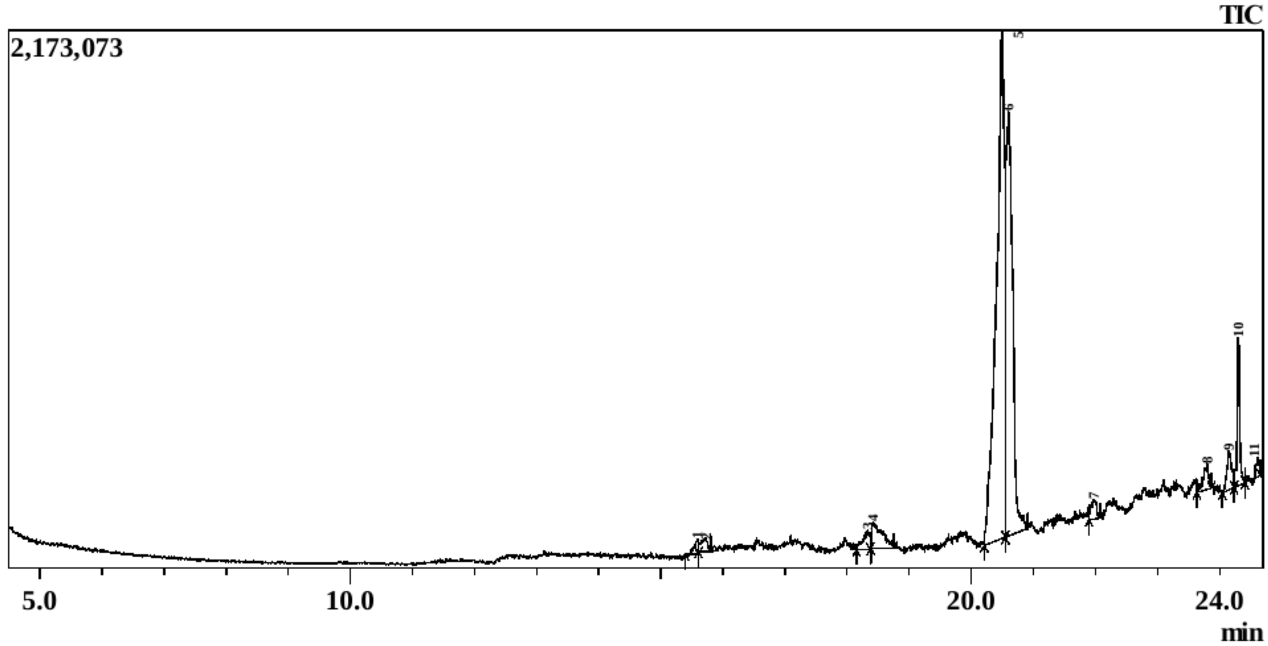

Figure 3: Chromatogram of *P. africana* Heartwood Ethanolic Extract

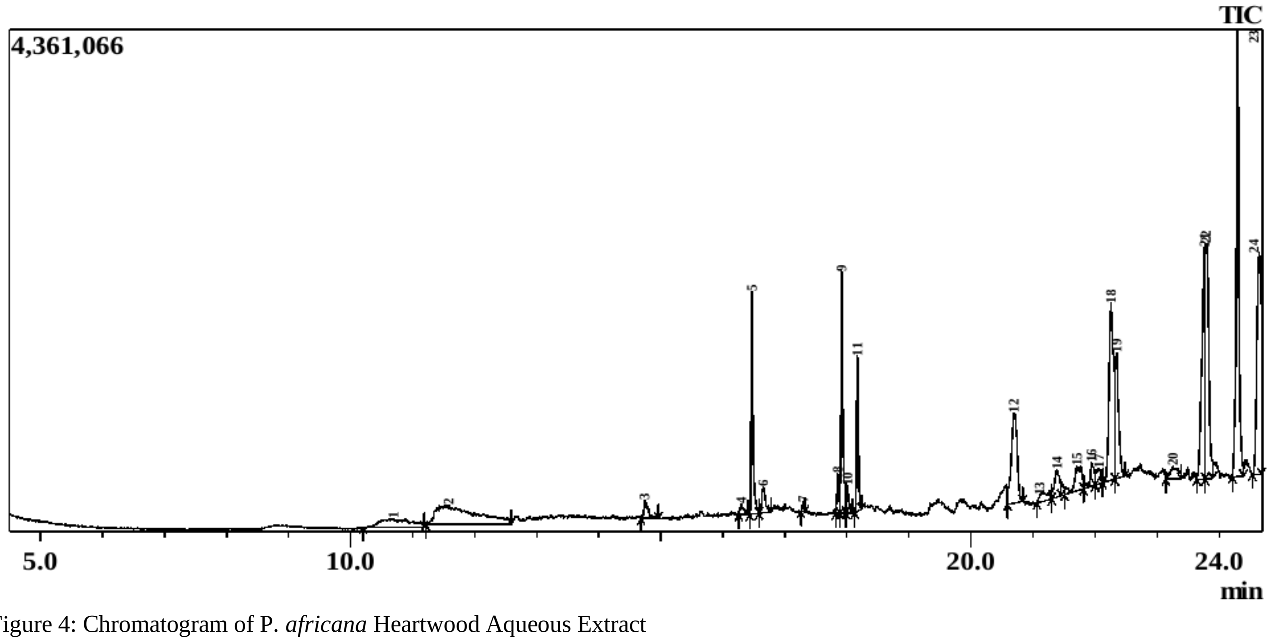

Figure 4: Chromatogram of P. *africana* Heartwood Aqueous Extract

The aqueous *P. africana* heartwood extract revealed 24 constituents out of which 5 compounds are considered to occur in fairly large amount. They include; tetracosapentaene 2,6,10,15,19,23-hexamethyl (13.74%); Campesterol (10.96%); 14.alpha.-methyl-5.alpha.-ergosta-8,24(28)-dis (17.95%); dl-.alpha.-Tocopherol (9.26%) and hydroquinone (8.70%) (Table 4). There were no compounds similar to both aqueous and ethanolic extracts of *P. africana*. The compounds that were revealed in the ethanolic extract were quite different from the aqeouos extract. This showed that extraction medium has great influence on the type of bioactive compounds extracted. This further corroborated the findings in earlier studies (Naczk and Shahidi 2004, Spigno et al. 2007, Kajdžanoska et al. 2011, Lolita et al. 2012) that different solvents extract different compounds.

Table 3: Biochemical Compounds in *P. africana* Ethanolic extract

Peak No.	R_{time}	Area (%)	Compound
1	15.591	0.63	(.+/-.)-Lavandulol, pentafluoropropionate
2	15.733	0.99	1,3,3-Trimethyl-2-(2-methyl-cyclopropyl)-cyclo
3	18.334	1.54	P-Mentha-6,8-dien-2-one, semicarbazone
4	18.417	3.29	Tetrahydroabietic acid
5	20.492	50.16	(7,7-Dimethyl-1-oxo-2,3,4,5,6,7-hexahydro-1)
6	20.600	33.20	1,4-Methanophthalazine, 1,4,4a,5,6,7,8,8a-oct
7	21.973	1.24	7,7-Dimethyl-9-oxatricyclo[6.2.2.0(1,6)dodec]
8	23.800	1.62	Thiositosteroldisulfide
9	24.150	2.24	9,19-cyclolanostan-3-ol, acetate, (3.beta.)-
10	24.304	4.41	Squalene
11	24.617	0.69	2-(4a,8-dimethyl-1,2,3,4,4a,5,6,7-octahydro-r)

Table 4: Biochemical Compounds in *P. africana* Aqeous extract

Peak No.	**R_{time}**	**Area (%)**	**Compound**
1	10.691	2.92	1,3-Diethoxybenzene
2	11.583	8.70	Hydroquinone
3	14.742	0.87	Tridecanoic acid, methyl ester
4	16.299	0.38	6-Octadecenoic acid, methyl ester, (Z)-
5	16.468	4.71	Hexadecanoic acid, methyl ester
6	16.651	1.08	Dibutyl phthalate
7	17.293	0.14	Methyl 8-methyl-nonanoate
8	17.852	0.82	9,12-Octadecadienoic acid, mthyl ester
9	17.918	5.52	10-Octadecenoic acid, methyl ester
10	18.008	0.84	Cyclopropanenonanoic acid, methyl ester
11	18.170	3.22	Methyl stearate
12	20.694	6.05	trans-Geranylgeraniol
13	21.108	0.96	Comarin, 3,4,4a,5,6,8a-hexahydro-6,8a-epidio
14	21.392	1.64	Dimethyl(bis{[(2E,6E)-3,7,11-trimethyldodec
15	21.706	2.06	Hexadecanoic acid, trimethylsilyl ester
16	21.944	1.10	Bis(2-ethylhexyl) Phthalate
17	22.067	0.91	2,2,4-Trimethyl-3-(3,8,12,16-tetramethyl-hept)
18	22.257	9.26	dl-.alpha.-Tocopherol
19	22.347	4.98	Oxirane, 2,2-dimethyl-3-(3,7,12,16,20-pentan)

Peak No.	R_{time}	Area (%)	Compound
20	23.256	1.20	3-Trimethylsilyloxystearic acid, trimethylsilyl
21	23.767	8.92	14.alpha. -Methyl-5. alpha. -ergosta-8,24(28)-di
22	23.785	9.03	14.alpha. -Methyl-5. alpha.-ergosta-8,24(28)-di
23	24.299	13.74	Tetracosapentaene, 2,6,10,15,19,23-hexamethyl
24	24.647	10.96	Campesterol

Bioactive Compounds in *Vitellaria paradoxa* Heartwood

The ethanolic heartwood extract of *V. paradoxa* wood contained 30 phyto-constituents, of these the most important is (S)-(+)-1,2-Propanediol which accounted for 73.51% of the heartwood constituent. However, Silane, [[(3.beta.)-lanosta-9(11), 24-dien-3yl]o only accounted for 5.23%. Other constituents occured in minute amount (Figure 5 & Table 5).

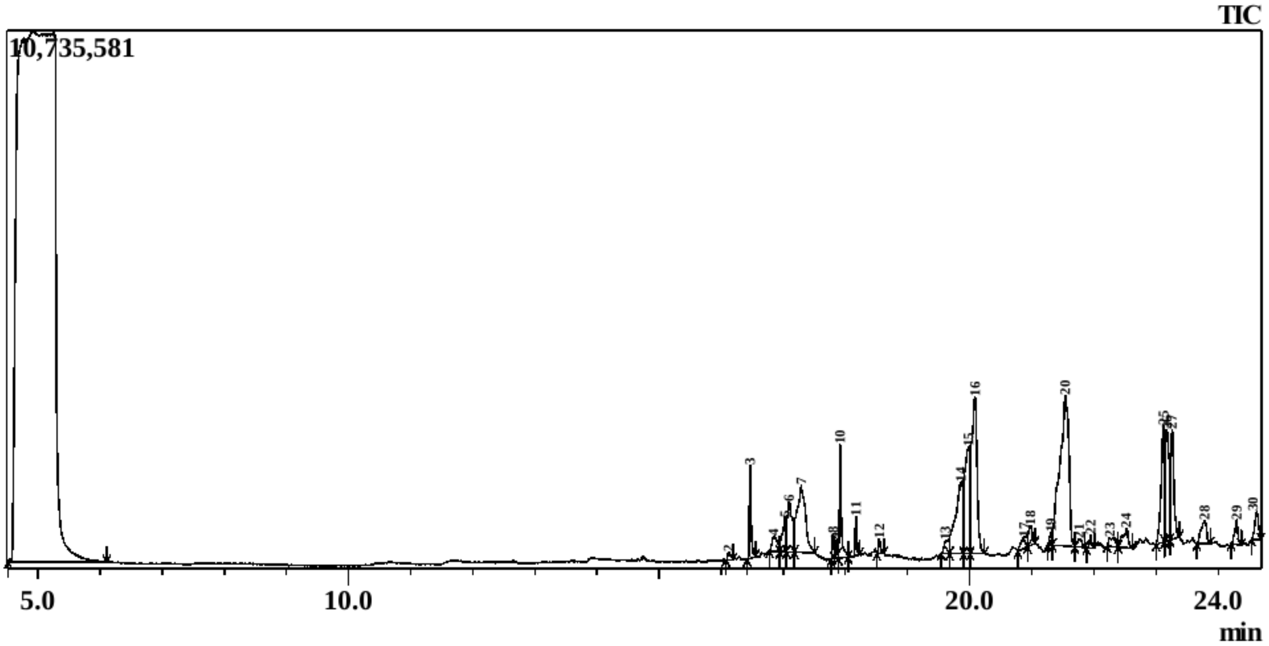

Figure 5: Chromatogram of V. *paradoxa* Heartwood Ethanolic Extract

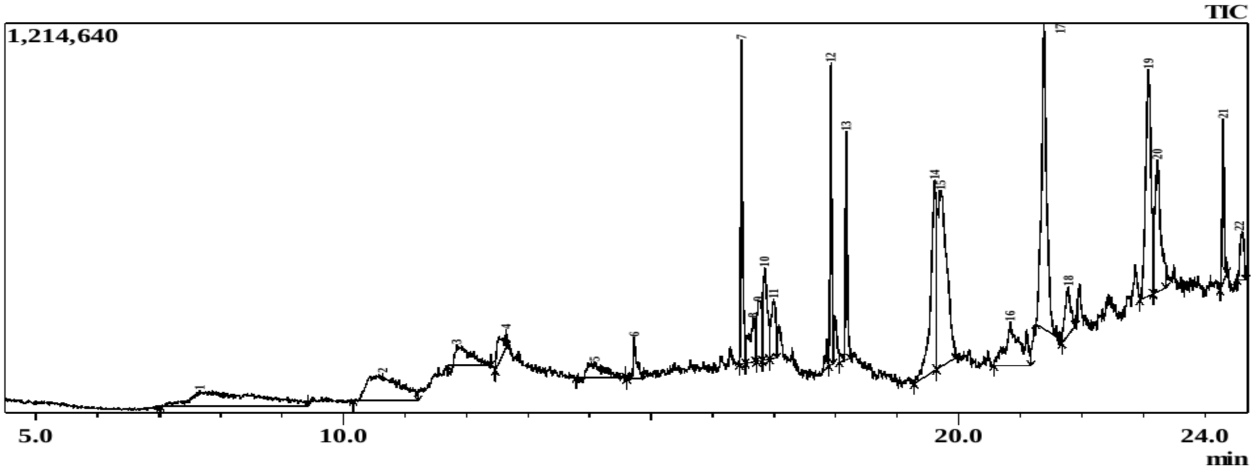

Figure 6: Chromatogram of *V. paradoxa* Heartwood Aqueous Extract

In the case of the aqueous extract, 22 compounds were revealed. Seven of the compounds were fairly large in proportion. 9,19-cyclchloestene-3,7-diol,4,14-dimethyl had the largest concentration of 12.21%; Acetic acid, 2-(4-cyclohexylphenoxymethyl)-4 had 8.24%. 4-Butoxyphenoxycarbonylamino acetic acid, Cyclohexanol, 3,5-dimethoxy-, stereoisomer, 9,19-cyclo-9.beta. -Ianostane-3.beta.,25-diol, 9,19-Cycloianostan-3-ol, 24-methylene-3.beta and Pregnan-17,21-diol-9,11-epoxy-3,20-dione accounted for 8.24%, 6.32%, 7.67%, 11.76%, 9.22% and 6.00% respectively (Table 6 and Figure 6).

Similarly as recorded for *B. africana*. 5 compounds were similarly revealed in both ethanolic and aqeouos extracts of *V. paradoxa*. The compounds were Hexadecanoic acid methyl ester; .gamma.-Sitosterol; .beta.-Sitosterol; 9-Octadecenoic acid methyl ester and Methyl stearate. These compounds are almost similar to those of *B. africana* except for a few of the compounds. From the result, *V. paradoxa* could serve as a raw material for the extraction of (S)-(+)-1,2-Propanediol owing to the concentration (73.51%) of the compound which occured in very large amount.

Table 5: Biochemical Compounds in *V. paradoxa* Ethanolic Extract

Peak No.	R_{time}	Area (%)	Compound
1	4.909	73.51	(S)-(+)-1,2-Propandiol
2	16.120	0.08	1-Tetradecanol
3	16.466	0.61	Hexadecanoic acid, methyl ester
4	16.842	0.32	.beta.-Sitosterol
5	17.026	0.49	Ethyl 14-methyl-hexadecanoate
6	17.094	0.98	.beta.-Sitosterol
7	17.288	2.13	.gamma.-Sitosterol
8	17.803	0.17	1-Hexadecanol
9	17.846	0.08	7,10-Hexadecadienoic acid, methyl ester
10	17.917	0.83	9-Octadecenoic acid (Z)-, methyl ester
11	18.170	0.25	Methyl stearate
12	18.545	0.11	Ethyl Oleate
13	19.608	0.27	9,19-Cycloergost-24(28)-en-3-ol, 4,14-dimethy
14	19.858	2.13	9,19-Cycloergost-24(28)-en-3-ol, 4,14-dimethy
15	19.983	2.13	Ergosta-5,22-dien-3-ol, acetate, (3.beta,22E)-

16	20.084	3.26	9,19-Cycloergost-24(28)-en-3-ol, 4,14-dimethy
17	20.875	0.28	.beta.-Sitosterol
18	20.978	0.28	.beta.-Sitosterol
19	21.308	0.14	Acetic acid, 3-hydroxy-6-isopropenyl-4,8a-din
20	21.541	5.23	Silane, [[(3.beta.)-Ianosta-9(11),24-dien-3-yl]o
21	21.765	0.13	Stigmastan-3,5-diene
22	21.947	0.11	Bis(2-ethylhexyl) Phthalate
23	22.256	0.24	dl-.alpha.-Tocopherol
24	22.520	0.42	Obtusifoliol
25	23.122	1.62	9,19-CycloIanost-25-en-3-ol, 24-methy-, (3.b)
26	23.175	1.67	9,19-CycloIanost-25-en-3-ol, 24-methy-, (3.b)
27	23.260	1.36	17.beta.-Methyl-18-nor-17-isopregna-4,13-die
28	23.783	0.50	14.alpha.-Methyl-5.alpha.-ergosta-8,24(28)-di
29	24.299	0.29	Stigmasten-3-one
30	24.622	0.40	Stigmasta-5,22-dien-3-ol, acetate, (3.beta.)-

Table 6: Biochemical Compounds in *V. paradoxa* Aqeuous Extract

Peak No.	R_{time}	Area (%)	Compound
1	7.666	7.67	Cyclohexanol, 3,5-dimethoxy-, stereoisomer
2	10.640	6.32	(4-Butoxyphenoxycarbonylamino) acetic acid
3	11.842	2.07	Phenol, 2-propyl
4	12.642	1.32	.beta.-D-Glucopyranose, 1,6-anhydro
5	14.085	1.60	Phenol, 3,4,5-trimethoxy-
6	14.726	1.12	Methyl tetradecanoate
7	16.468	4.65	Hexadecanoic acid, methyl ester
8	16.658	2.01	1,2-benzenedicarboxylic acid, bis(8-methylno)
9	16.742	2.05	5.beta., 6.beta.-Epoxy-7-bromocholestan-3-one
10	16.846	2.99	.gamma.-Sitosterol
11	16.991	2.12	.beta.-Sitosterol
12	17.922	4.19	9-Octadecenoic acid, methyl ester (E)-
13	18.171	3.48	Methyl stearate
14	19.608	8.24	Acetic acid, 2-(4-cyclohexylphenoxymethyl)-4
15	19.709	12.21	9,19-Cyclochloestene-3,7-dol, 4,14-dimethyl-
16	20.837	4.97	.beta.-Sitosterol
17	21.385	11.76	9,19-Cyclo-9.beta.-Ianostane-3.beta,25-diol
18	21.738	2.08	6,9-Octadecadiynoic acid, methyl ester
19	23.084	9.22	9,19-CycloIanostan-3-ol, 24-methylene-, (3.be
20	23.226	6.00	Pregnan-17,21-diol-9,11-epoxy-3,20-dione, ac

21	24.297	2.48	Squalene
22	24.604	1.47	2(3H)-Naphthalenone, 4,4a,5,6,7,8-hexahydro

Table 7: Dominant compounds present in the Heartwood Extractives of Three Nigerian Guinea Savannah Species.

Extract	Compound	Conc.(%)	MW (g/mol)	Formula	CAS No.
VHE	(S)-(+)-1,2-Propandiol (Polyols; Aliphatic acyclic compounds)	73.51	76.09	$C_3H_8O_2$	4254-15-3
VHA	9,19-Cyclochloestene-3,7-diol, 4,14-dimethyl-, 3-acetate	12.21	472.8	$C_{31}H_{52}O_3$	4254-15-3
	9,19-Cyclo-9β.-Ianostane-3β.,25-diol	11.76	444.7	$C_{30}H_{52}O_2$	26525-84-8
BHE	Hexadecanoic acid, methyl ester (Palmitic acid)	34.82	270.45	$C_{17}H_{34}O_2$	112-39-0
BHA	Hexadecanoic acid, methyl ester (Palmitic acid)	17.38	110.11	$C_6H_6O_2$	123-31-9
	1H-Pyrido [3,4-b]indole 2,3,4,9-tetrahydro-1-methyl	11.46	228.33	$C_{15}H_{20}N_2$	
	Stigmasterol (Sterol)	14.38	412.7	$C_{29}H_{48}O$	83-48-7
PHE	7,7-Dimethyl-1-oxo-2,3,4,5,6,7-hexahydro-1) (Bicyclic monoterpenoids)	50.16	250.34	$C_{15}H_{22}O_3$	139571-20-3
	1,4-Methanophthalazine, 1,4,4a,5,6,7,8,8a-oct	33.20	178.27	$C_{11}H_{18}N_2$	
PHA	14.alpha.-Methyl-5.alpha.-ergosta-8,24(28)-di (Triterpene)	17.95	412.7	$C_{29}H_{48}O$	10191-41-0
	Campesterol (Sterol)	10.96	400.68	$C_{28}H_{48}O$	474-62-4
	Tetracosapentaene, 2,6,10,15,19,23-hexamethyl (Triterpenoid)	13.74	414.4	$C_{30}H_{52}$	26266-08-0

MW = Molecular weight

Hit#:1 Entry:445 Library:NIST11.libSI:97 Formula:C3H8O2 CAS:4254-15-3 MolWeight:76 RetIndex:724

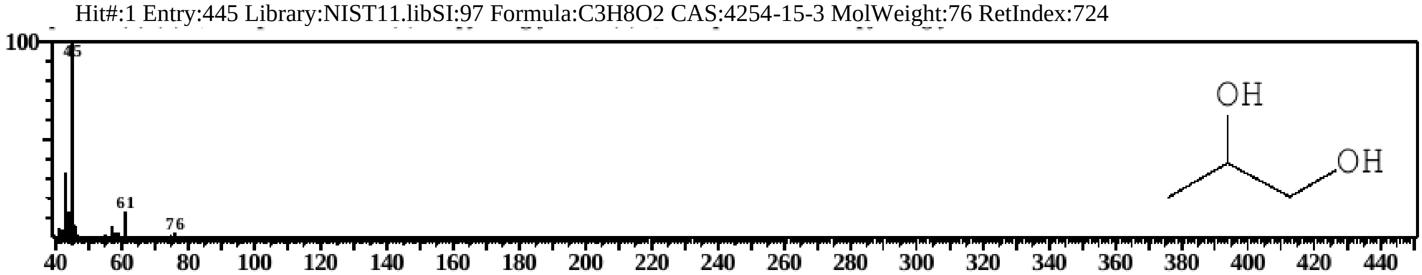

Fig. 7. Chromatogram of compound S)-(+)-1,2-Propanediol.

Hit#:1 Entry:201003 Library:NIST11.libSI:63 Formula:C31H52O3 CAS:0-00-0 MolWeight:472 RetIndex:3022

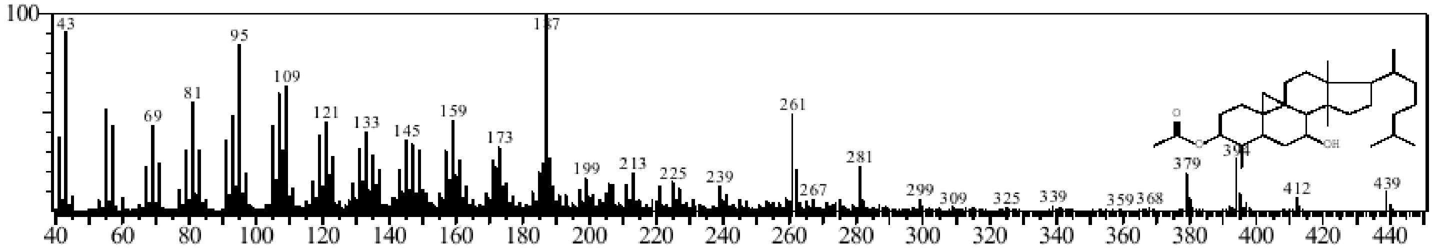

Fig. 8. Chromatogram of compound 9,19-Cyclochloestene-3,7-diol, 4,14-dimethyl-, 3-acetate

Hit#:4 Entry:24299 Library:NIST11s.libSI:88 Formula:C17H34O2 CAS:112-39-0 MolWeight:270 RetIndex:1878

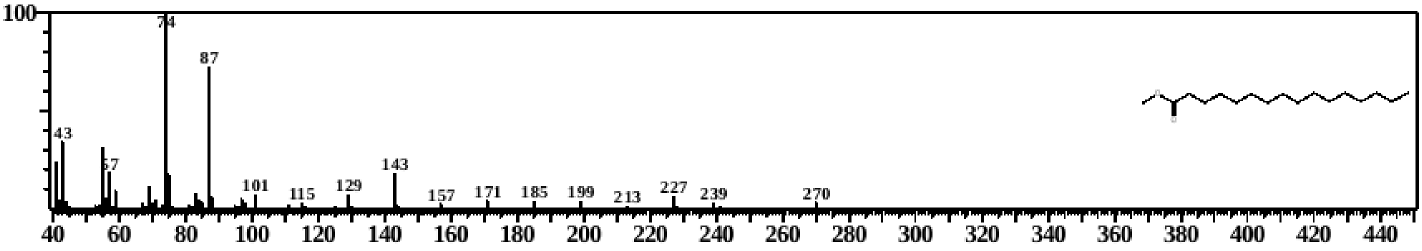

Fig. 9. Chromatogram of compound Hexadecanoic acid, methyl ester

Hit#:1 Entry:15456 Library:NIST11s.libSI:92 Formula:C12H14N2 CAS:2506-10-7 MolWeight:186 RetIndex:1820

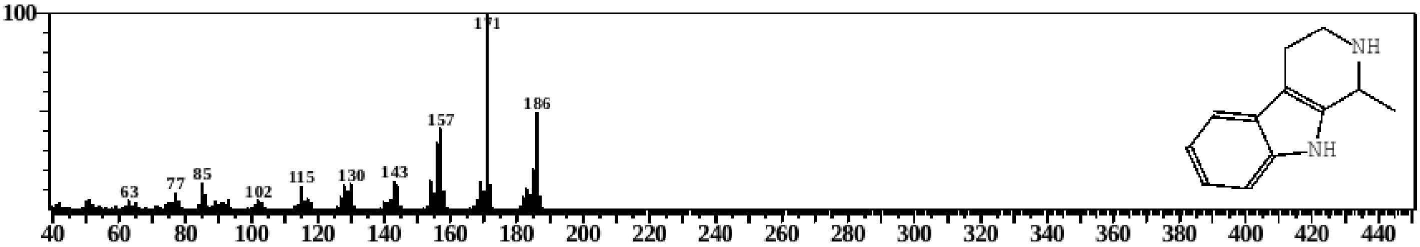

Fig. 10. Chromatogram of compound 1H-Pyrido[3,4-b]indole, 2,3,4,9-tetrahydro-1-methyl-

Hit#:1 Entry:79662 Library:NIST11.libSI:75 Formula:C15H22O3 CAS:139571-20-3 MolWeight:250 RetIndex:1853

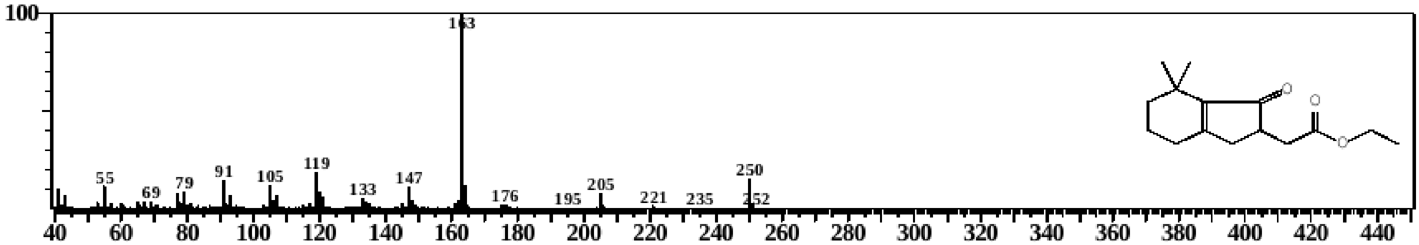

Fig. 11. Chromatogram of compound (7,7-Dimethyl-1-oxo-2,3,4,5,6,7-hexahydro-1H-inden-2-yl)acetic acid, ethyl ester

Hit#:2 Entry:47968 Library:NIST11.libSI:74 Formula:C13H22N2 CAS:109746-14-7 MolWeight:206 RetIndex:0

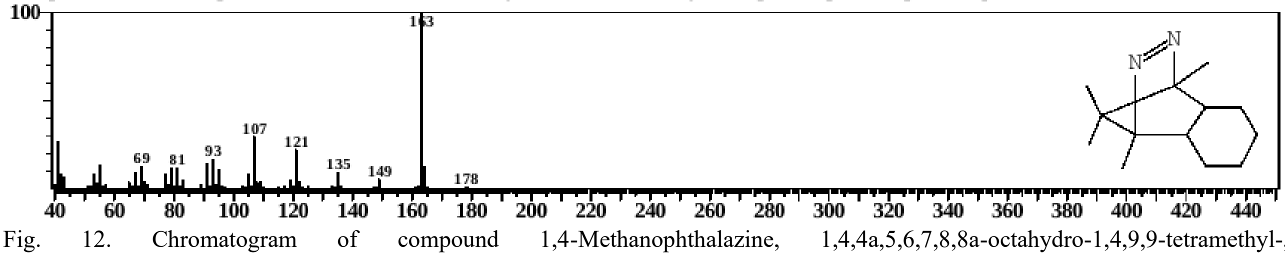

Fig. 12. Chromatogram of compound 1,4-Methanophthalazine, 1,4,4a,5,6,7,8,8a-octahydro-1,4,9,9-tetramethyl-, (1.alpha.,4.alpha.,4a.alpha.,8a.alpha100

Hit#:1 Entry:186839 Library:NIST11.libSI:72 Formula:C29H48O CAS:84693-05-0 MolWeight:412 RetIndex:2765

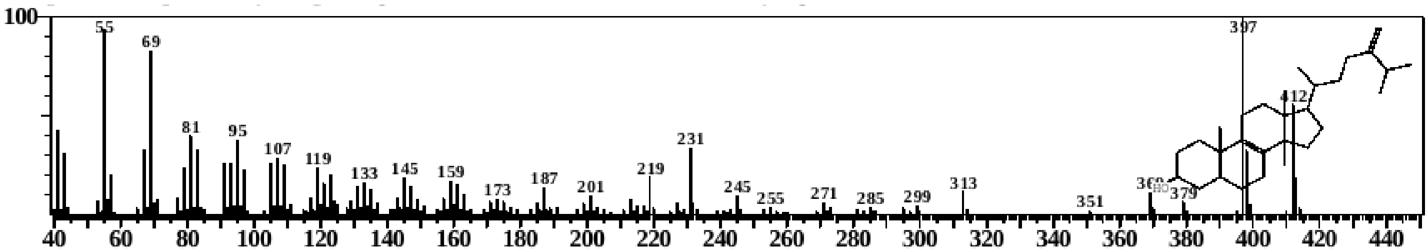

Fig. 13. Chromatogram of compound 14.alpha.-Methyl-5.alpha.-ergosta-8,24(28)-dien-3.beta.-ol $$ 14-Methylergosta-8,24(28)-dien-3-ol # 100

Hit#:1 Entry:182675 Library:NIST11.libSI:75 Formula:C28H48O CAS:474-62-4 MolWeight:400 RetIndex:2632

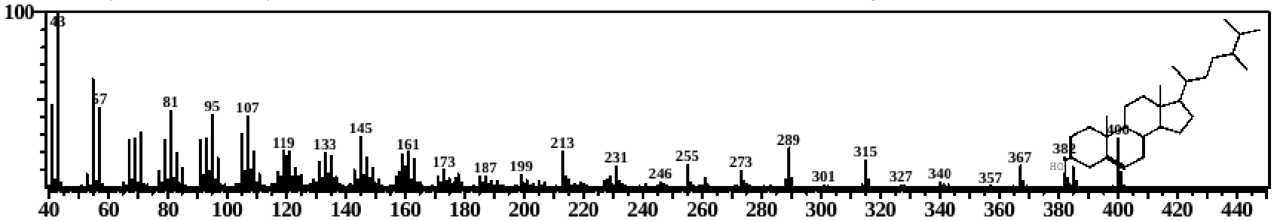

Fig. 14. Chromatogram of compound Campesterol

Hit#:1 Entry:186858 Library:NIST11.libSI:74 Formula:C30H52 CAS:26266-08-0 MolWeight:412 RetIndex:2865

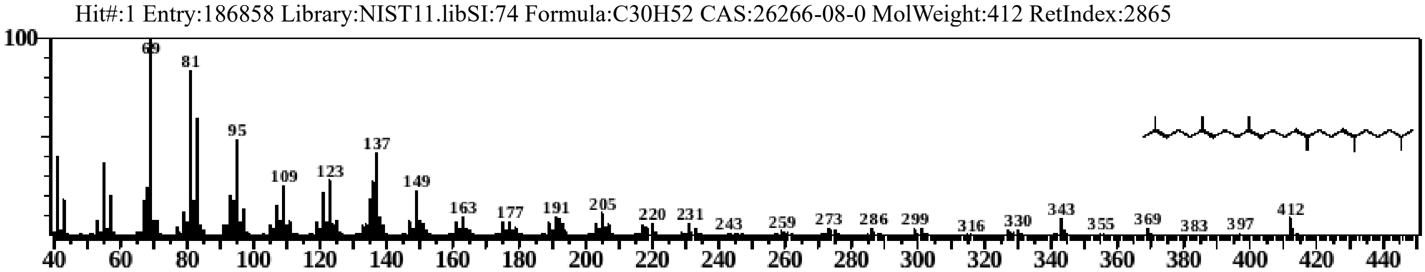

Fig. 15. Chromatogram of compound Tetracosapentaene, 2,6,10,15,19,23-hexamethyl-

DISCUSSION

The quantitative analysis of the chemical content in the ethanolic and aqeous extractives detected by GC-MS analysis of the heartwood extractives of the selected timber species are presented in Figures 1 to 19 and Table 1 to 6 while the principal compounds are presented in Tables 7. The GC-MS analysis of the selected timber species confirmed the presence of various pharmacologically active compounds. The heartwood of the selected timber species revealed the presence of fatty acids, coumarin, sesquiterpenes, flavonoids, alcohols, lignans, phenols, aldehyde, and ketone, etc (Table 1 to 5). The principal leading compound identified was (S)-(+)-1,2-Propandiol a polyol. This compound represented 73.51% of the total ethanolic extract of *V. paradoxa.* The remaining principal components were; 9,19-Cyclochloestene-3,7-diol, 4,14-dimethyl-, 3-acetate (12.21%) in VHA; Hexadecanoic acid, methyl ester (34.82% and 17.38%) in BHE and BHA respectively; 7,7-Dimethyl-1-oxo-2,3,4,5,6,7-hexahydro-1) (50.16%) in PHE and 14.alpha.-Methyl-5.alpha.-ergosta-8,24(28)-di (17.95%) in PHA (Table 6).

The phytochemicals in wood consist of fats, waxes, alkaloids, proteins, simple and complex phenolics, simple sugars, pectins, mucilages, gums, resins, terpenes, starches, glycosides, saponins and fatty acids which occur in minute quantities. According to Alireza (2012), main functions of these chemical components are to conserve energy in the tree metabolism, and protect against microbial attacks such as fungi, and/or insects [5,16] through the free radical scavenging and metal chelation activities of the wood extractives; wood are given enhanced protection against fungi degradation (Alireza (2012; Prayitno et al., 2021).

Generally, ethanol extract had more phytochemicals than water as revealed in the GC-MS result except in the case of *V. paradoxa* in tables …. . Likewise, the concentration of the phytochemicals that were revealed were more from ethanolic extracts compared to aqeuous extracts. This clearly shows that extraction media has great influence on the extraction of phytochemicals (Roszaini, 2017). Ethanol extraction led to the identification of 42 and 30 known compounds from the heartwood of *B. africana* and *V. paradoxa*. The ethanol extractives in heartwood were higher in composition and content than those of aqeuous for *B. africana* and *V. paradoxa* while they were low in *P. africana.* Due to the different species, the content of each component in each extract and species were different. However, some of the chemicals were common to all the species. According to (Qiu et al., 2019), the proportion of extractives in wood is small, but they play an important role in dictating some of the characteristics such as the color and smell of the wood as well as their resistance to bio-degrading agents. All the three timbers have brown to reddish-brown colours in their heartwood. These colours are as a result of these extractives in them which contains chromatic substances such as pigments, tannins and resins (Qiu et al., 2019. Most of these color-related components have been reported by (Qiu et al., 2019) to contain phenols, quinones, and ketones etc.

From the differences in compositions, it can be assumed that Hexadecanoic acid, methyl ester, and 1H-Pyridol[3,4-b]indole, 2,3,4,9-tetrahydro-1-; Stigmasterol could be responsible for the enhanced durability of *B. africana* because of their high concentrations in the extracts. Similalry, the enhanced durability of *P. africana* as claimed by local wood workers may be attributed to the concentration of 7,7-Dimethyl-1-oxo-2,3,4,5,6,7-hexahydro-1-methyl which represented more than half (50.16%) of the total constituents and in combination with 1,4-Methanophthalazine 1,4,4a,5,6,7,8,8a-oct which also represented 33.20% of the total constituents in *P. africana*. Other constituents of importance are 14.alpha.-Methyl-5.alpha.-ergosta-8,24(28)-di (a triterpene) Tetracosapentaene, 2,6,10,15,19,23-hexamethyl and campesterol may further contribute to the enhanced durability of *P. Africana*. Sadiku et al. (2021), reported *V. paradoxa* to be resistant to white (*Lentinus sajor-caju*) and brown rot (*Sclerotium rolfsii*) fungi and highly resistant to subterranean termite. (S)-(+)-1,2-Propanediol which occured in large amount (73.51%) is likely responsible for the resistance against these bio-degradingagents. Although, this may be in combination with 9,19-cyclchloestene-3,7-diol,4,14-dimethyl and 9,19-cyclo-9.beta. -Ianostane-3.beta.,25-diol. because these two compounds occured in fairly large amount in the heartwood of *V. paradoxa*.
Although, the principal compounds revelaed in the heartwood of these three timbers are assumed to provides the scientific evidences for their enhanced durabilty to biological agents of degradation, further studies will substantiate these claims. Therefore, isolation and investigation on the inhibitory activities of these principal components against various bio-digrading agents of wood is recommended.

CONCLUSION

The difference in content of the ethanolic and aqeuous heart wood extracts from each of the three timbers were distinct, the content of each component in each extract and species was different. The contents were obviously different based on extraction medium and from species to species. However, 5 compounds were similarly revealed in both ethanolic and aqeouos extracts of each of *V. paradoxa* and *B. africana*. Likewise, some compounds were common to *V. paradoxa and B. africana.* Generally, ethanol extract had more phytochemicals than water and the concentration of the phytochemicals were higher for ethanolic extracts compared to aqeuous extracts. This clearly shows that extraction media has great influence on the extraction of phytochemicals. The presence of some principal constituents in the heartwood of these species such as (S)-(+)-1,2-Propandiol which accounted for 73.51% of the total constituents in *V. paradoxa* ethanolic extract as well as 7,7-Dimethyl-1-oxo-2,3,4,5,6,7-hexahydro-1) and 1,4-Methanophthalazine, 1,4,4a,5,6,7,8,8a-oct which accounted for 50.16%, and 33.20% respectively in *P. africana* ethanolic extract and Hexadecanoic acid, methyl ester with concentration of 34.82% of the total constituents of *B. africana* Ethanolic extract could be responsisble for the enhanced resistance and durabilty of the three timbers to biological agents of degradation. The principal constituents may be isolated and investigate their termicidal as well as fungicidal activities..

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PRELIMINARY EVALUATION OF COMBUSTED FOREST FLOOR LITTERS FROM ACHALLA FOREST RESERVE AND INFLUENCE OF THEIR COMPOST ON GERMINATION POTENTIALS OF *Dacryodes Edulis* H. J. LAM

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ABSTRACT
The search for non-timber forest products as functional alternative and complimentary products aimed at reducing pressure on standing forest ecosystems to abate current decline in ecological contributions to global climate and sustainable livelihood crisis remains a global task. This study evaluated the potential of different forest floor litters, types and ages as compost sources in organo-mineral and alternative products production. Six (6) different forest litters were obtained from delineated vegetation patches of Pterocarpus erinaceus, Gmelina arborea, Tectona grandis, Bambusa vulgaris, Ceiba petandra and Mangifera indica in Achalla Forest Reserve. These were analyzed for nitrogen (N), potassium (K), phosphorus (P), calcium (Ca) and magnesium (Mg) before composting for 3, 6, 9 and 12 days respectively and then combusted to produce organo-minerals for growth of Dacryodes edulis in a-6 x 4 split-plot factorial experiments. Analysis of variance was conducted for litter characteristics, calorific values, moisture and ash contents and significant means separated with Duncan multiple range test (p > 0.05). The results showed that Mangifera had highest mean P (0.68%) and K (1.15%) while Bamboo had the highest mean N (1.92%). Germination of D. edulis was 6>9>12>3days with Bamboo > Ceiba > Teak>Mangifera>Gmelina>Pterocarpus at 6days compost age. Mean ash content and calorific values was 12>9>6>3days compared to moisture content 6>9=3>12 composting age with the 12days compost (16.76±4.61J/kg) and Mangifera (20.73±0.59J/kg) as potential energy product. The evaluated litters therefore constitute organic products that could be amended by microbes and thermal treatments to reduce agricultural pressure of deforestation in Achalla forest reserve.

Key Words: *Forest floor litters, Organo-mineral, Compost age, Germination percentage, Ash content.*

INTRODUCTION

The forest floor provides a dynamic platform in the ecosystem for variegated activities to generate essential energy outputs due to its interaction with the atmosphere and edaphic components at 0-5cm for a wide array of products to meet intermediate needs (Hoover and Lunt, 1952: Stephen and Patrick, 2005)). Essentially, floor litters depending on the thickness to permit air and moisture in the rhizosphere region create relative imbalance that alter underlying temperature (Groen and Savenije, 2006). Decomposition by microbial activities in this layer has been reported as critical to churning out precipitates for the modification and return of litters to the forest soil (Ochoa-Hueso *et al.*, 2019).

However, microbial activities under different thermal modifications have been observed as effective chemical pathways for bioturbation products in forest ecosystem (Lavelle, *et al*, 1997). This accounts for use of fire as a management tool in grassland and savanna ecosystems that reportedly release ash known for high quality of K, P, Ca and Mg along with a proportion of micronutrients (Bougnom *et al*., 2011). Controlled fire in land preparation as a means of combusting forest floor litters adjusted basic physicochemical soil properties that influenced tree growth characteristics due to the fertilizing capacity on both physical and chemical properties. In other climes, ash application to agricultural fields have been shown to compensate for critical nutrient deficiencies in leached and acidified soils (Saarsalmi *et al.*, 2006) while at the same time acted as anti-fungal agent against leafspot infections.

In the tropics, high soil fertility due to interactions between environmental factors and standing indigenous forest community has been observed as the attraction which has continued to endanger its sustainability by target for agricultural program (Egwunatum and Ezealisiji, 2020). This situation has accounted for loss of several hectares of protected forests in southern Nigeria because shifting cultivation has the fertile high forest as potential target for agricultural practices. Over 40% of forest reserves in Anambra State has been lost to agriculture with one-third gradually becoming degraded and encroached for residential purposes after several failures to practice inorganic agricultural due to search for fertile forest land coupled with high in availability of fertilizers(ICIR, 2022). Therefore, the propensity of agriculture to continually undermine forest reserves as a result of the soil fertility remains a serious bane to conservation and sustainable forest management.

However, standing forest patches in protected forests have been reported as notable sources of litters which can be relied upon for agricultural practices (Tjitrosemito *et al*, 2011). Whilst the forest is under strict conservation, effort at manipulating crucial parameters that aid high soil fertility status in tropical forest may provide basic rich organo-minerals for use in agricultural establishment. Organo-minerals are formed by a wide range of mechanism that involves activities of microbe on accumulated organic matter on the surface horizons of the forest floor layer in the presence of temperature, moisture and ambient soil conditions relying on the different rhizosphere qualities for individual tree (Becker *et al*, 2015; Jones *et al*., 2004).

It is in this light that litters of different forest parchments in Achalla Forest Reserve were studied and engaged by composting and combustion for the production of ex-*situ* materials as organo-minerals for the use in agro-allied conurbations and alternative energy product as substitute for fuelwood collection with a view to saving the standing forest under conservation from deforestation and degradation by agriculture and fuelwood crisis.

MATERIALS AND METHODS

Description of study area

The samples were collected from Achalla Forest Reserve in Awka North Local Government Area in Anambra State. Achalla forest reserve is located on latitude 6°20'39"N and longitude 6°57´43´´E in the South East region of Nigeria. The climate of the area is a humid sub–tropical, basically within the tropical rainforest ecological zone and dominated by broad–leaved hardwood trees that form dense, layered stands. Mean annual temperature is approximately 26°C, with minimum 19°C and maximum 34°C (NiMet, 2019).

The natural vegetation is similar to that of tropical lowland rainforest but heavy anthropogenic alteration over a long period of time had replaced previous forest with secondary forest (Dania – Ogbe *et al*., 1993).

Collection and analysis of forest floor litters

A reconnaissance survey was conducted by ground trotting to identify the various vegetation patches within the forest reserve portion not highly degraded. This was delineated into six vegetative portions of 50m x 50m plot respectively that comprised of *Gmelina arborea, Tectona grandis, Ceiba petandra, Bambusa vulgaris, Pterocarpus erinaceus* and *Mangifera indica*. Fresh forest floor litters were collected from ten quadrants (50cm x 50cm) in each plot for the six vegetations. Litters were collected from the forest floor layer (0-5cm depth) that consisted of twigs, barks, leaves and surface soil from the (L and F) layer as described by (Hoover and Lunt, 1952).

The collected forest floor litter samples were sundried at screenhouse temperature of 35-37.5°C for 24hours. Nitrogen was determined by the Microkjedahl digestion (Bremnar and Mulvaney, 1982). Then samples were dried to ashes at 120°C for 1hour before extraction with nitric-perchloric acid for determination of P, K, Ca and Mg. The P was determined by Vanado molybdate method while K, Ca and Mg by EDTA titration (Faithful, 2002).

Preparation of forest floor litter products

The six (6) forest floor litters were composted anaerobically in black litter bags at 3 replicates per litter types for 3, 6, 9 and 12days aging period under screen house temperature. Harvested composts were then combusted semi-anaerobically for a uniform time of 240seconds at 45°C.

Emanating combusted compost litters products were allowed to cool for 24hours and analyzed for moisture content, ash content and calorific value respectively. The moisture content was analyzed by heating at 105°C for a period of 60min while the ash content was determined by heating the sample at 600°C for 4hours (ASTM, 2008).

Then 150gm each of combusted compost litters were weighed into different troughs with 75cl of sterilized water and allowed to stand for 60minutes to produce twenty-four (24) different organo-mineral slurries.

Germination trials

Matured seeds of *Dacryodes edulis* were obtained from Eke Awka market, in Awka, and tested for viability using the floatation method. Four hundred and eighty (480) selected viable seeds were manually de-pulped before sowing in 6 germination troughs measuring 150cm x 50cm x 20cm and containing soils already inoculated with different organo-mineral slurries in uniform ratio of 1:2 at 80 seeds per organo-mineral type. Furthermore, 50gm of each ash type was applied by sprinkling 2days after sowing to support the efficacies.

Germination was then monitored at intervals of 1-5 and 5-10 weeks after sowing while germination recorded was expressed in percentage as the ratio of numbers that germinated to the total number sown per trough multiplied by 100.

RESULTS

Nutrient element composition of forest floor litters

The nutrient element composition of collected forest floor litters is shown in Table 1. The Bamboo litters have the highest mean N content of 1.92% and differed significantly from other litter types. The least mean N was recorded *Tectona grandis* and Pterocarpus that were not significantly different. The mean P was quite low with Ceiba and *Mangifera indica* litters showing highest means that were not significantly different. The *Gmelina arborea* litters showed the least mean P value (0.09%).

The highest mean K (1.15%) was recorded by Mangifera and was significantly different from all other types of litter. There were no significant differences in the mean K between Teak and Pterocarpus as well as between Ceiba and Gmelina. Pterocarpus recorded the highest mean Ca (1.92%) which differed significantly from other litters. there was no significant difference between mean Ca of Bamboo and Mangifera as well as between Ceiba and Teak.

Bamboo litters recorded the highest mean Mg (0.23%) that was not significantly different from Teak (0.19%). There was no significant difference in the mean Mg of Pterocarpus, Gmelina, Ceiba and *Mangifera indica*.

Table 1: Nutrient element composition (% dry weight) of forest floor litters in Achalla Forest Reserve

Litter Source/ Type	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Pterocarpus erinaceus	1.58^{c}	0.25^{c}	0.28^{c}	1.92^{a}	0.03^{b}
Gmelina arborea	1.18^{e}	0.09^{e}	0.16^{d}	1.16^{b}	0.08^{b}
Tectona grandis	1.57^{c}	0.15^{d}	0.27^{c}	0.28^{d}	0.19^{a}
Bambusa vulgaris	1.92^{a}	0.63^{b}	0.47^{b}	0.58^{c}	0.23^{a}
Ceiba petandra	1.78^{b}	0.68^{a}	0.18^{d}	0.38^{d}	0.10^{b}
Mangifera indica	1.36^{d}	0.68^{a}	1.15^{a}	0.61^{c}	0.09^{b}

Mean in the same column with the same superscript are not significantly different (p > 0.05)

Effect of combustion on compost forest floor litter types of Achalla forest reserve

Moisture content

Table 2 shows that the moisture content in *Tectona grandis* was significantly different ($p > 0.05$) from other forest floor litters types. There were no significant differences between *Pterocarpus erinaceus Ceiba Bombax, Mangifera indica, Bambusa vulgaris* and *Gmelina arborea.* The mean moisture content was *Tectona grandis* (13.99 ± 0.73%) > *Pterocapus erinaceus* (11.70 ± 0.79%) > *Ceiba petandra* (11.50 ± 0.90%) > *Mangifera indica* (9.65 ± 0.49%) > *Bambusa vulgaris (*8.80 ± 0.51%) > *Gmelina arborea* (8.45 ± 0.44%).

Ash content

There were significant differences ($p > 0.05$) in the ash contents of the different forest litter types at combustion (Table 2). The result of combusted litters shows that *Mangifera indica* recorded the highest ash content of 4.47±1.45%. The ash contents were *Tectona grandis* (4.30 ± 2.30%) > *Gmelina arborea* (4.24 ± 0.43%) > *Bambusa vulgaris* (3.53 ± 0.18%) > *Ceiba petandra* (3.17 ± 0.40%) > *Pterocarpus erinaceus* (2.32 ± 0.32%).

Table 2: Effects of combustion on composted floor litters in Achalla Forest Reserve

Litter source/Type	Ash Content (%)	Calorific Value (J/kg)	Moisture Content (%)
Pterocarpus erinaceus	2.32 ± 0.32^{e}	8.45 ± 0.40^{f}	11.70 ± 0.79^{a}
Gmelina arborea	4.24 ± 0.43^{b}	11.99 ± 0.43^{e}	8.45 ± 0.44^{c}
Tectona grandis	4.30 ± 2.30^{b}	14.78 ± 2.30^{d}	12.19 ± 0.73^{a}
Bambusa vulgaris	3.53 ± 0.18^{bc}	18.60 ± 0.85^{c}	8.80 ± 0.51^{c}
Ceiba petandra	3.17 ± 0.40^{d}	19.44 ± 0.90^{b}	11.50 ± 0.90^{a}
Mangifera indica	4.47 ± 1.45^{a}	20.73 ± 0.59^{a}	9.65 ± 0.49^{b}

Means ±std error in the same column with same superscript are not significantly different (p > 0.05)

Calorific value

There were significant differences ($p > 0.05$) in the calorific value of all the forest litters as shown in Table 2. The *Mangifera indica* recorded the highest calorific value (20.73 ± 0.59 J/kg) > *Ceiba petandra* (19.44 ± 0.90 J/kg) > *Bambusa vulgaris* (18.60 ± 0.85

J/kg) > *Tectona grandis* (14.78±2.30 J/kg) > *Gmelina arborea* (11.99±0.43 J/kg) > *Pterocarpus erinaceus/Gmelina arborea* (8.45±0.40 J/kg).

Effect of compost age on combustion

Moisture content

The mean moisture content of compost floor litters at 3 days age differed significantly from other ages (Table 3). There was no significant difference in the moisture contents of combusted floor litters at ages 6, 9 and 12 days. The highest moisture content of 10.12 ± 1.51 % was recorded by the 6days age forest floor litters while the others were D2 > D3 (9.60 ± 1.54 %) > D4 (8.91±0.32 %)

Ash content

There were significant differences in the ash contents of the forest floor litters at different composted ages as shown in Table 3. The highest ash content was produced by the 12days aged compost litters (4.45 ± 1.35 %) while the least of 2.95 ± 0.45 % was recorded at 3days. The 6- and 9-days aged compost produced ash contents of 3.53 ± 0.87 % and 3.77 ± 0.94 % respectively.

Calorific value

There were significant differences between the calorific values of different ages of composted forest floor litters at combustion (Table 3). The highest calorific value was produced by the 12days aged (16.76 ± 4.61 J/kg) and the least by 3days aged (14.73 ± 4.42 J/kg). The 9 and 6days aged forest floor litters recorded calorific values of 16.21 ± 4.69 J/kg and 14.95 ± 4.45 J/kg respectively that were significantly different (p > 0.05).

Table 3: Effects of Compost age on Composted floor litters in Achalla Forest Reserve

Compost Age (Days)	Moisture Content (%)	Ash Content (%)	Calorific value (J/kg)
3.00	9.92 ± 2.62^{b}	2.95 ± 0.45^{d}	14.73 ± 4.42^{d}
6.00	10.12 ± 1.51^{a}	3.53 ± 0.87^{c}	14.95 ± 4.45^{c}
9.00	9.60 ± 1.54^{b}	3.77 ± 0.94^{b}	16.21 ± 4.69^{b}
12.00	8.91 ± 0.32^{c}	4.45 ± 1.35^{a}	16.76 ± 4.61^{a}

Means ±std error in the same column with same superscript are not significantly different (p > 0.05)

Effect of compost on Germination of *Dacryodes edulis*

The effect of various litter compost types on germination of *Dacryode edulis* is shown in Figure 1. The highest and least germination percentages during the first interval of 1-5weeks were recorded by the 6 and 12days compost litters respectively. Bamboo (BB) compost litters recorded the highest (50.5%) while the Gmelina (GM) and Pterocarpus (PE) compost litters recorded the least (10%).

The percentage germination at 5-10weeks interval showed that the 6days compost litters and Bamboo had the highest germination percentage (87.5%). Ceiba (CB), Teak (TK) and Mangifera (MG) recorded 85%, 68.75% and 42.5% respectively with the 6days. The Bamboo recorded highest germination of 71.25% while Ceiba and Teak was 60% with the 9days compost

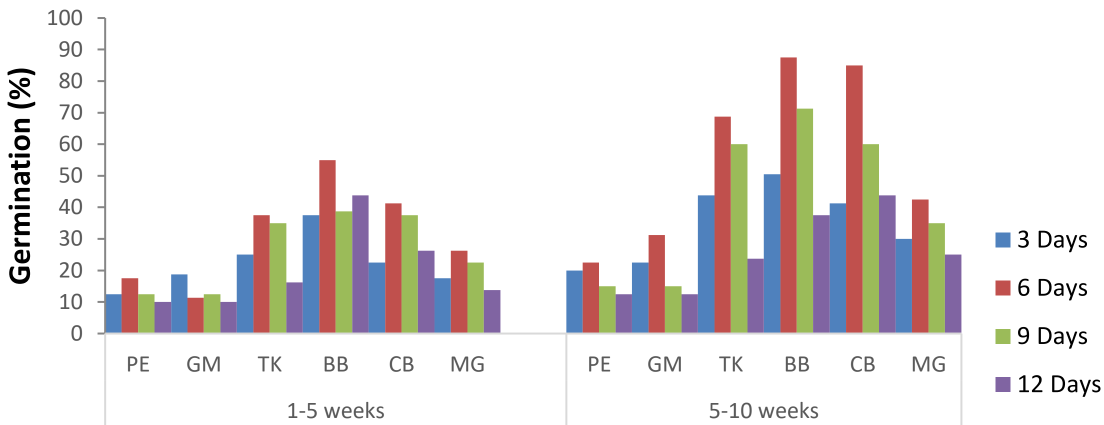

Figure 1:Effect of Forest Floor litter Compost Types and Age on Germination of Dacryodes edulis

DISCUSSIONS

The lower moisture contents of Gmelina, Bamboo and Mangifera may not be connected with growth characteristics of tree species but rather likely with the litter constituents which decreased with compost age. This may be due to the moisture use efficiency of microbes for the breakdown of vegetative matter. This finding is in line with Jonesberg (2017) that moisture availability decreases with high microbial activity as it is often employed in multiplication for enhanced services.

Ash content of combusted floor litters notably increased with age of composting. Since compost efficiency declines with age due to lower microbial population under regimented conditions, a large quantity of compost feed stocks may have contributed significantly to the ash content at combustion. Invariably, the low mean ash content could be as a result of low organic matter content and high microbial activity. Ash plays critical roles in agricultural practices and it represents critical source in adjusting soil acidity in soils. The utilization of forest fires under control in bush burning serves as latent ash source for organic agricultural practices in tropical forest to compensate for nutrient losses caused by harvesting and leaching and counter-act soil acidification (Nabatte and Nyombi, 2013). Unfortunately, the direct use of fire on soils has significant impact on resident microbial community which could reduce the potential of such forest soils to support productive agricultural activities over time. However, the fantastic germination achievement shown by the 6 and 9days compost organo-minerals implies better forest conservation, improved soil structure and capacity to retain water as well as nutrients (Atere and Olayinka, 2012). The high N and P-contents of Bamboo and Ceiba floor litters may have contributed substantially, especially during composting to the organo-mineral potential to account for the highest germination of *D.edulis*.

The calorific value of compost floor litters increased with compost age, attaining the highest mean (16.76±4.61J/kg) at 12days. Hence, longer composting age may enhance the calorific value of forest floor litters which essentially revealed and justified the need for composting before combustion. Materials with low calorific values have been reported to demonstrate poor thermal properties and may not function effectively as substitute for energy product. Consequently, the 12days compost combusted forest product and *Mangifera indica* tree species may have better potential as energy alternative products that could function as substitute of fuelwood to avert forest degradation.

CONCLUSION

This study indicated that investigated forest floor litter types in Achalla Forest Reserve represent veritable sources of compost and ash for use as organo-minerals products in soil enrichment. These will comparatively facilitate conservation of standing forest to enhance ecological services while still meeting the need of organic agriculture without forest degradation and deforestation in the already encroached forest reserve.

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COMPARATIVE ANALYSIS OF THE EARLY GROWTH OF *Bombax buonopozense* (P. BEAUV.) and *Ceiba pentandra* (LINN.) GAERTN, A SILK PRODUCING FOREST TREES IN NIGERIAN DRY-LAND.

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ABSTRACT
Nursery-experiments were conducted during the dry season at the FRIN central nursery, Kano. The study is aimed at evaluating the early growth and development of Bombax buonopozense and Ceiba pentandra for sustainable silk production development. Sown seeds of the plants were transplanted into polypots 2 weeks after sowing, selecting 10 specimens from each and replicated 4 times. These were represented graphically and the data was subjected to t-test analysis for comparative breakdown. Mean height, leaves, and leaflet numbers were recorded as 11.6 and 10.9cm; 3.6 and 3.8; 11.8 and 12.1 respectively for Bombax and Ceiba, while the basal diameters had 0.21cm constant for each species. Weekly growth rate was recorded as 1.66 and 1.56 centimeters for height, as well as 0.51 and 0.54; 1.69 and 1.73; and rhymed 0.03cm for leaf numbers, leaflets and basal diameters respectively for both Bombax and Ceiba species. At 0.05 level of significance therefore, calculated-t were 1.86cm, for mean height, 2.0 for leaf numbers, 1.20 for leaflets and 0.005cm for basal diameters, comparative within the 2 species**.** *Moreover, at 18 DF, t-tabulated were 2.1cm for mean height, 4.3 (leaves), 2.18 (leaflets), and 1.96cm (basal diameters). The growth and development of the two species in the nursery is very tremendous, compromising their enduring comparative advantage for no significant difference between both species. Profound effort is hereby recommended for their massive regeneration, conservation and resource maximization, despite propagation ease for raw materials and industrial development, employment generation, GDP growth, and environmental development.*

Key words: *Conservation; Employment; GDP; Raw material; Sustainable.*

INTRODUCTION

The floral complex of the world's forest estate is naturally structured to provide social services for mankind. Salami, *et.al*, (2014) however hypothesized that within the concept of this provisional framework is that of raw materials for domestic and industrial process. Specific example is however driven towards the provision of silk cotton as raw materials, among other valuables from *Bombax buonoposense* and *Ceiba pentandra*, a set of forest tree species profusely distributed in Nigerian dry-land. Unfortunately, man had done more harm than good in the course of utilization. The unfortunate scenario is further aggravated with the fact that, these tree species are hardly found in streaked plantation within Nigerian forest estate, but only as an ornamental or shade trees, and they are fast disappearing into the extinct, (Salami, 2014).

Ceiba pentandra (Linn.) Gaertn is a deciduous tree species in the family Bombacaceae. It is commonly called the silk cotton or Kapok tree, growing up to 60m high and 8m girth. Old trees are readily recognized by their enormous trunk, supported by large plank buttresses, and also by the widely spreading branches; but young trees have conspicuously whorled branches, and are often densely covered with large conical thorns, (Keay, 1989). *Ceiba pentandra* is however native throughout the American tropics, from Mexico to Central and South America, Peru, Bolivia, Brazil, as well as West Africa; extending from Cape Verde, eastward to Chad and Angola, descending to Nigeria and Ghana, (Woodward, 2010).

Trees normally start to bear fruit when they are 3–8 years old. The fiber is fine, lightweight, elastic, even though, it is not suitable for spinning into threads, (Brown, 2015). The fruit is often shaped like a small cucumber, 10-30cm long, but varying in size and shape with respect to the variety, (Keay, 1989). When fruiting occurs in March, the mature capsules split into five segments releasing the characteristic "silk cotton" also known as kapok, (Brown, 2015). A growing tree produces about 600 to 900 seed capsules or 6 to 9 pounds of clean floss (kapok) annually, (Swarbrick, 1997).

However, *Bombax buonopozense* (P. Beauv.), commonly known as the Gold Coast Bombax or Red-flowered Silk Cotton tree, is a tree in the mallow family, specifically known as malvaceae (Keay, 1989). The tree has almost the same characteristics with *C. pentandra* (Salami, 2014), and differs only slightly. It is native primarily to West Africa, where it is found in rainforests of Sierra Leone, Nigeria, Ghana, Uganda and Gabon, typically at an elevation of 900 to 1200 metres (Freebase, 2010). *B. buonopozense* is a large tropical tree that grows to 40 metres (130 feet) in height with large buttress roots that can spread 6 metres (20 feet).

The plant species start to bear within 4-5 years age. The conspicuous flowers emerge while the tree is leafless (Blench, 2006). The fruits are oblong and fairly large, 8 to 18cm in length by 3.5 to 6cm in diameter. They are glabrous, and open spontaneously at maturity. They contain many seeds that are 5 to 6mm in length, all of which have woolly kapok, a cotton-like fibre (Henk and Smith, 2001).

Common features to the two plant species include the floss on seeds (kapok) that is harvested for use in buoys, life belts, and similar articles, (Chudnoff, 1984; Salami, 2014). This floss is also used as an alternative to down feather, fillings in mattresses, pillows, upholstery, zafus, and stuffed toys such as teddy bears, and for insulation (Henk and Smith, 2001; Salami, 2014). It is also used for packaging industrial and agricultural products against transit damages (FRIN 2011). Nonetheless, it is only used as a cotton substitute and cannot be spun, and as such, its use is limited to stuffing for pillows and clothing (Henk and Smith, 2001; Brown, 2015). Additionally, they are both naturally dispersed by wind as well as water borne because of the cotton laden composition of the seeds, as the pods explodes mechanically at maturity (Henk and Smith, 2001; Salami, 2014; Brown, 2015).

Kapok bearing trees are found in both wet evergreen and dry semi-deciduous tropical forests, and grow well in a range of environments from savanna to forest, and rich volcanic and poor soils; as well as in moist uplands. They are rarely seen away from human settlement, (Yuncker, 1959; McMullen, 1999; Salami, 2014). The trees require abundant rainfall during the vegetative period and a drier period for flowering and fruiting. It is not tolerant of strong wind and raging fire, (Henk and Smith, 2001; Brown, 2015).

Both species' woods are rated as extremely vulnerable to decay when in ground contact, and very susceptible to insect attack, as they are soft and light, and not suitable for furniture, ((Henk and Smith, 2001; Woodward, 2010). It is easy to treat with good absorption and penetration; as it makes good plywood, packaging, lumber core stock, light construction, production of pallets, pulp and paper products, and for local canoes and rafts, (Chudnoff, 1984; Henk and Smith, 2001; Woodward, 2010). Moreover, it is suitable for making tubs, basins, stools and for carvings of all types, (Henk and Smith, 2001; Brown, 2015).

Kapok timber is desirable because of the great length of its trunks, the beautiful colour of its wood, and its straight grain (Salami, 2014). The wood is lightweight, with a density, ranging from (200–450) kg/m³ at 12% moisture content, which limits its uses to canoes and other implements. The density of the wood increases strongly from pith to bark, and varies between trees from different sites, (Henk and Smith, 2001). The wood seasons rapidly, with only slight risks of cupping, springing, twisting or bending, (Persada, 2010).

The seeds as well as the oil of both species can be used locally in soap making. Edible, the oil can be used for lighting, while the seed cake (leftover after pressing for oil) can be used to feed livestock, (Jukofsky, 2002; Woodward, 2010). Kapok oil has some potentials as a biofuel and in paint preparation; and that it can also be used as fertilizer, while flowers are an important source of nectar and pollen for honey bees, (Jukofsky, 2002; Woodward, 2010; Salami, 2014). It is reported that leaves, buds, and fruit are edible when cooked, (Henk and Smith, 2001). In Java, the young pod is eaten, and in West Africa, the seeds are eaten roasted or in soups. Cattle, goats and sheep, readily consume leaves (Henk and Smith, 2001; Brown, 2015).

The medicinal value of the both plant species is also great. The bark decoction of *Ceiba pentandra* has been used as a diuretic, aphrodisiac, and to treat headache, as well as type II diabetes, as it is also used as an additive in some versions of the hallucinogenic drink, (Brunken, *et al*, 2008). Many parts of Bombax are also utilized for medicinal and traditional purposes, and in Ghana, the bark is burnt to produce a smoke that is believed to drive away evil spirits, (Brunken, *et al*, 2008). The abundant thorns present on the bark are burnt, and the resulting charcoal is mixed with butter to treat swelling, in addition to the dried gum produced from the tree which is also used as incense (Blench, 2006).

Because of the above mentioned veritable socio-economic values of the two plant species, it is deemed necessary to dwell into their production and regeneration techniques in order to maximize the utilization of their endowment values, and sustainably for potential development.

MATERIALS AND METHODS

The Study Area

Kano is the capital city of Kano state, one of the largest Hausa states in Nigeria. The state is located in the north-west geo-political zone, with current population estimate of over 9 million people. It occupies a land mass of about 20,131 Km^2, on a geographic location of latitude 11.76^0 N, and longitude 8.66^0 E. Rainfall is between May and October, but stable for about 4 months between June and September, approximately 510-1140 mm. per annum. Relative humidity is low and temperature varies between 14^{0}C and 38^{0}C, typical of Sudan savannah dry-land ecosystem. Over 80% of the populace is however engaged in subsistence farming and animal husbandry. This is the reason why the zone is considered agrarian, as majority of the working adults engage in agriculture as a means of livelihood, (Salami, 2014).

Nonetheless, dry-land environments are the areas where average rainfall is less than the potential moisture losses through evapotranspiration processes. This implies that dry-lands are usually dry for the greater part of the year, with less than 0.65 aridity index, (UNEP, 1992). Apart from the semi-arid and sub humid ecosystems, arid and hyper arid form the major components of the dry-land environments. These subtypes are however recognized based on an increasing level of aridity or moisture deficit. Arid environment therefore, is an area with annual rainfall of about 0.03 to less than 0.2 aridity indexes, while the hyper arid has rainfall of less than 0.03, (USGS, 1997). The level of aridity typical for each of these subtypes is given by the ratio of its mean annual precipitation to its mean annual evaporative demand expressed as potential evapotranspiration. Moreover, the long term mean of this ratio is termed the aridity index, (Salami, 2014).

Seeds of *Ceiba pentandra* and *Bombax buonopozense* were collected within the corridors of Minjibir, Gezawa, and Kabo LGAs of Kano State towards the northern end, while the experiment was conducted within the Kano metropolis at the enclosure of the central nursery of Forestry Research Institute of Nigeria (FRIN), fig. I. These were processed and sowed in germination trays. Ten polypots, representing the treatments were filled using ordinary top soil, and replicated into 4 for each of the plant species. This amounts to 40 polypots per plant species. The germinated seedlings in the germination trays were transplanted into the filled polypots 2 weeks after sowing, picking specimen of the same size to ensure uniform age from the onset. The experiments were watered on daily basis, and were put under observation for 8 weeks after transplanting.

The results of the experiments were subjected to a couple of analysis. Growth parameter readings such as height (MH), number of leaves (MNL), number of leaflets (MNLF), and basal diameter (MBD) were recorded and analyzed for their mean, and was tabularized. The growth rate was determined from the growth record analysis for height (WMHGR), number of leaves (WMNLGR), number of leaflets (WMNLFGR), and basal diameter (WMBDGR) per week intervals, fig. II. Moreover, a t-test analysis was used to compare the growth variables between the two species.

RESULTS

Records of total mean heights of 11.6 and 10.9 centimeters; number of leaves at 3.6 and 3.8; number of leaflets at 11.8 and 12.1; and equilateral basal diameters of 0.21cm were observed for both species of Bombax and Ceiba respectively within 8 weeks from transplanting, table I. In addition to the above, a mean height growth rates of 1.66 and 1.56; mean number of leaf growth .

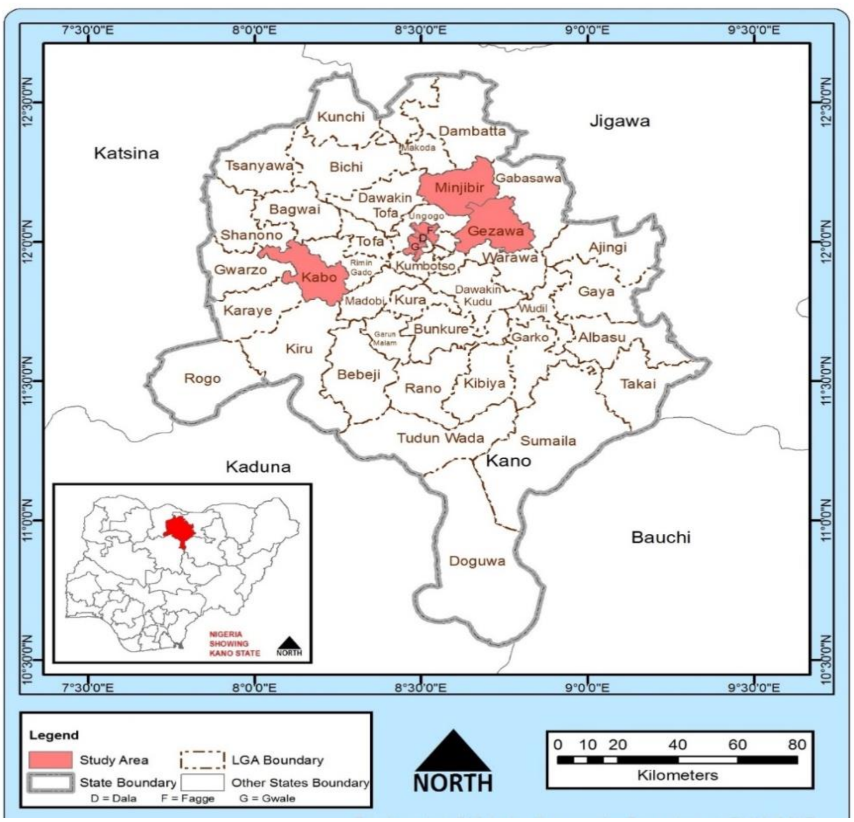

Fig. I: Map of the study area

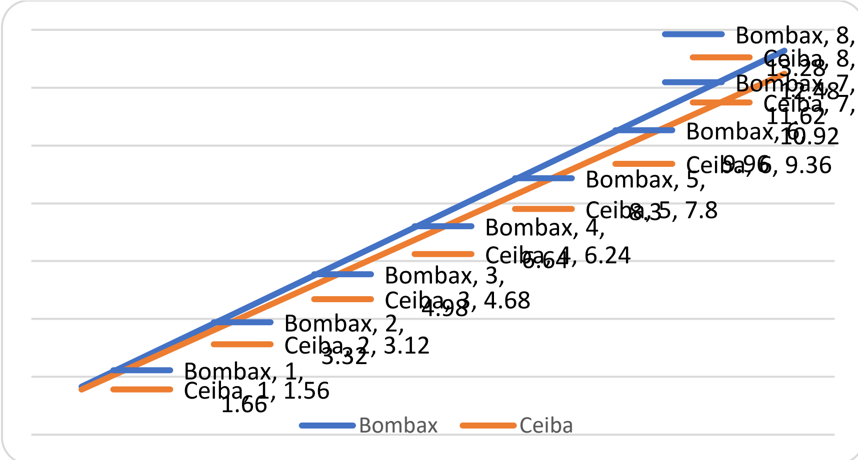

Fig. II: Weekly Growth Rate Summary for Bombax and Ceiba in the Nursery

Table I: Early growth parameter analysis of *Bombax bunoposense* and *Ceiba pentandra* in the nursery.

SPECIES	MH (cm)	WMHGR (cm)	MNL	WMNLGR	MNLF	WMNLFGR	MBD (cm)	WMBDGR (cm)
B. buonop.	11.6	1.66	3.6	0.51	11.8	1.69	0.21	0.03
C. pentan.	10.9	1.56	3.8	0.54	12.1	1.73	0.21	0.03

MH=Mean Height; WMHGR=Weekly Mean Height Growth Rate; MNL=Mean Number of Leaves; WMNLGR=Weekly Mean Number of Leaf Growth Rate; MNLF=Mean Number of Leaflet; WMNLFGR=Weekly Mean Number of Leaflet Growth Rate; MBD=Mean Basal Diameter; WMBDGR=Weekly Mean Basal Diameter Growth Rate

rates of 0.51 and 0.54; mean number of leaflets growth rates of 1.69 and 1.73; and rhymed mean basal diameter growth rates of 0.03 were also recorded per week for both plant species respectively. See table I.

Furthermore, the results of the t-test analysis on the plant species (Bombax and Ceiba) in a bid to test the significant differences in their growth and development for comparative analysis indicated that at 0.05 level of significance, calculated t were observed as 1.86cm for mean height growth, 2.0 for mean number of leaves, 1.20 for mean number of leaflets and 0.005cm for mean basal diameter, table II.

Moreover, at 18 degree of freedom (DF), t-tabulated were recorded as 2.1cm for mean height growth, 4.3 for mean number of leaves, 2.18 for mean number of leaflets, and 1.96cm for mean basal diameter. See table II. With the above comparative trends consequently, it was observed that there is no significant difference in the early growth and development of Bombax and Ceiba plant species in the nursery, as the null hypothesis is accepted.

DISCUSSION

The physical features of Bombax and Ceiba in the early stages of growth and development in the nursery is very tremendous. This growth trend (fig. II) however corroborates

Table II: T-test analysis for comparative growth and development of Bombax and Ceiba on various parameters.

PARAMETERS	MH	MNL	MNLF	MBD
0.05 Confidence Level				
T-Cal.	1.86 cm	2.0	1.20	0.005
18 DF				
T-Tab	2.1 cm	4.3	2.18	1.96

the reports of Swarbrick (1997); Henk and Smith (2001); FRIN (2011); Salami (2014); and Brown (2015) which compromised that Bombax and Ceiba plant species under focus grows well in the nursery.

Moreover, the comparative advantage of the two plant species over each other is also very enduring and competitive for no significant difference between the both species. This observation nevertheless is in agreement with the reports of Henk and Smith (2001); Blench (2006); FRIN (2011); Salami (2014); Brown (2015) that the two plant species has very common characteristics in most of their development facets, inclusive of nursery behaviours, growth and developments such as height growth, leaf and leaflets developments, and basal diameter growths.

CONCLUSION AND RECOMMENDATIONS

The production, multiplication and regeneration of Bombax and Ceiba plant species are not rigorous owing to the results of this experiment centering on the early growth and development of the two plant species from the nursery stage. These include the total mean heights of 11.6 and 10.9 centimeters; number of leaves at 3.6 and 3.8; number of leaflets at 11.8 and 12.1; and equilateral basal diameters of 0.21cm observed at their averages for both species of Bombax and Ceiba respectively within 8 weeks from transplanting; as well as a mean height growth rates of 1.66 and 1.56; leaf numbers growth rates of 0.51 and 0.54; leaflets growth rates of 1.69 and 1.73; and rhymed mean basal diameter growth rates of 0.03 per week for both plant species respectively is overwhelmingly encouraging.

Succinctly, the growth and development of the two species in the nursery is very tremendous, compromising their enduring comparative advantage for no significant difference between the both species. In essence therefore, profound effort is hereby recommended for their massive regeneration, conservation and resource maximization, despite ease of propagation for raw materials and industrial development, employment generation, GDP growth, and environmental development.

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INFLUENCES OF SEED WEIGHTS AND CONCENTRATIONS OF SULPHURIC ACID ON THE GERMINATION OF AFRICAN LOCUST BEAN (*Parkia biglobosa* JACQ BENTH) SEEDS

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ABSTRACT

There is dearth of quantitative information on the effect of seed weights and concentrations of acid on the germination of Parkia biglobosa seeds. Towards enhancing quality of planting stock and germination potential, this experiment was conducted. The experiment adopted a 3x4 factorial arranged in a completely randomized design with twelve treatments replicated five times to assess the effects of seed weights (0.57, 0.63 and 0.70g) and concentrations of sulphuric acid (0, 30, 60 and 90%) on the germination of Parkia biglobosa seeds. Six hundred (600) seeds stored in room temperature (27°C) for three month were used. Fifty (50) seeds each of different weights (0.57, 0.63 and 0.70g) were soaked in different concentration of sulphuric acid (0, 30, 60 and 90%) for 30 minutes and planted in 4cm depth of sterilized river sand. A 200ml of water per each pot was applied at two days' interval. Data collected were subjected to analysis of variance (ANOVA) using SAS 2003. Comparison of significant means was accomplished using Fishers Least Significant Difference (LSD) at 5% level of significance. Seed weights and concentrations of sulphuric acid significantly ($P<0.05$) enhanced the germination of P.biglobosa seeds. A significant germination percentage value of 100% was recorded from 0.70g seeds soaked in 90% concentration of sulphuric acid. Soaking of 0.7g P.biglobosa seeds in 90% concentration of sulphuric acid enhances its germination for mass production of planting stock for cultivation.

***Key words**: Seed weight, Concentrations of sulphuric acid, Soaking, Germination, Indigenous tree species*

INTRODUCTION

The world leaders agree that incessant existence of many societies and their livelihoods depends on the sustainability of the biodiversity of their forests for availability of more goods and services (Oboho *et al.,* 2015). However, Oboho *et al.* (2015) stated that deforestation is threatening the survival and health of natural forests, with consequences effect of man losing forests and associated benefits. Lapido (2010) reported that the deforestation rate in Nigeria at about 3.5%, meaning a loss of 350,000 to 400,000 hectares of forest land per year. The increase in world population and demand for forests and forest resources in Nigeria lead to deforestation and forest degradation that threaten forest productivity and sustainability (Okunomo, 2010).

The genetic erosion of indigenous forest tree species is affecting some of species that are necessary for survival of present generation as *Chrysophyllum albidum* and *Parkia biglobosa*. The *Parkia biglobosa* occurs in a diversity of agro ecological zones, ranging from tropical forest with high rainfall to arid zones, from the lower Sudan savanna Southwards to the derived savanna and lowland forest where mean annual rainfall may be less than 400mm (Gbadamosi *et al*., 2005). It is an important multipurpose tree of West African Savannah land and common species of the parkland agroforestry system (Sacande and Clethero, 2007). Okunlola *et al.* (2011) stated that the tree has capacity to withstand drought conditions, because of its deep taproot system and an ability to restrict transpiration. The different parts of the tree are used for food, fodder, soil enrichment and sources of rural economics of West African countries (Gbadamosi, 2002; Okunlola *et al.,* 2011; Alex *et al.,* 2022). Joshi and Joshi (2009) stated that more attention have been given to *Parkia* biglobosa in recent years due to an increasing recognition of its contribution to fulfil basic needs of people, household economics, food security and conservation of natural resources. Sacande and Clethero (2007) stated that the roots, barks, leaves, stems, flowers, fruits and seeds of Parkia biglobosa are all used medicinally to treat a range of ailments including diarrhea, ulcers, pneumonia, burns, coughs, jaundice etc.

The yellow pulp surrounding the seeds contains 60% sugar when ripe and is edible in many forms and also the seeds are made into condiments, used as flavouring and additives to soups and stews (Sacande and Clethero, 2007; Okunlola *et al.*, 2011; Sale, 2015). The seeds contain 54% fat and 30% protein in addition to vitamins and minerals such as calcium, potassium and phosphorus (Aliero, 2004; Sacande and Clethero, 2007). Locust bean seeds are rich in proteins (30-40%), contain significant amounts of carbohydrates (10-15%), fats (15-20%), minerals (4%) and vitamins mainly from Group B (Diawara and Diasso, 2004). Okunlola *et al.* (2011) mentioned that the trees are used as wind breaker and shade provider, while its branches are cut for firewood, pods and roots are used as sponges as well as strings for musical instruments. The use of *Parkia biglobosa* pod powder delayed the emergence of *Striga hermonthica* in maize (Ibrahim *et al.,* 2011). Sale (2015) reported that its fruit pods are used to produce an insecticide powder for treating crops.

In spite of enormous potentials of *P.biglobosa*, its propagation has been limited due to dormancy of its seeds. Owing to poor seed germination, there is rapid depletion of the natural population of the *P.biglobosa* tree. In an attempt to meet population demand of this species, dormancy associated with its seeds needs to be broken. The methods of breaking dormancy as well as appropriate selection of quality seed weight that promise quality planting stock are worth investigating. Various investigators have reported the efficacy of acid in breaking dormancy of forest tree seeds (Aliero 2004; Ajiboye *et al.,* 2009; Emerhi and Nwiisuator, 2010; Al-Menaie *et al.*, 2010; Okunlola *et al.*, 2011; Amusa, 2011). One needs to take into consideration the concentration of acid and appropriate seed weight in successful propagation of forest tree seeds. Adelani *et al.* (2018a) stated that out of all the challenges that are confronting the production of quality planting stock, the poor selection of the seed weight in seed lot appears to be critical. Selection of appropriate seed weight from seed lot of high physiological quality should be meticulously done to guarantee future planting stock as well as growth, development and high productivity (Adelani *et al.,* 2018a). Successful selection of quality seed weight requires appropriate concentration of acid for pre-sowing treatment to ensure seedlings of high vigour. Little information is available on the effect of seed weights and concentrations of sulphuric acid in breaking the dormancy of *P.biglobosa*. In this light, this experiment was conducted to assess the effects of seed weights and concentrations of sulphuric acid on the germination of *P.biglobosa* seeds.

MATERIALS AND METHOD

The research was conducted in the screen house of Federal College of Forestry Mechanization, Afaka, Kaduna State during wet season of 2015. The College is located in the Northern Guinea Savannah ecological zones of Nigeria. It is situated in Igabi Local Government Area of Kaduna State, Nigeria. It lies between Latitude 10 º 35' and 10 º 34' and Longitude 7 º 21' and 7 º 20' (Adelani, 2015). The mean annual rainfall is approximately 1000mm. The vegetation is open woodland with tall broad leave trees (Otegbeye *et al.,* 2001).

Experimental Procedure

The seeds were sourced from Afaka Forest, Kaduna State. The seeds were extracted from fruits and air dried for thirty minutes. Six hundred seeds were extracted from fruits. The viability of the randomly selected seed samples were assessed using cutting method (Schmidt, 2000). The sowing media (river sand), which was collected from the floor of College dam was made to pass through 2mm sieve and then sterilized at 160^{o}C for 24hours. The polythene pots used was 20x10x10cm in dimension and filled with the sterilized river sand and arranged in the screen house.

Influences of seed weights and concentrations of sulphuric acid on the germination of *Parkia biglobosa* seeds

A 3x4 factorial arrangement in a completely randomized design with twelve treatments replicated five times to assess the effects of seed weights (0.57, 0.63 and 0.70g) and concentrations of sulphuric acid (0, 30, 60 and 90%) on the germination of *Parkia biglobosa* seeds was adopted. A number of six hundred (600) seeds stored in room temperature (27^{o}C) for three month were used for the experiment. The seeds were washed and air dried for 30 minutes. The three seed weights of the samples of the seeds sorted out by sizes were determined by weighing the seeds on Mettler Top loading Weighing Balance (Model Mettler PM 11-K). Based on the method of Adelani *et al.* (2018b), the seeds were classified into 0.57, 0.63 and 0.70g. The seed weights (0.57, 0.63 and 0.70g) were soaked in different concentrations of sulphuric acid for 30 minutes. Ten (10) seeds represented a replicate. Five replicates were planted in 4cm depth of sterilized river sand. A 200ml of water per each pot was applied at two days interval. Seeds that were not soaked in concentration of acid served as control. A seed was considered to have germinated when the radicle was able to break open the seed coat and at the sight of plumule emergence. Noting of successful germinated seeds was as described by Hossain *et al.* (2005). Final germination count was taken when no further germination took place for several days. Germination count was converted to germination percentage.

Data analysis

Germination percentage was computed as expressed below:

$$\text{Germination \%} = \frac{Total\ seed\ germinated}{Total\ seed\ sown} \times 100$$

The data obtained were subjected to one-way analysis of variance (ANOVA). Comparison of means was carried out using Fischer's Least Significant Difference (LSD) at 5% level of significance**.**

RESULTS

Highest germination percentage value of 78% was recorded from 0.70g seeds soaked in acid. The least value of 66% was recorded from 0.66g seeds soaked in acid. An increase germination percentage was recorded with increasing seed weights. The germination percentage of seeds increased with increasing concentration of acid. Germination percentage value of 94% was recorded from seeds soaked in 90% concentration of sulphuric acid. The least value of 5% was recorded from seeds not soaked in concentration of acid (control) (Table 1).

Table 1: Influences of seed weights and concentrations of acid on the germination of *Parkia biglobosa* seeds

Seed weights(g)	Means Per. Germ (%)	Conc. of sulp acid (%)	Mean Per. Germ (%)
0.57	66.00^{b}	0	5.00^{d}
0.63	76.00^{ab}	30	40.00^{c}
0.70	78.00^{a}	60	62.00^{b}
-	-	90	94.00^{a}
SE±	1.31	SE	1.31

Means on the same column having different superscripts are significantly different (P<0.05)

Key: Per.Germ=Percentage Germination, Conc. of sulp. acid= Concentration of sulphuric acid

A significant germination percentage value of 100% was recorded from 0.70g seeds soaked in 90% concentration of sulphuric acid. The least value of 10% was recorded from seeds not soaked in concentration of sulphuric acid (control). An increase germination percentage was recorded with increasing concentration of acid.

Table 2: Interactive influence of seed weights and concentrations of sulphuric acid on the germination of *Parkia biglobosa* seeds

Seed weights (g)		Concentrations	of sulphuric acid	
	0	30	60	90
0.57	10.00^{a}	60.00^{a}	75.00^{a}	80.00^{c}
0.63	10.00a	40.00^{b}	60.00^{b}	90.00^{a}
0.70	12.00a	16.00^{c}	44.00^{c}	100.00^{a}
SE±	1.15	1.15	1.15	1.15

Means on the same column having different superscripts are significantly different (P<0.05)

DISCUSSION

The highest germination percentage recorded for highest seed weight. Similar observation had been reported by Adelani *et al.* (2018a, b) who reported highest germination percentage for 1.8g *C.albidum* seeds compared to other lower weights. Large-size of *Dialium guineense* seeds showed higher germination of 80%, while small size seeds had 60% (van Molken *et al.,* 2005; Ajiboye and Agboola, 2011). Contrary to afore mentioned reports, Ajiboye and Agboola (2009) reported highest germination of 100% in *Parkia biglobosa* with small seeds after sulphuric acid scarification.

The increased germination percentage of seeds with increasing concentration of acid could be ascribed to the ability of higher concentration of sulphuric acid to degrade the seed coat for imbibition better than lower concentration without damaging the embryo. Similar observation has been made by Aliero (2004) who adduced the ability of 98% concentrated sulphuric acid to enhance *Parkia biglobosa* seed germination better than lower concentration as 90%, 70% and 50% respectively, to its degradation of seed coat faster than others. Highest germination percentage was recorded for *Adansonia digitata* seeds soaked in 98% concentration of sulphuric acid (Falemara *et al.*, 2013; Falemara et al., 2014). Oyebamiji *et al.* (2019) reported highest germination percentage for *Parkia biglobosa* seeds soaked in 98% concentration of sulphuric acid for 4minutes

Various species respond to concentrations of acid differently. Sikiratu (2014) reported highest germination percentages for *Acacia senegal* soaked in 50% concentration of sulphuric acid (89%) and in 50% concentration of hydrochloric acid (65%) respectively for 15 minutes. Highest germination percentages were recorded for *Acacia auriculiformis* seeds (94.17%) (Adelani and Joseph, 2014) and *Tamarindus indica* (93.33%) (Adelani *et al.,* 2014) treated in 98% concentration of sulphuric acid at different times respectively.

Rajesh (2021) reported germination perentange of 70% for *Abrus precatorius* seeds soaked in 80 % concentration of sulphuric acid for 2minutes and 50% HCL concentration for 30 minutes in 21 days period of experiment. Immersing of Albizia lebbeck seeds in 37% concentration HCl acid for 30 and 45minutes gave germination percentage values of 35.56% and 46.67% respectively as compared to control treatment with 15.56% (Hivi and Othman, 2019). Wakawa and Akinyele (2016) stated that Tetrapleura tetraptera seeds treated with concentrated H_2SO_4 at 98% concentration recorded the highest cumulative percentage germination (61%) and mean of germination speed (15.25). Acid treatment of *Piliostigma reticulatum* recorded highest germination percentage of 76 when seeds were soaked in 98% of HCL acid for 90 minutes (Aduradola, 2004). Ehiagbanare and Onyibe (2007) reported that *Tetracarpidium conophorum* seeds treated for 5minutes with 98% concentrated sulphuric acid had the highest percentage germination of 66%.

The highest germination percentage value of 80% was recorded when *Parkia biglobosa* seeds were soaked in 98% sulphuric acid for 60 minutes (Isah, 2012). The reason for this could be partly adduced to the fact that 98% sulphuric acid was able to scarify seed coats through decreasing the inhibitory effect of seed coats and softening of the seed coat that accelerated water uptake and resulted in earlier and faster germination (Isah, 2012). Various investigators had reported improved seed germination response following chemical scarification pretreatments (Pendly, 2001; Olvera-carrillo *et al.*, 2003; Ajiboye *et al.*, 2009).

Highest germination percentage of 0.7g seeds soaked in the 90% concentration of acid could be attributed to compatibility of highest seed weight with highest concentration of acid.

CONCLUSION

Successful enhancement of seed germination is a pre-requisite for plantation establishment as well as conservation of diverse indigenous economic tree species. Appropriate selection of quality plant stock of priority species which start right from choosing appropriate seed weight needs to be embraced. Investigation conducted into selection of appropriate seed weight and concentration of sulphuric acid, revealed that for maximum germination percentage, 0.7g seeds need to be soaked in 90% concentration of sulphuric acid. The soaking of 0.7g *P.biglobosa* seeds in 90% concentration of sulphuric acid enhances its germination.

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DEMOGRAPHIC DETERMINANTS OF EDIBLE INSECT CONSUMPTION IN IDO LOCAL GOVERNMENT AREA OYO STATE.

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ABSTRACT
This study examined the determinant of edible insect consumption among rural dwellers in Ido Local Government Area, Oyo State. It was conducted to examine the level of understanding of the consumption of edible insect on the nutritive and health benefits. Snowball sampling techniques were used to select the respondents from Akinyemi, Ajibade, Araromi and Akufo communities in the LGAs. Data collected were analyzed using descriptive statistics to examine the relationship between the socio economic characteristics of the respondents and edible insects' consumption. The result revealed that a range of edible insects such as crickets, winged termites and grass-hopper were commonly harvested at adult stage at seasonal peaks which is raining season, while the palm weevil, rhinoceros beetle, Africa silkworm and Pallid emperor moths were harvested at larva stage. The study also showed that 44.78% of the respondents consume the edible insects as a food condiment, 61.46% consumed it as a cultural food while 10.42% consumed this insects as replacement for fish or meat. All (100%) of the respondents roasted and smoked the insects before consumption, 98.96% fried it and 1.04% consumed it in raw and boiled form. Majority 94.8% of the respondents encountered no challenge in harvesting the edible insects during the season. In conclusion, this study recommends the need for rearing of insects such as Africa silkworm (Ekuku), and Pallid emperor (Monimoni) in the study in order to enhance food security, improve accessibility for home consumption and commercialization as potential food, feed, nutritive supplements and Health benefits.

***Key words**: Edible insects, Consumption, Rural dwellers, Nutritive, Ido LGA.*

INTRODUCTION

Edible insects play an important role as part of human nutrition in different regions in the world and over half of people residing in rural areas in such regions suffer from malnutrition, especially protein energy (Siriamornpun and Thammapat, 2008). Insects account for the greatest amount of biodiversity in forests; and are the least studied of all fauna (Yen, 2009). Many of the poorest populations in the world such as Africa, Asia consume edible insects as part of their diet (Shockley and Dossey, 2014; FAO 2013; West Africa Trend Team 2014). Ordinarily, insects are not used as emergency food to ward off starvation, but are included as a normal part of the diet throughout the year or when seasonally available (Balinga, Fitzpatrick and Dierenfeld 2004).

Worldwide, more than 400 insect species are reportedly consumed by humans as food as most are harvested from natural forests, while others are harvested within human settlements (Ramos Elorduy, 2005). While 30 species or more of these edible insects are used by indigenous populations in many developing countries as food. DeFoliart (1990; 2002) reported that scores of species of edible insects are dominant items of commercial value in town and village markets of Nigeria as well as tropical and semi- tropical regions of the world. Nonetheless, the potentially substantial benefits of farming and utilizing insects as a primary dietary component, particularly to supplement or replace foods and food ingredients made from vertebrate livestock, are gaining increased attention in Africa. In addition to their fundamental contribution for pollen dissemination, insects also contribute significantly to livelihoods in both rural and urban areas (Stack, DeFoliart and Benevenge 2003). FAO (1995) noted that insects are important non wood forest products that under-privileged people gather, particularly women and children for either food or animal feed. According to Balinga, *et al.,* (2004) said that insects are not a source of protein alone but also vitamins, minerals and fats. Many insects contain abundant stores of lysine, an amino acid deficient in the diets of many people who depend heavily on grain. Further, more insects are easily converted as a protein supplement source more efficiently than meat and fish. Protein production for human consumption from edible insects would be more ecologically effective as they emit less carbon into the atmosphere and consume fewer resources than animal protein. This makes insect meat more ecologically sensible and climate smarter than vertebrate meat (Jongema, 2012). According to Banjo, Lawal and Songonuga, (2006,) the consumption of non-toxic insects should therefore be encouraged. Insects are traditional foods in most cultures, playing an important role in human nutrition as they can be reared with little or no specialized techniques for their high nutritional qualities and sold to the populace that regards them as delicacies (Finke, 2002). The potential of insects needs to be more seriously considered in food security and sustainable development goal (SDG) strategies in Sub-Saharan Africa (De Foliart, 1992).

Consumption of edible insects in Nigeria has not been socially acceptable. This may not be unconnected with the fact that most people have little or no knowledge about the nutritive value or health benefit that could be derived from consumption of edible insects. Edible insects have great potential for addressing food insecurity in Africa as they serve as a source of essential nutrients and food to rural dwellers. This will give us an insight into the species of edible insects that are consumed in the rural community in the study area. It will also enable us to know various means and sources where these edible insects could be obtained. In addition, this study will help us to know what influences their consumption of these insects as well as the challenges faced by the rural dwellers in accessing edible insects, hence, the need for this study. In addition, understanding the contributory factors that influence rural dwellers to consume edible insects need to be assessed. This study was therefore carried out to address this knowledge gap by providing answers to the following questions;

i. What are the edible insects species available in the area of study?
ii. From what sources can edible insect be collected from by the rural dwellers?
iii. What are the challenges faced in harvesting/ collecting edible insects?

Therefore this study access demographic determinants of edible insects consumed by rural dwellers in Ido Local Government Area of Oyo state Nigeria, in order to identify the species of edible insects available in the study area and to ascertain the means by which edible insects are sourced by the respondent in the study area. Finally, highlight the constraints to the rural dwellers accessibility to edible insects.

METHODOLOGY

Study area

The study was conducted in Ido Local Government Area of Oyo state, Ibadan in Nigeria. It headquarters at Ido Village. The Local Government covered a total area of 986km^2 and a total population of 103,261 based on 2006 National Population Census (NPC)**.** Ido local Government shares boundary with Oluyole Local Government, Ibarapa-East Local Government, Akinyele Local Government, Ibadan North West Local Government, Ibadan South West Local Government ,Ibadan North Local Government Area of Oyo state and Odeda Local Government in Ogun State. It covers an area of about 8,000 square kilometers and lies between latitude 6^0'451 and 9^0'451 North of the equator and longitude 2^0 301and 9a^0 451 East of Greenwich Meridian. Ido is characterized by two distinct seasons; the dry and rainy season. Ido enjoys abundant rainfall of over 1800mm annually and the south –westerly winds blow most of the year (OYSADEP, 2006).

Procedure for data collection

The focal area of study selected is Ido Local Government Area Oyo State Ibadan**.** Since there was no sample frame for this study, non probability method was used, specifically snowball, was used to locate insect consumer at Akinyemi there was 26 respondents, at Ajibade there was 22 respondents, at Araromi 20 respondents and at Akufo there was 28 respondents in these communities from which a total number of ninety six (96) respondents were selected for the study. Data was collected using interview schedule guide.

Method of data analysis:

Data was analyzed using descriptive statistics to examine the relationship between the socio economic characteristics of the respondents and edible insects' consumption**.**

RESULTS AND DISCUSSION

Socio-characteristics of respondents

Table 1 Presents the socio-economic characteristics of the respondents.

Age: Most of the respondents (45.8%) belong to the age range of 41-50 years while 40.6% were in the age range of 51 and above. It can be seen from this result that the respondents are still within the active age of farming.

Sex: Most of the respondents 63.5% were male while 36.5% were female which implies that most of the respondents were male farmers engage in edible insects' collection.

Marital status: Majority of the respondents 87.5% was married, 2% were divorce and 10.4% was widowed. The result showed that most of the respondents were married.

Educational qualification: Majority of the respondents 61.5% had no formal education, 22.9% were primary school educated, 11.5% had secondary school certificate while 4.1% had tertiary school education. This implies that most of the respondents had no formal education with only 38.5% had formal education.

Occupation: Findings revealed that the majority 56.2% were into farming, 35.4% were traders 4.1% were civil servants while 2.1% were artisan and bricklayers.

Household size: Findings shows that most of the respondents 53.12% fell within the categories of 4 and 5 household size, as presented in Table 1

Religion: This showed that 66.7% of the respondents were Muslims while 29.2% were Christians, and 4.1% were traditional religion. This means that most of the rural dwellers consuming edible insects were Muslims.

Tribe: It was revealed that 94.8% were Yoruba, 1.0% were Igbo while others 4.2% are other
Culture (Gara), as presented in Table 1

Table 1. Socio-characteristics of respondents (n=96)

	Range	Frequency	Percentage
Age			
	21-30	2	2.1
	31-40	11	11.5
	41-50	44	45.8
	51 and above	39	40.6
Sex			
	Male	61	63.5
	Female	35	36.5
Marital Status			
	Married	84	87.5
	Divorce	2	2.08
	Widow	10	10.4
Educational qualification			
	No education	59	61.5
	Primary education	22	22.9
	Secondary	11	11.5
	Tertiary education	4	4.1
Occupation			
	Farming	54	56.2
	Trading	34	35.4
	Civil Servant	4	4.1
	Artisan	2	2.1
	Others	2	2.1
Household size			
	1-4	40	41.67
	5-8	51	53.13
	9 and above	5	5.20
Religion			
	Christian	28	29.2
	Islam	64	66.7
	Traditional	4	4.1
Tribe			
	Yoruba	91	94.8
	Igbo	1	1.0
	Hausa	-	-
	Other culture (Gara)	4	4.2

Stages at which edible insect are collected for consumption

Table 2: Shows the list of edible insects available in the study area and the stage of harvesting them in the area. The result shows that 100% of the respondents harvested cricket (Ire), wings termite (Esunsun) at adult stage while 18.8% harvested grasshopper (Tata) at adult stage. 100% of the respondents agreed that palm weevil (Itun) and Rhinoceros (Ogongo), were harvested at larva stage, 84.4% harvested Africa silkworm (Ekuku), 41.7% harvested Pallid emperor (Monimoni) and 18.8% harvested grasshopper (Tata) at larva stage respectively.

Table 2: Stages at which edible insect are collected for consumption (n=96)

Name	Harvesting stage	Frequency	Percentage
Ccricket (Ire)	Adult	96	100
Wings termite (Esunsun)	Adult	96	100
Palm weevil (Itun)	Larva	96	100
Rinhocerus (Ogongo)	Larva	96	100
Pallid emperor (Monimoni)	Larva	40	41.7

Africa silkworm (Ekuku)	Larva	81	84.4
Grasshopper (Tata)	Adult	18	18.8

Harvesting techniques of edible insects

Table 3 shows the harvesting techniques of edible insects in the study area. The data collected shows that 100% of the respondents harvested cricket (ire) through digging soil with cutlass at night during full moon, wings termite (Esunsun) is taking water to where there is light at night, Palm weevils (Itun) and Rhinoceros (Ogongo) is by digging rusted palm tree and palm oil rusted trees respectively. While 84.38% of the respondent harvested Africa silkworm (Ekuku) by hand picking it from rusted trees, 41.7 % harvested Pallid emperor (Monimoni) by handpicking it from shear butter and 18.8% harvested grasshopper (Tata) by handpicking it from agricultural plant in the farm.

Harvesting techniques of edible insects (n=96)

Name of insect	Frequency	Percentage	Harvest techniques
Crickets	96	100	Digging of the soil with cutlass
Wings termites	96	100	Taking water to where there is light
Palm weevil	96	100	Digging of rusted palm wine tree with cutlass
Rhinoceros	96	100	Digging of rusted palm oil tree with cutlass
Pallid emperor	40	41.7	Picking from share butter plant
Africa Silkworm	81	84.38	Picking from tree
Grasshopper	18	18.8	Picking from crop plant

Table 4: Purpose of collecting edible insect: (n=96)

	Frequency	percentage
Mainly for consumption purpose	96	100
Mainly for marketing purpose	-	-
For both consumption and marketing	-	-
Total	**96**	**100**

Why eat edible insects?

Table 5 shows that 61.46% of the respondents said they inherited the consuming of edible from their parent, 44.78% of the respondent eat edible insect because it serves as condiment while 28.13% said it's because it's serves as supplement for fish and meat.

Table 5: Why eat edible insect (n=96)

	Frequency	Percentage
Serve as condiment	43	44.78
Inherited	59	61.46
Supplement for fish and meat	27	28.13

Table 6 shows that 100% of the respondents roasted and smoked edible insects before consumption while 98.96% fried it and 1.04% consumed it in raw and boiled form.

Table 6: Form of consuming edible insects (n=96)

Form	Frequency	Percentage
Raw	1	1.04
Roasted	96	100
Smoked	96	100
Fried	95	98.96
Boiled	1	1.04

The result in table 7 shows that 94.8% of the respondents encountered no challenge during the harvesting of the edible insects, while 5.20% encountered low difficulty during harvesting, because most of the trees which they source the edible insects from have been fell by the commercial loggers as fuel wood and for other domestic uses.

Table 7: The Challenges encounter during the edible insect collection

	Frequency	Percentage
No Challenges	91	94.80
Trees getting them from has been fell	5	5.20
Total	**96**	**100**

CONCLUSION

This study examines the determinants of edible insect consumption among the rural dwellers in Ido Local Government Area in Ibadan Oyo State. It was thereby concluded age of the respondents ranged from 41 to 50 years old constituting 45.8%, majority 63.5% were male, 66.7% practice Islam, 87.5% were married, 38.5% were educated and 56.2% had faming as occupation. This study revealed the edible insects as crickets (100%), winged termites (100%) and grasshoppers (18.89%) were harvested at adult stage, all (100%) of the respondents' harvested Palm weevil and Rhinoceros at larva stage while (84.4%) harvested Africa silkworm and 41.7% harvested Pallid emperor at larva stage, 100% of the respondents source the cricket by digging soil with cutlass, wings termite by water and hand picking of grasshopper by 18.8% of the respondents. However, 100% of the respondents dug rusted palm wine and palm oil trees with cutlass for Palm weevil and Rhinoceros, 41.7% source Pallid emperor at larva stage by hand pinking. The respondents harvested edible insects for consumption alone, 53.13% of the respondents ate edible insects as condiment, 36.50% consumed edible insects as culture and 10.42% consumed the insect as replacement for fish or meat. All the respondents roasted and smoked edible insects before consumption, 98.96% fried it and 1.04% consumed it in raw or boiled form. Majority 94.8% of the respondents encountered no challenge to harvesting edible insects, while 5.20% encountered low problems in the harvesting of the edible insects for consumption. The study also concluded that the edible insects researched on had great acceptance and consumption among the respondents. It however recommended the need for rearing the insects on a commercial scale which will solve the multi- complexity of seasonality and improve accessibility as human food and animal feed such as micro-livestock, in the study and in order to enhance food security, improve accessibility for home consumption and commercialization as potential food, feed, nutritive supplements and Health benefits.

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PROVENANCE VARIATIONS IN FRUITS AND SEED MORPHOLOGIES OF *Annona muricata* L. FROM SELECTED ECOLOGICAL ZONES IN SOUTHERN NIGERIA

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Abstract

Different fruits of Annona muricata were sourced from different ecological zones within the southern parts of Nigeria which include Port Harcourt, Ibadan, Umuahia and Benin. The fruits physiological characteristics were taken. Some of these were; fruit length, fruit breadth, fruit weight, average seed weight, number of viable and non-viable seeds. The results shown that fruit from Port Harcourt had the highest length (46.38 mm), fruit breadth (38.64 mm), fruit weight (4.33 kg), number of viable seeds (82.60) and average seed weight (0.54 kg) followed by this is the fruits from Ibadan provenance with a fruit length of (37.66 mm), fruit breadth (30.07 mm), fruit weight (4.92 kg), average seed weight (0.50 kg), number of viable seeds (70.93) and. However, fruits from Benin provenance had the least fruit and seed morphological features with fruit length (33.82 mm), fruit breadth (28.45 mm), fruit weight 3.51 kg and average seed weight (0.43 kg). It was generally recommended that fruit from Port Harcourt has most of the desired characters which are sought in seeds and seedlings production for plantation establishment and therefore the ecological zone is recommended for collection of seeds for raising planting stock.

***Keywords**: Annona muricata, ecological zones, provenance, fruit length, viability test.*

Introduction

Fruits and seeds characterization is a study which plays a major role in successful plant production. The role of good seeds in plantation establishments cannot be overemphasised, therefore maximum attention needs to be given especially at this era of climate change so that selecting good seed source (s) can be achieved as a basis for crop improvements (FAO, 2018). However, the choice of seed sources is a major factor affecting the establishment and productivities of forest plantation on a large basis. In the recent practice of silviculture, provenance research provides a sound basis for the selection of seed sources, which is a yardstick for tree improvement.

Differences in seed germination patterns and seedling growth rates may be due to climatic and geographic influences or more importantly the genetic composition (Villalobos *et al*.., 2002). The genetic component of variation among populations from different regions can, therefore, be identified by testing different seed sources and exploited through selection of superior plant populations.

Annona muricata L. popularly known as soursop is a home garden plant; it is also called guanabana (Melissa, 2018). It is a shrub or small tree of three to ten metres in height. It is adapted to humid tropical climate and can tolerate partial shade. This fruit crop grows in any kind of soil, but does well in loose, fairly rich, deep loam and well-drained soil with pH between 6.0 - 6.5. The young green fruits with soft seeds can be cooked as vegetable; the ripe fruits can be eaten off hand or as dessert, or processed into candies, jams and jelly or processed drinks. The leaves are used as herbal medicine. As a result of its moderate size, the tree can be intercropped as agroforestry species with tree and agricultural crops. It is a good source of vitamins B and C, calcium and phosphorus (Trupti and Rajendra, 2014).

Annona muricata is a promising tropical tree, a good species for agroforestry practices and wealth creation as it provides income generation. *A muricata* is proven to possess a wide spectrum of biological activities for body improvement processes (Orwa *et al*., 2013). According to De Lima *et al*., (2006), there are basic procedures that need to be employed for successful seedlings production that will guarantee plantation establishment of the species: selection of good viable seeds, raising of seedlings, site clearing and land preparation, planting-out of high graded seedlings, weeding, and continuous monitoring of the plantation. Therefore, to reproduce the species that have good vigour and withstand unstable environmental conditions especially for commercial or afforestation project, large number of high graded seedlings is required.

According to Oyebade *et al*., (2012), provenance trials serve as useful tool to support a rational planting decision on sustainable basis for forest improvement, and for fruit and wood production in this rapid changing environment (Akoun, *et al.,* 2009). In forestry sector, the concept of identifying similarities in the climates to match forest seed materials to certain sites in order to assist species selection is a well-established approach for efficient and sustainable forest production (Kapeller *et al*., 2012). The concepts of provenance trial remain valuable in the selection of seeds with desired qualities for propagation especially for seedling production

both for commercial nurseries and plantation establishment (Yeaman, 2006). Provenance is the geographical source or place of origin from where a given lot of seeds or plants materials are collected (Kapeller *et al.,* 2012). The survival of forest plantation, growth performance, volume and quality of forest produce harvested over time in a given plantation is by no doubt influenced by the seed qualities which give birth to quality seedling production (Wang *et al*., 2017). Therefore, this process could be achieved by determining a better seed zone for most forest species thereby reducing the risk of planting poorly adapted tree crops that pose a great threat for sustainable forest growth (Hamann *et al*., 2000) but making use of well adapted plant stock that is able to withstand any environmental imbalance (Charity *et al*., 2015).
Quality seed has been recognized as an important input in forestry and is considered essential for increasing production. Provenances has a great influence on phenological variation in fruits and seeds formation as it affects the fruiting time, fruit sizes and number of seeds per fruit in relation to different ecological areas. Many works have been done on some forest species but there is dearth of information as regard the fruit and seed physiological variation of *A. muricata* in relation to the provenances as this study will go a long way to identify a better seed zones for seedlings production.

MATERIALS AND METHODS

Reconnaissance survey on the abundance of *A. muricata* fruiting trees in some urban settlements in selected states in the Southern parts of Nigeria was carried out. This was done to determine the differences in relative abundance, fruiting period and maturity time for fruit/seeds collection and seasonality.
The provenances in Southern Nigeria were carefully studied and categorized into four major ecological zones; derived savanna, tropical rain forest, high rain forest and swampy forest zone. Two states were strategically visited for the pilot information with respect to selected provenances and studies. Some of the states visited in each classification include; Osun and Oyo (Derived savanna region), Cross River and Abia (humid rainforest region), Ondo, and Edo (dry rainforest region), and Bayelsa and Rivers States (freshwater swamp forest region). However, from the information gathered, four (4) States with highest abundance of the species were considered for fruit collection, one in each ecological zone. These include: Oyo, Abia, Edo and Rivers States. The State Capital of each states were selected since the abundance of the species was mostly observed in the cities. Accordingly, fruit/seeds were collected from Ibadan, Umuahia, Benin City and Port Harcourt.

Seed collection areas

Mature fruits of *Annona muricata* were identified and harvested from the suitable mother plants from the four (4) identified towns in the Southern part of Nigeria. In each of the state, a total number of five (5) locations were identified as fruit collection points. Each of the locations was considered at a distance of five (5) kilometres apart so that the whole community can be adequately covered. Twenty (20) locations were used for fruit and seed collections in all the ecological zones. For ecological zone, the fruits were harvested and number 1 to 25; total number of five (5) fruits were harvested per each location and arranged for fruit and seed morphological examinations. One hundred mature fruits of *A. muricaa* were used for the study.

Experimental site

The study was carried out in the greenhouse chamber of the Tree Improvement Section, Sustainable Forest Management Department, Forestry Research Institute of Nigeria (FRIN), Jericho, Ibadan, Oyo State, Nigeria. FRIN is located on latitude 7° 23' 5" to 7°24 0'0"N and 3° 51' 0" to 3° 52' 15"E (FRIN, 2015).

Seed processing and viability test

Twenty-five (25) fruits were carefully harvested from all the four locations per state (provenance). The fruits were numbered and kept separately in an open chamber to get fermented naturally. This was necessary for easy extraction of the seeds. Plate 1 and 2 showed the fruit and seeds of *Annona muricata.* The seeds extracted per fruit in each of the provenance were counted and carefully identified. Simple water floating test was conducted on the seeds to determine the viability potential of the seeds, the number of seeds extracted, the number of the sinkers and floaters were recorded and statistically analyzed. The seeds were packed separately and air dried for a period of forty-eight (48) hours in an open chamber to prevent fungi attack. The seeds in each of the fruit per provenance were mixed and shaken to allow a homogenous mixing. From the mixture, five hundred (500) seeds were randomly picked from each provenance. A total of two thousand (4 x 500) seeds were measured for various parameters.

Assessment of fruit and seed morphology characteristics of *Annona muricata* from different ecological zones in southern Nigeria

Four (4) states representing the major ecological zones in Southern Nigeria was studied for this experiment. From each selected town per state, five (5) locations were considered; four (4) to five (5) kilometers apart and all the harvested fruits from each location were labeled for the study. Total collected fruits were put together for random sampling. The assessment was carried out on the frame of completely randomized design with ten replicates. Ten (10) fruits of *A. muricata* were randomly selected from the total collections of each provenance for fruit and seed morphological examinations. The fruits collected were measured for the fruit sizes, this include length (cm), diameter (cm) and fruit weight (kg). Metre rule with the aid of thread was used to determine the length and diameter of the fruits while the sensitive weighing balance was used to determine the fruits weight. Each of the fruits was cut, depulped after it has fermented for two days and extracted for the different seed morphological experiments (Figs 1 &2). Total number of seeds per fruits was recorded, the average weight of seed per fruit was also determined. This was necessary to know the relative contents of the fruits. This was done according to each location and provenance. Data collected were subjected to analysis of variance (ANOVA).

Plate 1: Mature fruit of *Annona muricata*

Plate 2: Seed samples of *A. muricata* according to provenances

RESULTS AND DISCUSSIONS

The means' fruit and seed morphological parameters of *A. muricata* from the four provenances are presented in Table 1.

Fruit length

The value of the fruit length from all the provenances were significantly ($p<0.05$) different from one another as presented in Table 1. The fruits from Port Harcourt had the highest mean value of 46.38 cm, followed by the fruits from Ibadan provenance with the mean value of 37.66 cm while fruits from Benin provenance had the least mean value of 33.82 cm and followed by fruits from Umuahia provenance with the mean value of 34.66 cm.

Fruit breadth

The results of the fruit breadth as analyzed and showed on Table 1 indicated that fruits from Port Harcourt had the highest mean value of 38.64 cm which was significantly ($p<0.05$) different from those from other sources, while the fruit breadth from other provenances were not significantly ($p<0.05$) different from one another: The fruits from Umuahia and Ibadan provenances had the mean value of 30.73 cm and 30.07 cm respectively while Benin had the least mean value of 28.45 cm.

Fruit weight

The results presented in Table 1 indicated that fruit weights from all the provenances were significantly ($p<0.05$) different from one another. The fruits of *A.muricata* sourced from Port Harcourt had the highest mean weight value of 4.33 g; this was followed by the fruits from Ibadan (4.02 g), Umuahia (3.80 g) while the least was weight of fruits from Benin with the mean value of 3.51 g.

Number of viable seeds

According table 1 bellow, the results indicated that seeds of *A. muricata* sourced from Port Harcourt and Ibadan have a significant number of viable seeds with mean values of 82.60 and 70.92 respectively. While on the other hands the results also shown that seeds from Umuahia provenance had the least number of viable seeds with a mean value of (50.52) and was not significantly different from Benin provenance (52.52).

Number of non-viable seeds

The mean values of floated seeds of the *A. muricata* sourced from the different provenances indicated that seeds from Ibadan had the highest mean value of 3.48 and was significantly ($p<0.05$) different from seeds from other provenances. Seeds from Umuahia (3.12) and Benin (2.52) provenances were not significantly different from each other. Seeds from Port Harcourt had the least mean value of 2.20 for the number of floated seeds and were significantly different from other provenance studied.

Average seed weight

The Port Harcourt and Ibadan provenances were not significantly ($p<0.05$) different from one another with the mean value of 0.54 g and 0.50 g respectively but significantly different from the two other provenances (Table 1). Meanwhile seed weight source from Umuahia and Benin provenance were not significantly different from one another but significantly different from Port Harcourt and Ibadan (Table 1). The mean value of Umuahia provenance was 0.45 g while seed weight from Benin provenance had the least mean value of 0.43 g (Table 1).

Table 1: Means of fruit length, fruit breadth, fruit weight, seed weight, viable seeds and non-viable seeds of the provenances

Provenance	Fruit length	Fruit breadth (cm)	Fruit weight (kg)	Number of viable seed	Number of non-viable seeds	Average seed weight (g)
Port-Harcourt	46.38^{a}	38.64^{a}	4.33^{a}	82.60^{a}	2.20^{b}	0.54^{a}
Umuahia	34.66^{bc}	30.73^{b}	3.80^{c}	50.52^{b}	3.12^{ab}	0.45^{b}
Benin	33.82^{c}	28.45^{b}	3.51^{d}	50.96^{b}	2.52^{ab}	0.43^{b}
Ibadan	37.66^{b}	30.07^{b}	4.02^{b}	70.92^{a}	3.48^{a}	0.50^{a}

* Mean values with the same letters along the column are not significantly different at ($p<0.05$).

DISCUSSION

It was observed that fruits from Port Harcourt had the highest means' fruit length, fruit breadth, fruit weight, average seed weight and number of viable seed except the number of non-viable seeds which was least level as compared to other provenances. The results was also in line with Oluyole (2010), that *Jathropha curcas* sourced from Port Harcourt had highest germination rate than other sources within the Southern parts of Nigeria. Fruit variability analysis showed that Port Harcourt and Ibadan have the best fruit sizes and was significantly different from Umuahia and Benin provenances. Similarly, the result of the fruit weight, average seed weight and number of sank seeds which determine the germination potential of the seeds indicated that seeds from Port Harcourt and Ibadan were similar to one another but significantly different from the two other locations, while Umuahia and Benin were at the lower level, this also contributed to the amount of viable seeds available per fruit and per provenances that could be planted. On the other hands, the number of non-viable seeds from fruits sourced from Ibadan was on high side and was significantly different from the other three provenances while Port Harcourt source had the least non-viable seeds. This result is in agreement with Ogunwande *et al*., (2014) that average number of seeds of *Garcinia kola* varied with the pod sizes. This is also in contrast with Adeyemo and Odiaka (2005) which reported that there was no significant difference in the average number of seeds with the pod length and breadth of fluted pumpkin. Seeds from Port Harcourt and Ibadan provenances had higher mean seed weight (MSW) than the seeds from Umuahia and Benin. This is in agreement with the findings of Prusinski (2017) on *Lupinus albus* that the pod that produced the large number of seeds will also produce the largest seeds in terms of the sizes.

CONCLUSION

The seeds from Port Harcourt and Ibadan are recommended as the best source for plantation establishment of *Annona muricata* as both provenances displayed greater fruits and seeds characteristics that can guarantee quality seedlings production for plantation establishment as a means of growing multifunctional trees to combat climate change.

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ACHIEVING SUSTAINABLE DEVELOPMENT GOALS IN NIGERIA WITH BENEFITS FROM INSECTS

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ABSTRACT
In the bid to address various global challenges, seventeen sustainable development goals (SDGs) were set to replace the defunct millennium development goals (MDGs) in 2000. There is however urgent need to explore different avenues as provided by nature especially with year 2030 set to be the deadline for full achievement of the goals fast approaching. This paper uncovers various different potentials associated with insects that can be explored in achieving SDGs. Honey, beeswax, royal jelly, pollen, propolis and bee venom are products from apiculture which and can be used as food, source of income, employment and also provide healing of diverse ailments. Creation of gainful employment to ever-increasing labour force; treatment of headache, abdominal pain, blood pressure, reduction of blood glucose, treatment of mouth ulcers, fever, anaemia, dizziness, insomnia, hepatitis and constipation are potentials in sericulture that are relevant in achieving some of the SDGs. Edible insect such as bees, wasps, beetles, moths, caterpillars, crickets and grasshoppers are rich in fats, proteins, fiber, vitamins and minerals. They are therefore consumed as food in various part of the world. They are also useful in enhancing immune function, improve gastrointestinal health, prevent incidence of cancer, cardiovascular disease and diabetes in human being. These potentials when properly harnessed can go a long way a means of achieving the SDGs.

Keywords*: Sustainable development goals, beneficial insects, apiculture, sericulture, edible insect*

INTRODUCTION

At Rio de Janeiro, Brazil in June 2012 the United Nations conference on Sustainanble Development set up 17 Sustainable Development Goals (SDGs) to solve the global environmental, political and economic challenges. These goals were to replace the existing millennium Development Goals (MDGs) which were set in 2000. The MGDs were meant to tackle universal world challenges such as poverty, hunger, deadly plague and for the expansion of children education particularly at primary school level. In 2015, at the Conference of all Parties (COP 21) Paris climate conference, the SDGs coincided with another historic agreement reached. Together with the Sendai Framework for Disaster Risk Reduction, signed in Japan in March 2015, these agreements afforded a set of common standards and attainable goals to reduce carbon emissions, manage the risks of climate change and natural disasters.

These 17 SDGs are end poverty by all its forms; eliminate hunger, achieve food security and improved nutrition and promote sustainable agriculture; ensure healthy living and promotion well-being for all; ensure inclusive and equitable quality education and promote life-long learning opportunities for all; achieve gender equality and empower all women and girls; ensure access to affordable, reliable, sustainable and modern energy for all; promote sustained, inclusive and sustainable economic growth full and productive employment and decent work for all; build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation; reduce inequality within and among countries; make cities and human settlements inclusive, safe, resilient and sustainable; ensure sustainable consumption and production patterns; take urgent action to combat, climate change and its impacts; conserve and sustainability use the ocean, seas and marine resource for sustainable development, protect, restore and promote sustainable use of terrestrial ecosystems; sustainably manage forests, combat desertification halt and reverse land degradation and halt biodiversity loss; promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels and strengthen the means of implementation and revitalize the global partnership for sustainable development (SDGR, 2021).

The year by which these goals are to be achieved is between 2020 and 2030 (SDGR, 2021). It is not untrue that some of these SDGs might have been achieved to a reasonably extent, however, the fact remains that some are yet to be achieved. For instance, the first three goals such as end poverty, eliminate hunger, and ensure healthy living for all are still far away from realization, especially in some parts of the world especially Africa and Asia continents. The year 2030, believed to be the time that all these goals must have reached full actualization is fast approaching. To this end, there is need to gear up efforts to achieve the goals.
Nature has helped mankind with resources needed to achieve some if not all of these SDGs, one of such are beneficial insects which are component of the ecosystem. The paper aimed to unravel the potentials embedded in insects to achieve SDGs.

Potentials of Beekeeping practice in Achieving Sustainable Development Goals.

Beekeeping is a small-scale venture with wide range of products and activities that have potentials of achieving some of the SDGs. According to Ajao and Oladimeji (2013), it is an art and a science of domestication of bees in an artificially constructed hive in order to obtain honey and other bee products to address man's social and economic challenges. It is an aspect of agriculture without requirement for large expanse of land, water, feed or fertilizer to thrive.

Beekeeping requires comparatively low capital to start and manage without any drudgery thereby making it favourable for youth and women. This makes the venture suitable in achieving goal 5 (achieve gender equality and empower all women and girls) of the SDGs.

Benefits derivable from beekeeping include income generation from marketing of honey which is the main hive products and other products such as beeswax, propolis, pollen, royal jelly and bee venom. The activities involved in the production of these products, provide a non-gender-biased employment opportunities. The bees are important pollinators of both agricultural crops and fruit trees; and also provide other ecosystems services, thus, playing a significant role in food production and nutrition.

Merits from provision of pollination service, less need for expensive equipment, no need for food as bee forage on pollen and nectar which are viable all through the season of the year, easy-to-learn techniques, less requirement for daily attention, make the beekeeping venture a beacon of hope for all and sundry to address SDGs such as end poverty, eliminate hunger, ensuring healthy living for all and promoting sustainable agriculture.The role of beekeeping product to achieve goal 4 of SDG (ensuring healthy living and promote well-being for all) cannot be underestimated. Notably among the bee products with health benefits are propolis, pollen, beeswax, royal jelly and bee venom. For instance, honey naturally offers healthful properties like antibacterial and antiviral actions, wound-healing effects, dietary antioxidant and anti-inflammatory effects (Debra, 2021)

Natural unadulterated honey contains some compounds that serve as antioxidants as well as phytochemicals, flavonoids and ascorbic acid. All of these reduce oxidative stress in the body by mopping up free radicals. In a development, scientists have attributed oxidative stress to a range of chronic health condition including cancers. The consumption of these oxidant-rich diets drastically reduces risk of chronic diseases (Debra, 2021). Different hive products have roles they play in achieving goal 4 of SGD. Notably are royal jelly which is said to improve fertility in both men and women. In men, it is reported to increase sperm quality while it increases ovules quality in women (Bhalchandra and Yahaya, 2016). Furthermore, bee sting which consists of acid and alkali glands, the secretion of which form the venom and stored in poison sac which opens into stinging apparatus, is used in the treatment of rheumatoid arthritis with a success rate of between 70% and 90% (Son *et al*., 2007). Propolis is another natural dark sticky resinous materials collected by worker bees from buds and barks of the trees. Several scientists have established that propolis has antimicrobial, antiparasitic, antiviral, anti-inflammatory, antitumor, antioxidant, antibiotic and unaesthetic properties. Owing to these qualities, it is used as a raw material in the production of cough syrups, soaps, skin oils, lotions and toothpastes (Labe, 2017). When properly harnessed, all of these can make goal 4 of SGDs achievable. As further stated by Shakib and Sayad (2016), beekeeping is a venture that is being promoted in the rural areas with the view of improving off farm income and employment. However, it is an unexploited succor with huge potential of rescuing people from abject poverty and starvation when given credence, this will subsequently help to achieve goals 1 (end poverty) and 2 (eliminate hunger) of the SDGs.

Potentials of Sericulture in Achieving Sustainable Development Goals

Sericulture or silk farming is the rearing of silkworms for silk production (Bhattarcharjya *et al*., 2019). Silk is the most elegant textile in the world with unparalleled grandeur, natural sheen and inherent affinity for days, high absorbance, lightweight, soft touch and high durability; and known as the "Queen of Textiles" the world over (Dewangan, 2018b). Sericulture is an agro-based industry with a short gestation period, low investment, continuous cash flow and high pay off. The production of silk from silkworm (*Bombyx mori*) is made possible through feeding of the insect with leaves of mulberry plant (*Morus alba*) (Ashmita *et al*., 2017).

It is pivotal to state that sericulture is capable of generating more income when compared to other crops such rice, paddy wheat and sorghum just to mention a few because most of these crops can be grown once or twice in a year while sericulture can be practiced 4-5 times in a year, (Dewandan, 2018 b). This is the reason why sericulture is presently settled for by several farmers as a cash crop in the agricultural sector. Being a labour intensive venture, sericulture is ideally suited to developing countries like Nigeria for creating gainful employment to the ever-increasing labour force particularly the women and youths. This potential can be tapped into to achieve goal 5 and 8 (achieve gender equality and empower all women and girls and promote sustained, inclusive and sustainable economic growth full and productive employment and decent work for all) of the SDGs. Several activities involved in sericulture include mulberry cultivation, leaf harvesting, silkworm rearing, cocoon reeling, twisting, weaving, printing, dying, finishing and processing of silk waste. This implies that the indusrty has great potential to create employment and generate income for people. For instance, for every kilogram of raw silk produced, 12 people that are mostly women are engaged in silk reeling, threading and weaving, fabrication of machines for both the small filature and the big time miller (Prakasam and Ravi, 2014).

In his report, Qiu (2005) stated that in 22 out of 25 provinces in China, 20 million households who cultivated 2 million hectares of mulberry were employed in sericulture and a million workers were employed to operate 2.4 million reeling machines in 1000 silk factories.

Silkworm cocoon spinning and knitting are been practiced in more than 30 countries and are mostly done by smallholder farmers (Ogunlusi and Olaniyan, 2021). These countries include China and India which account for more than 50% of the world production followed by Japan, Korea and Thailand. In Europe, the main producers are Italy and Spain while Zambia, Kenya, Egypt and Uganda are main producers in Africa. Brazil is the largest producers in Latin America with Bolivia and Colombia as smaller producers (Giselle *et al*., 2017). Nigeria is not on this list but if the potentials embedded in this venture are properly harnessed with support from government and other stake holders, it will go a long way in achieving goals 1 and 7 of the SDGs. The role of silkworm in achieving goal 3 of the SDGs cannot be underestimated. For instance, silkworm's excreta is been used in the treatment of infectious diseases such as headache, abdominal pain and blood pressure (Vimolmangkang *et al*., 2014). Mulberry plant (*Morus alba*) cultivation is part of sericulture. The potentials from this plant part can also contribute immensely to achieving goal 3 of the SDGs. From their several investigations, scientists have reported antioxidant potential of the extracts from different mulberry plant part such as leaves, fruit, roots and branches (Arfan *et al*., 2012). In mulberry leaves, notably among the active compound present are alkaloids such as 1-deoxynijirimycin and fagomine (Hu *et al*., 2013). As reported by Hao *et al.* (2018) the two alkaloids are known to decrease blood glucose in human. Because of presence of phytochemicals such as coumarins, flavonoids and phenols in mulberry leaf, it is been used as a therapy in blood pressure and cholesterol level reduction in human body (Zhang *et al*., 2009).
Furthermore, mulberry fruits are rich in phenolic compound with flavonols being the most effective among them (Jin *et al.*, 2017). The fruit also contains moranolin, moran (glycopeptides), hydrophobic flavonoids (flavones and flavonone) and 2-arylbenzofuran which have been reported to play role in hypoglycemic action (Fallon *et al*., 2008). From the findings of Andallu *et al*. (2001), there was a reported improvement in glycemic control and reduction in very low density lipoprotein (VLDL) production in type II diabetic patient when treated with mulberry. All aforementioned benefits can play significant role in achieving goal 4 of SDG (ensuring healthy living and promotion of well-being for all). Several studies have also shown that mulberry fruit juice can be used to treat ailments such as mouth ulcers, fever, anaemia, dizziness, insomnia, hepatitis, constipations. It is also useful in boosting immunity, relieve tiredness and fatigue, and in hair growth enhancement in human (Nazim *et al.*, 2017).

Potentials of Edible Insects in Achieving Sustainable Development Goals
Another benefit of insect that can be harnessed to achieve SDGs is in the edibility of many of them. They have traditionally been consumed as a food source by nearly 2 billion people around the world therefore contributing to many countries' nutrition (Halloran *et al*., 2014). It is interesting to know that there are about 1,900 edible insects species from which humans eat eggs, larvae, pupae and adults. These edible insects range from bees, wasps, beetles, moths, caterpillars, crickets and grasshoppers. Many edible insects are rich in nutrients such as proteins, fats, fiber, vitamins and minerals which are important in human diet (Raheem *et al*., 2019). As reported by Dovie *et al*. (2010), in the bid to curtail the menace of poverty and starvation, wild natural resources such as edible insects have been exploited in rural safety-net strategy.
Edible insects are cheap and good sources of protein, amino acid, fats, vitamins and minerals (Hlongwane *et al.*, 2020). In a development, Raheem *et al*. (2019) explained that most insects particularly crickets, measure up or even in most cases surpass the recommended amounts of most of the essential amino acids such as histidine, leucine, tryptophan, lysine, isoleucine, threonine and valine for adults. It was further explained that chitin found in the exoskeletons of many several insects serves as a good source of fiber in human diet and may enhance the immune system. They are therefore being consumed or included to supplement diets particularly during period of hardship and staple food scarcity (Raheem *et al*., 2019). The ability of most edible insects to enhance immune function implies that they can be integrated as dietary supplements and substitutes in human diets to adequately improve health and general wellness thereby achieving goals 2 (end hunger) and 3 (ensuring healthy living and promotion of well-being for all) of the SDGs. Most edible insects tend to be rich in unsaturated fats, especially polyunsaturated fatty acids (PUFAs) (Dobermann *et al*., 2017). These PUFAs are heart-healthy fats that tend to be found mostly in plant oil, nut, seeds and fish.

Several components of edible insects such as chitin, short-chain fatty acids, medium-chain fatty acids and glycosaminoglycans have potential to benefit human health. In the study of Stull *et al*. (2018), probiotic bacterium *Bifidobacterium animalis* was reported to increase when human diet was supplemented with 25 grams/day but there was a decrease in plasma tumor necrosis factor (TNF)-α. The relative abundance of this *B. animalis* which is a probiotic associated with the prevention of ailments such as respiratory infections, diarrhea and antibiotic side effects was found very high after intervention suggesting that microbiota produced by cricket supplement has potential to improve gastrointestinal health. Commercial trade of edible insects is a good and lucrative business that generates income and improve livelihoods of people especially those in the rural communities. This is further corroborated by Makha *et al*. (2014) who earlier stated that trade of edible-insect is an excellent commercial business with high and profitable economic returns that can improve the rural economy while also creating job opportunities for many thus achieving goal 8 (promote sustained, inclusive and sustainable economic growth full and productive employment and decent work for all) of the SDGs. When properly explored, the consumption and commercial benefits of insects can be used to achieve goals 1, 2 and 3 of the SDGs which address poverty, hunger and ensure healthy lives.

CONCLUSION

The year 2030 deadline set for the full accomplishment of all the sustainable development goals is fast approaching. The aforementioned potentials from apiculture, sericulture and entomophagy can be fully exploited in bringing this to bear. It is however, important to state that government at all levels and other stakeholders have immense roles to play in achieving SDGs. This can be done by providing grants for further researches, rearing and domestication of insects such as honey bee, silkworm and edible insects as well as other commercial activities. Awareness programmes can also be organized to sensitize and educate people of how all these benefits from insects can be harnessed to achieve SDGs.

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FUEL PROPERTIES OF SMOKELESS BRIQUETTE MADE FROM DEAD LEAVES OF *Tectona grandis* (LINN.)

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ABSTRACT

As there is a huge demand to find alternatives clean energy that would replace the depleting and non-environmentally friendly fossils fuels for domestic and industrial purposes, biomass briquette shows great potential. Therefore, this study investigated the fuel properties of briquette made from dead leaves of Tectona grandis (Linn.). 500g of the samples of the raw material was pyrolysed at 450˚C and then mixed with cassava flour binder varied at 20%, 25%, 30% and 35% of the weight of biomass sample and briquetted using a mold with hydraulic press at an average pressure of 6 psi. The briquettes produced were subjected to both physical and combustion tests. The pyrolysed samples of the shredded leaves of Tectona grandis gave percentage yield of 56.03%, 1.47%, 4.91% and 37.59% for bio-char, bio-oil, water and gas respectively. The mean percentage value for the elements were: 41.78±0.01, 5.33±0.01, 40.70±0.09, 1.185±0.00 and 0.196±0.00 for Carbon, Hydrogen, Oxygen, Nitrogen and Sulphur respectively. The range of values for the briquette produced were: moisture content (11.33±0.47 - 12.65±0.49%), bulk density (0.50±0.01 - 0.67±0.01g/cm^3), water resistance (71.98±1.35 - 83.24±1.24), Volatile matter (41.40±0.58 - 47.60±0.32%), ash content (18.40±0.51 - 23.20±0.73%), fixed carbon and Heating values (26020.12±256.05 - 27621.15±180.13 KJ/kg). The briquette is ecological friendly because of low content of sulphur and nitrogen. Therefore, based on ultimate, physical and combustion characteristics, the dead leaves of Tectona grandis are recommended for the production of biomass briquette for domestic and industrial use.

Keywords: *Tectona grandis, dead leaves, Briquette, Biomass, smokeless*

INTRODUCTION

In every part of the world, biomass energy remains an integral part of renewable energy. Its importance in nationwide energy blend both for developed counties and in countries that have their economy in transition towards achieving sustainable energy cannot be over emphasized (Hoang *et al.,* 2021). In developing countries, 70% to 90% of the total energy uses are constituted by the energy used for cooking. The increased culture of cooking with solid fuels like traditional biomass and coal can have a negative impact on human health, forest, land as well as climate change (Kumlachew *et al.*, 2014).

In Nigeria, the main sources of domestic energy are fuel wood and charcoal. Statistically, over 50 million metric tons of fuel wood is consumed every year in which 60% of the consumers reside in the rural areas. These account for more than 50% of the total yearly energy usage. Natural gas 5.2%, hydroelectricity 3.1%, and petroleum products 41.3% which accounts for 5%, 3% and 41% are other sources of energy. (Oyelaran *et al.,* 2015). Due to high carbon emission, decreasing availability of fuelwood, deforestation as well as desertification, these sources of energy contributed to global warming. As such, there is a need for alternative sources of energy which is renewable for domestic, low-income society and industrial use.

Babajide *et al.* (2018) reported that this source of energy must be steady, cheap and renewable due to decrease in availability of fuelwood every year. As such, there is a need for an urgent shift into a sustainable source of energy. Aina *et al.,* (2009) opined that fuel briquette is a suitable replacement for fuelwood as fuel briquette is clean, very convenient to use and has a greater heat intensity than fuelwood. The solution to the present and future problems of energy need in developing countries is diversification of energy resources by producing energy from readily available renewable natural resources (Amalinda et al., 2020).

Fuel briquettes are a type of energy derived primarily from biomass. They are made by compacting biomass material into a solid unit using manual or mechanical equipment or other processes, with or without the addition of a binder. Briquettes for fuel can be manufactured from either non-carbonised or carbonised biomass. The objective of this study is to determine the fuel characteristics and suitability of *Tectona grandis* dead leaves for the production of briquette with a view to converting the dead leaves to a useful domestic energy products.

MATERIALS AND METHOD

Procurement of *Tectona grandis* Leaves

The leaf litters from *Tectona grandis* trees was collected at the Department of Forest Production and Products, University of Ibadan. Hammer mill was used to shred the leaves into smaller particles. In order to reduce the moisture content of the milled product,

samples were sundried for 7 days in line with Noah *et al* 2019. The milled and sundried biomass was pyrolysed at the Department of Mechanical Engineering, Faculty of Technology, University of Ibadan by using an electric pyrolyser.
Manual hydraulic press was used to produce briquettes at the laboratory of the Department of Mechanical Engineering, University of Ibadan from the pyrolysed leaf biomass of the tree species. For each of the briquette production set, 500g of the pyrolysed sample was mixed with prepared binder (cassava flour) until mould-condition was achieved with the binder content at 20%, 25%, 30% and 35% variation of the sample based on performance ratio described by Sotannde *et al*. (2010). The mixture of the biomass and binder was then fed into a hydraulic mold which was covered at each of the ends with a lid and compressed at a pressure of 6psi.

Determination of Physical Properties
The following physical properties were assessed on the briquette produced
Bulk Density
Density is the mass of a sample per its unit volume. The mass of the sample was determined by weighing on meter balance. The volume of each briquette sample was estimated from the dimensions measured, using a vernier caliper (Sawadogo *et.al*, 2018).

Bulk Density = $\frac{m}{v}$ gcm³ (1)

Where.
m = mass of the sample (g)
v = volume of the sample (cm³)

Water Absorption Capacity
The water resistance capacity of the dry briquettes was determined by submerging five different samples for each of the biomass produced in a container full of distilled water at room temperature for 120 seconds (Davies and Davies 2013). Changes in dimension of each briquette was measured.

%water gained by briquette = $\frac{M2-M1}{M1}$ X 100 (2)

Where,
M_1 = Initial weight of briquette before immersion and
M_2 = Final weight of briquette after immersion.

The equation becomes water resistance capacity (%) = 100% − %water absorbed (Davies and Davies 2013).
Proximate Analysis
Water Boiling Test
This test is used to compare the briquettes' cooking efficiency by calculating how long it will take each set of briquettes to boil an equivalent volume of water under the same conditions according to Onuegbu *et al.* (2011). 100g of each briquette sample was combusted to boil 100cm^3 of water in a small stainless pot using a household charcoal stove.

Ignition Time Determination
Ignition time was determined as described by Onuegbu *et al* (2011). In each test a single briquette was placed alone in the center with the Bunsen burner placed directly beneath it. Bunsen burner was adjusted to blue flame and it was also ensuring that the whole of the bottom surface of the briquette was ignited simultaneously. The time taken for the briquette to be ignited was recorded in seconds.

Burning Rates Determination
This is the determination of the degree at which a certain weight of fuel is burnt in the air. The degree of briquettes burning was determined by taking the record of the briquettes weight before ignition and after the briquettes were completely burnt in air, the degree at which briquette samples was burnt was determined using equation 3 (Onuegbu *et al.*, 2011).

Burning Rate (gmin^{-1}) = $\frac{\text{total mass of the burnt briquette in air (g)}}{Period\ \text{(min)}}$ (3)

Percentage Ash Content
2g of oven-dried briquette sample was weighed into a crucible set in a furnace at 550ºC temperature for 4 hours. The ash was weighed after cooling. The percentage of the ash content of the sample was calculated using the equation 4.

Ash Content (%) = $\frac{A}{W}$ x100 (4)

Where:
A = weight of ash (g)
W = weight of oven dried briquette sample (g)

Percentage Volatile Matter

This is the amount of compound that will evolve during a given period of time in the furnace under specified conditions. The volatile matter was gotten by placing 2g of crushed briquette sample in a crucible in the furnace for 10 min at 550ºC temperature. At the expiration of the duration in the furnace, the left over in the crucible was cooled in a desiccator before weighing to get the percentage of the volatile matter.

Volatile matter (%) = $\frac{B-C}{B} \times 100$ (5)

Where:
B= weight of oven-dried briquette sample (g)
C = weight of briquette sample after 10minutes in the furnace at 550^0C

Percentage Fixed Carbon

The fixed carbon percentage was determined by using the equation 6:
Percentage fixed Carbon = 100 – (%VM + %AC) (6)
Where:
%VM = percentage volatile matter
% AC = percentage ash content

Heating Value

This is the calorific value of the heat generated by a given sample. Good material for burning must possess high heating value. This was estimated using the equation 7.

HV = 2.326 (147.6FC + 144VM) KJ/kg (7)

Where,
HV = heating value (kJ/kg); FC = percentage fixed carbon; VM = percentage volatile matter

Moisture Content

Moisture content of a given material, is the percentage of water in that material. The moisture content was calculated according to Noah *et al* (2019). Samples of briquette produced was weighed on a digital weighing balance, placed in the oven at a 103±2ºC temperature and weighed at intermittently for 120 minutes until a uniform weight was obtained. The oven-dry moisture content of the briquette will be calculated as follows.

MC (%) = $\frac{A1-A2}{A2} \times 100$ (8)

Where, MC = percentage moisture content
A1 = initial weight of the sample before oven drying (g)
A2 = final weight of the sample after oven drying (g)

Data Analysis

A 1 x 4 factorial experiment with pyrolyzed biomass materials at 1 and 4 levels of binder was employed in a completely randomized design. The data obtained for the physical and combustion properties from the briquette produced were subjected to Analysis of Variance (ANOVA). Duncan multiple range test would be used as a follow-up technique. All of the investigated properties' means and standard deviations were computed. SPSS was used to conduct all analyses.

RESULTS AND DISCUSSION

Yield of each components of the biomass

Table 1 shows the percentage composition of the pyrolysis product in each of the biomass material. The pyrolysis carried out at 550ºC for the shredded dry leaves of Tectona grandis shows the yield percentage of 56.03%, 1.50%, 4.88% and 41.98% for bio-char, bio-oil, water and gas respectively. According to Shadangi and Mohanty (2014), the yield of each component of the biomass materials has a relationship with the pyrolysis temperature. This means that the yield of the solid and liquid components reduces with increase in temperature used for the pyrolysis. According to Demirbas (2007), char, persistent gases, and vapours that condense to a dark brown viscous liquid at ambient temperature are the three principal products of biomass pyrolysis.

Table 1: Yield of each components of the biomass

Components of *Tectona grandis*	Value (kg)	Yield (%)
Weight of Biomass	11.6	-
Weight of bio-char	6.5	56.03
Weight of bio-oil	0.17	1.47
Weight of water	0.57	4.91

Weight of gas	4.36	37.59

Weight of bio-char, bio-oil and water were measured while weight of gas was estimated.

Ultimate Analysis

The elemental analysis of biomass expresses the mass concentration of the key elements (Carbon, Hydrogen, Oxygen, Nitrogen, and Sulphur) present in the biomass. Table 2 shows the mean percentage of the elements analyzed. The mean values are 41.78±0.01, 5.33±0.01, 40.70±0.09, 1.185±0.00 and 0.196±0.00 for Carbon, Hydrogen, Oxygen, Nitrogen and Sulphur respectively. The findings corroborate those of Akowuah et al. (2012), who found that study of biomass utilizing gas analysis methodologies indicated carbon as the primary ingredient, accounting for between 30 and 60 percent of the dry matter and frequently 30 to 40 percent oxygen. Hydrogen, the third most abundant element, accounts for roughly 5% to 6% of dry biomass, whereas nitrogen and sulphur (together with chlorine) account for less than 1%..

Table 2: Mean value of ultimate analysis of the biomass materials

% Carbon	% Hydrogen	% Oxygen	% Nitrogen	% Sulphur
41.78±0.01	5.33±0.01	40.70±0.09	1.185±0.00	0.196±0.00

Bulk Density

Briquette density is a measure of its strength and it is determined by moisture content as well as compaction pressure (Gendek *et al*, 2018). The bulk density (Table 3) increased with increase in binder proportion. The briquette has the highest and lowest density of 0.67±0.01g/cm^3 and 0.50±0.01g/cm^3 respectively. These values are close to the range of 0.63 g/cm^3 and 0.54 g/cm^3 reported by Birwatkar *et al* (2014) in their work on physical and thermal properties of biomass briquetted fuel. Increased density enhances the briquettes' strength, at least in terms of handling characteristics.

Water Resistance Testing

Water resistance testing was conducted to evaluate the rate at which briquettes degrade in high humidity or water exposure. The water resistance (Table 3) range for the briquette was between 71.98±1.35 - 83.24±1.24. The values reported in this study are comparable to those obtained by Rajaseenivasan *et al.* (2016) for sawdust and neem powder briquettes. The hygroscopic property of briquettes at various binder proportions revealed that the amount of binder used increased the water resistance capacity. Briquettes exposed to rain or high humidity conditions during shipping and storage may have a negative impact on their quality.

Volatile Matter

Volatile matter is a mixture of short- and long- chain hydrocarbons that are released during burning, such as combustible or incombustible gases, or a combination of the two. These gases have a considerable impact on the burning of briquettes. The highest and lowest volatile matter (Table 4) was 47.60±0.32% and 41.40±0.58% respectively. The volatile matter of the briquettes produced in this study falls within the range of 43 - 49% obtained by Mulindwa *et al.* (2021) for briquettes made from mixed tropical hardwood species sawdust. However, Adetogun *et al.* (2014) discovered that maize cob briquettes had a higher volatile matter concentration, ranging from 57.82 to 62.91% High volatile matter results in high combustibility at low ash concentration.

Heating Value

The calorific value, often known as the heating value, is a standard measure of the energy content of a fuel. The heating value (Table 4) of the briquette ranges from 26020.12±256.05 - 27621.15±180.13. The heating value recorded in this study is within the range of values (4937 kcal/kg–12,665.67 kcal/kg) reported by (Aina *et al.*, 2009). The amount of energy produced by the briquettes created in this study is sufficient to generate heat for both household cooking and small-scale industrial cottage applications.

Ignition Time

The ignition time (Table 4) obtained in this study increases with increase in binder level. It ranges from 104.40±2.08 sec at 20% binder level to 143.80±2.29 sec at 35% binder level. This could be attributed to an increase in density, as evidenced by the findings of Ige *et al.*, (2020), who discovered that density affects flame propagation in briquettes. Because there are fewer open areas for mass diffusion in low porosity briquettes, drying, devolatilization, and char burning processes are hampered.

Burning Rate

According to the findings of this study, the obtained burning rate values of the briquettes reduced as the binder proportion increased. 0.17±0.002 at 35% binder level and 0.22±0.003 at 20% binder level. The implication of this observation is that cooking with briquettes made from 20% binder may demand more fuel than cooking with briquettes made from 35% binder (Imeh *et al.*, 2017). Briquettes made with a binder content of 35% had the slowest burning rate (Table 5). Onuegbu *et al*. (2011) showed that parameters such as chemical composition and geometry (bulk and packing orientation) of the biomass could be responsible for the burning rate of biomass (briquettes).

Moisture Content

One of the most essential considerations for evaluating briquette durability and igniting propensity is moisture content. Moisture content value of briquette made from *Tectona grandis* leaves ranged from 11.33±0.47% - 12.65±0.49% (Table 5). As seen, moisture content falls in the range of 10-15%, as reported by (Senchi and Kofa, 2020). Also, (Kpalo *et al*, 2019) report an overall, moisture content of 5.55% and 12.33% in their work on briquette produced from paper pulp and *Mesua ferrea* mixtures. The briquettes' low moisture content is capable of influencing the durability and storage, as well as reduce the amount of energy needed for water evaporation during combustion positively (Sotande *et al*, 2017).

Fixed Carbon

Fixed carbon indicates the percentage of char that remains after volatile stuff is distilled away. The fixed carbon of the briquette increased with increase in binder level and ranges from 32.40±0.5% at 20% binder level to 35.40±0.73% at 35% binder level (Table 5). The fixed carbon reported in this study is higher than 5.75 to 8.28 percent stated by Emerhi (2011) and 9.06 to 11.46% obtained by Mulindwa *et al*. (2021), who all worked on briquettes produced from homogeneous particles. In collaboration with the findings of this study, a good quality and efficient fuel briquette is dependent on reduced volatile matter and ash concentration with greater fixed carbon content.

Water Boiling Test

The results of the water boiling test presented in table 5 demonstrate that the time decreases as the binder concentration decreases and ranges from 11.16±0.01 to 14.25±0.05. This was in contrast to the findings of Ige et al., 2020, who found out that increasing the binder proportion decreased the time while increasing the residence time for the briquettes to complete combustion. The water boiling time was governed by two factors: the burning rate (how quickly the fuel burns) and the caloric value (how much heat is emitted) (Onuegbu et al, 2011). This explains why the lower density sample was able to boil water faster than the higher density sample, despite the fact that the former burns faster. This indicates that while the burning rate is significant, the calorific value is also important in determining cooking efficiency.

Table 3: Mean value of the Physical properties of the briquette

Binder Level	Bulk Density (g/cm^3)	Water Absorption (%)	Water Resistance Capacity (%)
35%	0.67 ± 0.01^{a}	21.35 ± 1.37^{b}	78.65 ± 1.37^{b}
30%	0.63 ± 0.00^{b}	16.76 ± 1.23^{a}	83.24 ± 1.24^{c}
25%	0.58 ± 0.01^{c}	17.25 ± 1.62^{a}	82.78 ± 1.62^{c}
20%	0.50 ± 0.01^{d}	28.02 ± 1.05^{c}	71.98 ± 1.35^{a}

Means with the same alphabet along the column in each category are not significantly different at $\alpha_{0.05}$

Table 4: Mean value of the proximate analysis of the briquette

Binder Level	Ash Content (%)	Volatile Matter (%)	Heating Value (KJ/kg)	Ignition Time (Seconds)
35%	23.20 ± 0.73^{a}	41.40 ± 0.58^{a}	26020.12 ± 256.05^{a}	143.80 ± 2.29^{d}
30%	22.20 ± 1.46^{a}	46.60 ± 0.81^{b}	26319.89 ± 504.36^{a}	135.60 ± 1.93^{c}
25%	19.20 ± 0.37^{b}	47.60 ± 0.32^{b}	27341.47 ± 125.70^{b}	111.60 ± 2.48^{b}
20%	18.40 ± 0.51^{b}	47.00 ± 0.51^{b}	27621.15 ± 180.13^{b}	104.40 ± 2.08^{a}

Means with the same alphabet along the column in each category are not significantly different at $\alpha_{0.05}$

Table 5: Mean value of the proximate analysis of the briquette

Binder Level	Fixed carbon (%)	Water boiling (min)	Moisture Content (%)	Burning rate
35%	35.40 ± 0.73^{a}	14.25 ± 0.05^{a}	12.65 ± 0.49^{a}	0.17 ± 0.002^{a}
30%	34.20 ± 1.46^{a}	13.15 ± 0.03^{b}	11.76 ± 1.14^{a}	0.19 ± 0.003^{b}
25%	33.20 ± 0.37^{b}	11.24 ± 0.01^{b}	11.73 ± 0.11^{a}	0.19 ± 0.004^{b}
20%	32.40 ± 0.51^{b}	11.16 ± 0.01^{b}	11.33 ± 0.47^{a}	0.22 ± 0.003^{c}

Means with the same alphabet along the column in each category are not significantly different at $\alpha_{0.05}$

CONCLUSIONS AND RECOMMENDATIONS

The outcome of this study shows that the briquettes produced from *Tectona grandis* dead leaves exhibit great prospect for use as possible and economical domestic fuel. This biomass material can be used because they are readily available. The comparatively high durability index indicates that the briquettes produced will not disintegrate easily during handling and transportation. The level of the moisture content of the briquettes produced is within acceptable limits and has minimal impact on its calorific value that is high enough to generate the needed energy. The low sulfur and nitrogen contents of biomass have a outstanding prospect to reduce emissions formed during combustion. Therefore, the dead leaves of *Tectona grandis* is recommended as a suitable biomass for briquette production.

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POTENTIAL OF BAMBOO IN RESTORATION OF DEGRADED FORESTLAND IN NIGERIA: A REVIEW

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ABSTRACT
Forest as a diverse biological system faced with critical degradation condition due to increasing over exploitation, fragmentation, climate change and other environmental problems that are mostly caused by human activities. This is creating threat that the world must be concerned now and years to come. Bamboo is one of multifunctional, fast growing and a renewable plant that can be considered in landscape reclamation and restoration of degraded forest. This paper reviewed the status of Nigeria forest with the causes of forest loss such as deforestation which is currently at alarming rate, fuel wood exploitation, timber exploitation, overgrazing and encroachment. The paper examined the consequences of forest degradation which include destruction of micro environment, lowering of water table, climate change, flooding and drought. Furthermore, the potential of bamboo as green gold in forest restoration was discussed. This is because bamboo is a fast growing plant and the biological characteristics made the plant to be excellent in soil function restoration. Other socioeconomic benefits of bamboo as contained in this article include provision of ecosystem services, erosion control, enhancement of livelihood and food security. This paper recommends a policy formulation that will enhance scientific and holistic approach to the research, cultivation, management and processing of bamboo products for economic development.

Keywords: *Bamboo; restoration; degraded; forest land; Nigeria*

INTRODUCTION

Forestry is vital to human existence. From time being it has attracted much attention. This is because a wide range of resources are extracted from forest with many ecosystem services supporting human survival. Forests are important as storage of carbon, for production of oxygen vital for human existence on earth. It helps in the regulation of hydrological cycle, water purification, habitat for wildlife and reduction of global warming. It also helps in reducing pollution and absorbing toxic gases as well as soil conservation (Saka-rasaq, 2019). Forest is a source of wood mainly used by mankind in various forms for constructional works, as basic raw materials, for pulp and paper production, particle board making, plywood manufacturing, veneer production, furniture making, as industrial raw materials, as fuel in industries and home and a host of other products. Forest also have added value of conservation for scenic purposes, prevention of erosion, reduction of pollution, provide food and habitat for wildlife, prevention of many environmental problems and stabilization of climate. One of the services afforded by forests is the regulation of the world's climate through carbon storage and sequestration (IPCC, 2001).

Nigeria has an estimated land area of 923,768 km². This was once covered by extensive forests. According to an estimate, as at 1897, Nigeria had 60 million hectares of forests and woodlands (Oguntala, 1993). There is an enormous diverse of plant species which according to NEST (1991) are about 4614, out of which 255 are endemic. Unfortunately, we have taken these forests for granted because they were found everywhere and we have the notion that it will always be there to meet our needs. However, recent evidences point to the fact that our interaction with the forests through unsustainable exploitation of its resources, negative attitude towards its wanton destruction for other uses is creating a number of serious environmental problems. A larger proportion of Nigerian forests either reserved or not had been degraded.

The end results of the degraded and destruction of forest ecosystem includes land degradation, drought, desertification, destructive gully erosion, flood, climate change, depletion of ozone layer and biological diversity amongst other environmental problems threatening the existence of mankind. There is, no doubt, nexus between presence of forests and prevention of ecological problems. Many research scientists and stakeholders whose research efforts and mission focused on environmental protection, amelioration of degraded environments and conservation of forest resources for sustainable development is deeply concern about the high rate of degradation and wanton destruction of vegetation in Nigeria. It is therefore important to harness sustainable option to halt the present escalating rate of forest land degradation. This could be supported with policy strategy for recovering Nigeria forest land only for environmental protection but for sustainable national development.

It is necessary to restore the status of Nigeria forestland. This is because majority of household particularly the rural population gain their livelihood through proper productivity of land (CSA, 2015). One of the options of land restoration is the use of bamboo. Bamboo is imperative for re-establishing degraded landscapes that deteriorated by mining activities (INBAR, 2015). The plant has potential for sustaining forest resources, maintaining land degradation and economically supporting rural communities' livelihood. Despite the potential of bamboo in landscape restoration, less attention is given and there is limited knowledge on the part of communities around forestland towards management and cultivation of bamboo. This paper therefore discussed the concept of ecological restoration with a view to examine the potential of bamboo as a green gold in the restoration of degraded forest land in Nigeria.

CONCEPT OF ECOLOGICAL RESTORATION

Ecological restoration according to the Society for Ecological was define as an activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability" (SER, 2014). The progression of an ecosystem is usually from a simple level of organization (this involves dominance of few pioneer species) to a more complex community (i.e. many interdependent species) over time. Based on the extent and severity of the disturbance, restoration always includes initiating, assisting, or accelerating ecological successional processes.

Ecological restoration is an approach that can reverse the trend of land degradation and loss of biodiversity (MEA, 2005). This approach is necessary for a development that ensures sustainability and improvement in conservation efforts that is rising more pronounce in recent tie(Hobbs *et al*., 2011; Roberts *et al*., 2009). This is reflected in the increasing role of restoring ecosystem at all levels of environmental policy and in the process of ensuring ecosystem services (Bullock *et al*., 2011). The process requires effective strategies that consist of collaborative efforts of different specialists from relevant discipline (Aradottir, 2013). Ecological restoration is concerned has to do with the process of recovering the degraded ecosystems and attempts to restore their historical development trajectories by establishing and enhancing ecological processes (SER, 2004). The strategies of these disciplines include appropriate efforts with a view of restoring and reflecting this difference. Restoration process is positive when the ecosystems have high resilient and changes in management of their degraded state are sufficient for natural recovery to take place (Holl and Aide, 2011).

Forest restoration is the process that involve improvement of health, productivity, and array of life of a forest. Forest restoration is concerned with efforts of protecting remnant vegetation (fire prevention, cattle exclusion etc.) or more active interventions to accelerate natural regeneration as well as tree planting and/or sowing seeds (direct seeding) of species characteristic of the target ecosystem (FAO, 2016). Planted tree species (or encouraged to establish) include those that are typical of, or provide a critical ecological function in, the target ecosystem.

Plate 1: Degraded Forestland
Source: worldwildlife.org

FOREST LOSS AND LAND DEGRADATION IN NIGERIA

Forest and land degradation is a serious problem worldwide. It occurs in many counties. It has been reported that larger part of world's land is degraded. According to Abadega and Abawaji (2021), about 25% of the total land has been degraded globally. Currently, degradation of land is one of the world's most pressing issues and even it will worsen if immediate action is not taken. Land degradation is one of ecological problems affecting the livelihood of people, food security and increasing risk of disease. Worldwide, 3.2 billion people have been affected by land degradation, the impact of the degradation is especially severed for smallholder farmers who heavily depend on natural resources. Mostly land degradation occurs through human-induced livelihood activity and rarely by natural processes (Abadega and Abawaji, 2021).

Loss of forest cover is presently a major problem in the tropical region and indeed in Nigeria. According to Kio (2000), between 1964 and 1984, forests and woodlands were diminished by 26% while croplands and permanent pastures increased by 5% and 9% respectively. About 300,000 hectares of closed forests were cleared each year between 1981 and 1985 (WRI, 1987). The Forest Resources Survey by FORMECU (1996-1998) revealed that the forest cover of the country decreased by about 20% over the preceding 18 years, that is, 1978 and 1996. Indeed, the total forest estate which stood at the 10 percent of the country's land area in 1976 is now less than 6 percent (Bada, 1996). It has been reported that Nigeria has the highest rate of deforestation in the world. This is according to the Food and Agriculture Organization of the United Nations (FAO, 2010). The estimate by FAO showed that the rate of deforestation in Nigeria between 1990 and 2010. It was also revealed that Nigeria lost an average of 409,650 hectares or 2.38% per year. In total, between 1990 and 2010, Nigeria lost 47.5% of its forest cover or around 8,193,000 hectares. The annual rate of deforestation in Nigeria is 3.5%, approximately 350,000-400,000 hectares per year. The greatest concern is mainly in respect of the significant loss of the high forest productive areas in the rain forest and derived Savanna losses.

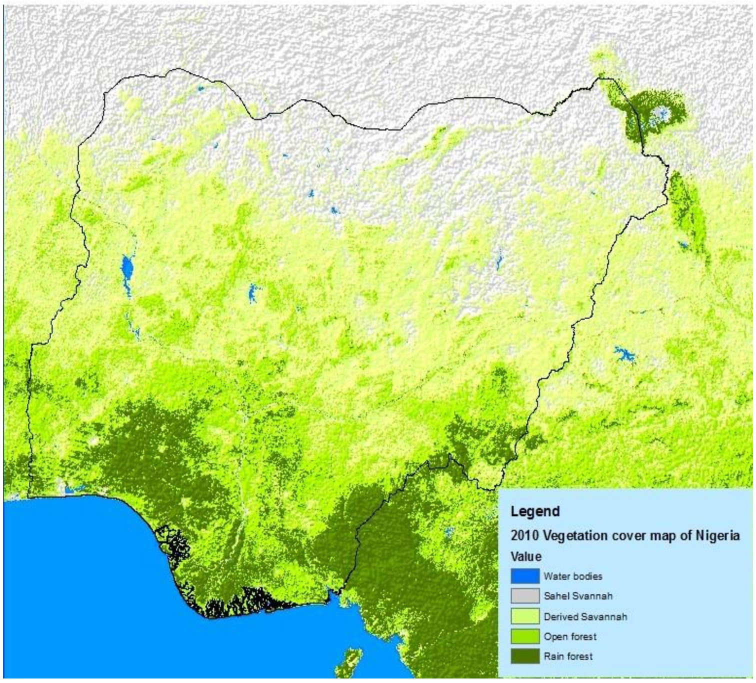

Figure 1: Nigeria Forest cover as at 2010
Source: FRIN Annual Report, 2016

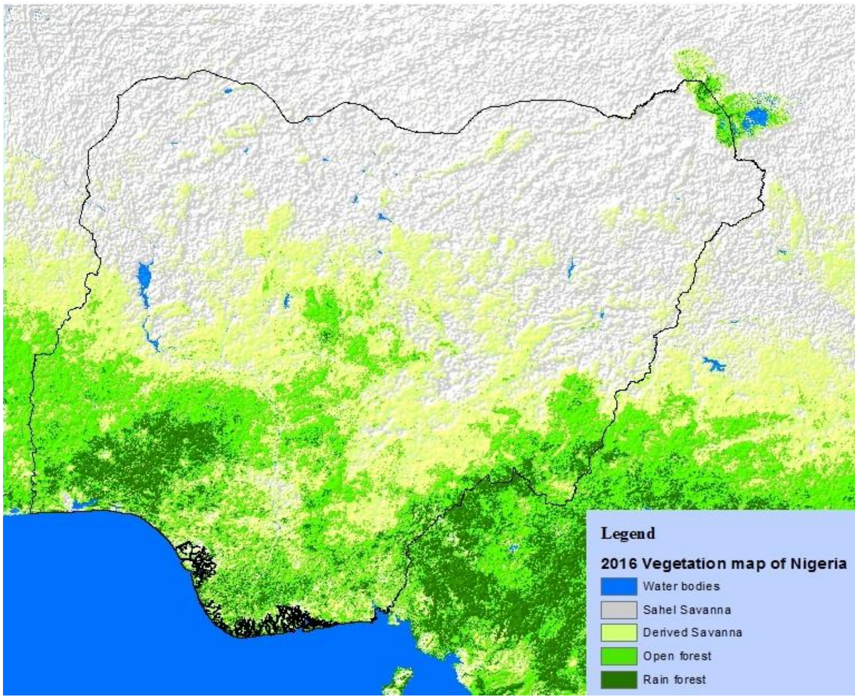

Figure 2: Nigeria Forest cover as at 2016
Source: FRIN Annual Report, 2016

CAUSES OF DECREASING FOREST COVER IN NIGERIA

In Nigeria, forest degradation is caused by population pressure, habitat degradation, over exploitation, change in land use, pollution and lack of emphasis on conservation (Adekunle, 2005).Causes or factors leading to reducing forest covers in Nigeria are summarized by several authors to include:

- **Deforestation**: The current rate of which deforestation is going on in Nigeria is becoming alarming. The forest reserves intended to be land under forest are been clear felled for agricultural purposes as a result of the availability of fertile land under forest cover.
- **Exploitation for fuel wood**: Till the present time, direct combustion of wood is used for heat supply households and rural industries. More than 80% of Nigerian population depends on firewood and charcoal as domestic source of energy. Adekunle (2005) noted that fuel wood is the only affordable energy source for the rural people who constituted about 77% of Nigerian population. In Nigeria, consumption of fuel wood, rose from 60.3million m^3 in 1980 through 90.75million m^3 in 1994 to 97.6 million m^3 in 2000 and has been predicted to rise 110.619 million m^3 by 2010. At this rate of consumption, if regeneration is not stepped up, reduction in forest cover will continue and its adverse effect on environment is imminent.
- **Timber exploitation:** In Nigeria large areas of natural forests are being exploited for tree species such as Mahogany, *Nauclea diderichii* (Opepe), *Terminalia ivorensis* (Odigbo), *Terminalia superba* (Afara), *Triplochiton scleroxylon* (Obeche) and other known timber species in International market. Indiscriminate logging and illegal harvesting of these tree species and others and continued to pose serious threats to the country's forest cover.
- **Overgrazing**: Intensification of herding activities lead to deforestation through overgrazing. The inadequate and non- provision of range levels for nomadic in Nigeria, has led to uncontrolled grazing and browsing of the forest covers. The livestock practice in Nigeria is nomadic in nature. Vast numbers of livestock, especially cattle, goats, sheep and camel roam and browse on forest covers on daily basis searching for fodder. When overgrazing occurs trees and shrubs destroyed, the land is eroded and trampled upon which automatically reduces its productivities capacities.
- **Construction**: Forest land is always cleared of the rich vegetation for construction of roads, public and private buildings, dams and provision of infrastructure. All these activities contribute to the reduction in forest cover of the nation.
- **Encroachments**: Despite the fact that Nigeria is not able to meet 25% of the landed area to be under forest cover as recommended by FAO, Nigeria forest covers are being destroyed to make way for other forms of land use such as farming, housing estate and roads. The high fertility of the forest lands as well as land hunger is the major factors which encourage land clearing of Nigeria's forest cover.

EFFECT OF FOREST DEGRADATION IN NIGERIA

Forest and land degradation cause soil erosion, and watershed destabilization resulting in flooding and drought. They reduce biodiversity (the range habitat species and genetic types). It contributes to regional and global climatic imbalances. According to Adedire (2002) the implications of reduction on forest cover include decrease in the amount of precipitation, increased in the amount of surface temperature and the alteration of local hydrology. Reduction in forest covers, has led to the increasing atmospheric concentration of carbon dioxide (Co_2), since the trees require for sequestration have been drastically reduced or completely lost. The consequences of reduction in forest cover include:

- ✓ **Soil erosion by rain and wind**: Forest cover destruction or reduction accelerates soil erosion case by rainfall, wind and sea waves. Deforestation in southern Nigeria with heavy rainfall resulted in the increase in amount of top soil removed every year and the incidence of gully erosion.
- ✓ **Destruction of micro-environment:** Excessive logging or removal of forest destroys the micro environment together with the habitats for flora and fauna. Climax trees and the animals that are often thriving under the canopies are destroyed when forests are excessively exploited.
- ✓ **Lowering of the water table:** The destruction of forests covers in Nigeria has led to the disappearance of springs, streams, rivers and lakes or total reduction in the sizes of many water bodies.
- ✓ **Changes in ecosystem:** A large proportion of the part of Nigeria, that was earlier classified as rainforest at the beginning of the 20th century now has the ecosystem of derived savanna woodlands as a result of excessive logging and bush burning.
- ✓ **Flooding and drought**: One of the functions of forest covers is to absorb and store great amount of water quickly when there are heavy rainfalls. When forests are cut down, the regulation of the flow of water is hindered which also leads to alternating periods of flood and drought in the affected areas.
- ✓ **Climate change:** It is commonly belief that global warming is being caused largely due to excessive reduction in forest covers and increase in greenhouse gasses like carbon-dioxide into the atmosphere. The effect of forest cover reduction is not limited to declining in number of rainy days and total volume of rain fall, but also increases surface run-off and reduce evapo-transpiration rate. The cumulative effect leads to reduction in amount of water available for atmospheric circulation.

BAMBOO: A GREEN GOLD AND CHAMPION IN DEGRADED FOREST LAND RESTORATION

Bamboo is an important plant in land restoration projects. The root system is long which can reach down deep that can draw up essential nutrients where other plants species find its difficult to assess, so they can grow on poor soil or on steep slopes. Bamboo offers important ecosystem services, making it an important plant for agro forestry (Akwada and Akinlabi, 2016). The reasons why bamboo is an excellent tool in degraded land restoration are discussed as flows.

Biological characteristics

Bamboo is basically a perennial grass with woody culms from rhizomes. The surface area of bamboo root is usually dense with a large network of rhizomes which form a mat-like structure that prevent seepage of soil water and provide good protection during sheet and gully erosion for soil conservation (Stapleton, 1994). Most of the bamboo species found in the tropics and sub tropics have sympodial/pachymorph type rhizomes (clumpforming). They have short and thick rhizomes. They cluster together. Large bamboo species under two genera (Bambusa and Dendrocalamus), and other smaller ones (Thamnocalamus and Drepanostachyum) fall in this category (Jackson, 1994). The rhizomes of amphipodial bamboos exhibit both running (leptomorph) and clumping (pachymorph) habits such as in Melocanna species. Monopodial bamboo has thin and longrhizomes such as species of Phyllostachys which run parallel to the ground, and produce isolated shoots at an interval of up to 3 m (Gautam *et al.*, 2018).

Fast growing plant

The growth rate of bamboo is approximately 121 cm in 24 hrs, hence, it is one of the fastest growth plant on earth (Adhikari, 2008). Depending on the species and other associated factors i.e. the prevailing edaphic and climatic factors, bamboo matures within 4—5 years (Yigardu *et al*., 2016). Due to its nature in terms of growth rate, it is acting as remedial materials for reducing land degradation through fast recovery.

Ability to restore soil function

Gautam *et al*. (2018) in their study reported that besides ecological and economical values of bamboo, it is taken as biological measures for soil conservation due to its silvicultural characteristics. Bamboo produces evergreen leaves with dense foliage, it also produce numerous culms. This made it to have capacity for rainfall interception and a thick layer of litter that could maintain a microclimate in the understory for the retention of soil moisture, increased water holding capacity of the layer thereby enhances the soil infiltration properties and reduces surface flow and peak run off. Furthermore, the leaves, branches and stems from bamboo enhance the nutrient circulation and preserve soil fertility.

Due to extensive rhizome system Bamboo, It is a very good as it holds the soil together which help to reduce erosion, particularly in areas prone to high amounts of run off like steep slopes, river banks or degraded lands. As a result, the root system creates an effective mechanism for watershed protection, stitching the soil together along fragile river banks, deforested areas and in places prone to earthquakes and mud slides. Unlike in most trees, proper harvesting does not kill bamboo plants, so the top soil is held in place. The arrangement of rooting system is usually spread with uniquely shaped leaves, and dense litter floor, the sum of stem flow rate and canopy intercept of bamboo is 25%, which means that bamboo greatly reduces run off, preventing massive erosion and keeping up twice as much water in the watershed (Pandey and Shyamasundar, 2008; BF, 2010).

]Bamboo and climate change mitigation

The impact of climate change is fast becoming global reality. It is already affecting patterns of production and consumption activities, including international trade (Akwada, and Akinlabi, 2016). One of the major causes of climate change is deforestation which accounts for almost 20% of all anthropogenic emissions (ITTO, 2005). Carbon sequestration potential of bamboo is very high (RMRDC, 2004). It grows both in the forest and plantations (INBAR 2009). Bamboo is an important plant in reduction of global climate change effects. It could be efficient that any other plant in sequestration of carbon (Akwada and Akinlabi, 2016). The growth potential of bamboo contributes to high energy production of oxygen more than equivalent stand of trees. The growth of bamboo has significant implication in reducing atmospheric carbon dioxide being the fastest growing canopy that releases 35% more oxygen than equivalent stands of trees and sequester up to 12 tonnes of carbon dioxide from the air per hectare per year in a year (EBF, 2001). Advancing bamboo cultivation has advantage in green house gas emission reduction.

Other socioeconomic benefit of bamboo

Bamboo provides a great number of benefits for people on global basis. Majority of rural population in sub tropics and tropics live in bamboo houses. They build their agricultural infrastructures and tools from bamboo and sleep on bamboo mats. Nearly all areas of livelihood such as transportation, storage, medicine and food depend on bamboo (Ogunwusi, 2012). Bamboo can help provide food security for both human and livestock. The shoots of many species are edible and nutritious and they are a common ingredient in many dishes, whilst bamboo leaves are common source of fodder for livestock and feed for fish INBAR (2009).

Bamboo has been reported to provide shelter when properly managed (Jalan, 2008). In terms of house material provision, bamboo has been described as a poor man material for rural dwellers that depends on it for the building of their houses, bridges, etc. In recent years, new designs and production technologies coupled with shifts in perception have made the construction of modern high quality houses that combine safety, durability and aesthetics from bamboo products possible and affordable (Jalan, 2008; Pandey, 2008). Bamboo can help reduce deforestation by replacing trees as a source of bio fuel (EBF, 2001). Bamboo is used as industrial raw material in a variety of sectors. Bamboo is used in the pharmaceutical, cosmetics, construction, wood, pulp and paper, textile industries, etc. In these industries, bamboo has largely replaced some of the traditional raw materials Ogunwusi (2011).

CONCLUSION AND RECOMMENDATIONS

Bamboo is a golden gold with distinguishable biological characteristics that makes it a valuable tool for land restoration activities. This characteristic includes the root system network of fibrous rhizomes and roots that can control erosion, flood and landslides. It is a resilient plant that can survive on marginal land. Planting bamboo can help speed up conversion of degraded lands into productive and economically viable systems. Bamboo can be grown as a pioneering plant in soil damaged by poor agricultural management techniques. Based on the excellent environmental and economic benefits of bamboo as well as potential role in forest degradation restoration, this paper recommends inclusion of bamboo in forest plantation establishment programme and policy formulation that will enhance scientific and holistic approach to the research, cultivation, management and processing of bamboo products for economic development.

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ASSESSMENT OF INSECT PESTS ASSOCIATED WITH STORED SHEA NUTS AND THEIR MANAGEMENT PRACTICES AT IFEDAPO REGION IN OYO STATE, NIGERIA

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Abstract

Insect pests' infestation is a major biotic factor affecting the quality and quantity of many agricultural products in storage including shea nuts. A study was conducted to assess the insect pests associated with stored shea nuts in nine communities at Ifedapo region in Oyo state. A random sampling technique was used to obtain information from 135 shea nut farmers using structured questionnaire and samples of stored shea nuts were randomly collected from the study area for laboratory assessments. Majority of the respondents were female (76.0%) and 58.0% of the respondents indicated that they observe insect pests in stored shea nuts. Five insect's species (carpenter ants, weevils, beetles, mites and cockroaches) were commonly seen in stored shea nuts. Laboratory assessment revealed that insect infestation is a serious challenge to stored shea nuts. Insect infestations were observed in samples from the nine communities and stored shea nuts were mostly attacked by beetles and mites. Samples from Ago-are recorded the highest insect attack (58.6%), followed by Oje-owode (46.7%). None of the respondents applied synthetic insecticides to protect shea nuts from insect attack and the most common storage system adopted is bagging. There was negative correlation (r = -0.064; p = 0.461) between the impact of insect pests and income generation from shea nuts. Thus, insect damage is major problem to stored shea nuts in the study area and there is need to educate farmers on the available control strategies to protect their stored shea nuts against insect attack for maximum income generation.

***Key words**: Control strategies, income generation, insect infestation, storage, Vitellaria paradoxa*

Introduction

The shea-nut tree, *Vitellaria paradoxa* (C.F.Gaertn) of Sapotaceae family is one of the major constituent of the woody plants of the Sudan and Guinea savannah vegetation zones of sub-Saharan Africa (Lovett and Hag ,2000) The shea nut tree is native to sub –Saharan Africa and are found usually in arid and semi-arid northern area of humid forest zones (Center for Agriculture and Bioscience International(CABI),2003). The shea nut tree is one of the several non-timber trees that is economically important but its potentials as an economic tree are not widely documented in Nigeria (Ani *et al*., 2012).The shea tree is not domesticated but it naturally grows in the wild and on farm lands and around homes. The tree was recommended among other trees like *Parkia* species as plant products priorities that requires funding for development because of its usefulness in tropical Africa (FAO,1991). Shea tree has prospects in maintaining the ecological balance and soil fertility for agricultural purposes and can also provide good fuel wood both as energy for household use and source of income. Almost all parts of the tree have some practical uses, the bark, leaves and roots are used for medicinal purposes for curing various illnesses and the shell of the nuts can repel mosquitoes (Ani, 2012). The shea butter is extracted from the dried shea kernel and the oil is widely used for domestic purposes like skin moisturizer, cooking and as a lubricant (Lovett and Hag, 2000). At commercial level, shea butter is used as ingredient in pharmaceuticals, cosmetics and edible products (Abbiw, 1990). The shea tree fruits which has sweet and spicy flavor pulp provides several nutritional benefits to humans and animals such as elephants, sheep, pigs, bats and birds. It has been reported that shea fruits provides vital supports to the livelihoods of parkland communities (Okullo *et al*., 2004; and Maranz *et al*., 2004).

The most important product of shea tree *is* the shea butter which is extracted from the dried kernels. Shea butter is referred to as 'women's gold' owing to the benefits that women farmer obtain from shea processing and production and across the value chain to improve their livelihood (Chen, 2017). The vegetable fat from shea nut is considered the second to palm oil in Africa (Hall *et al*., 1996; Bup *et al*., 2014). Insect pests is one of the major biotic factors causing damage and reducing the quality of many stored products including shea nuts (Aneni *et al*., 2020). It is estimated that 40.0-50.0 % of crops are lost to pests, diseases and poor storage system in many developing countries including Nigeria before they get to the market which is a threat to food security and income of farmers (Aneni *et al*., 2020). According to Odebiyi *et al*. (2004), 33 insect species from 17 families were associated with shea tree in the moist wood land savanna, dry savanna and southern guinea savanna of Nigeria. The study by Aneni *et al*. (2020) revealed that three insect species were observed in stored shea nuts and the mites and beetles were the major insects causing damage on stored shea nuts in Niger state, Nigeria. There is dearth information of the insect pests of store shea nut and their management practices by farmer in Nigeria. Therefore, insect species associated with stored shea nuts were assessed and the management practices among farmers in nine communities of Ifedapo area in Oyo State were determined.

Materials and Method

Study Area

The field survey was carried out at Ifedapo region of Oyo state while laboratory study was conducted at Biology and Entomology Laboratory of Federal College of Forestry, Ibadan. Ifedapo region is located in the Northern part (savannah belt) of Oyo State, Nigeria. It comprises three Local Government Areas (LGAs) out of the 33 LGAs in Oyo State: Saki West (Saki town), Saki East (Ago-Amodu) and ATISBO (Tede) (Figure 1). It has an estimated land area of 6410km and is located in Oyo North Senatorial District of Oyo State and located between Latitude 8.5^{o} North and Longitude 3.5 ^{o} East (Akanmu, 2013). The area is endowed with favourable climate and vegetation which permit the luxuriant grasses and crop.

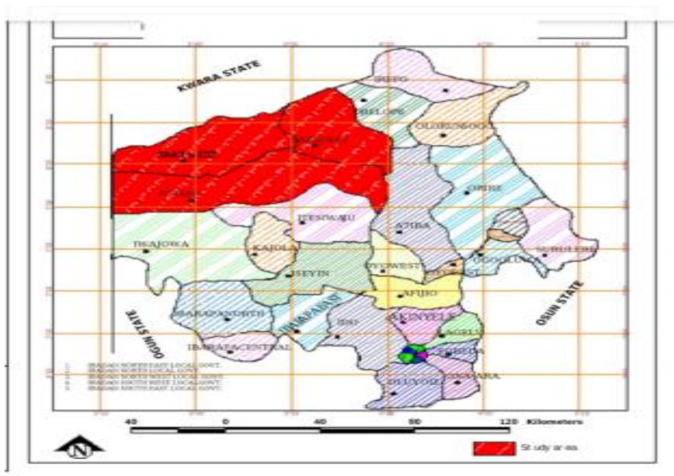

Fig 1: Map of Oyo state showing the study area

Sampling Technique and Data Collection

Three communities known for Shea nut production were purposely selected from each of the three LGAs in Ifedapo, Oyo State; Saki West (Ilua, Ago-oluwabi and Igbo-ologun), Saki East (Ago-amodu, Sepeteri and Oje-owode) and Atisbo (Tede, Irawo-owode and Ago-are). Structured questionnaire was used to collect data from respondents in the nine selected communities. Fifteen respondents were chosen from each community and a total of one hundred and thirty -five (135) questionnaires were administered and retrieved. Shea nuts were collected from the store at each community visited and were brought to the Biology and Entomology laboratory of Federal College of Forestry, Ibadan for insect pest infestations assessment. Laboratory assessment was done by close examination of all the shea nuts for signs of insect exit hole and larvae inside the nuts. Larvae samples collected were reared to adult for proper identification.

Data analysis

Descriptive and inferential statistics were used to analyze the data obtained from field survey while data from laboratory assessment of sampled shea nuts were subjected to analysis of variance and significant means were separated using Turkey's Honestly Significant Difference (HSD).

Results and Dicussion

Socio-demographic characteristics of respondents

The socio-demographic characteristics of respondents in the study area are shown in Table 1. The results revealed that majority (76.3%) of the shea nut processors were female while 23.7% were male. The results of this present study corroborate earlier report by Al-Hassan (2012) that over 90.0% of shea nut processors in Ghana are women, while minor roles are played by men. The most active group of people involved in shea nut processing are within the ages of 46-55 years which represented 31.1% of respondents. This result corresponds with the study by Matanmi *et al.* (2011) who reported that over 80.0% of shea nut processors in Kwara State were above 40 years of age. About thirty-two percent (32.0%) of the respondents were not formally educated while 30.4% had primary education. This is in line with the report by Matanmi *et al.* (2011) who also accounted that most shea nut processors were not well educated. The low level of education of the respondents may contribute in their production output. According to (Tshivunza *et al*., 2001), low level of education could affect the adoption of new practices among farmers such as improved processing methods and use of new technologies. Majority (80.0%) of the respondents in the study areas were married.

The result agrees with Matanmi *et al*. (2011) who reported that most shea nut processors were married. This could imply that shea nut processing could be regarded as a major domestic activity of married women in the study area. The percentage of divorce among the respondents in the study area was very low with only 8.9%. This could imply that shea trees are generally owned by men in the study area of which their wives are engaged in their processing activities with the permission of their husbands. According to Kipot and Franzel (2012), in matrilineal societies, the rights of women to their husbands' land, trees etc cease to exist upon divorce. Since the study area is a matrilineal society, the involvement of married women in shea nut processing indicated that only married women have access to shea trees belonging to their husbands. The results of this study further revealed that higher proportion (48.1%) of the respondents had household size of 4-6 people. This could imply that higher household size facilitates the shea nut processing than small household size. Similarly, Ani *et al*. (2012) reported that majority of the household size of shea nut processors in Benue state was 6 and above. Majority (61.5%) of the respondents were Muslims, follow by Christian with 33.3%, with few traditional worshipper of 5.2%.The study area is known to be dominated by Muslim religion , follow by Christians.

Table 1.The socio- demographic characteristics of the respondents in the study area

Socio-demographic characteristics	Frequency	Percentage
Sex		
Male	32	23.7
Female	103	76.3
Total	135	100
Age		
15-25	6	4.4
26-35	9	6.7
36-45	41	30.4
46-55	42	31.1
56 and above	37	27.4
Total	135	100.0
Education status		
No formal education	43	31.9
Primary education	41	30.4
Secondary education	42	31.1
OND/NCE	5	3.7
HND/University	2	1.5
Others	2	1.5
Total	135	100.0
Marital status		
Single	6	4.4
Married	108	80.0
Divorce	9	6.7
Widow/Widower	12	8.9
Total	135	100.0
Family size		
1- 3	10	7.4
4 -6	65	48.1
7 - 9	48	35.6
10 and above	12	8.9
Total	135	100.0
Religion		
Christianity	45	33.3
Islam	83	655
Traditional religion	7	5.2
Total	135	100.0

Source: Field survey, 2021

Shea butter production experience, patronage and profitability among respondents in the study area

The results of the shea butter processing experience, patronage, profitability and shea nut accessibility among the respondents in the study area is shown in Figure 2. The results revealed that 48.1% of the respondents had been involved shea butter production for 11-15 years, 24.4% had 16 years and above experience, 15.6% had 6-10 years experience, while 11.9% had 1-5 years experience. This result implies that the respondents were quite experienced in shea nuts/butter production in the study area. Majority

(85.2%) of the respondents in the study area indicated that Shea butter production business is highly profitable while 14.8% said it is not lucrative. The finding agrees with the report of Adams *et al*. (2016) that Shea nut processing is an important source of income earning for many women in Wa Municipality Ghana and a major source of income for some people in the region. Sixty (60.0%) of the respondents indicated that shea nuts /butter business are being patronized by foreigners while 40.0% indicated local customers (indigenes)patronize their business. Our findings agree with Akosah-sarping (2003) and Moore (2008) who reported that Shea nuts/butter are export products for the usage in cosmetics industry as a component in lotions, makeup, baby ointments, hair care products and soaps.

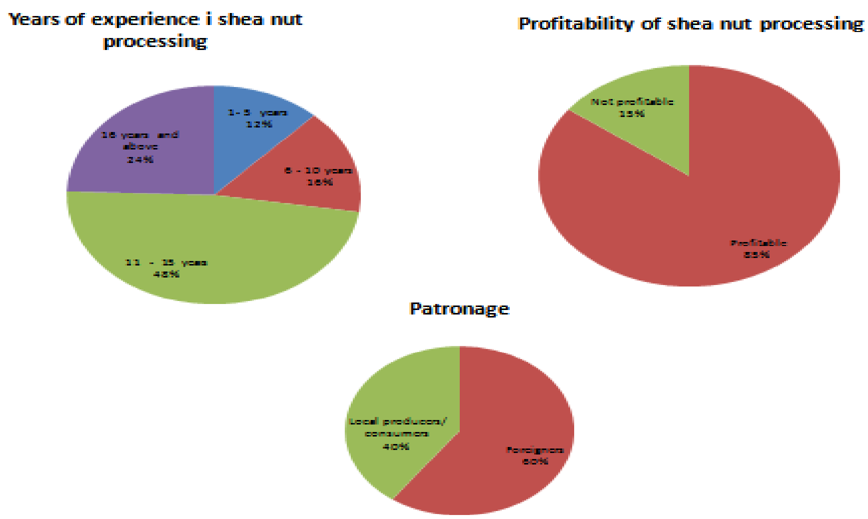

Figure 2. Shea nut processing experience, patronage and profitability in the study area

Estimated income generation from shea nut among farmers in the study area

Majority (62.2%) of the respondents generates monthly income of ₦16,000 - ₦35,000, About 17.8% of the respondents generates income of ₦36,000 - ₦45,000, 11.9% of the respondents generates above ₦46,000 while 8.1% of the respondents generates a monthly income of ₦5000 -₦15000. This implies that shea nuts provides substantial income to members of the community. Only 5.2% of the respondents indicated that insect damage on stored shea nuts affect the price of the nut negatively by reducing the price during sales while 94.8% of the respondents indicated the insect damage on stored shea nuts do not affect the price of the shea nuts during sales (Figure 3).

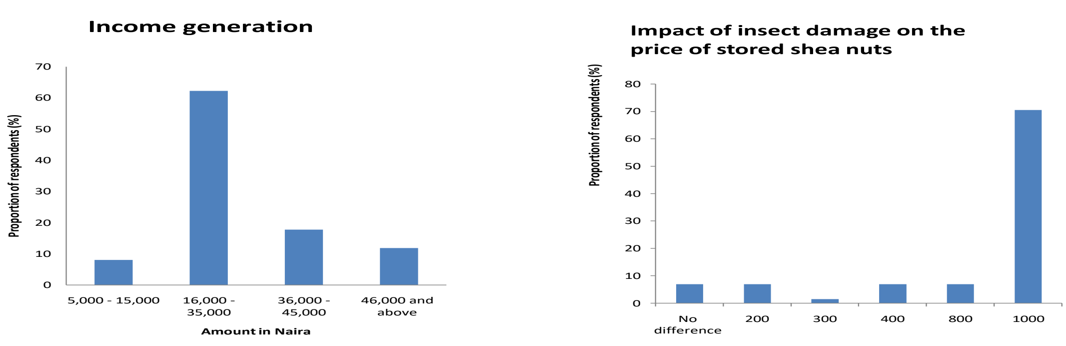

Figure 3 Income generation from Shea nuts and impact of insect damage in Ifedapo region

Shea nuts storage practices among the farmers in the study area

The result of the shea nuts storage practices among the farmers in the study area is presented in Table 2. Majority of the respondents (77.8%) stores their Shea nuts after purchase while 22.2% sells them immediately. The most common storage duration among 35.6 % of the respondents was 9- 12 months, followed by 5-8 months (25.2%). Seventeen percent (17.0%) of the respondents stores shea nuts for about 13-16 months while 3.7% stores their Shea nut for 17 months and above. This result supports earlier report by USAID (2004) that shea nuts can be stored for several years by retaining their moisture content between 6.0% and 7.0%. Most respondents (88.1%) store their Shea nuts until the price increases and the demand is high but 11.9% store until they are able to get buyers for their product. This implies that the major reason for storing the shea nuts is to attract higher prices during the scarcity. A good number of the respondents (47.4%) stores their shea nuts in jute bags, 28.9% stores by exposing them in empty room, 11.1% stores in containers while 12.6% store using other means of storage like keeping then in raised platform in the kitchen. This implies that the most common means of storing shea nuts in the study area is bagging system on jute bags. This result is in line with report by FAO and CFC (2005) that in West Africa Jute bags from Cocoa industry are widely use for storing Shea nuts.

Table 2 Shea nuts storage practices among the farmers in the study area

Variables	Yes		No	
Storage options	**Freq.**	**%**	**Freq.**	**%**
Store	105	77.8	30	22.2
Sell immediately	30	22.2	105	77.8
Duration of storage				
1-4 months	25	18.5	110	81.5
5-8 months	34	25.2	101	74.8
9-12 months	48	35.6	87	64.4
13-16 months	23	17.0	77	83.0
17 months and above	5	3.7	130	96.3
Reason for Storage				
Store till you see customer	16	11.9	119	88.1
Store pending the time the demand is high and the price is increased	119	88.1	16	11.9
Method of storage				
Bags	64	47.4	36	26.6
Containers	15	11.1	120	88.9
Exposed in room	39	28.9	39	71.1
Others	17	12.6	118	87.4

Insect species associated with shea nuts and their management practices in the study area

The insect species reported to be associated with stored shea nuts by the respondents and management practices adopted by farmers in the study areas is presented in Table 3. The results revealed that five insect species namely; carpenter ant, weevil, mites, beetles and cockroaches are commonly observed on stored shea nuts. Majority of the respondents (79.3%) reported that carpenter ants is one of major insect species that are commonly observed on stored shea nuts while 21.7% decline that they do not observe carpenter ant on their stored shea nuts. About Forty -five percent (45.2%) agrees that they usually observe weevils on their stored shea nut while 54.2% did not observe weevil on stored shea nuts. More so, 64.4% of the respondents reported that they observe Beetles on stored shea nuts while 36.6% declined that they do not find weevil. Similarly, 64.4% of the respondents identified that mites attack stored shea nuts while 36.6% of the respondents declined. Above seventy percent (71.9%) of the respondents submitted that they found cockroaches in stored shea nuts but 28.1% declined. The results of this study is in line with recent report of Aneni *et al.*(2020) who reported that Weevils, Mites, Carpenter Ant, and Beetles were observed causing damage to stored shea nuts in Bida, Niger State. In contrast, cockraoches were not reported to be associated with stored shea nut, However, cockroaches are commonly found everywhere especially in dirty environments and warehouses. The study also revealed that hundred percent (100.0%) of the respondents in the study area do not use any form of chemical to protect their stored shea nut from pest damage. However, 85.1% of the respondents submitted that they sundry shea nuts properly before storage while 14.9% do not sundry. Furthermore, 71.9% of the respondents sort their shea nut before storage by separating the good ones from the bad ones as a means of protecting the stored shea nut from pest damage during storage but 28.1% do not sort their shea nuts before storage. Also, 62.2% stores their shea nuts in a cool and dry place but 37.8% do not consider the storing environment. The results of this study is in line with the report by Aneni *etal.* (2020) who reported that proper drying of shea nuts before storage prevent pest attack.

Table 3. Insect species associated with stored shea nuts and their management practices in the study area

Name of the insect pests	Yes		No	
	Freq.	**%**	**Freq.**	**%**
Carpenter ant (Formicidae)	107	79.3	28	21.7
Weevils (Curculionidae)	74	54.2	61	45.2
Beetles	87	64.4	48	36.6
Mites	87	64.4	48	36.6
Cockroach	97	71.9	38	28.1
Pest Management practices				
Application of chemical pesticide to protect the shea nut from pest attack	0	0.0	135	100.0
Storing the infested shea nut separately	97	71.9	38	28.1
Keeping of shea nut in cool and dry place	84	62.2	51	37.8
Sun drying the shea nut properly s before storage	115	85.1	20	14.9

Source: Field survey, 2021

Observed insect damage on shea nuts by laboratory assessments

The results of the laboratory assessments on the sampled shea nuts revealed that insect pest attack stored shea nuts (Figure3). All the samples collected from different study sites showed signs of pest infestation at varied rates. Samples from Ago-are recorded highest (58.6%) insect pest infestation signs on shea nuts, followed by Oje-owode with 47.6%, while the lowest was Irawo-owode (13.7%.) There was significant variation on the percentage infestation of shea nuts collected from different location,

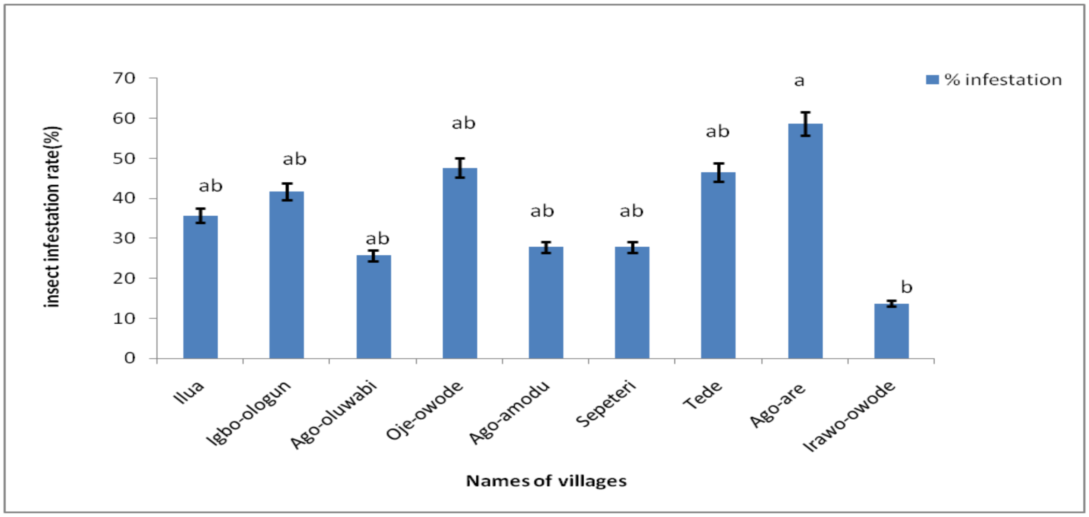

Figure. 4 Observed insect damage on shea nuts collected from the study area

Correlation between pest damage on stored shea nuts and income generation of farmers

Pearson correlation analysis revealed a negative relationship between the impact of pest damage and the cost of shea nuts (Table 7). The results revealed that there is negative relationship between impacts of insect pest attack on income generation of farmers on stored shea nuts with r value of -0.064 and P value of 0.461. As the incidence of insect pest infestation increases, the income generation decreases as it negatively affect the prices of the infected shea nuts. This result implies that there is need for the farmer in the study area to employ pest control measures to protect stored shea nuts from pest damage.

Table 4 Relationship between insect damage on shea nut and income generation of farmers

Variable	p	R
Income generation Vs Infestation of insect pest damage	0.461	-.064

Source: Field survey, 2021

Conclusion

The study revealed five insect species associated with stored shea nuts in the study area. The laboratory assessment showed that insect pests are major problems affecting stored shea nuts in the study area. However, the respondents did not relate insect pest damage as a major problem affecting their shea nuts in storage. The pest control measure for insect damage and shea nut storage facilities is very poor in the study. The study revealed that shea nuts are mostly stored in bags and they do not apply any pest control measures to protect their stored shea nuts from pest attack. There is negative relationship between the impact of insect pests damage and income generation of shea nuts farmers.

Recommendations

- Farmers should be trained on how to apply control measures to mitigate the problem of insect pests associated with stored shea nuts.
- Farmers should be trained on strategies for preserving their shea nuts in storage to minimize pest infestation.
- Adequate storage facilities should be provided by Government or NGOs to the shea nuts farmers in other to maximize their income generation.
- Further studies are required to assess the impact of insect pests on the quality of shea butter produced in the area.

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PRODUCTION AND FORMULATION OF SOLID CHARCOAL LIGHTER FROM LIGNOCELLULOSIC MATERIALS

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Abstract

This study was undertaken to determine the bioenergy properties of some selected lignocellulosic materials with the aim of producing a low risk and sustainable solid charcoal lighter. Citrus sinensis peels (A), Pinus caribaea needles (B), Thaumatococcus daniellii leaves (C), Hildegardia barteri leaves (D), Monodora myristica seeds (E) and Khaya grandifoliola wood sawdust were used. Materials were air-dried and stored after milling to pass through a 4mm standard sieve. Materials were combined (AB, ABC, ABCD, ABCDE) in equal proportion and compounded with Wood Sawdust (WS) at different ratios (10% and 15%). Data were taken on bulk density, calorific value (CV), lignin content, proximate analysis [%Ash, %Fixed Carbon (FC), %Volatile Matter (VM)] and combustion properties (Combustion rate and ignition time) of the tinder samples as well as the compounded lighters using standard test procedures. Data obtained were analysed using descriptive statistics and ANOVA at $\alpha_{0.05}$. Average bulk density of the lighter was 10.45 ± 0.55g/m^3. Significant differences were observed in the CV of the selected tinders with highest and lowest value being 22405.7±6.28kJ/kg and 1815.36±6.28kJ/kg obtained for M. myristica seeds and peels of C. sinensis, respectively. The highest and lowest CV was 30299.42±6.28kJ/kg and 25634±10.65kJ/kg obtained for AB10%WS and ABCD10%WS, respectively. The needles of P. caribaea had the highest lignin content of 44.16±0.13% and T. daniellii leaves the lowest (12.32±0.17%). The AB10%WS was found to be the best formulation and compounding ratio as it exhibits the least ignition time (13.33±0.33s) and highest combustion rate ($8x10^{-3}gmin^{-1}$) with low ash (4.085±0.85%).

Keywords: *Bioenergy, Calorific value, Charcoal lighter, Pinus caribaea, Proximate analysis, Thaumatococcus daniellii.*

Introduction

In the present day world, massive quantities of energy are being consumed, with much of that energy embodied by GHG-emitting fossil fuels (Bernstein *et al*., 2007). As projected by FAO (2003), the global consumption of fossil fuels will continue to be on the rise through 2040 with the exclusion of coal which is believed to level off around 2020. Energy is very essential in meeting the basic needs of human such as heating, lighting and cooking; it plays a pivotal role in cooking and processing of food materials for consumption which promotes healthy living (Eva, 2006).

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In the developing nations of the world, charcoal combustion constitutes a significant energy and lignocellulosic biomass has proven its potential to be an increasingly cost-competitive renewable source of energy which could make a valuable contribution to the global energy supply system mainly because of its renewability and very low cost (James and Behdad, 2007). As broadly reported, biomass constitutes an important material in the current world energy scenario and has been recognized as a major renewable energy which could serve as an alternative to the declining conventional sources of energy (McKendry, 2002; Lemm *et al.,* 2014). Biomass also presents some environmental benefits, which include neutral gaseous CO_2 emissions as well as low NO_2 and SO_2 emissions (Gil *et al.,* 2010). In light of this, biomass materials have shown considerable properties for use as combustion materials and bioenergy application. For example, the leaves of *Thaumatococcus daniellii* are moderately low in ash (8.95g/100g) compared to other parts of the plant (fruit and seed) having 21.08g/100g and 11.30g/100g respectively and this makes it suitable for combustion (Shalom *et al*., 2014). The phytochemical screening of the leaf confirms the presence of tannins, terpenoids, flavonoids, alkaloids and cardiac glycosides all making an essential compound which support biomass combustion. In the same vein, several authors recently studied gasification and pyrolysis of wastes of citrus peel as well as other fruit seeds in order to evaluate their potential for use as bio-fuel in thermal and electrical energy production (Tamelova *et al*., 2018).

Outdoor uses of energy such as charcoal combustion has long been a popular activity and to facilitate its starting and combustion for outdoor cooking or barbecue fires, several ignition lighter compositions have been developed. Charcoal lighter exists in different forms from solid to liquid. Liquid lighters are basically made up of flammable hydrocarbon mixtures such asterpene, surfactant, water, alcohol and a thickening agent. All these materials are aggregated to produce a lighter fluid which has so many deficiencies such as unclean burning, introduction of hydrocarbon odour onto grilled food and emission of Volatile Organic Compounds (VOC). According to Emmanouil and Panagiotis (2015), VOC emission contributes immensely to low air quality; approximately 14,500 Metric tonnes VOC/year are emitted from the combined combustion of charcoal lighter fluid. The combined combustion of charcoal lighter fluid and a bed of coal contribute to household air pollution which has often recorded a huge number of deaths per year (Mitchual *et al.,* 2014). Reports showed that indoor air pollution accounts for more than 1.5million deaths/year which is mostly of young children and their mothers with about 400-610 Indoor Air Pollution (IAP) deaths/million recorded in 2000 (Mitchual *et al.,* 2014). With risks associated with the combustion and ignition of charcoal through the use of liquid charcoal lighters as well as the high production cost, it is therefore necessary to shift focus from the use of heavy and non-biodegradable compounds in the production of these lighters and turn to the use of materials of biological origin which will present a level of resource sustainability and development with low risks of combustion.

The overall objective of this study was to formulate, compound and produce a solid charcoal lighter from lignocellulosic tinders. Based on this objective, the effect of formulation and compounding on the bioenergy properties of the solid charcoal lighter were hypothetically assessed in a bid to select the best tinder combination which expresses low ignition time, high intensity and rate of combustion with low ash content. This was achieved through the following specific objectives:

i. determination of calorific value of the selected lignocellulosic tinders
ii. determination of lignin content of the selected lignocellulosic tinders
iii. formulation, compounding and production of a solid charcoal lighter
iv. determination of calorific value and ignition rate of the formulated and compounded lighter
v. proximate analysis (percentage volatile matter, ash content and fixed carbon) of the formulated and compounded lighter

Materials and Methods

Citrus sinensis (Sweet Orange) fruits and *Monodora myristica* seeds were sourced from Bodija market in Ibadan. Needles of *Pinus caribaea*, wood sawdust of *Khaya grandifoliola* and *Hildegardia barteri* leaves were collected within the Faculty of Renewable Natural Resources, University of Ibadan premises. *Thaumatococcus daniellii* leaves were obtained from the Forestry Research Institute of Nigeria (FRIN), Jericho Hill, Ibadan. These samples were air-dried to constant weight, milled with an electric millings machine and stored in separate polythene bags (Plate 1) in accordance with procedures of Onuegbu *et al.,* (2011). Major materials for production were combined at ratio 1:1 and compounded with sawdust from *K. grandifoliola* at 10% and 15% by mass of the material combination as shown in Table 1. For example, AB10%WS is a combination of 500 g each of *C. sinensis* and *P. caribaea* compounded with 100 g of Wood Sawdust (WS) from *K. grandifoliola*.

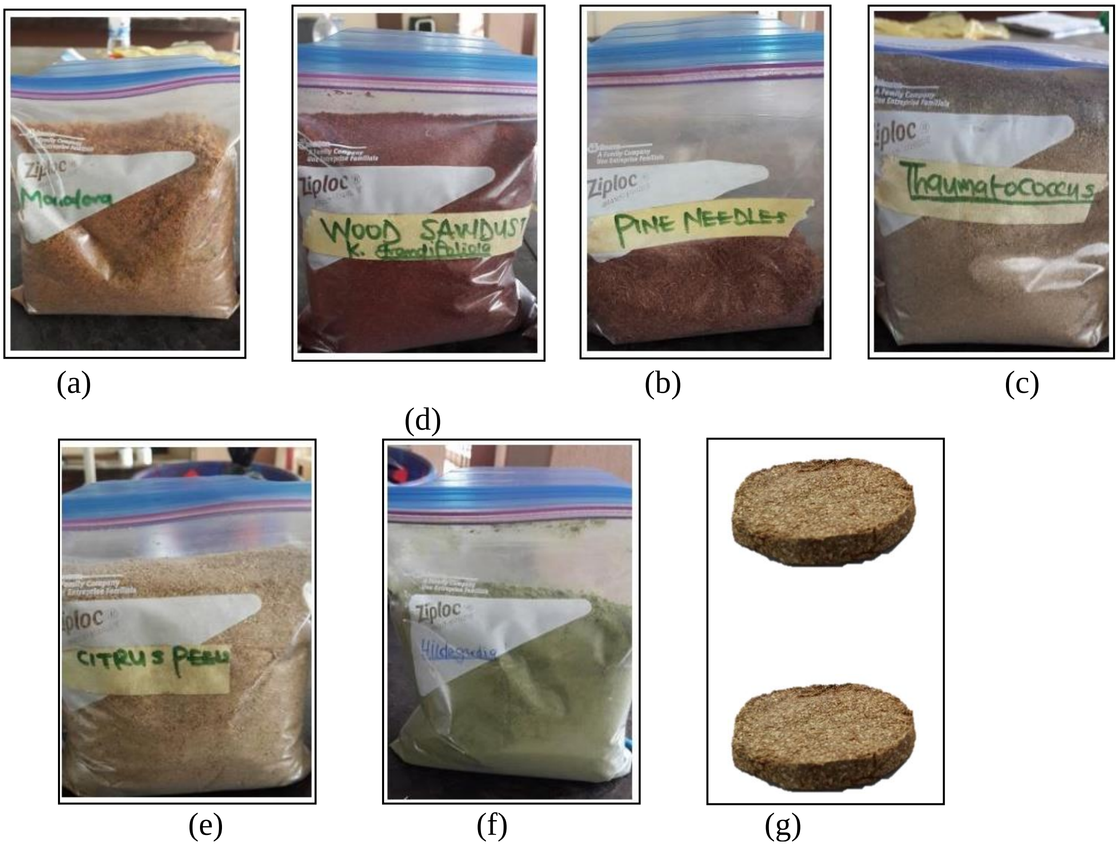

Plate 1: Pulverised tinder samples used for the lighter production

a: *Monodora myristica* seeds, b: *Khaya grandifoliola* sawdust, c: *Pinus caribaea* needles, d: *Thaumatococcus daniellii* leaves, e: *Citrus sinensis* peels, f: *Hildegardia barteri* leaves, g: solid charcoal lighter produced

Table 1: Material combination and compounding ratio

Materials	**Material Combination (1 kg)**	**Compounding with Wood Sawdust (WS)**	
		10%* (100 g)	**15%** (150 g)**
Citrus sinensis peels (A)			
Pinus caribaea needles (B)	AB	AB+10%WS	AB + 15%WS
Thaumatococcus daniellii leaves (C)	ABC	ABC + 10%WS	ABC + 15%WS
Hildegardia barteri leaves (D)	ABCD	ABCD + 10%WS	ABCD + 15%WS
Monodora myristica seeds (E)	ABCDE	ABCDE + 10%WS	ABCDE + 15%WS

* = 10% by mass of the material combination; ** = 15% by mass of the material combination

Each of the treatment combinations were replicated three (3) times. The mixture of the substrate and the wood flour were then bonded together using a synthetic resin adhesive. The ratio of the overall substrate to that of the binder by mass was 6:1 respectively. The only two varied factors are material combinations and compounding ratio with wood sawdust (10% and 15%).

After biomass collection, data on the weight (wet weight was determined using a digital weighing scale), density (bulk density), moisture content, calorific value and lignin content of each material were obtained by following standard procedures before drying them out to a moisture content of 12% using the oven-drying method.

Calorific Value

The gross calorific value of each lignocellulosic materials used was obtained using the Gallenkamp Ballistic bomb Calorimeter following the ASTM E711-87 standard as reported by Klasnja *et al.*, (2002).

A measure of 0.25g of each biomass sample (depending on bulkiness) was weighed into the steel capsule. A 10cm thread of cotton was attached to the thermocouple touching the capsule. The bomb was closed followed by oxygen charge at 30atm. Thereafter, the bomb was ignited burning the sample in an excess oxygen condition. The thermocouple and galvanometer system was used to measure the maximum temperature in the bomb. The temperature rise was compared with that obtained for 0.25g of Benzoic value of each sample which was then determined by calculation.

Lignin Content

Lignin content of each lignocellulosic material was determined using Klason method, where the carbohydrates in the biomass materials were hydrolyzed and solubilized with 72% sulfuric acid. The acid-insoluble lignin was filtered off, dried, and weighed (Daniel *et al*., 2014).

Ignition Time

This is basically the time taken for the lighter to catch fire after ignition. For the material combination and compounding ratio, each lighter sample was ignited at the base in a drought free area (Harada, 2001). The time required for the flare from an ignition source (match) to ignite the lighter was then recorded as the ignition time with the aid of a stop watch.

Rate of Combustion

The rate of combustion was assessed with full combustion in a furnace. Approximately 2g of the solid charcoal lighter produced was combusted in a furnace at 600^{o}C for 4hrs to attain full combustion. The weight of ash after combustion was subtracted from the initial weight of the lighter to determine the fuel loss (Jenkins *et al*., 1998)

Percentage Content of Ash

The percentage content of ash of both the lighter and various lignocellulosic materials used was determined. A measure of 2g of each weighed sample was put in a porcelain crucible and placed in the furnace to burn at 600^{o}C for 4 hrs to attain full combustion (ASTM D 1102-84). After full combustion, the samples were allowed to cool in a desiccator. A crucible containing the sample was weighed and subtracted from the initial weight of the crucible to obtain the weight of the ash.

The content of ash was determined using the formula below:

$$Ash\ Content = \frac{Weight\ of\ ash\ after\ full\ combustion}{Weight\ of\ lighter\ sample\ before\ combustion}\ x\ 100 \text{ ------------ (i)}$$

Percentage Volatile Matter and Percentage Fixed Carbon

The content of volatiles of each compounded lighter was determined following the ASTM D3175-11 procedure as reported by Mohan *et al.*, (2006). Approximately 2g of each compounded lighter as well as the various lignocellulosic materials were placed in porcelain crucible, kept in a furnace at 550^{o}C for 10 mins, weighed after allowing to cool in a desiccator.

$$\%VM = \frac{A-B}{A}\ x\ 100 -(ii)$$

A = weight of oven-dried sample

B = weight of sample after 10 mins in the furnace at 550^{o}C

$$\%FC = 100 - (\%Ash + \%VM) \text{ -- (iii)}$$

Data Analysis

Data obtained were analysed descriptively, means were separated using Analysis of Variance (ANOVA) while further analysis using Duncan Multiple Range Test (DMRT) was used to measure specific differences between the pair of means. Following a 4x2 factorial design, Full Factorial Analysis was used to study the effect of material combination, compounding ratio and their possible interaction on the various properties examined.

Results

Energy Value of the Selected Tinders

Table 2 shows the energy or heat value of the selected tinders, *M. myristica* seeds had the highest calorific value (22405.78kJ/kg) which was significantly different from other selected tinders. *C. sinensis* peels had the lowest calorific value (18155.36kJ/kg). The energy values of *K. grandifoliola* wood sawdust and *P. caribaea* needles (20797.94 kJ/kg and 20772.61 kJ/kg respectively) are not significantly different.

Table 2: Energy Characteristics of the Selected Tinders

Tinder Type	Calorific Value (kJ/kg)			
	Minimum	Maximum	Mean	C.V (%)*
Citrus sinensis (Peels)	18149.08	18161.64	18155.36 ±6.28[a]	0.05
Hildegardia barteri (Leaves)	18932.16	18944.72	18938.44±6.28[b]	0.05
Khaya grandifoliola (Wood Sawdust)	20791.46	20804.02	20797.74±6.28[c]	0.04

Monodora myristica (Seed)	22399.50	22412.06	22405.78±6.28[d]	0.04
Pinus caribaea (Needles)	20762.14	20783.08	20772.61±10.47[c]	0.07
Thaumatococcus daniellii (Leaves)	18438.02	18454.77	189446.40±8.38[e]	0.06

Mean values with the same alphabet are not significantly different using Duncan's Multiple Range Test at p<0.05
*C.V = Coefficient of Variation

Proximate analysis of selected tinder

Among all the selected tinder, the peels of *Citrus sinensis* had the highest percentage of volatile matter (71.25) though not significantly different from the volatile matter of *H. barteri* leaves (70.05) Table 3. Also the equivalent percentage fixed carbon and percentage ash content were 21.51 and 7.25 respectively. For all the selected tinders, percentage fixed carbon were not significantly different with p>0.05 except for leaves of *H. barteri* (15.25) and needles of *P. caribaea* (28.75). The peels of *C. sinensis* had the least content of ash which was significantly different from other selected tinders while *H. barteri*(14.25) had the highest content of ash which was not significantly different from that of *T. daniellii* (13.50). The needles of *P. caribaea* had the highest percentage lignin content (44.16 %) while *T. daniellii* leaves had the lowest percentage lignin content (12.32 %). There was no significant difference in the lignin content of C. sinensis peels and *H. barteri* leaves while other tinder samples (*K. grandifoliola*, *M. myristica*, *P. caribaea* and *T. daniellii*) were significantly different (p<0.05)

Table 3: Proximate Analysis of Selected Tinder Samples

Tinder Type	Proximate Analysis				
	Moisture Content (%)	Volatile Matter (%)	Fixed Carbon (%)	Ash Content (%)	Lignin Content (%)
Citrus sinensis (Peels)	11.00	71.25±0.75[a]	21.51±1.00[a]	7.25±0.25[a]	18.20±0.05[a]
Hildegardia barteri (Leaves)	12.10	70.05±0.5[a]	15.25±0.75[b]	14.25±0.25[c]	18.40±0.02[a]
Khaya grandifoliola (Wood Sawdust)	12.60	66.13±0.23[b]	23.63±0.48[a]	10.25±0.25[b]	16.20±0.02[b]
Monodora myristica (Seed)	12.40	67.75±0.75[b]	23.25±0.25[a]	9.00±0.25[b]	39.72±0.14[c]
Pinus caribaea (Needles)	12.04	61.00±0.5[c]	28.75±0.75[c]	10.25±0.25[b]	44.16±0.13[d]
Thaumatococcus daniellii (Leaves)	12.34	62.75±0.25[c]	23.75±0.75[a]	13.50±1.00[c]	12.32±0.17[e]

Mean values with the same alphabet (along the column) are not significantly different using Duncan's Multiple Range Test at p<0.05

Energy Value of the Compounded Lighter

Table 4 shows the energy value of the compounded lighter, AB10%WS (a combination of *C. sinensis* peels and *P. caribaea* needles) had the highest energy value (30299.42kJ/kg) while ABCD10%WS had the lowest energy value (25634.42kJ/kg). Energy values of all the material combinations are statistically different.

Table 4: Energy Value of the Compounded Lighter

Material Combination	Calorific Value (kJ/kg)		
	Minimum	Maximum	Mean ± S.E*
AB10%WS	30293.13	30305.70	30299.42±6.28[a]
ABC10%WS	26310.72	26323.28	26317.00±6.28[b]
ABCD10%WS	25623.95	25644.89	25634.42±10.65[c]
ABCDE10%WS	26779.73	26792.29	26786.01±6.28[d]
AB15%WS	29807.37	29819.93	29813.65±6.28[e]
ABC15%WS	29752.93	29765.49	29759.21±6.25[f]
ABCD15%WS	26712.73	26725.29	26719.01±6.28[g]
ABCDE15%WS	25665.83	25678.39	25672.11±6.28[h]

*S.E = Standard Error
Mean values with the same alphabet are not significantly different using Duncan's Multiple Range Test at p<0.05

Proximate analysis of the compounded lighter materials

From Table 5, percentage volatile matter reduces as the material combination increases though values were not significantly different. Unlike the percentage volatile matter, percentage ash content of all the material combinations are significantly different. Table 6shows the effect of material combination and compounding ratio on the proximate analysis of the compounded lighter. The material combination, compounding ratio and the interaction between them all had a significant effect on the percentage fixed carbon and percentage ash with p<0.05. Conversely, there was no significant effect of compounding on volatile matter of the compounded lighter with p=0.378.

Table 5: Proximate Analysis of the Compounded Lighter

Proximate Analysis	%Volatile Matter	% Fixed Carbon	% Ash
Material Combination	Mean*	Mean	Mean
AB10%WS	69.00±0.50[a]	26.92±0.59[a]	4.09±0.09[a]
ABC10%WS	64.50±0.50[d]	31.06±0.56[b,c]	4.45±0.06[b]
ABCD10%WS	64.68±0.33[d]	29.84±0.34[b]	5.49±0.02[c]
ABCDE10%WS	63.43±0.08[c,d]	31.52±0.02[c]	5.06±0.06[d]
AB15%WS	68.90±0.40[a]	17.60±0.40[d]	13.50±0.00[e]

ABC15%WS	67.45±0.04[a]	24.07±0.07[e]	8.49±0.02[f]
ABCD15%WS	63.68±0.68[c,d]	28.27±0.73[a]	8.06±0.06[g]
ABCDE15%WS	62.70±0.20[c]	27.79±0.22[a]	9.52±0.02[h]

*Mean ± Standard Error
Mean values with the same alphabet along the columns are not significantly different using Duncan's Multiple Range Test at $p<0.05$

Table 6: Analysis of Variance (ANOVA) showing effect of compounding and material combination on proximate properties of the compounded lighter

		Sum of Squares	Df	Mean Square	F	Sig.
Fixed Carbon (%)	Material Combination	135.979	3	45.326	120.102	0.000*
	Compounding	116.748	1	116.748	309.348	0.000*
	Interaction	35.296	3	11.765	31.175	0.000*
	Error	3.019	8	0.377		
	Total	291.043	15			
Volatile Matter (%)	Material Combination	78.535	3	26.178	82.859	0.000*
	Compounding	0.276	1	0.276	0.872	0.378[ns]
	Interaction	10.077	3	3.359	10.632	0.004*
	Error	2.527	8	0.316		
	Total	91.415	15			
Ash Content (%)	Material Combination	12.809	3	4.270	1.020E3	0.000*
	Compounding	105.062	1	105.062	2.509E4	0.000*
	Interaction	26.532	3	8.844	2.112E3	0.000*
	Error	0.033	8	0.004		
	Total	144.436	15			

* = significant; ns = not significant

Effect of compounding and material combination on the combustion properties of the solid charcoal lighter

Table 7 shows the combustion properties of the compounded lighter. AB10%WS had the least ignition time (13.33 s) with the highest rate of combustion ($8x10^{-3}gmin^{-1}$) while ABC10%WS combusts with high ignition time (35.33s). AB15%WS had the least rate of combustion ($7.2x10^{-3}gmin^{-1}$). From the factorial ANOVA (Table 8), material combination, compounding ratio and the interaction between them had a significant effect on the ignition and burning time (s) of the compounded lighter ($p<0.05$). Conversely, the material combination ($p=0.412$) and factors interaction ($p=0.442$) does not have a significant effect on the combustion rate ($gmin^{-1}$) of the compounded lighter.

Table 7: Combustion properties of the compounded lighter

Material Combination	Density (g/m^3)	Ignition Time (s)	Burning Time (s)	Combustion Rate ($gmin^{-1}$)
AB10%WS	39.56±4.21	13.33±0.33	117.33±2.91	$8.00x10^{-3}$
ABC10%WS	20.52±1.98	35.33±1.20	157.00±3.46	$7.96x10^{-3}$
ABCD10%WS	22.25±0.77	28.00±2.31	127.00±2.65	$7.88x10^{-3}$
ABCDE10%WS	19.02±0.51	21.33±0.88	85.67±2.03	$7.92x10^{-3}$
AB15%WS	20.20±0.48	30.33±2.33	129.33±2.40	$7.20x10^{-3}$
ABC15%WS	18.76±0.80	21.00±0.58	74.33±1.00	$7.63x10^{-3}$
ABCD15%WS	19.66±0.54	25.00±2.58	197.50±3.50	$7.67x10^{-3}$
ABCDE15%WS	22.32±1.33	27.67±6.28	70.67±4.26	$7.54x10^{-3}$

Table 8: Analysis of Variance (ANOVA) showing effect of compounding and material combination on combustion properties of the solid charcoal lighter

		Sum of Squares	Df	Mean Square	F	Sig.
Ignition Time (s)	Material Combination	62.188	3	20.729	4.198	0.046*
	Compounding	27.562	1	27.562	5.582	0.046*
	Interaction	672.688	3	224.229	45.414	0.000*
	Error	39.500	8	4.938		
	Total	801.937	15			
Burning Time (s)	Material Combination	123116.750	3	41038.917	887.328	0.000*
	Compounding	17556.250	1	17556.250	379.595	0.000*
	Interaction	113878.750	3	37959.583	820.748	0.000*
	Error	370.000	8	46.250		
	Total	254921.750	15			
	Material Combination	0.048	3	0.016	1.076	0.412[ns]

		Sum of Squares	Df	Mean Square	F	Sig.
Combustion Rate ($gmin^{-1}$)	Compounding	0.628	1	0.628	42.098	0.000*
	Interaction	0.045	3	0.015	0.998	0.442^{ns}
	Error	0.119	8	0.015		
	Total	0.840	15			

* = significant; ns = not significant

Discussion

The high energy content found in *Monodora myristica* could be attributed to inherent volatile essential oils in the seed which is believed to have high energy values. Owokotomo and Ekundayo (2012) noted that the essential oil of *M. myristica* seeds had tricyol (13.35%), germacrene (25.48%), cadinene (11.09%) and linalool (17.98%). The selected tinder samples had calorific values higher than some other biomass materials such as groundnut shell (13785-17428kJ/kg) and black walnut hull (17719-21193kJ/kg) as reported by Jekayinfa and Omisakin, (2005). In accordance to the Austrian standard for fuel pellets and briquettes, all the tinder samples selected are considered adequate since they had gross calorific values between 18000-22400 kJ/kg mostly within the range of the prescribed minimum value (18000 kJ/kg), (Austria ONORM M7135) and 17500-19500 kJ/kg reported by Germany DIN51731/DINplus standard (Stephen *et al*., 2014).

Khaya grandifoliola (sawdust) had average lignin content out of the range reported by Maha (2015) for hardwood stems (18% -25%); this could be attributed to the difference in ecological region. The inherent volatile essential oils of *M. myristica* may also have accounted for its high lignin content and which resulted in its high energy value. According to Demirbas (2010), Higher Heating Value (HHV) is highly positively correlated with percentage content of lignin which means that the higher the lignin content, the higher the energy value. From a general overview of nut shells, the lignin content of *M. myristica* seeds falls within the range reported by Maha (2015) for nut shells. By comparison, the leaves of *T. daniellii* had a lignin content slightly lower than that obtained for the stalk of the same species (13.04%) as reported by Oluwadare and Sotande (2014) and also lower than other Non-Wood Fibres (NWFs) such as kenaf and hemp (Dutt *et al*., 2009). In a report by Shalom *et al.,* (2014), the phytochemical screening of *T. daniellii* leaf confirms the presence of tannins, terpenoids, alkaloids, flavonoids and cardiac glycosides all making an essential compound which supports biomass combustion.

C. sinensis among other materials studied had the highest content of volatiles and this may imply that it loses most of its gases and essential oils during combustion which could practicably leave a good scent on foods cooked on the grill. Results of proximate analysis obtained for the selected tinders are in consonance with the report of Emmanouil and Panagiotis (2015) that most biomass had a higher volatile content than coal, while herbaceous biomass also tend to have volatile content slightly higher than that of woody biomass or certain agro-industrial residues. By comparison, percentage ash content, fixed carbon and volatile matter of other lignocellulosic materials such as rice straw, wheat straw and rice hull are reported by Jenkins *et al.,* (1998). By practical implication, solid fuels with high volatile-matter content will have a good ignition property and will be highly reactive in combustion applications though it could cause some problems to internal combustion engines (Li *et al.,* 2009). Fixed carbon which is the combustible residue remaining after heating a particle and the volatile matter is discharged**.** With the exception of *Hildegardia barteri* leaves, all the materials studied had a percentage fixed carbon higher than most biomass fuels reported by Miles *et al.,* (1995). This could imply that the tinder samples are appropriate for combustion applications. As compared to the energy values of the tinders, the compounded lighter had a higher energy value. This increase could be attributed to compounding and/or densification which is believed to enhance volumetric energy value of biomass materials and produce a consistent, stable and clean fuel, or an feedstock for further processes of refining (Shaw, 2008). All the material combination and compounding ratio could be considered adequate because their respective calorific value was higher than the recommended minimum standard for fuel pellets by Austria ÖNORM M7135.

The compounded lighter had a volatile matter and fixed carbon higher than some other fuels such as rice straw, wheat straw and rice hull. The observed difference could be as a result of material combination which had a significant effect on proximate properties of the lighter. Conversely, ash content of the compounded lighter is lower than some other fuels reported by Jenkins *et al.,* (1998). The proximate analysis result implies that the charcoal lighter could ignite easily, combust freely and burn with low ash.

From results obtained, it could be inferred that any of the material combinations and compounding ratio can be selected as it does not have a significant effect on the combustion rate of the solid charcoal lighter even though the compounding ratio had a singular effect on the combustion rate. According to Haugen *et al.,* (2016), combustion properties and gasification of biomass is chiefly influenced by important factors such as heating value, moisture, ash residue and content of volatiles. AB10%WS had the highest content of volatiles which was statistically different from other material combinations this could be a probable reason why it exhibits good combustion properties (low ignition time, high rate of combustion and low ash residue). Conversely, among other material combination, ABCDE15%WS had the least content of volatiles, a high ignition time, lowest burning time, low combustion rate and highest content of ash; this in a way seem less appropriate for the desired end use.

With a view to selecting the best material combination and compounding ratio of the solid charcoal, the major fuel properties (low ignition time, high combustion rate and low percentage ash content) of the lighter were considered. The formulation and compounding of the solid charcoal lighter was assessed to select the best tinder combination which expresses good ignition (as low as possible), high intensity and rate of combustion with low ash content.

Conclusions

As a result of compounding, there was an increase in the heating value of the lighter which reveals the effect of compounding on the energy value of lignocellulosic biomass. From the results revealing the various properties of the formulated and compounded lighter, it could be concluded that the solid charcoal lighter produced from lignocellulosic tinders could be a better substitute to existing liquid charcoal lighter because it could burn and combust freely with less ignition hazard and less volatile emission. The formulation and compounding ratio, AB10%WS was found to be the most preferred formulation and compounding ratio as it exhibits the least ignition time, better combustion rate and low ash. AB10%WS was the combination of *Citrus sinensis* peels with the needles of *Pinus caribaea* and compounded with 10% (by mass) of wood sawdust from *Khaya grandifoliola*.

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VALUE CHAIN OF RATTAN SPECIES FOR ECONOMIC DIVERSIFICATION IN NIGERIA: A REVIEW

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ABSTRACT
Rattan based cottage industry is one of the enterprising solution to socioeconomic hardship and poverty alleviation strategies in Nigeria. However, rattan based industry has not been fully developed for economy diversification. This paper reviewed value chain potential of rattan species for economic diversification in Nigeria. The paper reviewed rattan as an important non timber forest product for rural livelihood improvement. The uses of rattan as contained in this article include art and handicraft; building construction and production of agricultural articles. The paper emphasized the role of rattan cottage enterprise in economic diversification. Based on the review, rattan industry if properly managed can contribute significantly to Nigeria foreign exchange earnings. It has potential to create employment opportunity in terms of rattan harvesting, transportation and processing. It was revealed that Rattan business activities can take the following forms raw rattan supply; small scale manufacturing; integrated rattan supplies and cane manufactured products. The constraints to rattan entrepreneurship development in Nigeria include shortage of rattan cane processing products; use of manually operated tools for rattan activities among the major actors, the collectors and processors; limited market; limited knowledge on the need for prospects of commercial cultivation of rattan; unfavorable policies among others. For the development of rattan subsector, the study recommends the establishment of rattan plantation; development of rattan-based micro enterprise: establishment of rattan rural resource centre and continuous research to ensure sustainability of rattan resources.

***Keywords**: Value chain; rattan; economic diversification; Nigeria*

INTRODUCTION

Nigeria economy has been described as mono economy and over dependency on petroleum resources (Adepoju *et al.,* 2017). Bulk of Nigeria revenue is derived from oil export. The implication of this is that the economic fortune is tied to the boom and bust cycles of the oil market. However, the hope for the economy that is sustainable depends greatly affected and waned way below the expectation with larger percentage of labour force jobless and consistent increase in the unemployment rate. The current rate of unemployed people in Nigeria is alarming putting the global rate at 12.6%, South Africa's rate is currently 25.2%, in the case of Ghana it is about 14% while Nigeria unemployment estimate is around 37% (ILO, 2012). With economic hardship in Nigeria, the question of country economic pathway remains pertinent and subject of discussion.

Diversification of economic remains a viable option to alleviate the present economic hardship. In order to achieve the vision of becoming one of the largest economies in the world, efforts should be directed towards economic activities in which the country has comparative advantage and shift the country from present oil and gas reliance. Among the options for diversifying economy include agriculture, forestry, information and communication technology, tourism and mining among others. It is a matter of necessity to consider country-specific needs and circumstances before choosing an option for economic diversification. It is better to diversify the productive base of the economy with a specific target to reduce dependency on oil sector as well as sustaining the environment. Over dependent on a single commodity, in the case of Nigeria, has made the economy vulnerable to both internal and external shocks (Adepoju *et al*., 2017).

Forestry is an important sub sector of the economy that can be harnessed to improve Nigeria economy (Idumah *et al.,* 2016). Forest provides many economic and social benefits. Forestry contributes about 2.5 per cent to the Nation's GDP. There are numerous forest products and services not necessarily accounted for in the country's GDP but are very important in the daily lives of the majority of Nigerians. The utilization and production of forestry wood and non wood products, energy, shelter and health needs, as well as generating income. Forest contains a great number of resources that can change economic future of any nation. Nigeria is blessed with abundant of forest resources. Sustainable production and production transformation of these resources are capable of transforming the present economic status through improvement in foreign exchange.

Non-Timber Forest Products (NTFPs) formed the larger part of rural economy. It is an important integral part of livelihood activities for a great number of living around the forested areas (Asfaw *et al.,* 2013). As one of the important non timber forest products (NTFPs), after timber, rattan forms an integral part of rural and tribal populace of many tropical countries (Renuka, 2000). Non timber forest products are not only the primary source of resources for industries in many part of the world, but they contribute significantly to the source of livelihood for the communities around the forest (Renuka, 2000). Rattan is widely recognized as an important domestic and internationally-trade commodity. The According to an estimate by the International Network for Bamboo and Rattan (INBAR), the global and local usage of rattan is worth US $2.5 billion and according to Wulf and Ian (2000) the annual foreign trade of rattan was estimated to generate US $4 billion annually. Also, seven hundred million people worldwide use rattan (Wulf and Ian (2000). The largest demand for rattan canes is for making furniture, for which they provide both frames and decorative trimmings and facings. Uses of rattan cane among different products include the following mats, crafts and souvenirs. This important resource can also be used for riot control and judicial flogging Panayotou (1990). Without exaggeration rattan is one of the most important non wood forest resources products in the world (Panayotou, 1990). This paper reviewed the value addition to rattan for economic diversification in Nigeria.

Overview of rattan species

Rattans are spiny and climbing palms belonging to the family palmae (Aracaceae) and a large sub-family calamoideae. The rattan plant derives its name from the Malaysia word "raut" which means "pare". It has therefore been severally mentioned that the name is a reflection of how the products is being prepared, which includes surface peeling, to clean and splitting before being converted to numerous end- products (Dahunsi, 2000). According to Vorontsova *et al*. (2016), rattan belong to about 600 rattan species and has 8 genera and other 3 genera of climbing palms that resemble rattan having about 31 species in Asia-Pacific and Africa, among which *Eremospatha, Laccosperma*, and *Oncocalamus* are endemic genera restricted to Africa, while the remaining genera are distributed throughout the Asia-Pacific region (excepted African genera of Calamus).

Rattan has the ability to grow in diverse conditions though this varies with rattan species (Sunderland, 2001; Titi and Prameswari, 2018; Gonmadje *et al*., 2018). It was revealed that rattans are clustering in Africa. This implied that they produce numerous stems from one individual (Sunderland, 2001; Mialoundama, 2020). These rattan stems or canes are covered at first by the tightly sheathing and often densely spiny leaf bases. According to Sunderland (2001), the diameter of rattan stems is relatively constant within species. This made it possible to distinguish between "small-diameter" (20 mm) species. Furthermore, the diameter of rattans can be found between 3 mm to 20 cm (Dransfield *et al.*, 2002). The length of the stem of some the species of rattans have been estimated to reach up to 175 m in length. The average stem length of rattan in Africa is between 30 and 50 m (Sunderland, 2001). On the average, the rattan canes can grow at the rate of 0.70 m per year (Sunderland, 2001). Factors that determine the growth of rattan include condition of the environment and the management techniques (Razali *et al*., 1992; Sunderland, 2012). There is a wild distribution of rattans in Africa. This is as a result of rattan flexibility, and pliability, the utilization of rattan is across many sectors. The uses is not limited to the production of furniture, baskets, household materials and even bridges (Olawale and Wasiu, 2013; Myers, 2014; Gonmadje *et al*., 2018).

In Nigeria, rattan was identified in 1968 by Hutchinson as *Calamus deerratus*. There are two variety of this specie with large diameter which is referred to as big cane by cane product makers while the other is known as small cane and ranges from 2-3cm in diameter while the later ranges from 0.2-1.5cm in diameter. Rattan canes have long flexible stems that through trees in the forest. Some have been known to reach about 50 meter in length. The canes are used for furniture, mat and hat making. Rattan provides raw materials for handicraft and cottage industries. Rattan is among the minor forest resources found in considerable quantity in Nigerian forests (Adewole and Onilude, 2011). Rattan species have numerous benefits to rural and urban economies in developed and developing nations. The role of rattan in small scale industries cannot be over emphasized. It contributes to the growth of national economies the world over (Ogechukwu, 2006). Rattan enterprises have a great value in terms of employment generation and foreign exchange earnings.

Uses of rattan

Bamboo and rattan is a non-timber forest resource that has many uses and has commercial value for various products (Rahim and Idrus, 2018). Rattans are used to manufacture different products. The uses of rattan according to Olubanjo (2020) include the following:

- ✓ Arts and handicraft: Rattans are used for interior decoration. These include furniture, flower vases, wig holders, lampshade and stands, mirror picture frames, hand fans, shelves. Wardrobes, shopping and laundry baskets and walking sticks.
- ✓ Construction of building: Rattan are used traditionally to construct frames and walls. In mud houses it used as ceiling. It is also used in to construct barns and granaries.
- ✓ Agricultural Articles: Several agricultural items are produced from rattan for farm and on-farm activities. These include baskets, sieves, racks, winnowers, rope materials for tying ladders and trailing yam products.

Value addition to rattan products: Untapped gold mine in Nigeria.

Rattan production is capable of providing sustainable income for rural farmers and enhances development of small and medium scale rattan industry. However, Nigeria rattan industry is not yet developed compared to other part of the world. Professor Hussaini Ibrahim, Director General, Raw Material Research and Development Council noted that if rattan industry is properly managed, it can contribute about ₦30 billion foreign exchange to the economy on annual basis. It has potential to generate employment opportunity in terms of harvesting, transportation and processing. Akinyemi *et al*. (2019) also reported that rattan based cottage enterprise is profitable. In Akinyemi *et al* .(2019) analysis, the average gross profit of rattan cottage entrepreneur was ₦1,635,030,95 obtained per annum by deducting total variable cost (TVC) from the total revenue (TR). The average net profit was ₦1,605,094,40K. The rate of return was 686.43% while the rate of return on investment was 586.4%. There are a great number of socioeconomic opportunities associated with rattan value chain in Nigeria. These opportunities include the following:

- ❖ Presence of local and international market for rattan products. There are local and intermediate collectors and traders that ensure urban market linkages

- Small and informal nature of rattan cottage enterprises. Rattan business requires low capital which is mostly financed through personal savings and soft loan for market expenses.
- Employment opportunities in rattan local labour market. It has been noted that rate of unemployment is reducing in the informal sector. Rattan provides employment for a great number of labour force in informal sector
- Rattan business activities can take the following forms
    - Raw rattan supply
    - Small scale manufacturing
    - Integrated rattan supplies and cane manufactured products

Constraints to rattan value addition process in Nigeria

The following constraints were identified among rattan stakeholders according to the survey conducted by Olabanjo (2002).

- Shortage of rattan cane processing products, particularly during the rainy season due to poor accessibility into forest and collection sites. There is high cost of production due to low supply.
- Use of manually operated tools for rattan activities among the major actors, the collectors and processors. This requires more investment in rattan business
- Limited market. The sales of cane products are low and seasonal. The producers reported that the demand is only manifested during the festive period. There is no provision or management for tapping cane craft market.
- Limited knowledge on the need for prospects of commercial cultivation of rattan.
- Unfavorable policies. Due to unfavorable policies such as export control and prices that could create high economic barriers for producers (Pswarayi-Riddihough and Jones, 1995; FAO, 1987).
- Lack of market information. Producers often lack information about their product prices in the local market or input to processing a desired product demand in the market, the amount of competition and the quality of the desired product. Then it is also caused by the low source of raw materials which is a result of small range production often have not enough land and stocks growing (Rahim and Idrus, 2018).

Conclusion and Recommendations

Rattan is a natural resource that is commonly found in developing countries with economic development requirements and requires rattan products as part of economic boost and strategies. It is a potential option for economic diversification particularly in Nigeria. The following suggestions are important for rattan product development.

- Rattan plantation establishment: It is essential to incorporate rattan plantation into afforestation programme. This will ensure continuous supply of rattan raw materials that will be transformed to finished and semi-finished products
- Development of rattan-based micro enterprise: This can be incorporated into developmental and poverty eradication programme.
- Establishment of rattan rural resource centre: This will ensure awareness creation and sustainable exploitation of rattan species
- Establishment of rattan training and skill acquisition centre: Skill acquisition and entrepreneurship development programmes particularly among the youths are capable of transforming the economy of a nation. In most developed countries, entrepreneurship, skill development and creativity have been identified as major determinants of economic growth. Skill acquisition for the development and improvement of small and medium scale enterprise will enhance economic growth; employment generation; empowerment and capacity building among the working population.
- There is need for continuous research to ensure sustainability of rattan resources. Study and research should be conducted on the durability and rattan yields. This should always be reviewed from time to time.

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EFFECTS OF PRETREATMENTS AND GROWTH-MEDIA ON EARLY GROWTH PERFORMANCE OF *Uvariopsis tripetala* (Baker f.) G.E.Schatz. SEEDLINGS

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ABSTRACT
The study investigated the effects of pretreatments and growth-media on early growth performance of Uvariopsis tripetala seedlings with a view to providing the silvicultural requirements for seedling production and conservation of this species. The fruits for this work were procured from Akinlaja village, Odigbo Local Government Area, Ondo State. The extracted seeds were pretreated using three pretreatment methods (Cold stratification, Mechanical scarification and H_2SO_4). The seedlings were transplanted into three growth-media (Topsoil, Sawdust and Biochar) replicated thrice using Randomized Complete Block Design (RCBD). Seedlings from cold stratification planted on topsoil had the highest mean height value (5.12±0.14). Followed by the seedlings from mechanical scarification planted on biochar with (5.03±0.14). While the least mean value was recorded from H_2SO_4 pretreatment planted on topsoil (3.95±0.14) at ($p > 0.05$).Seedlings from mechanical stratification planted on sawdust had the highest mean collar diameter (1.95±0.34). Followed by seedlings from H_2SO_4 planted on sawdust (1.88±0.34) and least value (0.75±0.34) also from H_2S0_4 seedling planted on topsoil medium. Seedlings from cold stratification planted on biochar and topsoil had the highest mean number of leaves (3.99±0.23 and 3.67±0.23) respectively. While the least mean value (3.34±0.23) from H_2SO_4 seedlings planted on biochar medium. The results showed that cold stratification pretreatment and decomposed sawdust medium were most preferred for mass seedling production for the species at nursery stage. Further studies were recommended for more silvicultural requirements and floral biology of the species for sustainable production and conservation.

***Keywords**: Pretreatment, Growth-media, seedling-growth, Conservation, Uvariopsis tripetala*

Introduction

Uvariopsis tripetala is an indigenous forest fruit species which belongs to the family Annonaceae. It is a common ethno-medicinal plant in West Africa whose fruits appears red when ripe and green when unripe with a pungent and spicy taste. In English, *Uvariopsis tripetala* is called pepper fruit, "Mmimi" in Igbo, "Nkarika" in Ibibio and Efik, "Imako" by Urhobo of Niger-Delta region and "Ata igbere" by the Yorubas in Southwestern part of Nigeria (Onefeli and Akinyele, 2014). The parts used include the leaves, fruits, seeds, roots and stem (Timothy and Okere, 2008). It is widely domesticated in the rainforest belt of West Africa especially in Ivory Coast, Cameroon and Nigeria especially in the South, East and Western part of Nigeria (Okwu and Morah, 2004). Adedayo *et al.* (2010) noted that the fruits had alkaloids, tannins, saponins, flavonoids, terpenoids, steroids and glycosides which differs from the reports obtained in 2015 (Egharevba and Edah, 2015).

The fruit of this plant is edible and has a peppery and spicy taste. It serves as a mild stimulant and as a source of some vitamins which are vital for human wellbeing. The leaves are used to treat mild fever in combination with mango leaves. The fruits are used as masticators and the unique peppery effect is explored for treating mouth sore and other digestive tract problems (Keay, 1989). The fruits are sometimes taken with kolanut, garden egg and palm wine as stimulants for local deities in some area especially in the southeastern part of Nigeria (Enwere, 1998). Some studies revealed that pepper fruits contain Dennetia essential oils, phenolic acid, ethanol, alkaloids, ethylacetate, flavonoids, tannins and glycosides (Ejechi and Akpomedaye, 2005; Adedayo *et al*., 2010; Egharevba and Edah, 2015). Hence, Elekwa *et al*. (2011) affirmed that the medicinal properties of this species could be ascribed to the varieties of secondary metabolites such as alkaloids, flavonoids, tannins and terpenoids that are present in the plant. Studies showed that the high presence of essential oil called oleoresins accounted for the aromatic flavoring, colouring and pungent properties of pepper fruits (Aderogba *et al.,* 2011). However, *Uvariopsis tripetala* exhibit epigeal germination and it has inconsistent fruiting, poor seed germination and slow seedling growth (Osaigbovo *et al.,* 2010). Thus, this species have been identified as threatened species according to 2006 IUCN red list of threatened species (IUCN, 2006). Despite the multipurpose nature of this species, information on the ecology, silvicultural requirements and conservation are limited. Therefore, urgent research attention is needed towards salvaging this multipurpose medicinal plant species from extinction. This study therefore examined the effects of pretreatments and growth-media on the early growth trends of *U. tripetala* seedlings to enhance the sustainable production and conservation of this multipurpose plant species for human benefits.

Materials and Methods

Experimental Site

The experiment was carried out in the central nursery screen house of Southern Guinea Savanna Research Station, Forestry Research Institute of Nigeria, Mokwa, Niger State. The research station is situated along Mokwa to Bida road in Mokwa Local government area of Niger State. It is located on latitudes 9.26322 and 9.27531 N and longitudes 4.37528 and 4.38613 E with rainfall ranges between 800*mm*–1000*mm* with average temperature ranges between 25^0C – 35^0C (FRIN, 2014).

Collection of Seeds and Materials

Some mature fruits of *Uvariopsis tripetala* were collected from Akinlaja village in Odigbo Local Government Area of Ondo State. The seeds were extracted and then divided into three parts. The river sand used for seed germination was collected from Forestry Research Institute of Nigeria stream. This was thoroughly washed and sterilized by boiling at 100^0C for one hour. Plastic sieves used were purchased from Aleshinloye market in Ibadan South West Local Government area, Oyo State.

Study Design and Method

Seed Germination

Three hundred seeds (300) were used for the germination experiment. One hundred (100) seeds were selected for each pretreatment which was sown in tagged plastic sieves filled with sterilized river sand. The setup was placed under a propagator chamber for maximum protection and optimum germination condition. The pre-germination treatment methods used were cold stratification by soaking the seeds in cold water for 2 days, Seed scarification using sand paper to remove some part of the seed coat and soaking the seeds in conc. H_2SO_4 for 2 minutes. Twenty (20) seedlings of relative uniform height were selected after six weeks and transplanted into (25 x 15 x10) cm polythene pots size filled with three growth media. The seedlings were transplanted into the growth media of a cured sawdust, topsoil and biochar and the set-up was replicated three times each using Randomized Complete Block Design (RCBD). One hundred and eighty (180) seedlings of *U. tripetala* were used for this study.

Data collection and Seedling Growth

The initial data for the transplanted seedlings were recorded two (2) weeks after transplanting within which the transplanted seedlings have recovered from planting shock. This was carried out to determine the subsequent height, collar diameter and leave increment of the seedlings. The potted seedlings were arranged in the screen house to minimised the heating impact of direct sun and possible defoliators attack on the young seedlings. Further data collections were carried out every four (4) weeks due to slow growing nature of the species. The potted seedlings were tended and assessed for sixteen weeks (16wks). The variables assessed were seedlings height which was determined with meter rule (cm), Collar diameter evaluated with digital calliper and Leaf production was assessed by manual counting of the leaves on the plant.

Data Analysis

Statistical Package for Social Sciences (SPSS) for windows (version 17.0) and two-way ANOVA at 5% probability level were adopted for data analysis. Means were separated with Duncan Multiple Range Test (DMRT).

Results and Discussion

Results

Effect of Pretreatment and Growth Media on the Early Growth of *Uvariopsis tripetala* Seedlings

There were no significant differences in the effect of the growth media and the pretreatments except the H_2SO_4 which showed a significant effects on the height of *U. tripetala* seedlings (Table 1). The seedlings produced from cold stratification pretreatment which was planted on topsoil accounted for the highest mean height value of 5.12±0.14. This was followed by the seedlings produced from mechanical scarification pretreatment planted on biochar with 5.03±0.14. While the least mean value was recorded for seedlings produced from H_2SO_4 pretreatment planted on topsoil with 3.95±0.14 at 0.05 probability level.

Table 1: Effect of Pretreatment and Growth Media on the Height of *Uvariopsis tripetala* Seedlings

		Growth Media		
Pretreatment	**Topsoil**	**Sawdust**	**Biochar**	**Mean**
Cold Stratification	4.99±0.14	4.78±0.14	5.12±0.14	4.96 ± 0.09^a
Mechanical Scarification	4.86±0.14	4.56±0.14	5.03±0.14	4.82 ± 0.09^a
H_2SO_4	3.95±0.14	4.34±0.14	4.18±0.14	4.16 ± 0.09^b
Mean	4.60 ± 0.09^a	4.56 ± 0.09^a	4.78 ± 0.09^a	
P-value	0.003	0.001	0.001	

Means with similar alphabet are significantly the same ($p > 0.05$)

Effect of Pretreatment and Growth Media on Collar Diameter of *Uvariopsis tripetala* Seedlings

Significant differences were recorded in the effect of cold stratification pretreatments and sawdust growth medium on the diameter of *U. tripetala* seedlings (Table 2). The seedlings produced from mechanical stratification pretreatment which was planted on sawdust had the highest mean collar diameter of 1.95±0.34. This was followed by the seedlings produced from H_2SO_4 pretreatment planted on sawdust with 1.88±0.34. While the least collar diameter was also recorded for seedlings produced from H_2S0_4 pretreatment planted on topsoil with 0.75±0.34 ($p > 0.05$).

Table 2: Effect of Pretreatment and Growth Media on Collar diameter of *Uvariopsis tripetala* seedlings

		Growth Media		
Pretreatment	**Topsoil**	**Sawdust**	**Biochar**	**Mean**
Cold Stratification	0.86±0.34	0.89±0.34	0.84±0.34	0.86±0.18[a]
Mechanical Scarification	0.78±0.34	1.95±0.34	0.79±0.34	1.17±0.18[b]
H_2SO_4	0.75±0.34	1.88±0.34	0.82±0.34	1.15±0.18[b]
Mean	0.80±0.18[a]	1.57±0.18[b]	0.82±0.18[a]	
P-value	0.001	0.001	< 0.001	

Means with similar alphabet were significantly the same ($p > 0.05$)

Effect of Pretreatment and Growth Media on Leave Production of *Uvariopsis tripetala* Seedlings

No significant differences in the effect of all the pretreatments and growth media on the leave shoots of *U. tripetala* seedlings (Table 3). The seedlings produced from cold stratification pretreatment which was planted on biochar and topsoil had the highest mean number of leaves with 3.99±0.23 and 3.67±0.23 respectively. While the least mean value for leaves was recorded for seedlings produced from H_2SO_4 pretreatment planted on biochar medium with 3.34±0.23 ($p > 0.05$).

Table 3: Effect of Pretreatment and Growth Media on Leave Production of *Uvariopsis tripetala* seedlings

		Growth Media		
Pretreatment	**Topsoil**	**Sawdust**	**Biochar**	**Mean**
Cold Stratification	3.67±0.23	3.51±0.23	3.99±0.23	3.72±0.12[a]
Mechanical Scarification	3.46±0.23	3.43±0.23	3.57±0.23	3.49±0.12[a]
H_2SO_4	3.58±0.23	3.39±0.23	3.34±0.23	3.44±0.12[a]
Mean	3.57±0.12[a]	3.44±0.12[a]	3.63±0.12[a]	
P-value	0.001	< 0.001	< 0.001	

Means with similar alphabet were significantly the same ($p > 0.05$)

Discussion

This study shows that the seedlings produced from cold stratification pretreatment which were planted on topsoil accounted for the highest mean height value. This result corroborated the work of Osaigbovo *et al.* (2010) and Alex *et al.* (2020) who recorded the highest height value for *U. tripetala* seedlings planted on topsoil. However, the findings disagrees with Fredrick *et al*. (2020) who obtained the highest height value from *Dalium guinense* seedlings planted in sawdust potting mixtures. This work was also in accordance with the result documented by Okunomo *et al.*(2004) and Agboola *et al.*,(2018) on the mean height values of *Dacryodes edulis* and *Persia americana* seedlings planted on topsoil. The findings on collar diameter revealed that seedlings produced from mechanical stratification pretreatment which was planted on sawdust had the highest mean collar diameter. This result contradicts the reports of Aigbe *et al*. (2016) and Alex *et al.* (2020) on the least collar diameter of seedlings planted on river sand and topsoil accordingly. These findings also conformed to the observations of Omokhua *et al*. (2015) who recorded better performance in sharp river sand. Conversely, the result differs from Mathowa *et al.* (2014) who noted the highest diameter values on seedlings planted on sawdust. Undoubtedly, the number of leaves possess by seedling at the early stage determines the photosynthetic capabilities of the seedling. This in turn determines the rate of growth and development of the plant as opined by Aigbe *et al*. (2016). However, the research reported the highest number of leaves from seedlings planted on biochar growth medium. This may be attributed to the high releasable nutrients present in the biochar which boosted the flora production processes in the young seedlings. Nevertheless, the least number of leaves was also observed on seedlings planted on the same medium. These findings conformed to the report of Okunomo (2010), with the most and the least leaf numbers on seedlings planted on potting mixtures with poultry droppings. Thus, he ascribed the result to the rich nutrient in the growth medium which enhanced the fast growth of the seedlings causing some seedlings to be suppressed, thereby limiting their leave production as evident in this study.

Conclusion and Recommendation

Conclusion

The results of this study revealed that cold stratification pretreatment had significant effect and may be suitable for raising healthy and vigorous *U. tripetala* seedlings for plantation and conservation purpose. While, well decomposed sawdust medium also had significant effects on the growth variables which may also be appropriate for raising *U. tripetala* seedlings at nursery stage. However, mechanical scarification pretreatment and biochar growth medium also had effects as evident on the growth variables observed in the experiment. These effects are indications of possibly being an alternative pretreatment and medium for mass production of this species for plantation establishment. Nevertheless, this study was part of efforts towards formulating conservation strategies to protect this threatened multipurpose species from going to extinction.

Recommendations

In line with the findings of this study, further studies on other silvicultural requirements and floral biology could be considered to enhance sustainable seedling production and conservation of this species. Also, conservation effort should be geared towards making *U. tripetala* a key agroforestry component at local and state levels in order to prevent this species from total depletion.

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SAWDUST: SUSTAINABLE UTILITY FOR CLIMATE CHANGE MITIGATION, A REVIEW

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ABSTRACT
This comprehensive review explores the utilization and importance of sawdust, an essential wood residue litters, which can be turned into a valuable commodity for industrial and agricultural use. Among other materials manufactured from sawdust is a producer gas, which consists primarily of CO and H_2, artificial graphite (anode in lithium-ion batteries), activated carbon for water treatment, a base for spore culture in cultivating edible mushrooms, pyrolytic oil as an alternative to crude oil. Sawdust and other biomass materials are blended in specific quantities palletized into briquettes and mixed with animal digestion or wood ashes and calcium carbonate to make fertilizers were also considered for composting. Sawdust and wood shavings can both be used to make particle boards and other decorative household items. This review hereby showcased the utilization of waste for a profitable business venture and eradicating improper disposal of waste and also proffering innovative solutions for climate mitigation.
Keywords: Activated carbon, Pyrolytic oil, briquettes, compost, waste to wealth

INTRODUCTION
Wood residue has been a long term concern in the environment (Rominiyi, Adaramola, Ikumapayi, Oginni, & Akinola, 2017), they are tiny flakes obtained in sawmilling, and wood industries, notably in southern part of Nigeria, in enormous quantities in the form of heaps that are generally burned off, resulting in pollution (J. A. Adesina, Jiangang, & Xiaolan, 2022). Sawdust is commonly thought of as a polluting timber-industrial waste (Assiamah, Agyeman, Adinkrah-Appiah, & Danso, 2022), but it may be converted to a valuable raw material in the fabrication of notice boards, wall and roof sheets, and shelves, (Di Cori, Robert, Franceschinis, Pettenella, & Thiene, 2022). In energy sectors, sawdust can be utilized as a biofuel (Weiss, Emery, Corradini, & Živojinović, 2020), briquettes (Charis, Danha, & Muzenda, 2019), pellets, artificial graphite for lithium-ion batteries (Y. Yu et al., 2021) and other products like insulator for refrigerators systems and in clean up technology for bioremediation of pollutants from wastewater (K. Adesina *et al*., 2022). Sawdust has features similar to wood, however some structural properties have been altered because it is in particles (Soimakallio, Saikku, Valsta, & Pingoud, 2016). Some characteristics of the technology employed to accomplish the aforementioned will be discussed in this paper.

1.1 Briquette
Over the last few years, depleting energy, rising costs, and crisis have reignited the focus of researchers in developing alternative energy. Gases, flowing water, and nuclear energy were the world's energy requirements many years ago. Although, majority of conventional energy are non-renewable, it is also obvious that it will not be sufficient to supply the world's growing demand in the present and future. As a result, more emphasis has been dedicated to the creation of wood gas that would supposedly be a waste. Briquettes are an excellent alternative to using wood as a fuel due to technological advancements in sawdust (Umar & Academy, 2016). Wood waste has a competitive specific energy content of 16,795.96 kJ/kg while charcoal has a specific energy content of 18,711.70 kJ/kg (Y. Yu et al., 2021). Due to the presence of cellulose, it can also be transformed to bitumen by improvising it with chemical reactions of carbon (II) oxide (CO), sodium carbonate, and water at high temperatures between 250ºC and 400ºC (Weiss *et al*., 2020). Sawdust can also be used as an insulating material in the refrigeration system and for cold storage.
Interestingly, sawdust's heating value compared to other fuels when used as a source of energy has low thermal conductivity, reason why it is been utilized insulator to lower conductor's heat losses. Sawdust's bulk density could be as low as 150 - 200 kgm^3 (Harshwardhan & Upadhyay, 2017). Sawdust's positive application has been proven by technological development; for example, it is often used as prerequisite for enhancement in various materials, such as production of methanol (Isabirye *et a*l., 2012); it can be burned to create heat in three different methods to produce fuel (Sacchelli, Borghi, Fratini, & Bernetti, 2021):

i. As a home fuel energy source for cooking and space heating, using specific stones for household cooking and fire pits heat.
ii. In the agriculture industry, to produce heats to brood chickens, drying and curing.
iii. In industrial sector, to produce heat used in blacksmithing, brickmaking, and poultry production.

Most studies believed that the industry could absorb all readily recovered trash currently being generated for energy or being used as supplementary raw material for chipboard or board production (Mangi, Jamaluddin, Memon, & Bin Wan Ibrahim, 2019).

1.2 Sawdust utilization for Ionic liquid-modified biochar for enhanced Li^+ storage

Every year, hundreds of thousands of tons of sawdust are produced by forestry logging and wood processing, which is either dumped or burned. As a result of these unfriendly behaviors, there are some issues with greenhouse gas emissions through its use as fuel or filler, waste (Rajapaksha *et al*., 2016). Waste resources have garnered a lot of interest for producing LIB anodes because of their reduced cost and long-term material sustainability, thanks to a growing demand for synthetic graphite which is the anode material in lithium-ion batteries (LIBs) derived from petroleum-based materials (Dai, Zhang, Xing, Cui, & Sun, 2019). A long lasting carbon material produced thermochemically by decomposing biomass in a low-oxygen or zero-oxygen environment is called **Biochar** (Fuja, Ostrem, Probst-Fuja, & Titze, 2006). Recent research breakthroughs have enabled biochar designs to three-dimensional levels, resulting in features such as distinct pore structures, and surface dynamics that are ideal for storing energy (Arana Juve, Christensen, Wang, & Wei, 2022; Gupta, Ganjali, Nayak, Bhushan, & Agarwal, 2012; Xu *et al*., 2019). Sawdust being rich in lignin with significant amount of cellulose during pyrolysis can be modified into graphitic carbon while lignin forms an absolutely robust carbonaceous matrix with distinct pores following pyrolysis (Del Bubba *et al*., 2020; Muddemann, Haupt, Sievers, & Kunz, 2019). Utilization of wood residue to create graphitic carbon for LIBs, on the other hand, normally necessitates a high-temperature carbonization process of above 2600 °C (Selvam S & Paramasivan, 2022). Due to titaniumdioxide (TiO_2) environmental friendliness, high durable functionality, low cost, and strong performance, making it suitable as anode material (Ghadikolaei, Hosseinzadeh, Yassari, Sadeghi, & Ganji, 2017; Ghadikolaei, Yassari, Sadeghi, Hosseinzadeh, & Ganji, 2017; Zhang & Chu, 2022). However, the fundamental disadvantage of using TiO_2 in LIBs is its weak conductivity (Tobaldi *et al*., 2021).

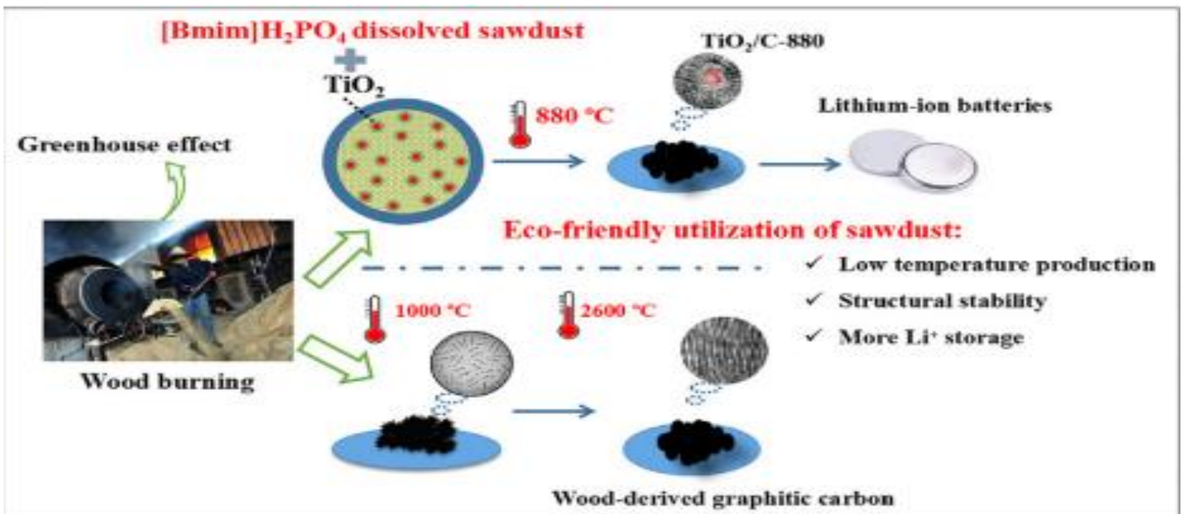

Fig 1: Modified sawdust for lithium-ion storage (J. Yu *et al*., 2021)

1.3 Water Treatment

Adsorption is the term used to describe the ability of lignocellulosics to absorb pollutants and impurities. The efficiency of biosorption technology in decreasing the concentrations of heavy metal ions, dyes, antibiotics, anti-inflammatory, and surfactants, as well as the utilization of readily available materials are two of its main advantages. Other advantages include biosorbent regeneration, adsorbate recovery, cheap cost, effective, and biosorbent regeneration (Ioannidou & Zabaniotou, 2007). Because binding occur through phenolics, amino or carboxyl, while raw lignocellulosic materials are being treated in various ways to boost their sorption capabilities. Recently, a lot of effort has gone into developing new adsorbents and improving current ones. Many researchers have looked into the possibility of utilising low-cost agricultural waste products (Adegoke, Adeleke, Adesina, Adegoke, & Bello, 2022; Eniola, Kumar, & Barakat, 2019; Ngah, W. S.Wan and Hanafiah, 2008; Patel, 2021) in place of traditional approaches for pollutants removal in wastewater treatment (Saravanan & Ravikumar, 2015; Sundararaman *et al.*, 2021; Suteu, Zaharia, & Blaga, 2012). In some circumstances, these approaches fail at low concentrations and are expensive. As a result, economy friendly adsorbents to remediate pollutants from aqueous solutions have been investigated (Varghese, Paul, & Latha, 2019). Elimination of zinc, lead, +3 and +6 chromium using modified lignin derived from lignocellulosic materials is utilized (Ofomaja & Naidoo, 2010; Salleh, Mahmoud, Karim, & Idris, 2011; Yang *et al*., 2020). Many heavy metal ions are known to bind to lignin. (Abdolali *et al.,* 2014*)*.

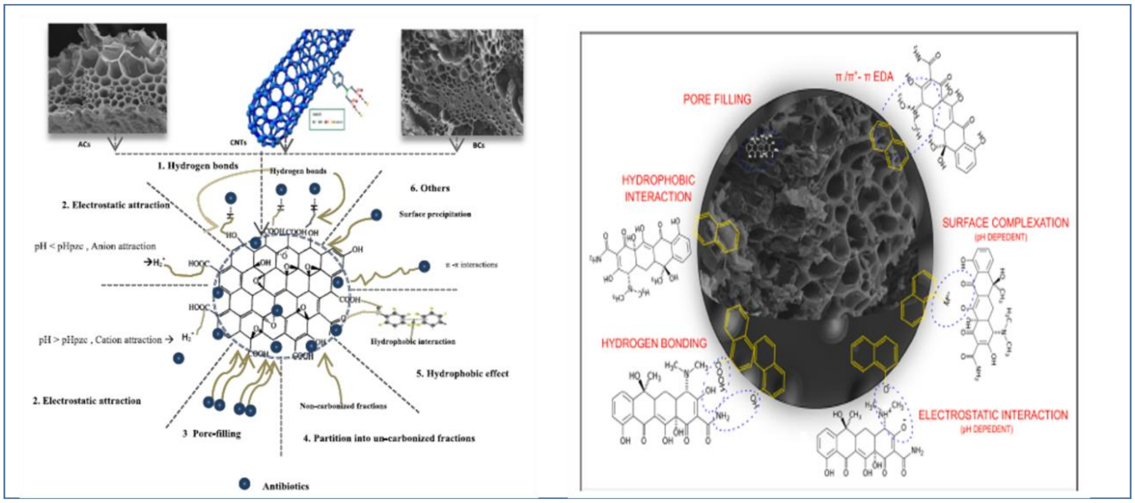

Fig. 2: A detailed scheme of mechanism involved in sorption of pollutant molecules on a biochar material (Del Bubba *et al*., 2020; Wu, 2019).

1.4 Composting

Sawdust is used in the agriculture business to make saw dust compost fertilizer. Southwest Nigeria produces tons of sawdust and other wood leftovers each year. While the majority of it is burned, a growing proportion were utilized for nurserymen, mulches, small fruit farmers while becoming more popular as barn and feedlot litter. Sawdust can induce a nitrogen shortage in soils while tannins and other extractives found in certain woods and barks may have a harmful effect on plants and soil microbes. However, mulching is well known for increasing crop yields using low-cost, commonly available materials. Wherever it is economically feasible, wood remains should be used for humus management. Although sawdust is the focus, it reacts similarly to shavings, bark and chips, with the exception that it decompose rapidly in fine material while mulches made of sawdust expand the aeration structure, water penetration and its absorption were increased. Reduce evaporation and weed control to conserve moisture.

1.5 Oxygen Sawdust gasification

This is the process of burning sawdust with a restricted amount of oxygen. CO, CO_2, H_2, and CH_3 make up sawdust gas. Except for carbon (iv) oxide, combustible liquid and gas can be used as fuel or fuel feedstock. Table 1 shows the normal composition of gasification in air, excluding water vapor. Although there are significant differences, the gas composition is mainly independent to feedstock composition owing to the fact that the final product is a combination of simple gases. If the feedstock contains a substantial amount of sulfur, hydrogen sulfide may be produced. By passing the gas, this can be simply removed across the water because when air source is substituted with oxygen, nitrogen will be removed, and the energy will reach 9 MJ/m^3. Hydro gasification, in which H_2 is introduced to react with CO to form hydro carbons, is another way to produce greater BTU gas.

$$CO + 3H_2 \rightarrow CH_4 + H_2O$$

Table 1. Sawdust gasification in air

Compounds	Percentage by volume (%)
H_2	20
CO	25
CO_2	10
CH_4	3
Higher hydrocarbon	1
N_2	40

Others	1
Total	100

1.6 Pyrolysis of sawdust for Bio-oil

Pyrolysis is the heat degradation of materials when there is no oxygen present. It is critical to distinguish between gasification and pyrolysis. By carefully managing the amount of oxygen available, gasification converts biomass to syngas. Pyrolysis is difficult to quantify properly, particularly when it comes to biomass. Pyrolysis is often confused with carbonization, which produces a solid char as the primary result. The word pyrolysis is now commonly used to describe operations in which oils are the preferred end product. Pyrolysis has a significantly shorter time span than the latter phase. Below are the list of general variation usually occur during pyrolysis (Mohan, Pittman, & Steele, 2006)

- Heat transmission raising the internal temperature of the fuel;
- Hot volatiles flowing toward unpyrolysed cooler solids resulting to heat transfer;
- Secondary reaction as a result of condensed volatiles in the cooler parts of the fuel producing tar;

Basic research on flash pyrolysis revealed carbonaceous feedstocks can provide superior yields of gases and liquids, with important compounds, petrochemicals, chemical intermediates, over the previous two decades. As a result, typical slow pyrolysis solid char can be substituted with fuel oil, chemicals or fuel gas produced.

Because sawdust primarily composed of hemicellulose and cellulose, CO and hydrogenation technologies can easily be applied to convert it to oil. Cellulose conversion to a liquid necessitates high-pressure hydrogenation, while cellulose to a bitumen necessitates treatment at high pressure and temperatures. Sawdust, catalyst, and water were heated in an autoclave with CO to about 250°C to 400°C (Galhetas *et al*., 2014).Water is required for both process and also serves as a solvent and reaction medium.

1.7. **Composite Panels**

Sawdust can be used to make particleboard, plywood, water board, and other wood panels, and the strength is highly influenced by particle size of sawdust.

Shavings, chips, and flakes are mixed together with binding chemicals and resin are further poured into hot-pressed mat for increment in density and adhesive curing. To fortify its potency dynamics, sawdust flakes can be directed to some extent in the panels to enhance exterior characteristics thereby creating a more sophisticated output (Rominiyi *et al*., 2017).

Consolidation of the board to an appropriate texture and compactness can be employed to achieve material stability because of its direct impact on finishes product efficacy and quality (Jasmani, Rusli, Khadiran, Jalil, & Adnan, 2020). When compared to multi-opening presses, improved panel aesthetics, regulated solidity, and reduced trimming losses are guaranteed (Joshi *et al*., 2020).

1.8 Sawdust Utilization for Feed Meal, Compost and Mushrooms Production

To absorb surplus moisture in wet compost, unadulterated sawdust and wood shavings are useful to dampen them and prevent them from air flow restriction in the heap. Alternatively, more moisture is supplied when adding sawdust preventing the heap from complete dry out.). As long as the animal is vegetarian, sawdust can be applied as animal beddings e.g rabbits or poultry droppings can be composted together. Beneficial symbiotic interaction with microbes in the rumen region of ruminant animals digestive tract allows them to eat cellulose materials. During times of national emergency, cattle and horses were fed with wood residues as maintenance meals. Feeding trials with wood residue was conducted on cattle and sheep, they were undertaken by utilizing a formula that include sawdust and oyster shell. A purified experimental chick ration using an inexpensive supply of cellulose resulted in a considerable boost in growth was also considered while compared to the control set, 20.2% wood flour fed to chicks had no negative influence and caused small growth improvements at 28 weeks of age.

Conclusions

Sawdust, which is normally a hazard at sawmills, can be used to make animal feed stocks, biogas, particle board, briquettes, activated carbon and Li^+ ion anodes. Internal combustion engines can benefit from the flame-purified gas. In addition, for safety and health reasons, plywood and particle boards products are preferred over other materials for wall sheathings and roofing. Finally, composting sawdust with cattle droppings has the potential to improve soil quality.

Future perspective

The government should create an atmosphere that encourages the local manufacture of pressing and briquetting machinery. More money can be made in forex if briquetting and pressing machinery were built for export and local consumption. Sensitization through sponsored seminars and workshops across the country for indiscriminate sawdust burning should be projected. Kerosene and firewood should be replaced by sawdust briquettes as an alternative fuel for climate control. Also, sawdust biochar and modified biochar for waste water treatment and lithium-ion storage will create a massive industrial growth and also boost our economy.

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FACTORS INFLUENCING CONSUMERS PREFERENCE OF WOOD FOR FURNITURE IN JAMA'A LOCAL GOVERNMENT AREA, KADUNA STATE.

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ABSTRACT
The factors influencing consumers preference of wood for furniture was conducted in Jama'a Local Government Area, Kaduna State. A total of sixty (60) questionnaires were randomly distributed among the respondents via Simple Random Sampling. Simple descriptive statistics was employed in data analysis. Result shows that majority of the respondents (70) were male and were married (55%) were married, and they were ages between 31 and 40years. Sixty percent (60%) of the respondents have household size of between 1-5, and (68.3%) having secondary education. Majority of the respondents (19.60%) identified availability as a major factor responsible for the choice of preferred wood species for furniture making. Over thirty percent (34.29%) of the respondents identified price as one of the major factor militating against the choice of preferred wood species. Some identified species of wood used in this study includes; Encalyptus sp 12.05%≥ Khaya senegalensis 7.95%, Gmelina arborea 6.41% ≥ Terminalia superba 5.90% ≥, Milicia excelsa 5.13%. In conclusion, this findings evidence that: availability, durability, appearance, wood price, etc have significance influence on consumers' choice of wood for furniture making. Therefore, the massive regeneration of the user's choice species must be considered paramount in afforestation programme.

***Keywords**: Consumers, preference, choice, wood and furniture*

INTRODUCTION

Nigeria has considerable wealth in tropical wood or timber resources and has been noted for the supply of forest timber and wood to the rest of the world, this is because of the significant of wood to man in term of building materials, energy, cook food, constructs arms and tools (Rowell, 2005).The wood furniture business has surely not been exempted from increased rivalry and rising consumer expectations of quality. Schuler and Buehlmann, (2003) stated that world over, the growth in consumer populations and incomes has raised the demand for household furniture. He stated further that the boom in the modern housing and cottage industry has been and will continue to drive the demand for quality furniture.

Changes in the composition and value of wood resources, as well as changing market demands, consumer tastes, species availability and the design of the manufacturers are having far reaching effects on the wood industry (Bumgardner *et al.,* 2007).

Most timbers in Nigeria are not being used to their full potentials due to lack of information on the many promising characteristics, thus, affecting consumer's preference for choice of wood species in furniture making. Consequently, leading to decline in Nigeria timber resource making timber very expensive in the local timber market. In the light of this, this paper seeks to assess consumers' preference to choice of wood for furniture in Jama'a Local Government Area of Kaduna State.

METHODOLOGY

Study Area

The study was conducted in Jema'a Local government of Kaduna State, Nigeria. The Local Government population projection is about 278, 202 and it is about 3,923km^2 in line with 2006 census, and lies between latitude 9^0, 10^1-9^0 30^{1}N and longitude 8^0 00'' E-8^0- 30E. The area is situated in low savannah plains and it has 190.5cm of rainfall annually which makes the area arable.

Method of Data Collection

Primary data were used for this study and it was generated through the use of structured questionnaire. Information was also sourced from journals and book of proceedings to support the research.

Sampling Techniques

Simple random sampling was employed in this study. Sixty (60) questionnaires were distributed to the respondents where wood products marketing and industries such as carpentry, wood plants or sawmills, lumber sheds are mostly common.

Method of Data Analysis

Simple descriptive statistic was used for the data analysis.

Results

Social factors play a vital role in the decision of buying certain products such as home furnishing. The table below shows the socio-economic variables examined.

Table 1: Socio-economic characteristics of the respondents

S/N	Variable	Frequency	Percentage
1	**Gender**		
	Male	18	70.0
	Female	24	30.0
2	**Marital Status**		
	Single	21	35.0
	Married	33	55.0
	Divorced	3	5.0
	Widow	3	5.0
3	**Age**		
	11-20	2	3.3
	21-30	18	30.3
	31-40	23	28.3
	41-50	13	38.3
	50-above	05	6.7
4	**House-Hold size**		
	1-5	36	60.0
	0-10	17	28.3
	11-15	7	11.7
5	**Education Status**		
	Primary	9	15.0
	Secondary	41	68.3
	Tertiary	9	15.0
	Non Formal Education	1	1.7
6	**Occupational Status**		
	Furniture/Artisan	34	56.7
	Trading	16	26.7
	Farming	3	5.0
	Tailoring	1	1.7
	Civil Servant	5	8.3
	Total	60	100

Table 2: Identified Tree Species Used for Furniture Making in the Study Area.

S/N	BOTANICAL NAME	FAMILY NAME	COMMON NAME	FREQ.	%
1.	*Milicia excels*	Moracceae	Iroko	20	5.15
2.	*Terminalia superb*	Combretaceae	Afara	23	5.90
3.	*Triplochyton sahceroxylon*	Malvadeare	Obeche	14	3.59
4.	*Nuclea diderrchii*	Rubiaceae	Aloma	10	2.56
5.	*Tectonia grandis*	Verbenaceae	Teak	14	3.59
6.	*Khaya senegalensis*	Meliaceae	Mahogany	31	7.95
7.	*Parkia biglobosa*	Mimosoiceae	Locust beans	9	2.31
8.	*Vitex do doniaana*	Lamiaceae	Dinya	17	4.56
9.	*Pinus caribea*	Pinaceae	Caribean pine	11	2.82
10.	*Ceiba pentandra*	Bombacaceae	Java cottin	19	4.87
11.	*Gmelina arborea*	Verbenaceae	Gmelina	25	6.41
12.	*Eucalyptus camaldulensis*	Myrtaceae	River red gum	47	12.05
13.	*Isoberlinia doka*	Caesafinoioleae	Doka	13	3.3
14.	*Ficus glumosus*	Moraceae	*African Rock/ Kwari*	7	1.79
15.	*Terminalia ivorensis*	Combretaceceae	Black afara	3	0.77
16.	*Adansonia dogitata*	Bombacaceae	Baoba	10	2.56
17.	*Anthocleina vogelii*	Moraceae	Murderer	10	2.56
18.	*Antiaris Africana*	Moraceae	**Sacking tree**	5.	1.28

19.	*Vitellaria paradosa*	Sepotaceae	Shea- butter	8	2.05
20.	*Cola acuminate*	Malvaceae	Cola-nut tree	14	3.59
21.	*Cola gigantean*	Sterculiaceae	Giant Cola	3	0.77
22.	*Diospyros meslliformis*	Ebanaceae	*African ebony*	6	1.54
23.	*Entanda Africana*	Mimosoideae	Tawatsa	10	2-56
24.	*Prosopis Africana*	Mimosodeae	*iron tree or Malinke*	12	3.08
25.	*Ficus congoensis*	Moraceae	*Clusterfig*	14	3.59
26.	*Erythrophylum spp*	Combretaceae	Sasswood	9	2.31
27	*Terminalia avicennioides*	Combretaceae	*Bambara*	7	1.79
28.	*Lophira alata*	Ochnaceae	Red iron wood	5	1.28
29.	*Anogeisus leiocarpus*	Combritaceae	Marke	4	1.03
30.	*Anona senegalensis*	Annonaceae	*Gwandar daajii*	2	0.51
	Total			**390**	**100**

Table 3: Factor that support and against the choice of the preferred species

S/N	Variable	Frequency	Percentage (%)
1	**Supporting Factor**		
	Durability	40	13.51
	Appearance	52	17.57
	Availability	58	19.60
	Taste	40	13.51
	Colour	20	6.76
	Suitability/Usability	28	9.46
	Income	36	12.16
	Product	22	7.53
	Total	296	100%
2	**Militating Factors**		
	Cost/Price	60	34.29
	Non sustainability of Usage	19	10.86
	Lack of Expert Advice	38	21.71
	Income	46	26.29
	Product	12	6.86
	Total	**175**	**100%**

Table 4: Factors Militating Against the Choice of Less Use Species

S/N	Variable	Frequency	Percentage (%)
	Expert Advice	48	19.67
	Types of Product	19	7.79
	Customer Preference	42	17.21
	Cost of Treatment	17	6.97
	Appearance	18	7.38
	Defects	7	2.87
	Quality	42	17.21
	Durability/Perish ability	51	20.90
	Total	**128**	**100%**

Discussions

Table.1 above shows that male respondents represented 70% of the population while female respondents represented 30% of the studied population. This result revealed that we have higher number of male respondents in the study area. This could be due to the custom of the respondents (Nigeria) where men determine the choice of house equipment/material especially the household furniture.

Maritally, 55% of the respondents were married, 35% of them were single while Widows and Divorced respondents were 5.0% each. This could be attributed to the fact that the married individuals have settled down and hence the need to keep their homes habitable for their families as well as making it presentable for their visitors as the case may be.

On the basis of age distribution, 3.3% of the respondents were between the ages of 11-20, 30.0% of them 21-30, 38.3% of them were between the ages of 31-40, 21.7% of the studied population was between the ages of 41-50, while 6.7% of them were between 50 years of age and above. From this analysis, the ages of 31 and 40 had the highest population with respect to woody furniture utilization. This is the age range where many people strive to marry and have families of their own hence, house furniture becomes one of the basic necessity required of a good and responsible home, this concur with Belk, (1988) Furniture's' are also used to convey a person's identity, or a "family personality"..

Household size of the respondents was examined as an indicator of socio- economic characteristics with regards to furniture wood utilization; result revealed that 60% of the respondents had household size of 1-5, 28.3% of them 6-10 while, and 11.7% of them 11-15. From this result, it could be deduced that the use of wood furniture reduces with household size. This implies that, the higher the household size, the greater the responsibility and the lesser the individual interest in furniture except for the few financially buoyant families.

Educationally, 15% of the respondents had primary education, 68.3% of them had secondary education, 15. 0% of them were educated at tertiary education level while only 1.7% of the respondents had non-formal education. From the result, it could be observed that the highest percentage of the respondents were educated at secondary school level, hence they could communicate and make enquiry on the type and quality of wood to be used for different purpose, and whether wood durability could be enhanced or not. We can therefore infer from this study that education status have positive impact in the use of wood and the choice of wood for furniture in the study area. This result agrees with Kotler, (2009); Solomon, (2009) who reported that buying behavior of individuals is frequently unconsciously affected by some factors. One of these factors is social factors which are determined by their level of awareness and educational status.

Occupationally, results reveals that majority of the respondents 56.7% were furniture makers, 26.7% of them were traders, 8.3% of the respondents were civil servants 5.0% were farmers while tailors were least 1.7% of the respondents identified with respect to furniture wood utilization. From the results analyzed, it could be observed that furniture makers were the highest categories of respondents making choice of wood for furniture. This could be linked to their experience on wood utilization over the years or because they are the easily identified respondents with regards to wooden furniture. This result agrees with Belk, (1988) reported that variety of factors may persuade the buyer and customer to make the choice of wood for furniture.

Identified Tree Species Used for Furniture in Jama'a LGA, Kaduna State

That table 2 above, revealed total numbers of 30 tree species use for furniture in the study area, the identified plants were classified into twenty (20) families with their common names, frequency of utilization by the individual respondent and their percentages were also calculated. Results from table2 showed multiple responses, the percentage of individual responses to the use of the identified species are arranged in decreasing order as; *Eucalyptusbsp 12.05%≥ khaya senegalensis* 7.95%, *Gmelina arborea 6.41% ≥ Terminalia superb 5.90% ≥ , Milicia excel sa 5.13%, ≥ Ceiba petemdra 4.87% ≥ Vitex doniana 4.36% ≥ Triplochyton seleroxylong, Tectona grandis,, Vitellaria paradoxa and Ficus congensis respectively 3.59% ≥ Isoberlinia doka 3.33% ≥ Prosospis Africana 3.08% ≥ Pin*us *caribea 2.82% ≥ Nuclea diderrichii, Terminulia ivorensis, Adansonia digitata and Entanda Africana* represent 2.56% respectively ≥ *Parkia biglobosa and Erythrophylum spp 2.31% ≥ Antiaries afracana and Cola gigantia 2.05% ≥ Terminalia irvecinvidea and Ficus glumosus ≥ Anogeisus leocarpus 1.03% ≥ Cola acuminate 0.77% ≥ Anona senegalentis* which represented 0.51% of the choice wood in furniture making in the study area. The reason for the selection or choice of one species over the other may be due to one of these factors; durability, workability, strength properties, availability, appearance etc. This is consistence with Arowosoge *et al*. (2009) who submitted that the high preference for Mansonia among end users is the high value attached to its beautiful grains which are of varied colours.

Factors Responsible for the Choice of Wood Species for Furniture

Table 3 above shows the factors responsible for the choice of wood for furniture in the study area. The criteria for the choice of wood species for furniture were classified into two categories: Supporting factors and Militating factors:

The factors that support the choice of preferred wood species for furniture were identified. Multiple responses were given for these factors, majority of the respondents 19.60% identified availability as a major supporting factor responsible for the choice of wood species for furniture, 17.57% of them recognized appearance as a factor supporting choice of species. 13.51% identified durability and taste of such wood species by 9.46% of them; income was identified by 12.16% while 7.33% identified the type of products to be produced as a determinant of the choice of wood for achieving such production. From this result, majority (19.60%) of the responses favors availability; hence, we deduced that choice of wood for furniture is subject to availability. This result opposes previous studies in Jordan furniture who found that the most vital factors touching consumer's purchase of wood furniture are: quality, price, reference group, color, and family (Farah, 2013). Yoon and Cho (2009) also found that; type of wood, properties of wood, moisture content of the wood, purpose of utilization, colour, grains and rays arrangement, price and wood quality are potential factors influencing the consideration of wood for furniture.

Factors Militating against the Choice of preferred Wood Species for Furniture

Various factors militating against the choice of preferred wood species for furniture were identified in table3 above. Majority of the respondents (34.29%) acknowledged that price is a major factor militating against the choice of preferred species. More than ten percent (10.86%) identified inconsistent usage which could be due to scarcity of the preferred species coupled with high demand

and its high cost (price) in the market. Over twenty-one percent (21.71%) stated that lack of expert advice militate against the choice of some species of wood for furniture, (26.29%) attributed income as one of the factors militating against the choice of preferred wood for furniture making. Higher income enhances the choice of preferred species and vise versa, since most of the preferred species are known to be more expensive. We deduce from this result that price is one of the major factors militating against the choice of preferred wood species for furniture in the study Area. This is in consonance with Ganz, (2000) who said that increasing price of good quality timber species has led to increase in the demand for less quality timber species. Adeyoju and Enabor (1995), reported that price of wood species kept rising geometrically over the years both within producing and consuming areas.

Factors Militating against the Choice of Lesser used Species

Table 4 above shows the eight (8) factors militating against the choice of lesser used species of wood for furniture. From the table, (19.67%) of the respondents specified that expert advice does not favor lesser used species. Over seventeen percent (17.21%) specified poor quality. Close to thirty percent (20.90%) of identified less durability, 7.79% were of the opinion that quality of the furniture desired by individual consumers and high quality furniture is a function of good quality wood. While 7.38% of them stated poor appearance of LUS limit it use for furniture. More than six percent (6.97%) identified high cost of treatment especially in a situation where cost differences of using the preferred species is not significant. 2.87% of specified presence of defect on lesser wood species. From the analysis, majority of the specified that the major militating factor against the use of LUS is the less durable nature of these categories of wood. previous study have found that the most important factors affecting consumer's purchase in Jordan furniture consists of quality, price, color, appearance and most important wood durability (Farah, 2013).

Conclusion

This finding make available evidences that; availability, durability, appearance, wood price, wood grain and rays arrangement play vital role influencing consumers' choice of wood for furniture. Most consumers depend on furniture manufacturers their choices of furniture wood and that wooden furniture manufacturers understand the tree species that have suitable properties and appealing appearance which are major determinants of customer's choice of wooden furniture.

Recommendations

Scientist should intensify efforts towards enhancing the utilization potentials of lesser used species using inexpensive locally made preservatives. Also, massive afforestation of the users' choice species should be considered paramount in the study area.

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PRELIMINARY STUDY ON DRYING CHARACTERISTICS OF END-COATED *Brachystegia eurycoma* BOARDS SEASONED UNDER AIR -AND SOLAR KILN DRYING ENVIRONMENT

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ABSTRACT
Board end-coating is known to control checking which reduce wood drying quality. Information on drying characteristics of end-coated *Brachystegia eurycoma* boards is limited. End-coating of *Brachystegia eurycoma* towards improving its drying quality was investigated. The experiment was conducted at the Forestry Research Institute of Nigeria, Ibadan. Corewood (25mm x 300mm x 2125mm) were sampled from base of a 45year old *Brachystegia eurycoma* log and end-coated with paint to prevent moisture loss prior to air drying (AD) and solar kiln drying (SKD). Twenty-four flatsawn boards (25mm x 300mm x 1800mm) were processed. Boards' initial moisture content was determined. Samples were grouped into three: 8 paint end-coated (PEC), 8 wax end-coated (WEC) and 8 control (CON). Four boards each were seasoned in AD and SKD for 28 days. Final moisture content-FMC (%) and drying rate-DR (%/day) were calculated. Checks were evaluated according to standard procedures. Temperature-T°C and relative humidity-RH% of AD and SKD were measured. The study was a 3x2 factorial experiment in a Randomised Complete Block Design. Data were analysed using descriptive statistics and ANOVA ($p \geq 0.05$). The FMC was least (SKD=9.25 and AD=15.70) in CON and highest (SKD=12.01 and AD=30.49) in WEC. The DR of CON (6.25%/day) and WEC (5.62%/day) were significant different. Percentage of checked boards was highest (100% and 50%) in CON and least (25% and 0%) in PEC for AD and SKD, respectively. Average temperature and relative humidity were 32.75°C and 80.25% in AD and 47.48°C and 57.75% in SKD. End-coating boards with paint produced best drying quality.

Keywords: Boards, temperature, relative humidity, solar kiln and control

INTRODUCTION

Wood is a versatile renewable natural resource. From time immemorial, wood has been used for manufacture of several viable products in domestic and industrial applications (Elder *et al*., 2021). Due to its hygroscopic nature, wood absorbs or desorbs moisture in relation to amount of moisture in its prevailing environment. Upon its exposure to influence of changes in environmental moisture, wood becomes dimensionally unstable in service. Consequently, in order to improve the dimensional stability of wood used in many desired applications, it is imperative to dry or season timber prior to its utilization (Broda *et al*., 2021).Wood drying is one of the major processes involved in wood products manufacture. It is an important aspect of production which affects performance of the resultant wood products. Drying influences wood workability, finishing, treatability and service life. More so, wood becomes less susceptible to the influence of environmental fluctuations which makes it dimensionally unstable in service (Amoo-Onidundu, 2019; Broda *et al*., 2021).

According to Redman *et al*. (2016) the process of wood drying is complex and requires adequate knowledge regarding moisture movement mechanism as it influences the drying outcomes. During drying, the external layers of wood dry more rapidly than the internal ones. The moment moisture in the outer parts dries below the fibre saturation point which is between 25%-30% moisture content, wood starts to shrink. Hence, because the inner layers still remains saturated, shrinkage in external areas becomes uneven. This phenomenon generates stresses in wood. Consequently, the moment stresses in wood exceeds the mechanical strength of the material, it starts to crack and split (Bond and Espinoza, 2016). The type of drying degrade which develops in wood is dependent on wood anisotropic properties and mode of moisture loss at boards surfaces and ends. Defects may result from shrinkage anisotropy, resulting into warping: cupping, bowing, twisting, crooking, spring and diamonding. More so, uneven drying stresses causes rupture of the wood tissue leading to defects such as checks (end, surface or internal), honey combing and case hardening (Hoadley, 2000). Defects caused by wood anisotropic nature are basically connected to wood property such as features such as low density, high knot volume, high spiral grain, large microfibril angle, high longitudinal shrinkage and compression wood. Defects caused by uneven drying stresses may be caused by improper drying techniques, in appropriate drying methods, exposure to unfavorable environmental condition and so on (Bond and Espinoza, 2016).

Researchers are identifying effects of wood properties and drying practices on wood drying quality. Consequently, studies are conducted to develop measures towards reducing incidences of wood drying degrade and improving drying quality (Pinchevska *et al*., 2016). One of such procedures through which defects can be reduced is end-coating treatment on boards. End-coating is the used of pigments, paints, wax, oil, varnish or other substances such as commercial green wood sealers for coating end of boards to control drying processes in order to reduce or prevent defects formation on wood. It has been observed that excessive drying out of water from ends of board can be controlled through end-coating (Armousegar, 2010). Reports revealed that end-coated lumber were less susceptible to end checks and had improved drying quality (Rowell, 2006).

Brachystegia eurycoma is an evergreen tree with a dense, spreading crown; it can grow up to 36 metres tall. The tree is harvested from the wild for its wood, which is used locally and also exported. The texture is medium to coarse; the grain usually deeply interlocked, producing a pronounced roe figure; the wood is also characterized by high lustrous property. Traditionally, the bark has been used to make a coarse cloth used as protection against rain and as a shield against arrows. The heartwood of *Brachystegia eurycoma* is pinkish brown with vague bands and rather distant fine streaks, it is clearly demarcated from the whitish sapwood, wood grain is usually interlocked and the texture is medium. The heartwood is rated as moderately durable. The wood dries rather slowly, with a marked tendency to check and warp. However, upon drying, it becomes fairly stable in service. The wood of *Brachystegia eurycoma* is suitable for flooring, interior trim, interior carpentry, stairs, veneer and plywood (Femi-Ola, 2008).

Materials and Methods

Materials, tools and equipment used for the experiment

Wood samples of *B. eurycoma*, weighing balance, oven, solar kiln, air drying shed, gloss aluminum paint, wax, record book, thermo-hygrometer, marker, biro, stickers, measuring tape, flat table.

Study area

The experiment was carried out at the Forestry Research Institute of Nigeria (FRIN) Ibadan, located on latitude 7°23'15" to 7°24'00" N and longitude 3°51'00" to 3°52'15"E. Annually, the average temperature of FRIN ranges between 18.07˚C and 34.4˚C (for minimum and maximum value respectively). According to Ariwaodo *et al.* (2012) the study area is characterised by two seasons which are distinctly different: The rainy season (which begins in April and end in October) and the dry season (which starts in November and ends in March). A distinct harmattan often characterises the dry season in December.

Timber procurement and preparation of Wood Samples

Timber conversion processes was carried out at the wood workshop, and wood drying experiments (air and solar kiln) were set up at the Department of Forest Products Development and Utilisation, FRIN. Tree of *B. eurycoma* was harvested and corewood was sampled from diameter at breast height of the log. The wood samples (25mm x 300mm x 2125mm) were end-coated with paint to prevent moisture loss prior to drying experiment.

Preparation of oven dry samples for determination of initial moisture content (IMC)

According to FPRL (1999), test samples (25mm x 25mm x 300mm) were obtained at 300 mm away from boards' ends. Initial weight (W1) of samples was measured. Test samples were oven-dried at temperature of 103±2˚C until constant weight (W2) was obtained. The IMC was calculated as shown in Equation 1.

$$IMC = \frac{W1-W2}{W2} X100 \quad \ldots\ldots 1$$

Where:

IMC= Initial moisture Content

$W1$= wet weight of wood

$W2$ =oven dry weight of wood

Dimensioning of sample boards

Twenty-four sample boards were dimensioned into 25mm x 300mm x 1800mm. Equal number of boards (8 samples each) were grouped into three classes: 8 boards were end-coated with paint, 8 boards were end-coated with wax while 8 boards were uncoated (control). Four samples from each group were prepared for air- and solar kiln drying experiments.

Stacking of boards under the air drying shed or in the solar kiln.

Wet weight of boards (WWB) were measured on a sensitive weighing balance. Equal pieces of boards were stacked under the shed (air drying method) and in solar kiln (artificial drying method) with sticker (25mm x 25mm x 300mm) separating alternate boards.

Periodic moisture content

Periodic moisture content is a measure of the amount of water contained in wood and is expressed as a percentage of its oven dry weight. The periodic moisture content of boards was determined using equation 2 according to FPRL (1999) and Timber Queensland (2014).

$$PMC\ (\%) = \frac{CWB-DWB}{DWB}\ X\ 100 \quad \ldots\ldots 2$$

Where:

PMC = Periodic moisture content
CWB = Current weight of board

DWB = Dry weight of board

$$DWB = \frac{WWB}{\frac{IMC}{100}+1} \quad \text{……………………………………………………………… 3}$$

Where:
WWB = Wet weight of board
IMC = Initial Moisture content

Drying rate (DR-%/day)

The drying rates of the wood samples were determined according to FPRL (1999) and calculated using equation 4. The rate of drying was determined on a weekly basis. The drying experiment progressed until wood reaches its equilibrium moisture content (EMC). After 28 days (4 weeks), the average daily DR was calculated.

$$DR = \frac{PMC - CMC}{Time\ (days)} \quad \text{………………………………………………4}$$

DR=Drying rate
PMC= Previous moisture content
FMC= Current moisture content

Measurement of environmental conditions (Temperature-T°C and relative humidity-RH%)

Digital thermo-hygrometers were positioned inside the kiln and under the air drying shed for measurement of environmental condition (T and RH). Readings were taken 10 times daily (between 8:00 am to 5:00 pm) at interval of 1 hour. Measurements of T and RH at the selected period of time is a modification of climatic data capturing system in meteorological information (KNMI, 2000, GLOBE, 2005). Average of daily readings was calculated for weekly evaluation. Overall average of T and RH was calculated after 28 days of drying.

Experimental design

The experimental design adopted was a 3 x 2 factorial experiment in a Randomized Complete block Design (RCBD). Data obtained was subjected to analysis of variance (ANOVA) for significant difference that exist between the drying rate of end-coated boards and control while comparison of means were conducted using Least Significance Difference (LSD) to separate means that are different from one another.

Assessment of Checks

Checks were measured on end-coated and uncoated boards and evaluated according to Rasaily (1993). The planks were placed on flat table and checks were measured using measuring tape.

Results and Discussion

Table 1: The FMC (%) of end-coated and uncoated *Brachystegia eurycoma* wood

End-coat	FMC of boards	
Treatment	Solar	Air
Control	9.25	15.70
Paint	11.49	16.24
Wax	12.01	30.49

FMC represents Final moisture content

Final moisture content (FMC) of end-coated and uncoated *Brachystegia eurycoma* wood was presented in Table 1. Results revealed that FMC of Control, wax-coated and paint-coated boards under solar- and air-drying environments differed considerably. The FMC for solar kiln-dried boards were 9.25%, 11.49% and 12.01% in control, paint-coated and wax-coated boards, respectively. This indicated that moisture migration was highest in Control and least in wax-coated samples. However, due to the fact that FMC of Control (9.25%), paint-coated (11.49) wax-coated (12.01%) boards reached equilibrium moisture content-EMC (12-15%) as stated by TRADA Technology (2011), both end-coated and uncoated solar kiln-dried samples dried to recommended moisture content for applications such as internal joinery in conformity with BS EN 942-2007.

In air-dried samples, the FMC were 15.70%, 16.24% and 30.49% for Control, paint-coated and wax-coated boards, respectively. This implied that moisture loss in wood was highest in Control and lowest in wax-coated. Control (15.70%) attained the range of EMC (12-15%) while paint-coated (16.24%) and wax-coated (30.49%) boards did not. This may mean that the paint and wax pigments used for end coating of boards sealed the fibres pores and reduced the moisture flow to the wood surface. This is in conformity with Haygreen and Bowyer (1989) and Armousegar (2010) that moisture movement from ends of wood is influenced by the type of end coating pigment applied on timber.

With reference to recommended EMC of 12-15%, a comparative study on FMC of control, paint coated-and wax coated boards in SKD and AD environment revealed that solar kiln-dried boards attained lower FMC compared to AD. This indicates better final moisture content compared to AD. The observation is in line with Amoo-Onidundu (2019) and Broda *et al*. (2021) that SKD-dried boards had lower final moisture content.

Table 2: Analysis of variance (ANOVA) for FMC of end-coated and uncoated boards

SV	df	SS	MSS	F	Sig
End coating treatment (ECT)	2	1364.49	6.82.22	1084.50	0.004*
Drying method (DM)	1	1066.13	106.13	99.67	0.003*
ECT*DM	2	367.62	183.81	62.17	0.002*
Error	18	137740.80	7652.27		
Total	23	140539.11			

*value significant at $p \leq 0.05$

ANOVA for FMC of boards was presented in Table 2. Results revealed that effect of end-coating treatment and drying method were statistically significant on FMC of boards at $p \leq 0.05$. More so, effect of interaction between end coating and drying method was significant on FMC. The follow-up test for separating FMC (Table 3) revealed that FMC of Control (24.95) and paint end-coated (27.73) boards were same. However, they were not same with wax end-coated samples (42.56). This implied that end coating of *Brachystegia eurycoma* boards with wax did not have that same influence on moisture flow like paint coating and Control.

Table 3: The follow-up test for separating FMC

End-coating Treatment	FMC (%)
Control	24.95a
Paint	27.73a
Wax	42.56b

Values with same letters are statistically the same

Table 4: Drying rates (%/days) for Control, Paint-coated and wax-coated boards

End-coat Treatment	DR of boards	
	Solar	Air
Control	3.24	3.01
Paint	3.16	2.99
Wax	3.14	2.48

Drying rate for Control, Paint-coated and wax-coated boards is presented in Table 4. Results revealed that drying rate of solar kiln-dried boards were 3.24%, 3.16% and 3.14% for Control, paint-coated and wax-coated, respectively. Highest (3.24%) and least (3.14%) DR values in Control and wax coated samples, respectively, indicates that rate of moisture movement from *Brachystegia eurycoma* boards was highest in uncoated boards and least in wax coated. This may mean that moisture movement was slowed down by coating pigments which blocked fibre pores at boards' ends thereby reducing the rate of moisture flow to the surface. The observation agrees with Armousegar (2010) that end coating reduces moisture loss at boards' end.

The DR of air-dried boards were 3.01%, 2.99% and 2.48 for Control, paint-coated and wax-coated, respectively. Highest (3.01%) and least (2.48%) DR value in control and wax coated samples, respectively indicates that rate of moisture movement from *Brachystegia eurycoma* boards was highest in uncoated boards and least in wax coated. This may mean that wax coating pigments caused highest degree of blockage in fibre pores which are responsible for moisture flow in wood. Hence, drying rate in wax-coated *Brachystegia eurycoma* boards was least.

The DR in solar kiln drying was higher than in air-drying for coated and uncoated boards. This may mean that higher temperature and lower relative humidity in solar kiln chamber- compared to air drying shed (Table 7) favoured the rate of moisture loss in SKD. This is in line with Broda *et al*. (2021) that solar kiln drying environment favours wood drying better than air drying condition.

Table 5: ANOVA for drying rate of of end-coated and uncoated boards

SV	df	SS	MSS	F	Sig
End coating	2	1728.12	864.06	6.88	0.02*
Drying method	1	367.62	367.62	2.93	0.03*
End coat*drying mtd	2	6.13	3.06	0.02	0.04*
Error	18	2260.19	125.57		
Total	23	4362.06			

Ns=not significant

Table 6: The follow-up test for separating drying rate

End-coat Treatment	DR (%/day)
Control	6.25a
Paint	6.15a
Wax	5.62b

Values with same letters are statistically the same

The ANOVA for drying rate of end-coated and uncoated boards was presented in Table 5. Results revealed that effect of treatment (Control, Paint-coated and wax-coated boards) is statistically significant on drying rate of *Brachystegia eurycoma* boards. This implied that Control, paint end-coated and wax end-coated boards dried at significantly different drying rates. The follow-up test (Table 6) revealed that DR of Control (6.25) and paint end-coated samples (6.15) were same, while DR of wax end-coated samples (5.62) was different. This implied that untreated and paint end-coated *B. eurycoma* boards responded to drying (moisture flow) at a similar rate while wax end-coated boards responded to drying at dissimilar rate.

Table 6: Drying defects (checks) on end coated and uncoated *Brachystegia eurycoma* boards

End-coating treatment	Drying method	Total number of boards	Severity of defects			No. of defected boards	% of defected boards
			Mild	Moderate	Severe		
Control	Solar kiln	4	1	1		2	50
	Air drying	4	1	1	2	4	100
Paint end-coated	Solar kiln	4	-	-	-	-	0
	Air drying	4	1			1	25
Wax end-coated	Solar kiln	4	1			1	25
	Air drying	4	1	1	1	3	75

Number of defected boards was evaluated as a percentage of total boards

Drying defects/checks on end-coated and uncoated *Brachystegia eurycoma* boards was presented in Table 6. Results revealed that in Control (samples with uncoated ends), the percentage of boards that developed end checks were 50% and 100% for solar kiln drying and air drying, respectively. On the contrary, 0% and 25% of boards end-coated with paints developed end checks while 25% and 75% of boards end-coated with wax developed end checks in solar kiln-dried and air-dried boards, respectively. It was observed that out of the two categories (end-coated and uncoated boards), end-coated samples performed better in terms of lower percentage of boards with defect formation.

Despite that fact that uncoated *Brachystegia eurycoma* boards attained least FMC (Table 1) with highest DR (Table 4), percentage of boards with check formation was highest. This may mean that the rate of moisture movement from boards with uncoated ends was too high leading to tearing apart of fibres which caused end checks. This is in line with the submission of Filippou *et al*. (2017) that too high rate of moisture loss from boards' ends causes end checks. Considering the results (in relation to defect formation), it could be observed that the drying quality in Control (uncoated boards) is lower compared to end-coated *Brachystegia eurycoma* samples.

A comparative study on response of samples (in terms of defect development) to environmental conditions revealed that solar kiln-dried samples performed better than air dried. This may mean that heat energy distributed within that solar kiln chamber enhanced a more controlled and gradual moisture movement from boards' ends. Hence, drying stresses which causes checks development on wood were regulated. This corroborates Filippou *et al*. (2017) that environmental conditions in solar kiln chambers enhances reduction in timber checks, compared to air drying.

Table 7: Weekly average of daily T and RH

Weeks	Temperature (°C)		Relative Humidity (%)	
	SKD	AD	SKD	AD
Week 1	44.30	30.00	70.90	91.60
Week 2	46.50	32.00	65.10	87.70
Week 3	48.52	33.40	50.90	73.80
Week 4	50.58	35.60	44.10	67.90
Overall average	**47.48**	**32.75**	**57.75**	**80.25**

SKD= Solar kiln; AD= Air drying

Table 7 revealed that average T°C were 47.48 and 32.75 while RH were 57.75 and 80.25 for SKD and AD, respectively. Highest and least T°C in SKD were 50.58 and 44.30 while highest and least RH in AD were 30.00 and 44.10. Least and highest relative humidity (RH%) were 44.10; 70.90 and 67.90; 91.60 for SKD and AD, respectively. The variability in temperature and relative humidity might have been responsible for variations observed in the drying characteristics of end-coated *brachystegia eurycoma* boards seasoned under air -and solar kiln drying environment. Higher temperature and lower relative humidity in SKD could have been responsible for better drying performance which resulted into improved drying characteristics in SKD (Table 1 and Table 4), compared to ADS. This corroborates Filippou *et al*. (2017) that wood drying characteristics is influenced by environmental condition.

CONCLUSION

This study has provided relevant information on effects of end-coating on selected drying characteristics of *Brachystegia eurycoma* such as final moisture content, drying rate and drying defects- which were used as indices for drying quality evaluation. Although, drying rate of Control was higher when compared to treated samples, it was observed that moisture migration from surface of paint- and wax-coated *Brachystegia eurycoma* boards was better controlled. This was evident in terms of lower percentage of defects (end-checked) in end-coated boards and higher percentage of defects in uncoated *Brachystegia eurycoma* wood. It was observed that environmental condition influences final moisture content, drying rate and checking.

Drying of *Brachystegia eurycoma* wood in solar kiln suggested that the drying rate of the species can be increased without causing severe degrade (checks) to boards. Increase in the drying rate of a slow drying species such as *Brachystegia eurycoma*, could be a viable means of improving drying properties and optimizing utilization potentials in the wood industries. More so, drying quality of *Brachystegia eurycoma* could be enhanced under favourable drying condition such as a solar kiln drying environment.

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SUB-THEME 5

ECOTOURISM AND WILDLIFE MANAGEMENT AMIDST INSECURITY AND GLOBAL PANDEMIC

ECOTOURISM AND WILDLIFE MANAGEMENT AMIDST INSECURITY AND GLOBAL PANDEMIC

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Thought*: Ecotourism involves the marketing of wildlife resources, ecological, geomorphological and cultural features of a destination in order to aid sustainable use of these features.*

INTRODUCTION

Tourism in the general perspective is the act of practice of travelling temporarily out of one's place of abode for more than 24 hours to destinations outside the home and workplace to do activities and use facilities at destination visited to meet ones need of leisure and recreation (Geoffrey Alister, 2006; Mathieson and Wall, 2002) Ecotourism in specific terms involves visiting natural sites not grossly altered by human activity or intervention (Newsome, Moore and Dowling, 2002; Reynolds & Braithwaite, 2001).

Wildlife management is the "active manipulation of wild animals and their habitat for the benefit of humankind". It is an art and science (Agbelusi, 2009). It is the management process influencing interaction among and between wildlife, its habitats and people to achieve some pre-defined goals. Wildlife management is an interdisciplinary approach that deals with protecting threatened species, subspecies and their habitats. It applies to some agricultural animals and game animals. The bases of management is often ecological principles such as population and habitat control (Ogunjemite, 2017). These two in one mobile discipline are currently faced with challenges of insecurity and pandemic in Nigeria.

The twin brothers confronting economic activities, including ecotourism all over the world today, are Insecurity and the Corona Virus Pandemic (COVID-19 Both are working to cripple economic activities across the globe, particularly in the third world. These pairs are more impactful on ecotourism, which has now occupied the space of marketing wildlife resources. The third world, the developing country or emerging economies, as it may be referred to, are the hubs of ecotourism development. Although, it appears the more advanced nations are the epicenters of Corona Virus Pandemic, these are the people directly involved as tourists to the ecotourism destinations in the developing nations and without them, it is impossible to generate the much-needed economic activities at the destinations. It is also known that most of the destination are found within the Food-in-secured Regions of the world which most often are prone to conflicts and therefore corresponding with the areas of high risk of insecurity (FAO, 2022).

ECOLOGICAL TOURISM / ECOTOURISM

Ecotourism resources

Ecotourism resources include a variety of plants and animals within the human environment (Conservation International, 2001). The ecological destination of an ecotourism site has ecological values, which are those natural resources that exist in the environment and are relatively undisturbed by man (Ezealor, 2002; Fadipe, 2014). An ecological destination is thus characterized by biodiversity within the various ecosystems. Biodiversity comprises those living things include all habitats, ecosystem and species, the physical environment such as beaches, rivers, oceans, mountains, caves, forests, grassland and wetland among others (Kolawole, 2019). These living components are referred to as the wildlife resources.

The term Ecotourism, had been subjected to some controversy. It is believed to be originally coined by Hector Cellabos Lascurain, an environmentalist from Mexico in 1987 Ceballos-Lascurain (1993). It has now gained a wide usage. Ecotourism is defined as travelling to relatively undisturbed or uncontaminated natural areas with the specific objective of studying, admiring and enjoying the scenery and its wild plants and animals, as well as any existing cultural manifestations. Human society is becoming more ecologically mindful thus, nature-based travel is growing and the term ecotourism attaining wider acceptability. More ecologically minded, responses to nature-based travel opportunities grew and the term ecotourism was evolved strengthened and widely accepted (Diamanlis 1999; Honey, 1999; Weaver, 2005).

At the dawn of this century, ecotourism emerges as a rapidly growing subsector of human endeavor (Cousins, *et al.*, 2009) until diseases at epidemic and pandemic proportions suddenly emerged (Ogunjemite, 2017). Local communities were benefiting through revenue generation and employment opportunities in ecotourism (Ijeomah and Eniang, 2018, Ijeomah, *et al*., 2015). Wildlife resources that are the bedrock of this initiative were receiving increasing attention (Okekedunu *et al*., 2014; Okello and Wishitemi, 2006).

The concepts of ecotourism

Ziffer (1989) is one of the earliest authorities to introduce the idea of benefits and perceived cost to the definition of ecotourism. The concept as proposed could be viewed as placing an economic value on ecological features for the benefits of humanity. It has been observed from many locations in Africa, for example, the Obudu Northern Cross River Area (Ijeomah and Eniang 2018), the Okovango Basin of Namibia, the Swadini Resort of Limpopo Division of South Africa that Ecotourism might not enjoy local support without derivable benefits to the support zone populace. So many of these locations have alternative uses to which, if financial benefits are not involved, ecotourism might have not thrived. Fennel (2005) brings in the concepts of sustainability. This is the concept that made many of the die-heart preservationist to accept ecotourism as developmental factors in conservation parlance. Ecotourism implies some scientific, esthetic, or philosophical approach. This concept is now exploited by protected area mangers in Park Management across the globe toward their development. It is not only applicable to *In situ* but to an *Ex-situ* management of the Botanical Garden (Adedayo *et al.*, 2021) and Zoological Gardens (Adetola *et al*., 2014). According to the World Travel and Tourism Council (2019), tourism must be environmentally compatible with activities of the tourists, especially in situations where the environment is the attraction and main motive for tourists visit to a destination.

Ecotourism is practiced throughout the world. However, Ecotourism destinations are restricted to some few specific protected natural areas within specific geographical regions thus we have the East Africa Destinations of Kenya, Tanzania and Uganda, The Great Carryon of Colorado valley in USA, the Great Lake of Canada, the Montanes of Nepal in South East Asia as different packages to mention but a few. There are different areas of attraction that serves as local hubs in each of these larger regions. Ecotourism has grown in influence and importance on man's understanding of his environment and the role he plays in its improvement or demise (UNWTO, 2015). Ecotourism is a nature-based travel that involves education on interpreting the natural environment, as it is ecologically sustainable (Mchunu and Hlengwa, 2018; Kiper, 2013). In this definition, we recognize that the natural environment also includes cultural components. Thus, ecological sustainability involves an appropriate return to the local community for long-term conservation of the resources (Adejumo *et al*., 2014; Hughes, and Warin, 2005). Ecotourism is to provide tourists with new knowledge about a certain natural area and the culture that is found within, along a little adventure. It is to help improve the local economy and conservation efforts and to help gain new appreciation for nature and people and to allow more in-depth tours and educational opportunities.

Ecological destination and natural sensitive sites

For any site or location to be designated as an ecotourism destination, the natural landscape must be relatively without interruption for people to study, enjoy, and admire (Olaniyi, 2017). The scenery and its wild animals and plants must be in their natural state. Nature-based tourism considers the natural ecological attraction, their conservation and development (Ogunjemite et al., 2016; Schaller, 2010; Stankov *et al*., 2011). Sustainable nature-based tourism is aimed at safeguarding the main aim is to safeguard the environment, making it beneficial to local people by generating revenue and educating and serving the pleasure of the tourists. Particularly as several communities in developing countries still engage in traditional methods of farming, consequently facing land use constraints (Buba, 2013; Egbe and Vange, 2008). The rising prices of petroleum products, especially cooking gas and kerosene, have encouraged both rural and urban households to rely on fuel wood and charcoal as their main sources of energy (Jayeola *et al*., 2009), leading to further impact on ecotourism sites in Nigeria.

Ecotourism destination, particularly the physical environment, is vulnerable to human pressures caused by the burgeoning population and intensive economic activities (Fabricius *et al*., 2007; Williams and Ponsford, 2009). These resources are often overexploited by men in their search for livelihood and comfort. This is clear in the activities of poachers, hikers and others who destroy the flora and fauna resources of the environment.

WILDLIFE

Wildlife are animals that have not been domesticated or tamed and are living in their natural environment, including game and non-game animals. Most often, they are vertebrate animals hunted by human. Wildlife are living things and especially mammals, birds and fishes that are not human and domesticated. Wildlife management is the harmonization of related knowledge and policies for the conservation of wildlife within and outside protected area.

Although, it appears there is no clear taxonomic or behavioural boundary definition of wildlife. In view of this, it is not surprising that the debate is continuous so long and from different perspectives of the related disciplines and the body of knowledge involved in wildlife management. In their natural habitat, wildlife embraces all vertebrate animals.

WILDLIFE MANAGEMENT

Wildlife management is the "active manipulation of wild animals and their habitat for the benefit of humankind". They are living resource that will die and be replaced by others of their kind. According to Agbelusi (2009), wildlife can be defined simply as "Native plants and animals in their natural environment" or "Wild terrestrial and aquatic vertebrates and plants (i.e., all non-cultivated plants and non-domesticated animals. They are key component of natural resources known as renewable natural resources. They are potentially inexhaustible if properly managed. Examples include forests, rangeland and water sources, unlike the non-renewable resources, which are exhaustible and finite. After use they cannot replenish themselves, e.g. gold, petroleum, diamond, etc.

Based on our discussion in relation to ecotourism, wildlife will be viewed as animals; vertebrates, which include mammals, birds, reptiles, amphibians and fishes that had not been domesticated or are in domestication but attract human curiosity and are hunted by man as game and for their trophy. They may be found in the protected areas or outside them. However, they are commonly encountered in the PAs today. Agbelusi (2009) provided their list of their status as shown in Table 1

Perspectives of Wildlife Management

The East African wildlife perspective sees Wildlife Management as harmonizing of the polices on the different component of wildlife resources for their conservation within and outside the protected area. There are different areas of management; the habitat, which is the range, mammalian composition, the arboreal components; birds and the aquatic and wetland components. It is the wildlife manager that sees how best these components are synergized to achieve the overall goal of conservation and ecotourism.

In America, the North American model of Wildlife Management supports the notion that wildlife is a public trust, an American birthright and that wildlife populations must be sustained forever. Today there are strict prohibition of any form of exploitation of some wildlife resources. Their management of wildlife resources carries some legal implications. In the South America's parlance, wildlife are biological diversities and the profession of wildlife management had largely been overshadowed by biodiversity conservation with much of biological sciences inclination. It should be borne in mind that ecotourism originated from the region in response to safeguarding the resources.

In the West African subregion, wildlife policies started with the inherent consumption tendencies embedded, and consequently domestication had been one key area in wildlife management in the subregion. Nevertheless, this has not mitigated the level of wild exploitation of these resources. Even though these policies are giving way in many of the countries around Nigeria, from across Liberia, Ivory Coast, Ghana, Togo Benin over Nigeria to Cameroon. Here in Nigeria, we have held tenaciously to this and much of our wild sources had been depleted. There had been cases of some of these animals extinct in the wild environment of Nigeria. Examples include Rhino, *Procolobus verus* and many others.

A good number of the large bodied game animals are rare or endangered in their Nigerian range. Most times, some of these species are listed as data deficient in several international criteria. This is clear inditement to wildlife professionals in Nigeria. This is so because many of us are "Jack of All Trades and master of non" With the array of this resource found in Nigeria (limited to the groups call wildlife in our definition) wildlife profile, no single individual could claim overall authority of the groups referred to as wildlife. While it will be acceptable to have clear authorities in such areas as Ornithology, Primatology, Herpetology, Fisheries, Anura species studies, Habitat Management, Domestication, Policy and administration, Wildlife Biometric, Wildlife genetics, etc, it will be impossible to convince the outside world that one is a specialist in all these areas combined. These are the bane of Wildlife Management in Nigeria. It is high time we see wildlife studies as in Education Discipline where the general principles are thought and specific areas are attached, e.g., Education (Geography), Education (Economics) and so on and so forth.

History of Wildlife and ecotourism development in Nigeria

The Wildlife Management as a profession serves as the impetus to Ecotourism Development in Nigeria. The development of Wildlife in Nigeria can be traced back to 1889, the beginning if its parent department, when the colonial government took steps to establish the first forest reserve in the colony of Lagos. Since then, the number of protected areas in Nigeria has increased and expanded to include Forest Reserves, Wildlife Sanctuaries, Game Reserves, Strict Nature Reserves, Communal Forest and National Park. The establishment of these protected areas at any point in time came as a response to an adverse trend, especially within the last 80 years, when environmental degradation set in.

The foremost protected area specifically earmarked and developed for ecotourism in Nigeria is the Yankari Game Reserve, which was later upgraded to National Park status in 1991. Formerly known as the Yankari Forest Reserve, it was converted to a game reserve in 1956. By 1962, Yankari Game Reserve had opened to public visitation and enjoyment. In 1963, this was followed by Borgu Forest Reserve, which was later converted to Game Reserve in 1976, and later to the status of a National Park; Kanji Lake National Park, the first in Nigeria in 1979. In curriculum development, Ecotourism and Wildlife Management was first developed as discipline at the Federal University of Technology, Akure in the year 2008. This is in the quest to find an alternative attractive model for the Wildlife Management to thrive when admission for the course was becoming unpopular and it appears the course might go into extinction. The fisheries component to which the course had been traditionally married to from the Nigeria premier university: University of Ibadan was the next to follow. Wildlife Management still exists in many Nigerian institutions in collaboration with main disciplines, such as Forestry and Environmental Management. The FUTA experiment has brought about a significant growth in students' enrolment now in hundreds and widens job opportunity. It is therefore not out of point to state categorically that ecotourism is assisting in the marketing of Wildlife Resources. It is a welcome initiative that the Forests and Forest Society of Nigeria recognized Ecotourism and Wildlife Management as an important component of their endeavor, and it is hoped that this recognition will remain.

INSECURITY AS IT AFFECTS ECOTOURISM AND WILDLIFE MANAGEMENT IN NIGERIA

Conflicts leading to insecurity had been on the increase all over the world. Conflict resolution is now a well-developed discipline in human endeavor and it is now being incorporated in education curriculum at all levels of learning. In Nigeria, insecurity has assumed a worrisome trend affecting all areas of national life (Odeku, 2020; Okoli and Agada, 2014). Virtually all the protected areas in Nigeria's drier environment had been taken up by insurgency and banditry as their abode.

Causes of Insecurity in Nigeria

Rising poverty, inequality, and inadequacy of employment opportunities, particularly among the youth, had been the fuel to Nigeria's insecurity problem. These has coincided with rising level of poverty among the populace, reaching an estimated 83 million people standing at about 39% of the country population, living in extreme poverty (less than $2 per day) as at April 2022 (Economic Newsletter, 2022). This is a significant 18% increase from 70 million people recorded in 2016. The increasing level of insecurity in Nigeria has reach a crescendo whereby investor confidence is negative and no foreigner is ready to take a risk of coming to our country talk less of making direct investment (FDI) inflows. Ecotourism which is an emerging market to improve Nigeria Economics has therefore, suffered a downward trend. It's ascertained that Nigeria recorded $699 million (*National Bureau of Statistics)* in FDI inflows in 2021, representing the lowest level since 2013.
The country's level of insecurity, and the implication for business activity thus, heightened uncertainty and instability, hindering business operations including ecotourism. In many cases, the country's security situation has resulted in the suspension of commercial operations and expansion plans, thereby increasing unemployment and poverty levels. The Nigerian National Parks and Game Reserves which either to should serve as the hubs of country Ecotourism enterprise are no go areas any longer as a result of this scenario. Taken for instance locations such as Kanji Lake National Park (Table 2 and 4) and Gashaka-Gumti National Parks that have been attracting foreign tourists (Adetola, 2014, Ogunjemite *et al*., 2012 and 2014) are today theater of banditry, insurgencies and kidnapping with serious casualties among the protection staff of the Parks

Figure 1: Nigeria's Insecurity Map

Source: Africa Center for Strategic Studies

PANDEMIC
Diseases out brake had always been a serious impediment to economic growth. No wonder it is accepted that health is wealth. Ecotourism has yielded dividends to Conservation and Nigeria when the COVID 19 Pandemic struck. So many designated ecotourism sites particularly the National Parks, Conservation Centre like Lekki, spectacular sites as the Ado Awaye Suspended Lake, Ikogosi Warm Spring, Owu Waterfall and so many others were already making significant contribution to the local economy of their host communities and consequently the Nation at large. Even in *ex-situ* conservation sites such as Zoological Gardens, Wildlife Park and Botanical gardens and Horticultural gardens, ecotourism was already making waves and becoming an acceptable means of recreation. The economic incentive of ecotourism as a non-consumptive use of wildlife

resources was outweighing the consumptive uses, contributing to conservation (Lorimar, 2009 and Bruyere, *et al.*, 2009). Suddenly, ecological in-balance was set in from many fronts across the local to national and global environment. From the local Lasa fever in Nigeria (Olayemi *et al.*, 2016a and b) to Ebola virus on a regional level in the forest zone of African Sub-Saharan Region (Ogunjemite, 2017) and the Corona Virus (COVID 19) pandemic on global scale and most recent the Monkey Pox. These were traceable to improper handling of wildlife resources because of conflicts (Insecurity) and consequently the marketing strategies to these resources which are now referred to as ecotourism plummeted. Although pandemic is not a permanent condition, it is subsiding and once more the sun will shine again. The major cycles of pandemic in the word are presented in Table 4.

Well managed and sustainable ecotourism will contribute directly to conservation needs and provide tangible economic opportunities to the local community (Ogunjemite, 2010; Ogunjemite, 2013; Umah, 2012). However, when this initiative is confronted with the twin brother of insecurity and pandemic, it is sure that a devastating effect will be enacted. This is the current logjam being experienced in this sector in Nigeria.

Despite Insecurity and Pandemic, we are not left without consolations

All said and done, we are not left without some consolations, even with the effects of insecurity and pandemic on Ecotourism and Wildlife Resources in Nigeria. Just as the women of Bethlehem said while rejoicing with Naomi at the birth of Obed by Ruth the Moabitess in the Bible (Ruth Chapter 4, verse 14). Insecurity and COVID 19 had somehow given us some hope of restoration in the management of our Ecotourism and Wildlife Resources. This period has enacted a new wave of development in the intellectual capability of the local scientists and capacity building of our younger academics. Now that the foreign researchers have restricted their patronage of the Nigerian environment, the abilities of the local scientists are becoming known, especially in Wildlife Resource Management. In previous times when these “so-called” foreign expatriates were coming, they go through the back doors of Government and Non-governmental agencies and before we know it, they have entered our protected areas and get their works done without collaboration or even leaving information for the local scientists (Ogunjemite and Ashimi, 2008). Courtesy of the known ‘Nigerian factors’. By this many opportunities to develop and adapt our own technology and widen the knowledge base were lost. Most of those foreign partners who explored the Nigerian factors to abuse our intellectual abilities now see Nigerian scientists as worthy partners in training of their students and sourcing for samples in these days of insecurity and pandemic.

There had been an increase in scholarship awards to deserving students and grant opportunities to local scientists since they know a lot of risks are involved in coming to the country. In term of endowment, Nigeria has the resources, in quantity and in diversity and many of these advanced societies could not do without us. Equipment Grants are coming in for our students and field researchers. New laboratories such as the Centre for Emerging and Re-emerging Infectious Diseases at the Ladoke Akintola University of Science and Technology, Ogbomoso, Oyo State and the Malarial Vector Surveillance Laboratory, Taraba State University, Jalingo, Taraba State, under the Global Fund Supported Project are being established with the state-of-earth equipment. Most often, the leading Private Universities are the highest beneficiaries of these opportunities in Nigeria today.

In terms of Project Sites, a good number of such sites are now held in trust for the partners by local scientists. In Biodiversity Conservation and Management and particularly in Primatology, sites are held in trust for them by Nigerian Scientists. Such include:

- The Gashaka Primate Project of the Chester Zoo, Taraba State.
- The Nigerian Montane Forest Project, Yelwa, Mambilla Plateau, Taraba State.
- The Niger Delta Red Colobus Project in Bayelsa State
- The Cross River Gorilla Project of Afi Montane. Cross River State.
- The Chimpanzees Project of Ise Forest Reserve, Ondo State
- The Omo Forest Elephant Project, Ogun State
- The Key Biodiversity Area National Coordination Group (KBA-NCG)

Animals both wild and domestics had been identified to play crucial roles in the spread of diseases and as reservoirs. Zoonotic diseases are becoming issues of critical concern across the globe. Collaborative effort across national and continental barriers had been postulated as panacea to solving their menace and spread. In these, ecotourism and wildlife have to play significant roles.

CONCLUSION

A simple and straight forward information on how insecurity and the pandemic has impacted Ecotourism and Wildlife Management in Nigeria is presented in this write. The dynamism of this impact may have not been presented. The tourists' activities at home and from abroad and their motivation at this period had not been taken into consideration. Even so, the situations at most of the destinations except at *ex-situ* destinations such as Zoological Gardens, Parks and Botanical Garden is difficult to assess. Neither is the vulnerability of the resources in qualitative and quantitative terms had been attempted other than the general information circulated on the social media such as “Elephant was killed, Hippo harked down, Manatees caught in rural folks fishing net, shacks caught” and so and so forth.

This presentation therefore, largely depends on the theoretical perspectives and observed happenings around the industry. Empirical data on how impactful security and pandemic had affected this sector is still awaited. Nevertheless, from available evidences and careful observations of activities within the sector, it is known that things are on the downward trend. Visitations to destinations by local and foreign visitors had reduced drastically. As the demand for recreation services is reducing, the more the reduction in the drivable economic outputs. The visible impetus that has been noticed is in the level of local players to rescue the sector from total collapse and the assistance of foreign expects to tap as much information to advance their knowledge base are being documented.

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Table 1: Wildlife species of Nigeria's National Parks and Yankari Game Reserve

S/N	Name	GGNP	CBNP	KLNP	OONP	CRNP	ONP	KNP	YGR
1.	Red front gazelle (*Gazella rufifrons*)	P		A	A	A	A	A	E
2.	Elephant *(Loxodonta africana)*	?	?	??	?	P	P	??	P
3.	Buffalo (*Syncerus caffer)*	P	P	P	P	P	P	P	P
4.	Roan antelope (*Hippotragus equinus)*	P	P	P	P	A	A	P	P
5.	H/beast (*Alcelaphus baselaphus)*	P		P	P	A	A	P	P
6.	Band (*Tauratragis derbianus)*	P	A	A	A	A	A	A	A
7.	White rump waterbuck (*Kobus ellipsiprymnus)*	P		A	A	A	A	A	P
8.	Common waterbuck (*Kobus sp)*	P		P	A	A	A	P	P
9.	Kob *(Kobus kob kob)*	P		P	P	A	A	P	A
10.	Reedbuck *(Redunca arundinum)*	P		?	?	?	A	A	P
11.	Yellowback duiker *(Cephalophus silvicultor)*	P	A	A	A	P	P	A	A
12.	Maxwell's duiker *(Cephalophus maxwelli)*	P	A	A	P	P	P	A	A
13.	Redflanked duiker (*Cephalophus rufilatus)*	P	A	P	P	P	P	P	P
14.	Bush duiker *(Grimma) Syhioapra ginnia*	P	P	P	P	A	P	P	P
15.	Oribi *(Ourebia Ourebia)*	P	P	P	P	A	A	P	P
16.	Bushbuck *(Tragelaphus scriptus)*	P		P	P	P	P	P	P
17.	Warthog (*Phacochoerus africanus)*	P	P	P	A	A	P	P	P
18.	Bush pig *(Patamochoerus larvatus)*	P		A	P	P	P	A	P
19.	Red river hog *(Patamochoerus porcus)*	P		A	A	P	E	A	A
20.	Hippopotamus (*Hippopotamus amphibius)*	P	?	P	?	P	P	P	P
21.	Giraffe (*Giraffa camelopardalis)*	?	?	A	A	A	A	A	A
22.	Lion (*Panthera leo)*	P	E	P	P	A	A	E	P
23.	Leopard (*Panthera pardus)*	P		P	P	P	?	A	P
24.	Hunting Dog (*Lycaon pictus)*	P		P	P	A	A	E	E
25.	Striped hyena (*Hyaena hyaena)*	E		E		A	A	E	E
26.	Spotted hyena (*Crocuta crocuta*)	P		P	P	A	A	P	P
27.	Jackals (*Canis aureus)*	P		P	P	A	A	P	P
28.	Civet cat (*Viverra civetta)*	P	P	P	P	P	P	P	
29.	Genet cat (*Genetta genetta)*	P	P	P	P	P	P	P	
30.	Mongoose (*Herpestes sp)*	P	P	P	P	P	P	P	
31.	Gorilla (*Gorilla gorilla diehli)*	A	A	A	A	P	A	A	
32.	Chimpanzee (*Pan troglodytes elliotis)*	P	A	A	A	P	A	A	
33.	Drill *(Mandrillus leucophaeus)*	A	A	A	A	P	A	A	
34.	Black and White colobus monkey (*Colobus vellerosus)*	P		P	P	A	A	A	P
35.	Red colobus (C*olobus badius)*	A	A	A	A	P	A	A	A
36.	Grey-cheeked mangabey (*Cercocebus albigenia*)	P	A	A	A	P	A	A	A

37.	Red cap mangabey (*Cercocebus torquatus)*	A	A	A	A	P	P	A	A
38.	White throated monkey *(Cercopithecus erythrogaster)*	A	A	A	A	A	P	A	A
39.	Red-eared guenon *(Cercopithecus erythrotis)*	A	A	A	P	P			
40.	Mona monkey (*Cercopithecus mona)*	P	P	P	P	P	P	P	P
41.	Green monkey (*Cercopithecus aethiops)*	P	P	P	P	P	P	P	
42.	Putty nose monkey (*Cercopithecus nictitans)*	P	P	A	A	A	P	A	A
43.	Preuss's guenon (*Cercopithecus preussi)*	A	A	A	A	A	P	A	A
44.	Potto (*Perodicticus potto)*	P	A	P	P	P	P	P	P
45.	Baboon (*Papio anubis)*	P		P	P	P	A	P	P
46.	Patas monkey *(Erythrocebus patas)*	P	P	P	P	P	A	P	P
47.	Galago (Bush baby) (*Galagoides)*	P	A						
48.	Manatee (*Trichechus senegalensis)*	P	A	?	A	P	?	A	A
49.	Tree hyrax (*Dendrohyrax sp.*	P	A	P	P	P	P	P	P
50.	Rock hyrax (*Procavia sp)*		A		P	P	A	A	P
51.	Brush-tailed porcupine (*Atherurus africanus)*	P	A			P	A	P	A
52.	Tree pangolin (*Muris tricuspis)*		A						
53.	Aardvark (*Oryterropus afer)*	P	A		P	A	P	A	A
54	Water chevrotain (*Hyemochus acuaticus)*	A	A		E	A	P	A	A
55.	Bay duiker (*Cephalophus dorsalis)*	A		A	A	A	P	A	A
56.	Giant pangolin (*Maris sp)*	A	A	A	P	P	A	A	A
57.	Two-spotted palm civet cat (*Nandria biritata)*	A	A		A	P	P	A	A
58.	Blue duiker (*Cephalophus monticola*	A	A	A	A	P	A	A	A
59.	Ogilby's duiker (*Cephalophus ogilbyi)*	A		P					
60.	Bate's dwarf antelope *(Neotragus batesi)*	A	A	A	A	P	A	A	
61	Sitatunga (*Tragelaphus spekei)*	P	A	A	A	P	A	A	A

Source: Agbelusi, E. A. (2009)

Key

GGNP- Gashaka-Gumti National Park
CBNP- Chad Basin National Park
KLNP- Kainji Lake National Park
OONP- Old Oyo National Park
CRNP- Cross River National Park
ONP- Okomu National Park
KNP- Kamuku National Park
YGR- Yankari Game Reserve
P Present
A Absent
? Not sighted in the last 5 years

??	Not sighted over 10 years
E	Extinction

Table 2: Categorization of Visitors to KLNP between 2002 -2012 into Local and Foreign .

Year	Total number of visitors	Number of local /domestic (Nigerians)	Number of foreigner (International)
2002	2151	2068	83
2003	1143	1118	25
2004	4734	4656	78
2005	5593	5544	49
2006	4712	4671	41
2007	4837	4794	43
2008	4092	4025	67
2009	4879	4854	25
2010	6103	6054	49
2011	4677	4648	29
2012	3429	3422	07
Total	46,350	45,854	496
Percentage	100%	98.93%	1.07%

Source: Adetola *et al*., 2014

Table 3: Frequency of visits by foreigners to KLNP between 2002-2012.

Countries	Frequency of visitation
USA	4
Britain	12
Germany	7
Spain	5
Finland	1
Ireland	2
Ghana	9
Israel/Lebanon	4
Benin republic	14
Japan	3
South Africa	4
Afghanistan	2
Switzerland	2
Pakistan	2
France	3
India	2
China	1
Togo	2
Cameroon	1
Senegal	1

Source: Kainji Lake National Park Headquarters

Table 4: Twenty of the worst epidemic and pandemics in history

	Epidemic/Pandemic	**Years of occurrence**	**Death toll**
1	The Black Death	1347-1351	Between 75 – 125 Million
2	Smallpox	1520 - 1980	Over 500 Million
3	Spanish Flu	1918 - 1919	Between 17 - 50 Million
4	**Plague of Justinian**	541 - 542	**Between 17 and 100**

5	HIV/AID	1981 - Present	**Between 25 and 35 Million**
6	The Third Plague	1885	Up to 12 Million
7	Antonine Plague	165 - 180	Up to 5 Million
8	17th century Great Plague	1600	Up to 3 Million
9	The Asian Flu	1957 - 1958	Up to 1.1 Million
10	Russian Flu	1889 - 1890	About 1 Million
11	**The Hong Kong Flu.**	1968 - 1970	**1 Million**
12	The 6th Cholera Outbreak	1817 – 1923	1 Million
13	Japanese Smallpox Epidemic	735 - 737	1 Million
14	18th Century Great Plague	1700	600,000
15	Convi-19	2019 - Present	467,000
16	Swine Flu	2009 - 2010	200,000
17	Yellow Fever	Late 1800s	100,000 – 150,000
18	Ebola	2014 - 2016	11,300
19	MERS	2012	850
20	SARS	2002 - 2003	770

Source: Chestnut Hill College's Logue Library Services available at www.library1.chc.edu, retrieved on 30th 7, 2022.

ASSESSMENT OF WILDLIFE RESOURCES FOR ECOTOURISM DEVELOPMENT IN TWO ZOOLOGICAL GARDENS IN SOUTHWESTERN NIGERIA.

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Abstract
This paper focused on assessing the wildlife resources in zoological gardens for ecotourism development. Information was collected from visitors and staff at the University of Ibadan Zoological Garden (UIZOO) and Obafemi Awolowo University Zoological Garden (OAUZOO) through a structured questionnaire. A total of one hundred and thirty-eight copies of questionnaire was administered with eighty in (UIZOO) and fifty-eight in (OAUZOO) to visitors and staff. Data were analysed with the use of descriptive statistics. The result revealed that UIZOO has sixty different species of animals with a total of one hundred and fifty nine animals while OAUZOO has nineteen species of animals with a total of sixty five animals. Majority of the respondents at both zoological gardens were male UIZOO (55.7%) and OAUZOO (56%), they were in the age range of 15-25, and 26 to 36. A high percentage of the respondents at UIZOO (78.6%) and OAUZOO (84%) visit the zoo mostly for recreation and relaxation. The result revealed that UIZOO (50.0%) and OAUZOO (32%) were not impressed with animal species, population and infrastructural facilities in the two zoological gardens, there is need to increase the number of animals and also improve the standard and quality of infrastructural facilities in the two gardens as this will increase tourist influx. There is need to publicize zoological gardens in Nigeria to develop ecotourism.

Keywords: *Zoological Garden, Ecotourism, Wildlife, Population, Animal species*

Introduction

Nigeria is blessed with abundant wildlife species but it is bound to deplete if not managed on a sustainable basis (Ajayi and Ayodele, 1995). The development of ecotourism in Nigeria can be traced back to 1889, when the colonial government took steps to establish the first forest reserve in the colony of Lagos. Since then, the number of protected areas in Nigeria had increased greatly and expanded to include forest reserves, wildlife sanctuaries, game reserves, strict nature reserves communal forest and recently national parks (Aremu, 2001). The establishment of these protected areas came as a response to an adverse trend, especially within the last 80 years, when environmental degradation set in. By the mid-1980s, it had become an established fact that Nigeria had approximately lost 90% of her original tropical rain forest cover to logging, bush burning, virtually the remaining 10% of these important resources is now located in Cross River State of Nigeria (Aremu, 2001). The first national park in Nigeria, Kainji Lake National Park, came into being in 1979, and today we have seven national parks and over sixty game and forest reserves in Nigeria created in line with government policy on the preservation of our natural heritage (Ayodele and Falade, 1990). These resources constitute the major pillars of the Nigerian eco-tourism industry. Some eco-tourism facilities however exist other than those established by the government all over the country. These include nature conservation initiatives by Non-Governmental Organizations such as Lekki Conservation Centre in Lagos, the Gorilla Refuge and conservation Education Centre at ObuduPlateau, Obudu Mountain Resort, the Drill Rehabilitation and breeding Centre at Afi Forest, Zoological garden and Botanical garden (Ayodele and Falade, 1993).

Ecotourism involves encounter with non-domesticated animals either in their natural environment or in captivity. It includes a wide range of activities such as bird watching, whale watching, visiting zoos, recreational fishing and hunting (Melleye,1991). Wildlife based tourism is non consumptive use of wild resources to benefit human population (Barnes *et al.,* 1992). Barnes *et al.*1992) went further to note that wildlife tourism, if sensitively managed, offers a nation the chance to develop a high value added industry that simultaneously protect wildlife by removing or reducing the incentive or export wildlife for consumptive uses. Eco-tourism sensitizes people to the beauty of nature and also satisfies several general criteria including conservation of biological diversity and cultural diversity through ecosystem protection (Martha and Honey, 2000).

Wildlife conservation in zoo and game reserve are sources of revenue, aesthetic recreation, education, education, employment and scientific value (Adams and Salome, 2014). The number of animal species whose existence is threatened is increasing at an alarming rate mostly due to rapid world population increase, hence there is need to conserve the environment and the diversity of species. This gives enough justification of our conservation of plants and animal species ex-situ by botanical and zoological garden (Ayodele *et al.,* 1999). Zoological garden is a form of ex-situ conservation, which involves conserving and maintaining the genetic resources outside its area of origin or occurrence (Ayodele *et al.,* 1999). Zoo can be defined as a place where wild animals and strange domestic animals are kept and exhibited to the public (Ajayi and Ayodele,1995). They are educationally planned and oriented life animal displays, presented to the visitors in the most aesthetically pleasing, interesting and naturalistic context. The role of zoo has changed structurally by responding to the pressure on wildlife and also on cultural values (Sterling *et al.*,2007). The objectives of zoological garden are recreation, education, captive breeding, and economic research.

Therefore, the assessment of wildlife resources in zoological gardens is very crucial for the promotion of eco-tourism. Effective management of wildlife resources and their habitat must be taken with utmost seriousness to obtain maximum returns and at the same time preserve them sustainably for future generations (Buckey, 2014*)*. This research work seeks to assess the wildlife resources and ecotourism potentials of University of Ibadan and Obafemi Awolowo Zoological gardens.

Materials and Methods

Study Areas

University of Ibadan Zoological Garden

The University of Ibadan Zoological Garden is situated some 3km to the North of the city of Ibadan, Oyo state, Nigeria at latitude $7°26'N$ and longitude $3°53'E$ and a mean altitude of 227m above sea level. The garden was established in 1948 primarily as a menagerie, and it later became a full-fledged zoo in 1974. The garden welcomes a large number of visitors from far and near all year round and is home to a wide array of animals comprising mammals birds, reptiles, about 95% are native to Africa. The animals are housed in metal and concrete cages in small units and according to behavioural patterns and species. The topography of the University of Ibadan zoological garden is both sandy-loam and loamy soil (Aderenle, 1993), further observations shows that soil under the tree canopies would be expected to be rich in potassium since leaching or erosion is reduced to the barest minimum by the canopy cover. The kind of soil found in a location within the zoo determines the site selection for particular species of animal. For example, lion (*Panthera leo)*is located in a bit rocky side of the zoo while the paddock's of herbivores are sited close to the stream due to ecological reasons. The zoo opens 7days a week, 365 days a year from 8am to 6:30pm (Student Information Handbook, 2012)

Obafemi Awolowo Biological Garden

Obafemi Awolowo University is situated in Ile-Ife, an ancient city in the South Western part of Nigeria (OsunState). The zoo lies on latitude 7.4669˚N and longitude 4.5669˚E. The vegetation in its natural state consists of tall trees with thick undergrowth of shrubs and intertwining climbers, which make it impenetrable. The area lies in the dry deciduous forest zone. Obafemi Awolowo University zoological garden was established in 1956 to support the Department of Zoology and it was opened to visitors in1964 for recreation, education and other related purpose (Olawuyi, 2021*)*. The zoo is located in front of faculty of Environmental Design and Management.

Data Collection

Information was collected from visitors and staff at both zoological gardens through the use of structured questionnaire. The secondary source includes oral interview, extraction of information from materials such as books, journals and the internet.

Sample and Sampling Techniques

The population studied comprised of visitors and staff of University of Ibadan and Obafemi Awolowo University gardens in South-West, Nigeria. Simple random sampling was used to select the staff and visitors in the University of Ibadan and Obafemi Awolowo University zoological gardens. A total number of one hundred and thirty eight (138) respondents were used for the study, with seventy in University of Ibadan zoological garden due to the fact that the garden has the highest flock of visitors and fifty in Obafemi Awolowo zoological garden also ten staff was selected from University of Ibadan zoological garden and eight from Obafemi Awolowo University zoological garden (this is because the number of staff are not up to ten)

Data Analysis

Data obtained from the staff and visitors were analysed using descriptive statistics. The analysis of research questions was done using the formula

$$\text{Percentage\%} = \frac{\text{number of responses}}{\text{Total no. administered}} \times 100$$

Result

TABLE 1: Demographic characteristics of UI and OAU staff

Variables	Frequency UI (n=10)	Percentage (100%) UI	Frequency OAU (N=8)	Percentage (100%) OAU
Sex				
Male	8	80	5	62.5
Female	2	20	3	37.5
Educational status				

Variables	Frequency UI (n=10)	Percentage (100%) UI	Frequency OAU (N=8)	Percentage (100%) OAU
Secondary	3	30	2	25
Tertiary	7	70	6	75
Age				
21-30 years	2	20	1	12.5
31-40years	7	70	5	62.5
41-50years	1	10	2	25
51 and above	0	0	0	0
Marital status				
Single	3	30	2	25
Married	6	60	6	75
Divorced	1	10	0	0
Widow/widower	0	0	0	0

Source: Field Survey (2021)

Table 1 shows the result obtained of the demographic characteristics of the sampled staff respondents from the both zoo. The result revealed that 80% of University of Ibadan Zoo staff were male and 20% were female. Also, 62.5% of Obafemi Awolowo University Zoo staff were male and 37.5% were female.

In terms of educational status, majority of the University of Ibadan Zoo staff had tertiary education (70%) and the remaining 30% had secondary education. Similarly, 75% of OAUZOO staff had tertiary education while 25% had secondary education. In terms of age, 70% of University of Ibadan staff falls between age 31 and 40 years while 20% were between 21 and 30 years and 10% were between age 41 and 50 years. The result shows that the majority of University of Ibadan (60%) and Obafemi Awolowo (70%) zoo staff were married. Also, 30% of UIZOO staff were single and 10% divorced while 25% of OAU zoo staff were single.

Table 2: Feeding regime of animals in UI and OAU zoological garden

	UI zoo	OAU zoo
Birds	Once per day	Once per day
Primate	Twice per day	Twice per day
Herbivore	Twice per day	Once per day
Carnivore	Thrice per day	Once/twice per day
Reptile	Twice per week	Once per week

Source: Field Survey (2021)

The result shows the feeding regime of the two gardens. Birds (granivorous) were fed with grains and are fed once per day, Carnivorous birds were fed with flesh or intestine of goats. Some birds were also fed with cooked beans, boiled yam and palm oil. Primates like Monkey, Baboon, and Chimpanzee were majorly fruit eaters (frugivore) are fed twice daily in the, morning around 9:00am and in the afternoon around 3pm with varieties of fruits like banana, pineapple, pawpaw, apples, oranges, and watermelon etc at the two gardens. Herbivores such as horse, giraffe and donkey are fed twice per day, in the morning and evening with grasses (elephant grass, Bahamas grass, etc), shrubs and herbs.

Carnivorous animals(animals that feed on flesh of other animals) animals like Lion, Hyena, Jackal etc, Lions are fed with slaughtered goats and are fed thrice a week (Monday, Wednesday and Saturday) around 10am in the University of Ibadan zoological garden. In ObafemiAwolowo University zoological garden, Lions are fed once and twice a week and this is due to unavailability of enough funds to support the zoo, Reptiles are fed twice per week in UIZOO with a day old chick, eggs, white rat. In OAUZOO, reptiles are fed once a week. In University of Ibadan Zoological garden, there are Warthogs and Domestic Pig which are fed with both flesh and fruits because they are Omnivorous animals.

Table 3: Increase or decrease in animals.

		UI ZOO	OAU ZOO
Number of Animals	Increasing	7(70%	2(25%)
	Not Increasing	3(30%)	6(75%)

Source: Field Survey (2021)

The result revealed that animals of University of Ibadan were increasing over the years. Most (70%)of the staff agreed that the animals were increasing while 30% said the animals were not increasing. But OAU zoo animals seem not to be increasing, 75% of the staff said they were not increasing while 25% oppose that they were increasing.

Table 4: Suggested animals that can attract visitors

		UI zoo	OAU zoo
Suggested animals that can attract visitors	Elephant	8 (80%)	8 (100%)
	Antelope	5 (50%)	-----------------------
	Hippo	2 (20%)	4(50%)
	Gorilla	4 (40%)	6 (75%)
	Leopard	8(80%)	1(12.5%)
	Zebra	4(40%)	2(25%)

Source: Field Survey (2021)

Table 4 shows the list of animals suggested by the staff that could possibly increase the tourist/ visitor's influx. Majority(80%) of the University of the Ibadan zoo staff stated that if the management could bring in Elephant, the rate at which visitors will patronize the garden will increase, 40% said gorilla,80% said leopard, and 40% said Zebra, 50% said antelope, 20%said hippopotamus, All Obafemi Awolowo University zoo staff indicated that having an elephant in the garden will increase the tourist influx, 50% said Hippopotamus,75% said gorilla, 12.5% said leopard, while 25% said Zebra.

Results on the demographic characteristics of the visitors at UI and OAU zoological garden

Table 5: Demographic characteristics of visitors

		UI zoo (n=70)	OAU zoo (n=50)
Sex	Male	39 (55.7%)	28(56%)
	Female	31(44.3%)	22(44%)
Educational status	Primary	2 (2.9%)	0 (0%)
	Secondary	13 (18.6%)	11 (22%)
	Tertiary	54 (77.1%)	36 (51.4%)
	Vocational	1 (1.4%)	3 (6%)
	No response	0 (0%)	0 (0%)
Age	15-25	34(48.6%)	21 (42%)
	26-36	27 (38.8%)	18 (36%)
	37-47	6 (8.8%)	7 (14%)
	48-58	2 (2.9%)	4 (8%)
	59 and above	1 (1.4%)	0 (0%)
Marital status	Single	46 (65.7%)	31 (62%)
	Married	20 (28.8%)	16 (32%)
	Divorced	0 (0%)	1 (2%)
	No response	4 (5.71%)	1 (2%)
Occupation	Students	44 (62.9%)	15 (30%)
	Teachers	5 (7.1%)	4 (8%)
	Researchers	8 (11.4%)	7 (14%)
	Retirees	1 (1.4%)	0 (0%)
	Corp member	8 (11.4%)	13 (18.8%)
	Clergy	1(1.4%)	2 (4%)
	Others	3 (4.3%)	7 (14%)
Nationality	Nigerian	68 (97.1%)	50 (100%)

	Non Nigerian	2(2.9%)	0(0%)

Source: Field Survey (2021)

Table 5 shows the results of the demographic characteristics of the respondents from both zoos. Majority of the respondents were male at both zoological gardens; UIZOO (55.7%) OAUZOO (56%) while female were (44.3%) in UIZOO and(44%) in OAUZOO. In terms of educational qualifications, most of the respondents were literate with (77.1%) having tertiary education at UIZOO and (51.45%) at OAUZOO, while for secondary education, (18.6%) in UIZOO, (22%) in OAUZOO and the least were primary. Most of the respondents were single with (65.7%) in UIZOO and (62%) in OAUZOO, followed by married people with UIZOO (28.8%) and OAUZOO (32%). For the age categories, the age range 15-25 has the highest percentage at both zoos with UIZOO (48.6%) and OAUZOO (42%) followed by 26-36 UIZOO (38.8%) and OAUZOO(36%). This means most of the respondents were youth. The respondents were mostly students UIZOO (62.9%) and OAUZOO (30%) followed by corp members UIZOO (11.4%) and OAUZOO (18.8%).This means that the students visit the zoo more for educational purposes. In terms of nationality, majority of the respondents at both zoos were Nigerian UIZOO (97.15%) and OAUZOO (100%).

Table 6: Visitation rate and visitors perception

		UI zoo (n=70)	OAUzoo (n=50)
Frequency of visit	Once in a while	33 (47.1%)	19 (38%)
	Often	8 (11.4%)	1 (2%)
	Rarely	4 (5.7%)	3 (6%)
	First time	25 (35.8%)	27 (54%)
Purpose of visit	Recreation and relaxation	55 (78.6%)	42(84%)
	Education and research	8 (11.4%)	7(14%)
	Know about the garden	5 (7.1%)	1 (2%)
	Others	2 (2.9%)	0 (0%)
Visit to other zoos	Yes	49 (70%)	42 (84%)
	No	21 (30%)	8 (16%)
Visitors view			
	Impressed	35(50%)	16 (32%)
	Not impressed	35 (50%)	34 (68%)
Visitors satisfaction			
	Satisfactory	57 (81.4%)	31(62%)
	Unsatisfactory	13 (18.6%)	19(38%)

Source: Field Survey (2021)

The result shows that 47.1% of the respondents of UIZOO and 38% of OAUZOO visits once in a while, 35.8% of the respondents of UIZOO and 54% of OAUZOO were visiting for the first time. For the purpose of visit, 78.6% of respondents of UIZOO and 84% of OAUZOO visit for recreation and relaxation, 11.4% in UIZOO and 14% in OAUZOO visits for research and educational purpose. Majority of the respondents visits for recreational purpose. Most (70%) of the respondents at UIZOO and 84% of OAUZOO have visited other zoos, 30% of respondents of UIZOO and 16% OAUZOO stated that they have not visited any other zoo. Also, 50% of UIZOO and 32% of OAUZOO respondents were impressed with the species and population of animals sighted in the zoo while 50% of UIZOO and 68% of OAUZOO respondents said they were not impressed. In addition, 81.4% of UIZOO and 62% OAUZOO respondents were satisfied with the tourist facilities in the zoo while 18.6% of UIZOO and 38% of OAUZOO respondents said they were not satisfied with the tourist facilities.

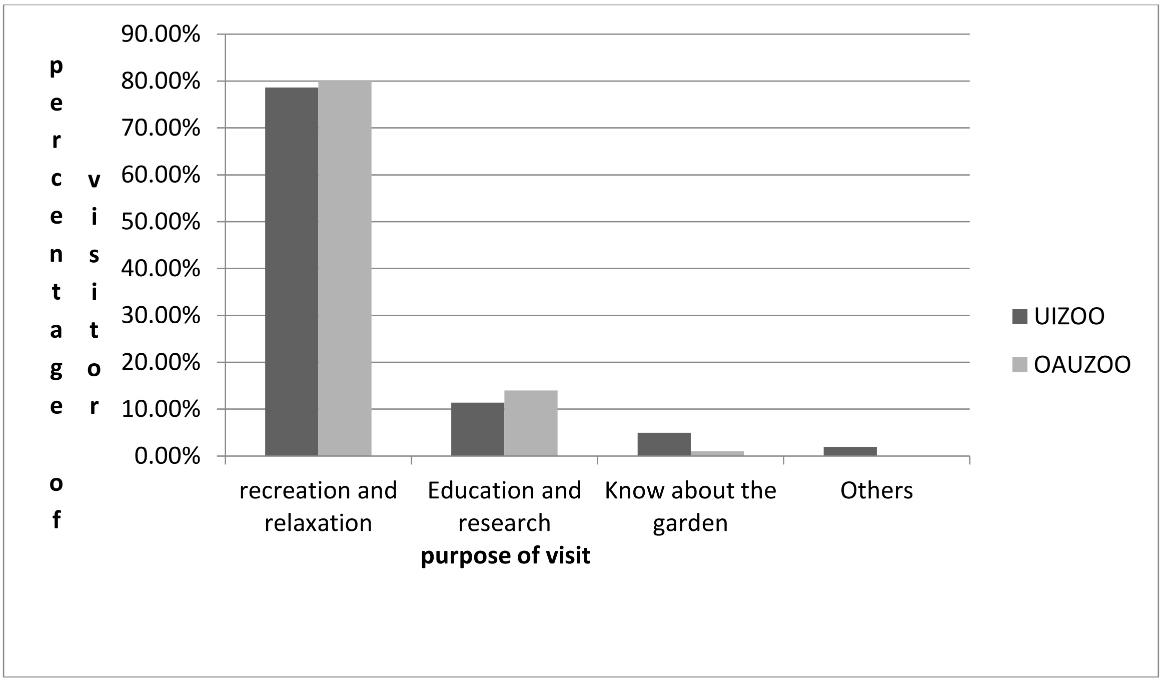

Figure 1: purpose of visiting the zoological garden

Table 7: Visitors perception about the animal

		UI zoo (n=70)	OAU zoo (n=50)
Animals that attracted the respondents	Snake	4 (5.7%)	6 (12%)
	Lion	32 (45.7%)	18 (36%)
	Monkey/Baboon/Chimpanzee	10 (14.3%)	10 (20%)
	Birds	9 (12.9%)	3 (6%)
	Ostrich	2 (2.9%)	3 (6%)
	Donkey	6 (8.7%)	0 (0%)
	Others	7 (10%)	10(20%)
Animals the visitors would love to see on their next visit	Elephant	33 (47.1%)	28 (56%)
	Zebra	10 (14.2%)	6 (12%)
	Gorilla	5 (7.1%)	5 (10%)
	Hippopotamus	2 (2.9%)	1 (1.4%)
	Neutral	20 (28.6%)	13 (26%)
Tendency to revisit	Yes	51 (72.9%)	29 (58%)
	No	19(27.1%)	21 (42%)

Source: Field Survey (2021)

For the animals that attracted the visitors, results showed that majority of the respondents of both zoos came to zoo to see the lion; UIZOO 45.7% and OAUZOO 36%.Most of the respondents of the two gardens got attracted to the lion because of its scary look, while some came to see how the lion run after, catch, kill and feed on its prey. Also majority of the respondents of the two zoos would prefer to see an elephant on their next visit to the zoo, UIZOO (47.1%) and OAUZOO (56%).Majority of the respondents in UIZOO (72.9%) and OAUZOO (38%) said they would like to revisit the zoo, while some respondents in UIZOO (11.4%) and OAUZOO(14%) OAUZOO respondents said they would not like to revisit the zoo due to inadequate animal, poor tourist facilities or poor infrastructural development.

Table 8: fauna resources in University of Ibadan zoological garden

S/N	Name of animal	Scientific name	Total
	Aves		
1	African grey Parrot	*Psittacuseri thacus*	1
2	Purple Swamp hen	*Porphyro porphyro*	5
3	Owl	*Athene noctua*	4
4	Spur-winged Goose	*Plectropterus gambensis*	3
5	White Geese	*Chen caerulesucens*	4
6	Brown Pelican	*Pelecanus occidentalis*	2
7	Marabou Stork	*Leptoptilos crumeniferus*	2
8	Lizard Buzzard	*Kaupifalco monogrammicus*	1
9	Budgerigar	*Melopsiitacus undulates*	4
10	Senegal Parrot	*Poicephalus senegalus*	4
11	Mallard Duck	*Anas platyrhynchos*	6
12	White Peacock	*Pavocristatus muticus*	2
13	Vulture	*Necrosyrtes monachus*	1
14	Laughing Dove	*Spilopelia senegalensis*	3
15	Speckled Pigeon	*Columba guinea*	2
16	Rose- Ringed Parakeet	*Psiitacula krameri*	2
17	Emu	*Dromaius novaehollandie*	1
18	Ostrich	*Struhio camelus*	3
19	Peafowl	*Pavo cristatus*	3
20	White Stork	*Ciconia ciconia*	3
21	Crown Cane Bird	*Balearica pavonina*	2
22	Rose- faced Bird	*Agapornis roseicollis*	2
	MAMMALS		
23	Camel	*Camelus aromedarius*	1
24	Horse	*Equus caballus*	4
25	Giant eland	*Taurotragus derbianus*	2
26	Donkey	*Equus asinus*	2
27	Maxwell duiker	*Cephalophus maxwelli*	2
28	Dorcas Gazelle	*Gazellae dorcas*	2
29	Warthog	*Phacochoerus africanus*	1
30	Giraffe	*Giraffa camelopardalis*	1
31	Lion	*Panthera leo*	5
32	Chimpanzee	*Pan troglodytes*	2
33	Spotted Hyena	*Crocuta crocuta*	1
34	Stripped Hyena	*Hyaena hyaena*	2
35	Common Jackal	*Canis aureaus*	2
36	Domestic Pig	*Sus scrofa*	9
37	Mona Monkey	*Cercopithecus mona*	3
38	Rabbit	*Oryctolagus cuniculus*	2
39	Cane rat	*Thryonomys swinderianus*	3
40	Crested Porcupine	*Hystrix hystrix*	2
41	Giant Rat	*Cricetomysgambianus*	2
42	Civet Cat	*Civettictis civetta*	1
43	Drill Monkey	*Mandrilus synix*	2
44	Patas Monkey	*Erythrocebus patas*	5
45	Mangabey Monkey	*Cercocebus torquatus*	3
46	Green Monkey	*Cercocebuss abaeus*	8
47	White Monkey	*Cercopithecus erythrogaster*	1
48	Anubis baboon	*Papio anubis*	6
	REPTILES		
49	Royal python	*Python regius*	3
50	Monitor Lizard	*Varanus veranus*	4
51	Gaboon Vipers	*Bitis gabonica*	1
52	African crocodile	*Osteolamus tetrapis*	1
53	Nile Crocodile	*Crocodylus niloticus*	4
54	Land Tortoise	*Terrapene carolina*	1
55	Water Snake	*Nerodiar hombifera*	1

S/N	Name of animal	Scientific name	Total
56	Black Cobra	*Naja naja*	1
57	Black Splitting Cobra	*Naja nigricollis*	1
58	Common adder	*Causus rhombeatus*	2
59	Soft Shelled turtle	*Trionyx trionyx*	3
60	African Python	*Python sebae*	2

Source: Field Survey (2021)

Table 9: fauna resources in Obafemi Awolowo zoological garden

S/N	NAME OF ANIMAL	SCIENTIFIC NAME	TOTAL
	AVES		
1	Ostrich	*Struthio camelus*	1
2	Guinea fowl	*Numida meleagris*	1
3	Peacock	*Pavo cristatus*	2
4	White geese	*Chen caerulesucens*	1
5	Duck	*Porphyrio porphyrio*	2
6	Crown crane bird	*Baleari capavonica*	1
	REPTILES		
7	Rock python	*Python sebae*	1
8	Soft –Shell turtle	*Trionyx triungus*	2
9	Tortoise	*Terrapene carolina*	1
10	Dwarf Crocodile	*Osteolamus tetrapis*	1
	MAMMALS		
11	Mona Monkey	*Cercopithecus mona*	2
12	Stripped Hyena	*Hyaena hyaena*	1
13	Civet cat	*Civettictis civetta*	1
14	Baboon	*Papio anubis*	1
15	Rabbit	*Oryctolagus cuniculus*	12
16	White/Albino rat	*Rattus albus*	22
17	Patas Monkey	*Erythrocebus patas*	1
18	Maxwell Duiker	*Cephalophus maxwelli*	1
19	Lion	*Panthera leo*	2

Source: Field Survey (2021)

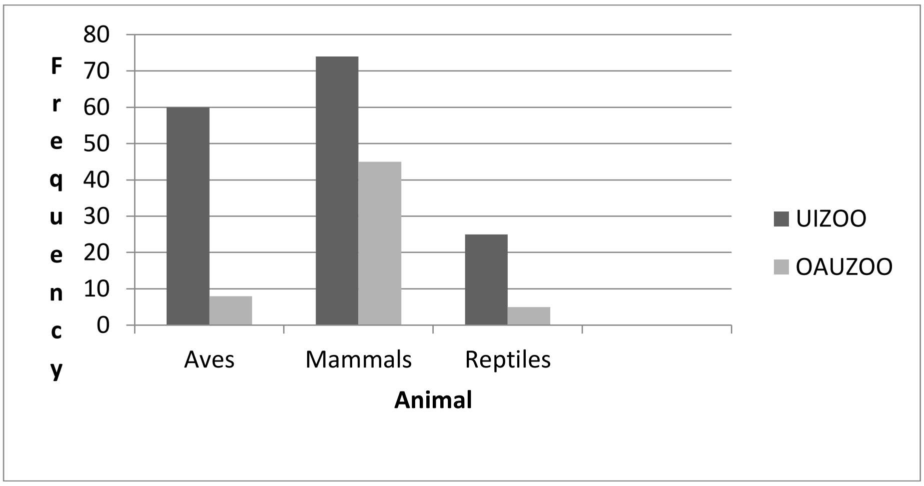

Figure 2: Frequency distribution of animal population in UIZOO and OAUZOO

Figure 2 shows the total number of animals in University of Ibadan and Obafemi Awolowo zoological gardens. In UIZOO, there are 60 birds, 74 mammals (primates, herbivores and carnivores) and 25 reptiles making a total of 159 animals in UIZOO. There are 12 birds, 45 mammals (primates, herbivores and carnivores) and 8 reptiles making total of 65 animals

Flora Species in University of Ibadan zoological garden

The dominant species within University of Ibadan Zoological Garden includes: *Musa sapientium, Hura crepitans, Elaeis guineensis, Mangifera indica, Terminalia catapa, Bambusa vulgania, Eucalyptus globulus, Elaeis species*

Facilities and structures in University of Ibadan zoological garden
Tourists facilities and structures at University of Ibadan zoological garden include
Museum, picnic site, restaurant and children zoo
Flora resources in ObafemiAwolowo University zoological garden.
Terminalia ivorensi, Gmelina arborea, Eucalyptus torelliana, Triplochiton scleroxylon, Millicia excels, Magnifera indica
Facilities and structures in Obafemi Awolowo University zoological garden
The relaxation site is located at the extreme part of the zoo with several bamboo chairs for tourist/ visitors to rest

Discussion
This paper focused on the assessment of wildlife resources for ecotourism development in zoological gardens and the selected zoological gardens were University of Ibadan zoological garden (UIZOO) and Obafemi Awolowo zoological garden(OAUZOO). According to findings, majority of the respondents were male, UIZOO(55.7%) and OAUZOO (56%) and they were in the age range 15 to 25 UIZOO (48.6%), OAUZOO (42%)and 26-36, UIZOO (38.8%) and OAUZOO (36%) this means majority of the respondents were youth, and this could be due to the fact that , the youths are in their active years are more adventurous and fun seeking than the older ones and it agrees with Yager *et al.* (2015) findings which says people at that stage are curious to learn and pursue their interest. From the study, it was shown that students, UIZOO (62%) and OAUZOO (30%) visit the zoo more compared to other professions like teachers, researchers etc., It could be due to the fact that both zoological gardens are situated in a University premises. Also, from the findings, it is shown that most of the respondents in UIZOO (78.6%) and OAUZOO (84%) visit the zoo mostly for recreation and relaxation and (11.4%) in UIZOO, 14% in OAUZOO for education and research. This also agrees with Puan and Zakaria (2007) findings that despite the public understanding that zoos can be centres of conservation, the top motivation for visiting the zoo is still for recreational purpose. In this study, it is shown that majority of the respondents, UIZOO (70%) and OAUZOO (84%) have visited other zoos, while, 30% of UIZOO and 16% in OAUZOO have not visited other zoological gardens. There is need to publicize most zoological gardens in Nigeria to develop ecotourism. Also, among the sections indicated by the respondents, Visitors mostly preferred the carnivore section the most as they love to watch the animals especially when they are being fed, followed by other sections such as the herbivore, reptile, primate due to different factors such as behaviour, appearance and display. In terms of abundance of species on display, UIZOO has sixty (60) different species of animals with a total of one hundred and fifty-nine (159) animals while OAUZOO has nineteen (19) species of animals with a total of sixty-five (65) animals. This abundance of species is due to the fact that the management of UIZOO is more effective than OAUZOO. Also UIZOO has more sponsors than OAUZOO and this generate more funds, which helps in acquiring and feeding the animals.

Conclusion
The assessment of wildlife resources in University of Ibadan and ObafemiAwolowo University zoological garden shows that the two gardens have high eco-tourism prospects. Though most visitors wished for some species of animals like elephant, gorilla, hippopotamus, zebra to be in the zoological gardens as these animals are absent at the moment. It can be said that the level of ecotourism at the two zoological garden is at the developing stage as there is still a lot to be done. The facilities and structures in the duo gardens must be well constructed and of high standard which will increase the influx of tourist. The walkways, animal displays cages, restaurant should be improved. Lastly the two gardens need to be stocked with more exotic and indigenous wild animals since visitors are always enthused to view the animals.

Recommendations
Improvement in the standard and quality of infrastructural facilities so as to attract visitors and give them satisfaction. Animal cages need to be refurbished to improve the health of the animals in captivity as well as make it appealing to the tourists, picnic sites should be beautified by planting ornamental plants. Obafemi Awolowo University zoological garden needs to publicize the garden using mass media, the road network should be improved by clearing grasses and leaf debris to prevent snakes and other harmful things from injuring the tourists. Also Lavatory and dust bins should be put at specific places in the garden for visitor use. More so, construction of office blocks for staff and employment of more staff for better service and management. Zoological gardens should not only be for game viewing, other recreational activities like swimming, indoor games such as table tennis, snooker, scrabbles, ludo and chess can also be introduced. The use of visitors feedback comment card on the zoological garden services should be encouraged, first aid boxes should be made available at both zoological garden. There is need for acquisition of animals both exotic and indigenous that are not present as this will increase the influx of tourists into the zoological garden.

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SURVEY OF WILD ANIMAL SPECIES HUNTED IN OWOTORO COMMUNITY, ATISBO LOCAL GOVERNMENT AREA, OYO STATE, NIGERIA

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Abstract
This study focused on survey of wild animals' species hunted in Owotoro communities, Atisbo Local Government Area, Oyo State, Nigeria. It involved the use of field survey, structured questionnaire and focus group discussions among local hunters and bush meat marketers. Data collected for the study were analyzed using descriptive statistics. The socio-demographic characteristic of the respondents revealed that majority (76.0%) of the respondents were male and age group 31-40 years and above had the highest with 42.0%. Majority of the respondents were married (66.0%) while 28.0% were single. Most of the respondents were Muslim with 54.0% and traditional religion was the least (18.0%). Seventeen (17) species of wild animals were discovered to be hunted in the study area and most of them were from the adjourning Old Oyo National Park, which is close to the communities. The reasons, seasons, time and equipment for hunting were revealed. More awareness should be created on the need to conserve these threatened wild species for the purpose of conservation and ecotourism development in the Old Oyo National Park, Nigeria.

Keywords: *Survey, hunting, Wild animals, Owotoro community, Atisbo*

Introduction

Wildlife is animal which is outside the direct control of man and is predominantly found in their natural habitat, caring and fending for itself. In rural tropical areas, a large proportion of human residents continue using a variety of wildlife species as sources of protein, fat, medicinal substances, clothes, tools, adornments, ritual objects, and income, among other purposes (Milner-Gulland and Bennett, 2003). Most wildlife resources are obtained through hunting, considered a subsistence activity when its primary purpose is to satisfy the hunter's and his family's basic needs (Ojasti, 2000). Hunting is a process of capturing animals alive or dead mostly in its natural habitat. Hunting is deadly to conservation of wildlife, but yet it plays a paramount role in conservation such as reducing intra specific competition for food, shelter etc. The term bush meat has particularly been used to refer to meat from wild animal in west and central Africa. Impacts of hunting on wildlife populations include declines in vertebrate biomass and shifts in the relative abundance of size classes (Peres, 2000). Studies on sustainability of hunting show that species are being extracted much above sustainable limits (Hart, 2002). Market demands for wild meat have also contributed in pushing the harvest levels of wildlife to unsustainable limits (Apaza, *et al*., 2002). The effect of hunting by rural people has led to quantified changes in structure of mammal assemblages (Jerozolimski and Peres, 2003). Wildlife plays an important role in the lives of local people and is used for food, rituals and medicines. The sale of wild meat and wildlife products provides cash income and hunting of wildlife is also for recreation (Datta, 2002).The main motivation for commercial hunters is to exchange their prey for money. In contrast, subsistence hunters usually go hunting for food, although the sale of surplus meat within their communities may occur (Ojasti, 2000). Subsistence hunting frequently implies lower risks for wildlife populations than commercial hunting (Fa and Peres, 2001). However, studies had suggested that subsistence practices increase pressure on hunted species, generally large and medium-sized vertebrates (Peres, 2000; Wright, 2003). Among the wild terrestrial vertebrates providing food and other products to rural hunters in the rural communities are dozens of mammals (ungulates, primates and large rodents), birds and some reptiles (tortoise, turtles, snakes, iguanas and crocodiles) (Ojasti, 2000). A number of dedicated hunters usually are present in rural communities and search for game in a selective way towards highly regarded species. These dedicated hunters sometimes manage particular habitat types (e.g. they keep a harvest portion for wildlife consumption) to attract their prey and increase their hunting success. However, most subsistence hunters frequently take their prey with very little or no management strategies in an opportunistic way while traveling to their croplands and grazing areas (Naranjo, *et al.*, 2010). In addition to harvesting wild meat, subsistence hunting is practiced to prevent or mitigate crop damage by game species.

Control of this problem requires information on hunting patterns and understanding on the factors that drive local hunting (Bennett, 2003). This study seeks to answer the questions whether the roles and activities of the actors in wildlife hunting, undermine state security and National Park stability. The research focused on these gaps and attempt to identify appropriate policy responses. This study is intended to shed light on the changing dynamics of illegal hunting of wildlife resources by critically examining its actors, their motivators, driving factors, consequential implications on wildlife resources and management. Identify species of wild animals hunted in Owotoro community and examine the implication of their hunting activities to conservation of these wild animals in Old Oyo National Park, Nigeria.

Materials and Methods

Study Area

Atisbo is a rural Local Government located in the North-West of Oyo State, Nigeria, about 175km from Ibadan, the state capital. Its headquarters is in Tede. The name Atisbo is an acronym of eight (8) rural communities that made up the Local Government. Thus, Atisbo stands for Ago-are and Agunrege, Tede, Irawo, Sabe, Baasi, and Ofiki and Owo-tooro communities. It is predominantly Agrarian communities with some mining land where precious stones such as tourmaline and tantalite can be found. There are 10 wards in the Local Government and bounded in the North by Saki East, South by Itesiwaju and Iwajowa, East by Orire and Republic of Benin to the West. It has a population of 110,792 (National Population Census, 2006). Among the cash crops widely grown include cashew, Shea butter and mango.

Methods of Data Collection

This study involved the use of field survey which was conducted in the community. Purposive sampling techniques were used to select the hunters and bush meat marketers. Fifty copies of questionnaires were administered to both accessible marketers of bush meat and hunters. The hunters and the marketers were accessed through their association and leaders. Personal visits to shops, homes and observations were made in the process, discussions and interview were conducted with hunters, marketers and relevant stakeholders in the community as it relate to the study. Camera was used to obtain the photography's of some the wildlife, captured, hunted and sold by the marketers in the study area.

Data Analysis

Data collected were subjected to descriptive statistics, such as charts, tables and percentages.

Results and Discussion

The demographic characteristics of the respondents were revealed in table 1, in which male recorded the highest (76.0%) and female recorded 24.0%. Age group 31-40 years recorded the highest (42.0%), followed by 41-50 with 34.0% and the least was 51 years and above with 10.0%. The table revealed the marital status of the respondents in which majority (66.0%) was married and the least were separated with 2.0%. Also majorities (54.0%) of the respondents were Muslim and 28.0% were Christian. Species of wild animals hunted are revealed in table 2, in which seventeen (17) wild animals were recorded belonging to different species. The reasons and season of hunting are shown in table 4. It revealed that income generation is the major purpose of hunting with 54.0%, followed by consumption with 32.0% while for trophy is the least with 14.0%. Dry season recorded the highest period of hunting with 62.0%, followed by both season with 28.0% and wet season recorded the least with 10.0%. Table 5 showed the instrument used for hunting. Which include Dane gun that recorded the highest with 72.0%, followed by traps with 22.0% while bow and arrow is the least with 2.0%. Figure 1 revealed the time of hunting activities, in which during the night recorded the highest with 32% and during the morning is the least with 5 %. Figure 2 revealed the distance covered during hunting activities, in which 16km and above recorded the highest with 22 respondents, followed by 11-15km with 14 respondents and the least is 1-5km with 6 respondents. The sources of bush meat are revealed in figure 3, in which near National Park recorded the highest with 24 responses, followed by inside National Park with 17 responses and farmland is the least with 9 respondents.

The status of wild animals in the study area are revealed in table 6, in which decrease recorded the highest with 66.0%, followed by stable with 22.0% and increase is the least with 12.0% from the respondents. In table 7, it revealed that the conservation status of the hunted species in the study area were 53%, 18% and 29% for Least Concern, Near Threatened and Threatened respectively.

Table 1: Demographic characteristic of the respondents

Demography	Variables	Frequency	Percentage (%)
Gender	Male	38	76.0
	Female	12	24.0
Age Group	21-30	7	14.0
	31-40	21	42.0
	41-50	17	34.0
	51 and Above	5	10.0
Marital status	Married	33	66.0
	Single	14	28.0
	Divorce	2	4.0
	Separated	1	2.0
Religion	Christianity	14	28.0
	Islam	27	54.0
	Traditional	9	18.0
	Total	50	100.0

Table 2: Species of wild animals hunted in the study area

S/No	Common Name	Scientific Name
1	Kobs	*Kobus kobs*
2	Bush Buck	*Tragelaphus scriptus*
3	Roan Antelope	*Hippotragus equinus*
4	Olive Baboon	*Papio anubis*
5	Giant Rat	*Cricetomys gambianus*
6	Hare	*Lepus capensis*
7	Stripped Ground Squirrel	*Epixarus epii*
8	Grass Cutter	*Thryonomys swinderianus*
9	Patas Monkey	*Erythrocebus patas*
10	Warthog	*Phacochoerus aetheiopicus*
11	Guinea Fowl	*Numida meleagris*
12	Francolin	*Francolinus bicalcaratus*
13	Stone Partridge	*Ptilopachus petrosus*
14	Red Flanked Duiker	*Cecphalophus rufilatus*
15	Python	*Python sebae*
16	Cobra	*Naja nigricolis*
17	Viper	*Bitis arientans Spp*

Source: Field Survey, 2021

Table 3: Classes of wild animals hunted in the study area

Class	Frequency	Percentage (%)
Mammals	11	64
Aves	3	18
Reptiles	3	18
Total	**17**	**100**

Table 4: Reasons and seasons of hunting in the study area

	Variables	Frequency	Percentage (%)
Reasons for Hunting	Food	16	32.0
	Income Generation	27	54.0
	Trophy	7	14.0
Seasons	Dry season	31	62.0
	Wet season	5	10.0
	Both season	14	28.0
	Total	**50**	**100.0**

Source: Field survey, 2021

Table 5: Instruments used for hunting in the study areas

Instruments	Frequency	Percentage
Dane Gun	36	72.0
Bow and Arrow	1	2.0
Traps	11	22.0
Pitfall	2	4.0
Total	**50**	**100**

Source: Field Survey, 2021

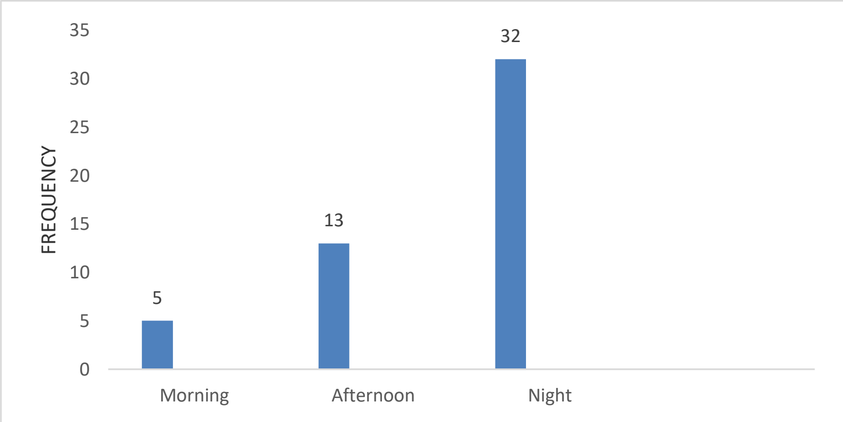


Figure 1: Time of hunting in the study area

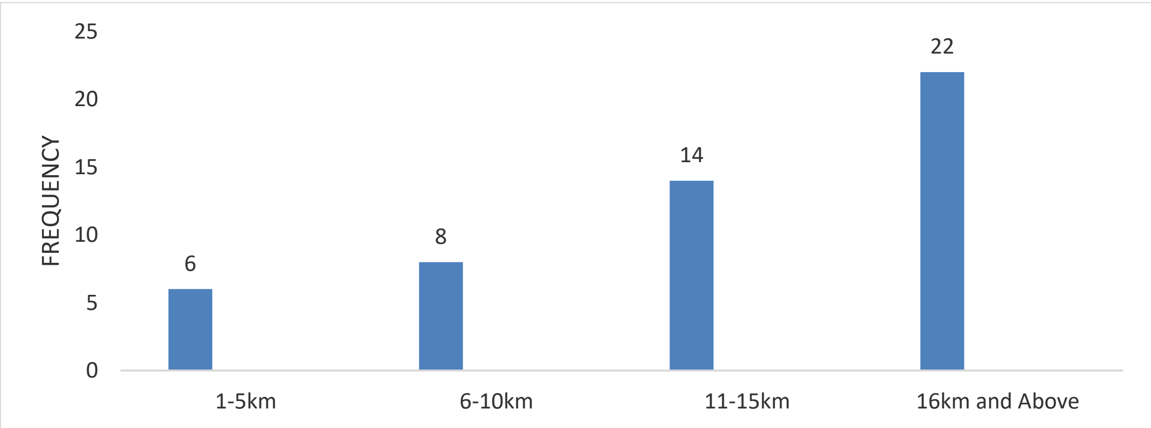
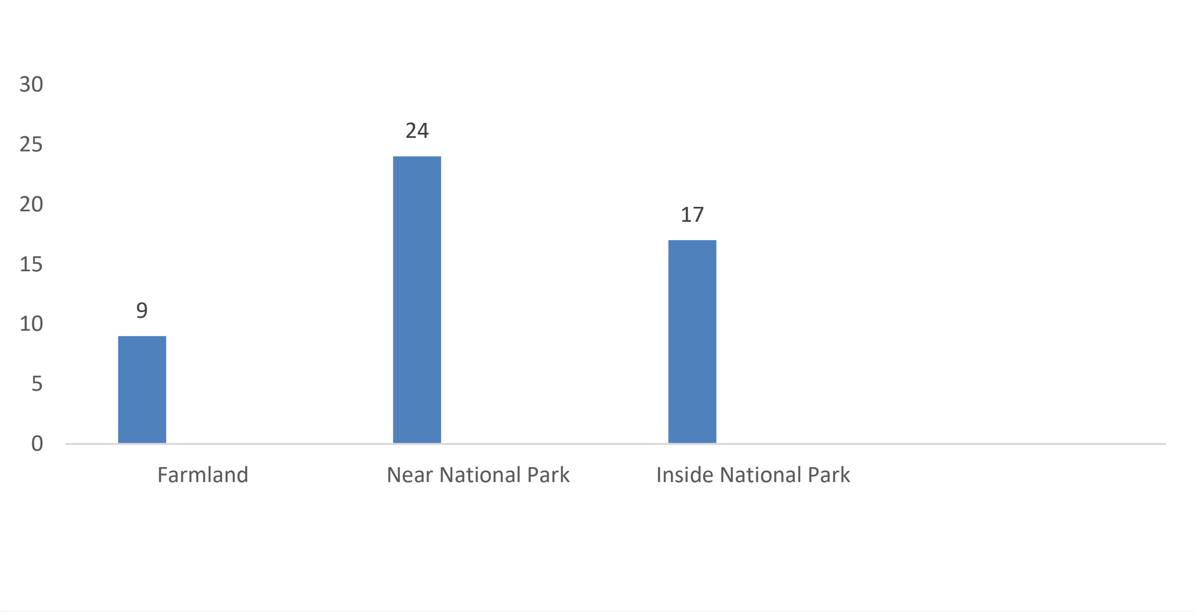


Fig 2: Distance covered during hunting activities in the study area.



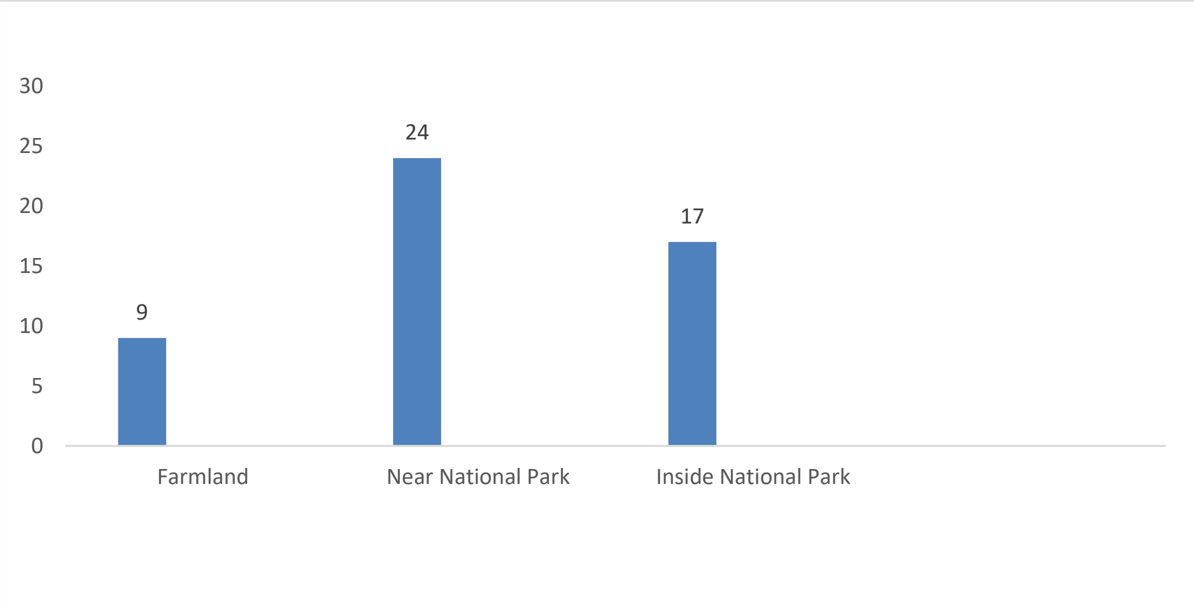


Fig. 3: Source of Bush meat in the study area

Table 6: Perceived status of wild animals hunted in the study Area

Variables	Frequency	Percentage (%)
Increase	6	12.0
Stable	11	22.0
Decrease	33	66.0
Total	**50**	100.0

Source: Field Survey, 2021

Table 7: Conservation status of wild animals hunted in the study Area

Conservation status	Frequency	Percentage (%)
Threatened	5	29
Near Threatened	3	18
Least Concern	9	53
Total	**17**	**100**

Discussion

The socio-economic contributions of wild animal species hunted as bush meat in Owotoro communities play a vital role in the living standard of the respondents, during the survey; gender variable showed that males were dominant in the bush meat hunting than females. This is in agreement with report of Ajayi, *et al.,* (2021) that men dominated hunting in selected communities in Ekiti State. Most of the hunters/marketers are within the age range of 31–40 years. This is similar to the report by Ojo, *et al.,* (2019) that men from an early age were involved in hunting and selling of bush meat. The result shows that most of the respondents were married people only few of them were single and divorced or separated. The major reason for hunting wild animals is for income generation. This is in line with report by Ajayi, *et al.,* (2021) that bush meat sale contributes 6-40% of all household daily income. Ajayi, *et al.,* (2021) that 72% of hunters generate an average of fifty thousand naira to one hundred and forty-nine thousand naira in bush meat trade in Ekiti state. Bush meat trade in the study area is lucrative and it is a significant source of income. This is in agreement with the report by Gally and Jeanmart, (1996) that hunters made 19% profit from the sale of monkeys and traders made 20% profit. Bush meats are available in the study area throughout the seasons but are more abundant during the dry season. Dry season was the preferred hunting season for most hunters (93%). According to hunters, wildlife ranges are open by dry season fire during dry season and hunting is easier then. During this season, they are also free from farming activities as the harvest season is over by October–November. There are some specific times during dry season when hunting expeditions are undertaken. Hunters report that hunting success is greater when a rainy night is followed by a bright morning. Seventeen (17) wild animals were identified to be hunted in the study area. However, the respondents' benefits from bush meat trade include payment of children's school fees and catering for their individual families need. Also, the socio-economic contributions of wild animals as bush meat to the people in the study area include serving as a source of animal protein for consumption, being used in traditional medicine for treating various ailments such as hypertension, protection against enemies and witches. They are important source of income to both the hunters and marketers. All the respondents said that they preserved bush meat stock using the smoking, drying and salting methods.

Conclusions

The study revealed a year round supply of bush meat amidst insecurity and global pandemic. It was established that hunting is an income generating venture for the upkeep of their family. Majority of the bush meat hunters were males, who are bread winners. Seventeen (17) species of wild animals were reported to be hunted with the use of Dane gun, traps, bows and arrows. Most of the respondents agreed that wild animals' population have decreased in the study area.

Recommendations

More conservation awareness programmes should be made to the major stakeholders in the communities to protect the dwindling wild animals' population in the study area. Game farming/wildlife domestication should be encouraged among individuals or families or groups through Non- Governmental Organizations provision of grants to discourage hunting.

Acknowledgement: I acknowledge the field contributions of my student, Mr. Aderonmu, Joseph Okiki, who hailed from the community.

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Plate 1: Adult Duiker

Plate 2: Warthog

Plate 3: Captured Young Duiker

Plate 4: Bush bucks

Plate 5: Young Duikers

Plate 6: Hare


Plate 7: Cobra snake


Plate 8: Python snake


Plate 9: Kob

ECOTOURISM AND WILDLIFE MANAGEMENT AMIDST INSECURITY AND GLOBAL PANDEMIC

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Introduction

Wildlife generally refers to any living thing that is not tamed and this includes non-cultivated plants and non-domesticated animals. Conservation on the other hand may be defined as the wise use of resources without compromising the future (Okeyoyin, 2016).

Therefore, Wildlife Management can be referred to as an art and or science of making land produce valuable populations of wildlife, for harvest or other uses sustainably from generation to generation. Wildlife Management consist of series of decisions—such as deciding on whether to carry out early controlled burning of dried grasses to stimulate the growth of succulent, fresh grasses for herbivores or late burning, whether to make use of scarce resources in constructing water points for animals to keep them from wandering away from a protected area or to buy modern equipment for monitoring, surveillances and antipoaching patrols im order to enhance ecological integrity of a protected area. These decisions must be made (in any protected area) at regular intervals. Therefore, Wildlife Management involves the manipulation of wildlife and the environment to enhance their population, growth and wellbeing. Wildlife management is borne out of wildlife conservation.

Why Do We Need To Conserve Wildlife

The biosphere supports a variety of life forms that are interrelated, interconnected, interdependent and intertwined (i.e food web). The varieties of lives on earth are so diverse that makes the world to become not only a beautiful and exciting place, but also a balanced system that requires intentional management strategy. Because of the complex interactions in the food web, when we cause the extinction of a species, we break a link in the web and this could ultimately affect the entire world's ecosystems negatively. Therefore, it is important for humans to ensure sustainable coexistence with other species on earth for perpetuity (Strahler and Strahler, 2005).

Some important areas where wildlife has significantly impacted human lives include:

- Health and Medicine
- Food and agriculture
- Agro-allied uses
- Pharmaceutical uses
- Education and Research
- Environmental value
- Aesthetic/ recreational value

Wildlife Management in Nigeria:

Nigeria has witnessed a rapid increase in the number and size of protected areas in the 20th century. The first forest reserve created in 1899 marks the beginning of designating protected areas in the country. In 1900, protected areas in Nigeria represent 0.01% of the country's total land mass, equivalent to 97,125 hectares. Five decades later, a substantial achievement was recorded as the figure increased to 8% in 1950 representing 7,332,031 hectares, and after that, it increased slowly to 11% in 1980 [Marguba, 2003]. The protected areas include forest reserves, biosphere reserve, game reserves, game/wildlife sanctuary, strict nature reserves, and national parks. They are established for the purpose of conservation of valuable environmental/-ecological resources, to meet tourism and recreational needs and to support research and education through proper management [Marguba, 2003]. In Nigeria, National Parks and Game Reserves constitute the greater percentage of the protected area system. [GEF, 2002] estimates the total area covered by Nigeria's protected areas to be over three million hectares, and about 2.3 million hectares fall into category Ia and II of the IUCN category.

There are 1,000 protected area records stored in the WDPA for Nigeria, 988 are national-level protected areas with 12 designated under international and regional agreements or conventions (UNEP-WCMC, 2015, UNEP-WCMC and IUCN, 2021)). These include national designations (988) of 7 National Parks, 35 game reserves, 933 forest reserves, 5 strict nature reserve, 2 wildlife sanctuary, 1 community forest and international designations (12) of 4 UNESCO-MAB Biosphere and 11 Ramsar site, wetland of international importance, all constituting 13.93% (127,332km2) of 914,306km2 total land area of Nigeria.

It is important to mention here that in 2021, President Muhammadu Buhari approved the upgrading of 10 Game Reserves to National Parks across the country of which 2 are Marine National Parks for the protection of the country's marine wildlife.

Summary of protected areas in Nigeria:

S/N	Protected areas	Number
	National designations	
1	National parks	7
2	Game reserves	35
3	Forest reserves	933
4	Strict nature reserves	5
5	Wildlife sanctuary	2
6	Community forest	1
	International designations	
7	UNESCO-MAB biosphere reserve	4
8	Ramsar site, wetland of international importance	11
	Total	1,003
	Land area covered	127,332km2
	% of total land area covered	13.93%

Source: Adapted from UNEP-WCMC and IUCN, 2021.

What is Tourism?

The World Tourism Organization defines tourism more generally, in terms which go "beyond the common perception of tourism as being limited to holiday activity only", as people "traveling to and staying in places outside their usual environment for not more than one consecutive year for leisure and not less than 24 hours, business and other purposes" (UNWTO, 2009). Tourism can be domestic (within the traveller's own country) or international, and international tourism has both incoming and outgoing implications on a country's balance of payments.

The tourism industry generates substantial economic benefits to both host countries and tourists' home countries. It is, especially, an important industry to developing countries. The main benefits of tourism to a country are:

- Foreign exchange earnings,
- Tax revenues,
- Business opportunities for budding entrepreneurs, and
- Employment for workers in the industry.

For these reasons, the tourism industry provides tremendous opportunity for relatively small businesses to thrive and is a leading generator of jobs. The World Tourism Organization (WTO) estimates that tourism represents 8 percent of jobs world-wide.

Tourism is widely regarded as one of the largest and fastest growing economic sectors in the world. Since the 1980s, tourism has been one of the leading growth sectors in the global economy according to United Nation World Tourism Organization (UNWTO) statistics, from 1950 to 2010; international tourist arrivals grew from 25 million to 940 million. The sector has seen significant growth in revenue and employment as well as the development of new and fledgling markets. It contributes significantly to national GDPs and is a top employer in the economies of many nations. Tourism is labor intensive service which means it employs a lot of people in developing world where jobs are still limited. It is also a security sensitive activity which means that any hints of threat and danger to tourists can damage it.

There are numerous specialty forms of tourism that have emerged over the years, each with its own adjective. Many of these terms have come into common use by the tourism industry and academics (Lew and Alan A. 2008) others are emerging concepts that may or may not gain popular usage. Examples of the common tourism are: educational tourism, agritourism, birth tourism, culinary tourism, cultural tourism, dark tourism (also called "black tourism" or "grief tourism"), extreme tourism, geotourism, heritage tourism, medical tourism, film tourism, nautical tourism, pop-culture tourism, religious tourism, sex tourism, slum tourism, sports tourism, virtual tourism, war tourism, wellness tourism, and ecotourism which is one of the main focus of this presentation.

For the purpose of this presentation, there is the need to define the following key words; ecotourism, security, insecurity and pandemic.

Ecotourism also known as ecological tourism, is responsible travel to fragile, pristine, and usually protected areas that strives to be low-impact and (often) small-scale. It helps educate the traveller; provides funds for conservation; directly benefits the economic development and political empowerment of local communities, and fosters respect for different cultures and for human rights.

Pandemic are large-scale outbreak of infectious disease that increase morbidity and mortality over a wide geographic area and cause significant economic, social and environmental disruption (Madhav et al, 2017).

Experts in emerging infectious diseases have been warning for decades that habitat fragmentation and degradation, and live animal markets increase the risk of diseases spilling over from wildlife to humans. The emergence of some new diseases of our time i.e. HIV, Ebola, SARS, COVID-19 among others can be at least attributed in part to increased human impact on wildlife and natural systems.

The Covid-19 case is over 108.2 million and over 2.3 million people dead globally (WHO, 2021). In the past, several significant disease and pandemic such as the Spanish flu, SARS, Hong Kong flu, Ebola recorded to cause extensive disruption of

ecotourism and wildlife management across the globe ((Madhav et al, 2017). Traveling and integration on the global scale, urbanization, land-use changes, and greater biodiversity exploitation led to the recent increase in pandemics (Wu et al. 2017). **Security** is protection from, or resilience against, potential harm (or other unwanted coercive change) caused by others, by restraining the freedom of others to act. Beneficiaries (technically referents) of security may be of persons and social groups, objects and institutions, ecosystems or any other entity or phenomenon vulnerable to unwanted change.
The range of security contexts is illustrated by the following examples Computer security, corporate security, ecological security, food security, home security, human security and national security. While **Insecurity** on the other hand, is a potential for violation of security, which exists when there is an entity, circumstance, capability, action, or event that could cause harm.

What are the major causes of insecurity in the country?
Nigeria in recent times has witnessed an unprecedented level of insecurity such as Boko Haram activities, banditry, kidnapping and Herders – Farmers clashes. This has made national security to be a major issue for the government. However, the recent surge of insecurity in the country has been broadly linked to staggering poverty. Youth unemployment currently stands at 32.5%. The other major causes of security threats include:

- **Pervasive Material Inequalities and Unfairness** – Greater awareness of disparities in life is a major root cause of insecurity in Nigeria. This is a rooted general perception of inequality and unfairness which has resulted in a grievance by a large number of people. This perception stems from the perception of marginalization by a section of the people, government development policies, and political offices and this has become a primary source of disaffection and resentment. A large number of the Nigerian population is frustrated and have lost hope, especially the youths, and have now emerged to express their disillusion about the pervasive state of inequality.
- **Ethno-Religious Conflicts** – Ethnoreligious conflicts are major source of insecurity in Nigeria. These have arisen from distrust among various ethnic groups and among the major religions in the country. The ethnoreligious conflict was defined as a situation in which the relationship between members of one ethnic or religious group and another of such group in a multi-ethnic and multi-religious society is characterized by lack of cordiality, mutual suspicion, and fear, and a tendency towards violent confrontation. Frequent and persistent ethnic conflicts and religious clashes between the two dominant religions (Islam and Christianity), present the country with a major security challenge. In all parts of Nigeria, there exist ethnoreligious conflicts and these have emerged as a result of new and particularistic forms of political consciousness and identity often structured around ethnoreligious identities.
- **Conflict of Perceptions between the Public and government** – Over the years, there has been a standing mismatch between public and government perceptions. A situation that often results in the reactions of the public to the excesses of the military regimes which governed Nigeria and has continued after the end of military regimes and created a sensitivity by those in government at public intrusion in matters of state.
- **Perceived Weak Security System** – It is perceived that the security arm of government is inadequately equipped both in weaponry and training to combat the daunting challenges posed by insecurity.
- **Loss of Socio-cultural and communal value system** -The traditional value system of the Nigerian society like most African societies is characterized by such endearing features as collectivism, loyalty to authority and community, truthfulness, honesty, hard work, tolerance, love for others, mutual harmony and co-existence, and identification of an individual with another (Other distinctive features of Nigerian traditional society are abhorrence for theft and high value for life. Stealing was considered extremely disgraceful and lives were also highly valued). All of these values which made society secured and safe have all gradually been thrown away and lost. New values have taken over their place over the years, with the so-called ‘modernity and civilization’. All our endearing values and morals have been traded off for western values.
- **Porous Borders** – One major immediate factor which has enhanced insecurity in Nigeria is the porous frontiers of the country, where individual movements are largely untracked. The porosity of Nigeria’s borders has serious security implications for the country. Given the porous borders as well as the weak and security system, weapons come easily into Nigeria from other countries. Small Arms and Light Weapons proliferation and the availability of these weapons have enabled militant groups and criminal groups to have easy access to arms. Nigeria is estimated to host over 70 percent of about 8 million illegal weapons in West Africa. Also, the porosity of the Nigerian borders has made it possible for an unwarranted influx of migrants from neighbouring countries such as the Republic of Niger, Chad, and the Republic of Benin. These migrants which are mostly young men are some of the perpetrators of crime in the country.
- **Rural/Urban Drift**– The migration of jobless youths from rural areas to urban centres is also one of the causes of insecurity in Nigeria. Nigeria is one of the countries in the world with very high rural/urban drift. Most urban areas in Nigeria have grown beyond their environmental carrying capacities and existing infrastructure and this has resulted in increased poor quality of the living conditions in urban areas in Nigeria. Out of frustration, these youths are drawn into crime.
- **Unemployment/Poverty** -As a result of the high level of unemployment and poverty among Nigerians, especially the youths, they are adversely attracted to violent crime.
- **Terrorism** – At the most proximate and least disputable level, terrorism is the most fundamental source of insecurity in Nigeria today, and its primary bases and sources of support have generally been located in religious

fanaticism and intolerance. As "the premeditated use or threat of use of violence by an individual or group to cause fear, destruction or death, especially against unarmed targets, property or infrastructure in a state, intended to compel those in authority to respond to the demands and expectations of the individual or group behind such violent acts" which has cost 13.4 percent of the world gross domestic product. Nigeria has lost large numbers of lives in the Northern region since 2009 to the insurgency of this infamous sect, Boko Haram which has been ravaging the northern region of the country.

- **Environmental Degradation and Loss of Soil Fertility**: The insecurity situation in Nigeria is concentrated in the Niger-Delta and the Northeastern areas. While residents in Niger-Delta have lost their farmlands and water meant for drinking and fishing to widespread pollution as a result of oil explorations and exploitations, those in the northern states have lost their farmlands to rapidly encroaching desert rendering hundreds and thousands of individuals jobless in these areas.

What are the Major Impacts of insecurity on Ecotourism & Wildlife Management?

a. **Habitat Loss:** Apart from population growth, fast industrialization, urbanization and modernization, insecurity is having a great deal of destruction on natural habitat of plants and animals.

b. **Pressure on Wildlife Resources:** the inhabitation of some parts of the forest reserves in the country has led to connivance with poachers and loggers to kill and poach wild animals and this is resulting in reduction and even extinction of many wild species.

Confiscated logs

Poachers arrested by Park Rangers

Poachers arrested with their Kills

Tree House burnt in Okomu National Park

c. **Negative Image on Tourist Destinations:** Foreign countries in response to negative image created by insecurity, issue travel advisories to their citizens against traveling to countries with the slighted security activities. On 26 June 2015, 38 people, mostly British tourists, were killed by a gunman at a tourist resort in Port El Kantaoui, just outside the city of Sousse in Tunisia. Not to mention the human tragedy, the immediate economic consequences were devastating for an economy that gets almost 15% of its GDP from tourism. Several tour operators and air carriers adjusted or cancelled tourist bookings in the months that followed the attack. Many potential visitors shifted their holiday trips to safer destinations such as Spain or Italy.

d. **Attack on Park Officials:** The National Parks in the North East, North West and North Central have had a fair share of bandits' and terrorist attacks in the recent past. It is important to note that the Service has been grappling with banditry in these parks viz; Chad Basin, Kamuku, Kainji Lake and Gashaka Gumti. Many lives and Park assets have been lost to this heinous act. Records available in the Service indicate that between 2012 and 2013, Chad Basin National Park lost a total number of 5 Park Rangers to Boko Haram. Similarly, Kamuku National Park lost 2 Park Rangers in 2012 while Gashaka Gumti National Park recorded the loss of 6 Park Rangers from 2018 to 2019. However, the Park recently hit by this security threat is the Kainji Lake National Park which between 2020 and 2021 has lost 3 Park Rangers.

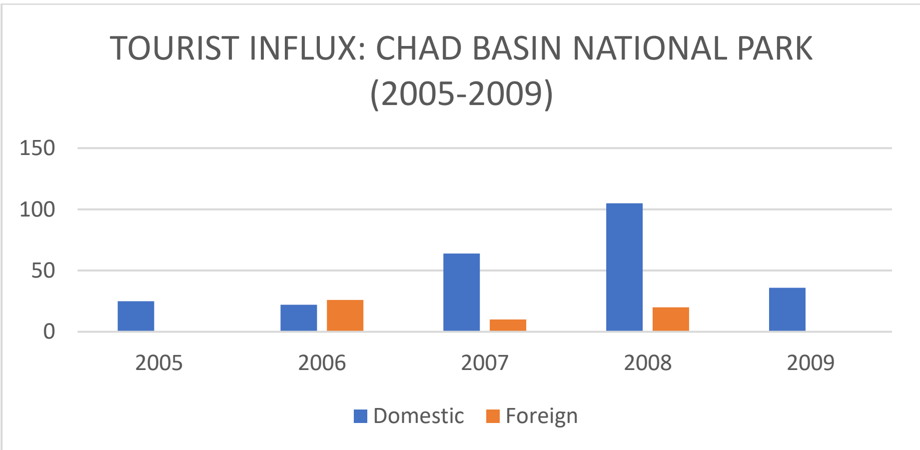
Some parts of these Parks have become inaccessible especially the Chingurmi-Duguma Sector of Chad Basin National Park in Bama local government area of Borno State as well as Kamuku National Park. However, with the collaborative efforts with the Nigeria military and other sister paramilitary agencies sanity has begun to return to these areas of the Parks.

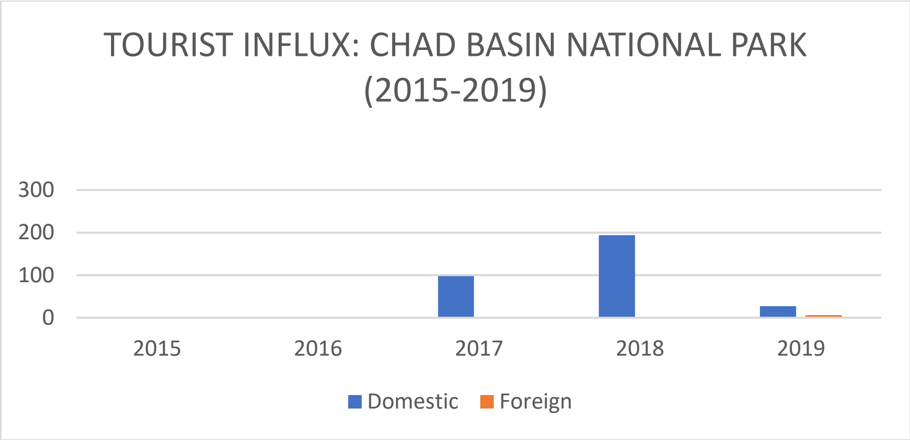
Park Rangers killed Suspected Bandits in KLNP

Burnt Patrol Vehicle by Bandits in KLNP, March, 2021

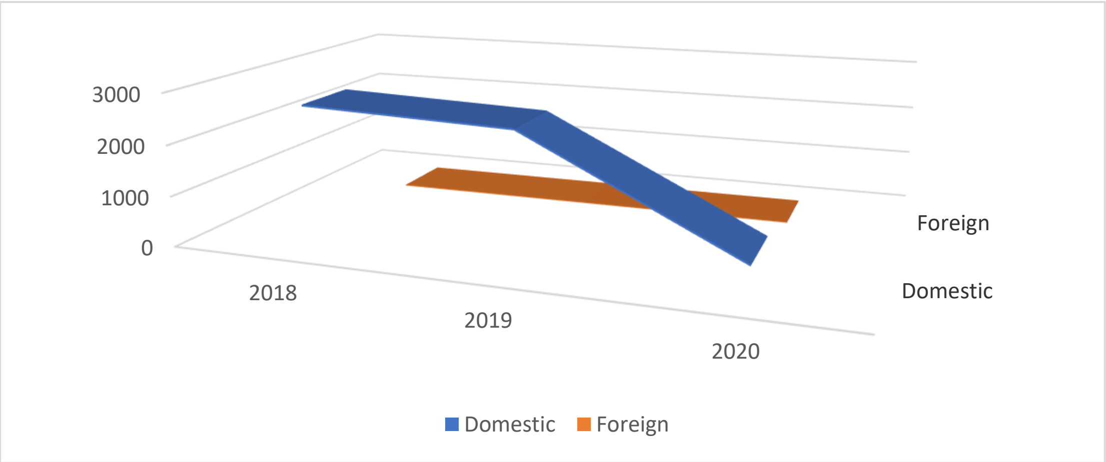
Razed Ranger Camp by Bandits in KLNP

e. Low Tourist Influx: The effects of insecurity might cause political instability, which leads to the decline or disappearance of tourist arrivals in some tourist destinations. The available literature and statistics confirm that terrorist attacks alter tourism demand patterns, indicating an increasing demand to cancel travel or holiday plans. Safety and security are highly prized assets. Tourists and visitors naturally avoid destinations with widespread reports of the presence of terrorist activities. Below is the statistics of tourist arrivals to two (2) of the Nigeria's National Parks; Chad Basin and Kainji Lake before and during terrorism in the country.

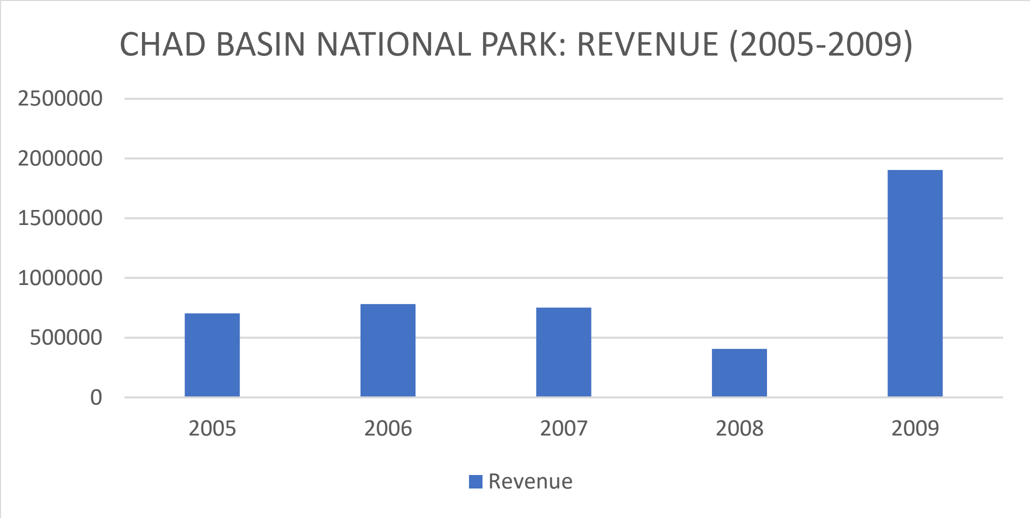


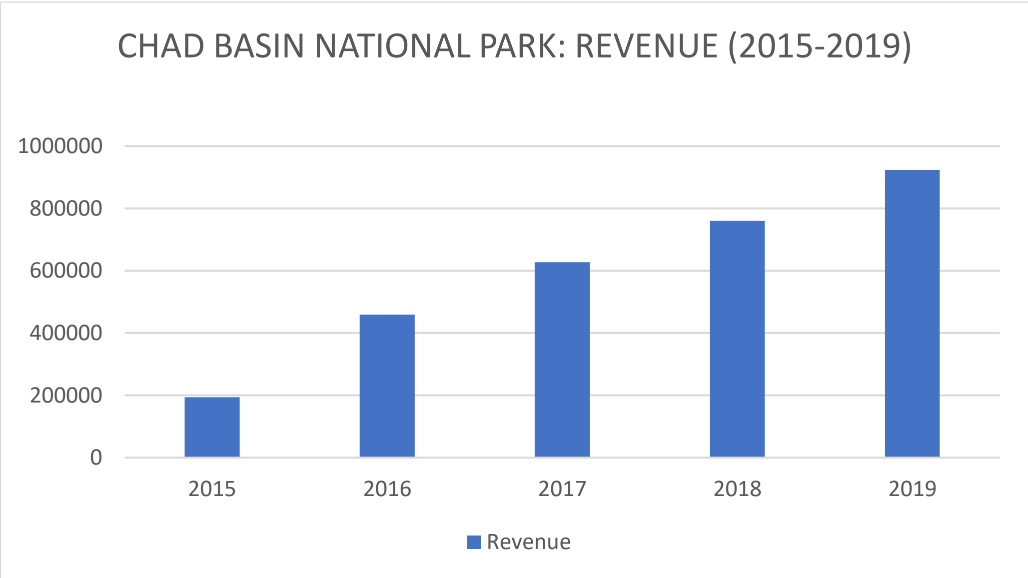


TOURIST INFLUX: KAINJI LAKE NATIONAL PARK (2018-2020)



f. **Reduction in Foreign Earnings:** Insecurity reduces tourist demands and revenue expected to be generated. Tourism, both domestic and International, gives impetus to national income (Mill, 1990). Tourists have to pay for different types of goods and services in the host country. The flow of money generated by tourist spending multiplies as it passes through various segments of the economy. A tourist makes an initial expenditure into the society which is received as income by local tour operators, shopkeepers, hotels, taxi drivers. So, tourism constitutes a demand for consumer goods and services and therefore when tourist inflow is hampered by acts of terrorism the negative effect is reflected in national travel receipts/GDP of the host country. Below is a case study of internally generated revenue pattern of Chad Basin National Park:





g. **Creates Unemployment:** Tourism offers great employment opportunities to our teeming population in the areas of tour operation, sales of souvenirs and provisions, transportation, hotel accommodation, entertainment and local art and craft etc. The advent of terrorism and the consequent absence of tourists in the country therefore evaporate these employment opportunities created in the tourism industry. And of course, loss of jobs leads to loss of income which translates to poverty and insecurity.

h. **Infrastructural decay:** Tourism business necessitates the provision of infrastructures, utilities and amenities which are not only used by the visitors/tourists but become valuable to the local population as well. The economic importance of tourism in national economy can be appreciated with reference to its contribution in infrastructural development (Mathleson and wall, 1982). Unfortunately, tourism facilities and utilities are often targeted and destroyed by terrorists. Apart from this, the disruption of tourist flows to these destinations over time results in the decay of the infrastructure due to lack of tourist revenues to finance their maintenance.

Effects of Global Pandemics on Ecotourism & Wildlife Management:
The Covid-19 pandemic affected virtually all sectors and the biodiversity conservation sector at local, regional and global levels (Corlett et al. 2020). Its effect on biodiversity conservation are many and either negative or positive in form but the negative impact outweighed the positive one (Muhumuza and Balkwill, 2013; Roe et al, 2015; Corlett et al, 2020). In the same vein as the previous disease outbreaks, Covid-19 led to the inability to manage the protected areas and carryout conservation programs because of the total lockdown (Corlett et al, 2020). The positive impacts include;

- Reduced atmospheric Pollution
- Reduced Human Pressure on Wildlife

The Negative impacts of the pandemic include:

- Loss of Skilled Personnel and Funds
- Ineffective and Lukewarm Staff
- Weakened Performance in the Protected Area
- Reduced Revenue and Staff Strength
- Human/Resource Conflict
- Increase in local exploitation
- Lack of Research, Assessment, and Monitoring on Biodiversity

Global Pandemics remain a threat to Ecotourism & Wildlife Management through tourism revenue loss in Pas. The financial loss affects the budget, population monitoring/assessment programs, and the job loss to negative human behavior that drives human-wildlife conflicts and natural resources destruction. Pollution and Poaching activities may increase or decrease depending on accessibility to locals and vehicular restriction to long distant poachers.

Challenges of Ecotourism & Wildlife Management in Nigeria:

However, despite the number of PAs in the country, their management status remains questionable. It has been observed theoretically that the PAs are protected by law at different levels of governance but in practice the situation is different as most of them are only protected by names and can be best described as “paper reserves”. This situation is attributable to a number of challenges confronting the management of the PAs such as;

- Inadequate and untimely release of allocated funds.
- Inadequate manpower.
- Inadequate infrastructural facilities (poor road network, communication, medical facilities, etc.).
- Poaching (logging, grazing, mining, hunting, fishing, etc.).
- High rate of rural and urban poverty: about 70% of Nigerians live below poverty level.
- Population explosion
- Urban expansion and infrastructural development.
- Uncoordinated land use policy.
- Inadequate data on status of biodiversity.
- Unsustainable agricultural production on marginal lands and other unsustainable farming practice.
- Lack of transboundary Protected Areas configuration in some reserves.
- Use of Protected Areas as hideouts for organized crimes (banditry, kidnapping, rustling, etc).
- Inadequate Synergy among the Security Agencies
- Existence of human enclave.
- Climate change and natural disasters.
- Corruption
- Government long neglect of the sector due to early crude oil discovery.
- Fuelwood exploitation

Way Forward

I. The Federal Government afforestation programme (green bond project) be sustained to mitigate the effect of climate change, habitat degradation and enhance forest cover.
II. Effective anti-poaching patrols of the parks and other forest/game reserves in the country.
III. Enhanced border security along Nigeria’s international boundary lines. Federal Government should collaborate with state governments to address the challenge of border porosity.
IV. There should be concerted efforts to recruit, train and post personnel of the security agencies to boost surveillance and stem the free flow of arms and questionable persons into the country.
V. Aggressive implementation of the newly approved 2020 National Forestry Policy which guarantees sustainable management of the forest ecosystems, social economic growth and environmental sustainability and provision of goods and services for domestic and export purposes.
VI. Aggressive public enlightenment programmes at all levels of government on the importance of conservation via print and electronic media, billboards, flyers, jingles, etc.
VII. Introduction of wildlife conservation in the school’s curriculum and both elementary and post – elementary levels.
VIII. Establishment of conservation clubs in both primary and secondary schools (catch them young).

IX. Establishment of forest monitoring team to carryout coordinated patrols against illegal loggers like it happens in Customs, Police, etc.
X. Establishment of mobile courts to try offenders for quick justice delivery (both illegal loggers and erring forest officials).
XI. Creation of more National Parks (as recently done by the Federal Government), as well as Forest and Game Reserves, wildlife parks and zoological gardens, etc.
XII. Resuscitation and development of the abandoned forest and game reserves in the country.
XIII. Empowerment of the forest officers i.e. provision of the needed logistics to carryout their job efficiently and effectively.
XIV. Review other obsolete forest and wildlife laws at all levels of governments in the country to reflect the current situation in the sector.
XV. The ongoing military response to insecurity should be sustained through strategic coordination with the Nigeria Police and other security agencies.
XVI. The Federal Government should prioritize law enforcement solutions in tackling rising insecurity in the country. Community policing is critical to intelligence gathering in identifying and tracking the cells of criminal groups in the states and aiding community response to insecurity.
XVII. Federal Government should replicate the multilateral joint task force with other countries in the West African sub-region to share information and enforce security just like it did in the Lake Chad Basin.
XVIII. The current commitment of the Federal Government to strategic investments in human and infrastructural development can work to solve the protracted underlying challenges. This should be sustained.
XIX. The three tiers of government should collaborate with established religious and traditional institutions to build community resilience against insecurity. In this wise religious and traditional leader should be apolitical and endeavour to teach adherents that the God they claim to worship and serve is neither blood-thirsty nor a confusionist that sets humanity against itself in his name.
XX. Citizens should be encouraged to tour Nigeria, visiting natural and cultural places and peoples to modify their egocentric temperaments and foster national unity and peace.
XXI. National parks provide aesthetic attractions which have the potentials of turning Nigeria into a major ecotourism destination with attendant foreign exchange earnings, thereby raising the revenue profile of the country and facilitating the much-desired economic diversification. There is therefore need for conservation and tourism education at all levels to re-orientate Nigerians on virtue and to have pride in the nation.
XXII. Provision of fuel-efficient cooking stoves to local communities to reduce their impacts on the forests.

By way of my conclusion, Nigeria is blessed with abundant wildlife resources but the various unwholesome human activities enumerated in this paper have negatively affected their full growth and utilization. It is thus my strong belief that if the way forward recommended in this paper are diligently considered and implemented, without any doubt in my mind, the country will witness a positive growth and steady improvement of the country's forest cover which is presently about 6% against the 25% targeted to be met by 2030.

Dear invited guests, participants, ladies and gentlemen, I wish to thank you all for the opportunity given to me to present this paper. Thank you for listening and God bless.

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Associating *Azadirachta indica* A. Juss and *Eucalyptus camaldulensis* Dehnh Shelterbelt on the Growth yardsticks, Microbial Population at Kiyawa, Dutse, Jigawa State

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Abstract

This study was carried out in the year 2021 at Kiyawa community which aimed to investigate growth attributes, identified the fungi, bacteria and determined the microbial load in the neem and eucalyptus shelterbelts. 1 kilometer line transect was laid with four sample plots established (30 × 30m) which were used for collecting data of the tree with an interval of 100m from each plot. Also, 1×1m mini-plots were used for measuring quantity of litters. Diameter at breast height and height were accessed with the aid of meter rule and Haga altimeter while volume and Basal area were calculated. Potato Dextrose Agar (P.D.A) media used for the isolation of fungi while Nutrient Agar (N.A) medium was used to isolate bacteria sterilized in autoclave for 15 minutes at 121°C. Fungi Morphology was studied with aid of microscope by observing colony features. The data collected was analyzed using descriptive statistic (table) and inferential statistic: t-test was employed. The results showed that *Azadirachta indica* plots had the highest Dbh, Basal area, Height, and volume of 82.25cm±1.23, 0.90m^2±0.15, 15.90m±0.24, 970.78 m^3±4.27m^{3}followed by the *Eucalyptus camaldulensis* hotspot which had the least value of 62.50cm±0.93, 0.463m^2±3.43, 3.75m±0.03 and 347.85±2.43m^3 respectively. The findings showed the presence of three (3) species of bacteria in each study site. Eucalyptus shelterbelt has *Staph avenus* and *Bacillus cereus* while *Bacillus subilis* and *E. coli* were presence in Neem hotspot. *Pseudomonas spp* can be traced to both hotspots. Fungi traced to the both study sites were *Aspergillus niger* and *Penicillum species*. However, *Aspergillus flaming* occurred in eucalyptus hotspot while *Fusarium oxysporum* present in Neem shelterbelt. Result revealed that grand mean microbial load of fungi (Eucalyptus 1.45x 10^6; Neem1.50x10^6) is higher than bacteria (Eucalyptus 1.24 x 10^6; Neem1.3 x10^6). There is significant difference between the bacterial microbial loads between the study sites at ($p \leq 0.05$). The hotspots support better growth attributes of neem tree and fungi microbial load. Therefore, neem tree is recommended for economic and ecological reasons and adaptive arable crops should also intercrop with tree to supply improve economic value of shelterbelt and land user.

Keywords: Comparative, Growth yardsticks, Kiyawa, Microbial population and Shelterbelts.

INTRODUCTION

Forest inventory has been defined by Husch *et al.,* (1972) as the procedure for obtaining information on the quantity and quality of the forest resource and many of the characteristics of the land area on which the tree is growing. A complete forest inventory for timber resources evaluation provides the following basic information: a description of the forested area including ownership and accessibility, estimates of timber quality and quantities and estimates of growth and drain. Non-timber information may also be included on wildlife, areas of recreational and touristic interest, soil and land use capabilities on water shed values. Forest biodiversity protection relies on the ability to assess hot spots, quantify and predict spatial and temporal trends of key species which maintain a natural disturbance regime and limit harmful human activities (Stohlgren *et al.*, 1999). Protected areas made to known by the International Union for Conservation of Nature (IUCN) as an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means (IUCN, 1994). Forest protected areas help conserve ecosystems that provide habitat, shelter, food, raw materials, genetic materials, a barrier against disasters, a stable source of resources and many other ecosystem goods and services and thus can have an important role in helping species, people and countries adapt to climate change. They can thus continue to serve as a natural storehouse of genetic material into the future. They help in the conservation of indigenous species that are resistant to pests, diseases and pathogens, environmental stresses and nutrient loss.

Soil is a complex and dynamic ecosystem where substantial physical, chemical, and biological processes take place (Jelena *et al*., 2018). According to Nannipieri *et al.* (2003), the most important biological processes in soil (80-90%) occur due to microbial enzyme systems reactions. Rousk *et al*. (2008), stated that soil chemical and physical characteristics are major factors of soil microbial community structure. The physico-chemical properties of soil are ultimately related to soil fertility which affects the floristic composition of forest. There is a mutual connection between the soil microflora and the vegetation of an ecosystem. Microorganisms help in mineralization and decomposition of plant materials to a form that can be absorbable by plants (Pietikainen, 1999). Sigstad *et al*., (2002) also pin pointed that bacterium as the most occurrence and it is through their metabolic activity that minerals and soil organic matter are transformed in a way that important nutrients such as N, P, and S are simultaneously converted into useable forms for plant and other micro-organisms. *Eucalyptus camadulensis* tree has phyto-chemicals that are known to possess antitermic repellent activities (Jibo *et al.,* 2021; Geoff, 2007) and releases compounds which inhibit the germination or growth of other potential competitor's plants. Outside their natural ranges, eucalyptus is both lauded for their beneficial economic impact on poor populations (Luzar, 2007). According to "Merriam Webster" Shelterbelt are barrier of trees and shrubs that provide protection (as for crops) from wind and storm and lessens erosion. A shelter belt is a planting usually made up of one or more rows of trees or shrubs planted in such a manner as to provide shelter from wind and to protect soil from erosion. Shelter belts can also be known as windbreak because they are commonly planted in hedge rows around the edges of field on farms. It's uses cannot be unnoticed and it plays a vital role in our daily lives and specially as farmers. Some of the uses are to: Providing habitat for wildlife and serve as woods if the trees are harvested, Windbreaks within one's environment reduces the cost of heating and cooling and saves energy. This research seeks effort to generate information on the essence of utilizing shelter belts. Therefore, the aim of the study is to access the growth variables and microbial population of Katika Shelterbelt, along Kiyawa-Jahun road, Jigawa State, Nigeria with the view of providing better management and conservation strategies for the shelterbelts.

Materials and method

The study area

The two protected areas i.e shelter belts are located in Katika along Kiyawa and Jahun road. The shelter belt was established in 1989 by the Department of Forestry, Ministry of Environment, Kano State. Kiyawa is located in the southern region of the state. The region is about 500-600m above the sea level Maryam *et al.,* (2019). Jigawa and Kano are ruled under the same government and later fall under Dutse Emirates. It covered an area up to 3 hectares. The Shelterbelts comprises of Neem and Eucalyptus tree species which are planted in rows (JARDA, 2016). The Shelterbelt is located at the coordinate of Latitude 11°47'05"N, 09°36'30"E and Longitude 11°78°472°N, 9°08°33°E. The annual mean temperature is about 25ºC but the mean monthly value ranges between 21ºC in the coolest month and 31oc in the hottest month (Azare *et al.,* 2019) and also soil type is sandy (Salami and Lawal, 2018); Jibo *et al.,* 2021)

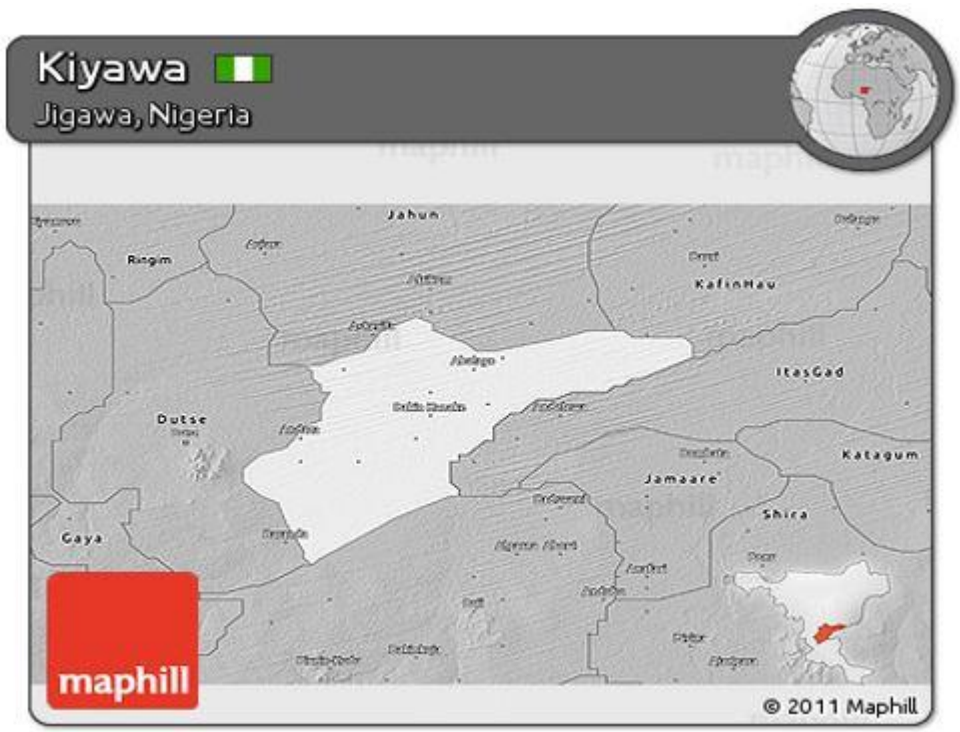

Figure 1: Showing map of Kiyawa

Source: Cartography and GIS Lab, Bayero University, Kano (2020)

Source: Field source (2021)
Plate 1: Shelter belt of *Azadirachta indica* (Neem)

Source: Field source (2021)
Plate 2: Shelter belt of *Eucalyptus camaldulensis*

Data collection

Sampling Layout and procedure

Systematic sampling design (systematic line transects) was used in laying out of the plot. A line transects of 1km with four samples of size 30m × 30m was laid in each shelterbelt. Eight sample plots were assessed during experiment for both studies. All woody plants within transects were enumerated while 1m x 1m sample plot was laid within each of the main sample plot for soil collection (Aminu, 2021; Salami, 2017)

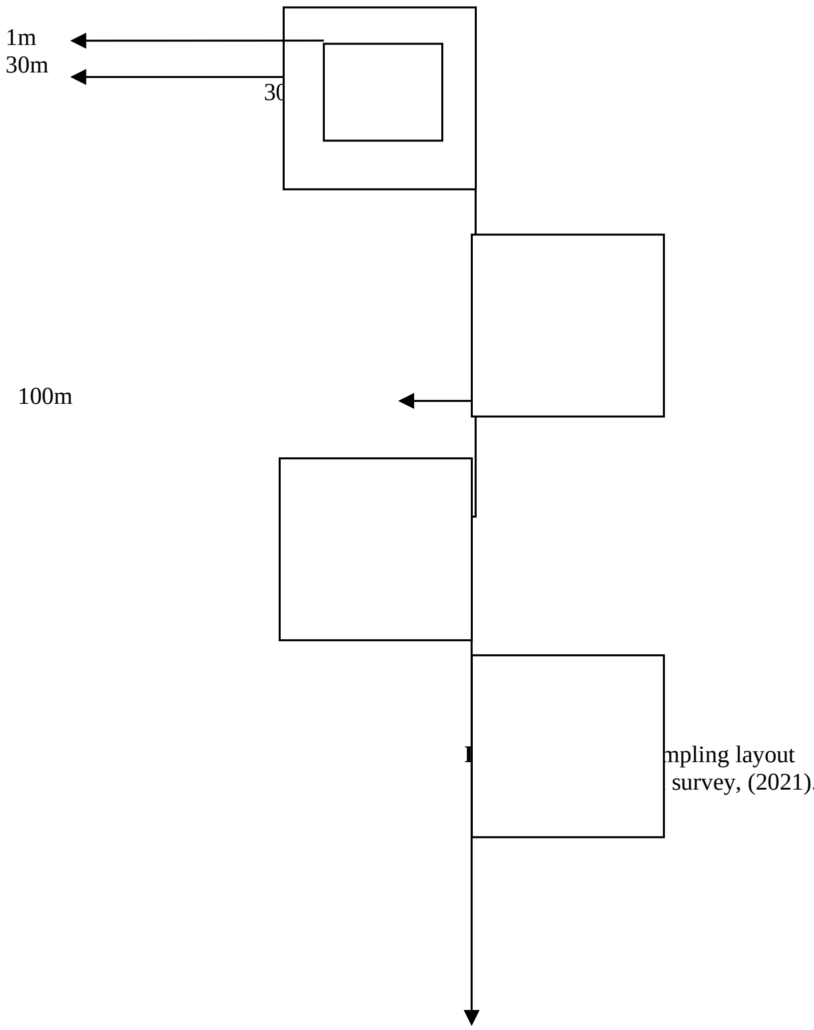

Figure 2: Plot layout for the methodology

Tree enumeration

All Woody plants with DBH of 10 cm was enumerated. Tree growth variables such as the diameter at the base (Db), Diameter at breast height (DBH), diameter at the middle (Dm), Diameter at the top (Dt) and height was measured with Spigeal relascope. Basal area and volume was evaluated with appropriate formula with equation 1 and 2.

Soil collection

The sample plots laid in the shelter belts, thus, was used for soil collection. Soil samples were collected at three depths along the diagonal for each of the sample plot with the aid of a soil auger. The soil sample was collected at soil depth of 0-15cm only, because the number of count of bacteria and fungi always decrease with the depth of soil sample (Lawal *et al.,* 2018)

Identification of Micro-Organisms

Fungi Morphology was studied with aid of microscope by observing colony features (Colour and texture) and by staining with lacto phenol cotton blue and observed under compound microscope for the conidia, conidiophores and arrangements of spores (Ameba, 2001). Gram's staining was carried out on the growth culture plate to differentiate gram's negative organism from gram's positive organism. Biochemical test was carried out base on Gram's result.

Isolation of Micro-organisms

Potato Dextrose Agar (P.D.A) media was used for the isolation of fungi, the plate was kept at room temperature for 7 days. Dilution was prepared and used for the isolation of Bacteria. One (1g) of soil sample was taken and serial dilution was carried out in distilled water. Nutrient Agar (N.A) medium was used to isolate bacteria sterilized in autoclave for 15 minutes at 121°C. After 2 hours of incubation at 37°C. Streaking plate method was used to get single colonies of the culture, (Shanmugam *et al.,* 2013).

Data analysis

The data collected was analyzed using descriptive statistics such as tables while inferential such as T- test was employed to compare fungi, bacterial and microbial population in the study sites.

Stem Volume estimation

Volume of individual trees encountered in the plots. Mean volume for sample plots were calculated by dividing the total plot by the number of sample plots. Volume per hectare was obtained by multiplying mean volume per plot (VP) with the number of 50×50m plots.

The volume of all trees in the sample plots was calculated using this formula:

V = B.A × H **………………………………………………………………..……..(***eqn 1*).

Basal area calculation

The basal area of all trees in the sample plots was calculated using this formula:

$$BA = \frac{\pi D^2}{4}$$

…………………………………...(*eqn 2*).

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

The total basal area for each of the sample plot was obtained by adding the BA of all trees in the plot while mean BA for the plot (*BAp*) was obtained by dividing the total BA by the number of sample plots. Basal area per hectare was obtained by multiplying mean basal per plot with the number of 30 x 30m plots in a hectare (4).

Where *ha BA* = Basal area per hectare.

Where BA = Basal area (m^2),

D = Diameter at breast height (cm) and

Pie (3.142).

Results

Table 1: Growth Variables of Neem and Eucalyptus Species in the Shelterbelts

Parameters	Study site	Min	Max	Total	Mean	Stand Error
DBH(cm)	Neem	19.5	145	8441.75	82.25	±1.23
	Eucalyptus	18.0	107	6562.25	62.50	±0.93
Basal area (m^2)	Neem	0.15	1.65	92.70	0.90	±0.15
	Eucalyptus	0.025	0.90	48.56	0.463	±3.43
Height (m)	Neem	2.90	13.00	818.85	15.90	±0.24
	Eucalyptus	1.20	6.30	393.75	3.75	±0.03
Volume (m^3)	Neem	56.55	1885	99,989.8	970.78	±4.27
	Eucalyptus	21.60	674.1	36,524.25	347.85	±2.43

Table 2: Occurrence of Soil bacteria in Eucalyptus and Neem Shelterbelt

SN	Species	Eucalyptus hotspot	Neem hotspot
1	*Staph averus*	V	
2	*Bacillus cereus*	V	
3	*Pseudomonas spp*	V	V
4	*Bacillus subilis*		V
5	*E.coli*		V
Total		**3**	**3**

Note: V= *present*

Table 3: Occurrence of Soil Fungi in Eucalyptus and Neem Shelterbelt

S/N	Species	Eucalyptus hotspot	Neem hotspot
1	*Aspergillus niger*	V	V
2	*Aspergillus flamings*	V	
3	*Penicillum spp*	V	V
4	*Fusarium oxysporun*		V
Total		**3**	**3**

Note: V= *present*

Table 4: Mean microbial population of soil bacteria in Eucalyptus and Neem shelterbelt

SN	Species	**Eucalyptus hotspot** (CFU/g)	**Neem hotspot** (CFU/g)
1	*Staph averus*	1.32×10^6	
2	*Bacillus cereus*	9.2×10^5	
3	*Pseudomonas spp*	1.48×10^6	2.18×10^6
4	*Bacillus subilis*		1.46×10^6
5	*E.coli*		1.56×10^6
Grand mean		**1.24×10^6**	**$1.3 X10^6$**

Note: CFU/g is colony forming unit

Table 5: Mean microbial population of soil fungi in Eucalyptus and Neem shelterbelt

SN	Species	**Eucalyptus hotspot**(CFU/g)	**Neem hotspot**(CFU/g)
1	*Aspergillus niger*	1.30×10^6	1.88×10^6
2	*Aspergillus flamings*	1.01×10^6	Nil
3	*Penicillum spp*	2.04×10^6	1.38×10^6
4	*Fusarium oxysporun*	Nil	1.23×10^6
	Grand mean	**1.45×10^6**	**1.50×10^6**

Note: CFU/g is colony forming unit

Discussion

Growth parameter indices

The results showed that *Azadirachta indica* plots had the highest Dbh, Basal area, Height, and volume of 82.25cm±1.23, $0.90m^2$±0.15, 15.90m±0.24, $970.78m^3$±$4.27m^3$ followed by the *Eucalyptus camaldulensis* hotspot which had the least value of 62.50cm±0.93, $0.463m^2$±3.43, 3.75m±0.03 and 347.85±$2.43m^3$ respectively. However, the results were obtained from two different studies sites. It showed that *Azadirachta indica* had the greatest volume not only even volume even in terms of richness, height and growth compared to *Eucalyptus camaldulensis.* Mean basal area obtained was 0.90±$0.15m^2$ from Neem shelterbelt which implied that the study area had a high values of trees density and values that can be useful when properly managed and harvested for human purposes such as the construction of furniture's, electric poles, foal fuel, charcoal production followed by 0.463±$3.43m^2$. The inventory count of different species in the study area was fifty (50) in number. The result disagrees with the finding of Salami *et al*. (2021), whose reported higher mean volume and Basal area ($14126.59m^3$; $339998m^2$) at Warwade plantation in the area. No documentation on the growth assessment of shelterbelt in the past years.

Presence of fungi and bacterial

Table 2 and 3 revealed the presence of soil bacteria and fungi in the study sites. The findings showed the presence of three (3) species of bacteria in the study site. Eucalyptus shelter belt has *Staph avenus* and *Bacillus cereus* while *Bacillus subilis* and *E. coli* were presence in Neem hotspot. *Pseudomonas spp* can be traced to both hotspots. This implies that this species can thrive and found in many habitats despite nature habitat. The presence of fungi: *Aspergillus niger* and *Penicillum species* were present in both study sites. However, *Aspergillus flaming* occurred in Eucalyptus hotspot while *Fusarium oxysporum* present in Neem shelterbelt. Four different species of fungi present in both sites. Two (2) was common to both while a species found in each of the sites respectively.

Relationship between Microbial populations of the study sites

The findings of the comparative analysis of the microbial load of both fungi and bacteria were influenced by physical features of the soil. This agrees with finding of (Ateh *et al.,* 2020) who reported that the texture of the soil determine the nature of microbes present. Microbial organism plays importance roles in the decomposition of organic matter, nitrogen fixation and nutrient cycling (Lawal *et al*., 2018; Ateh *et al.,* 2019). The effects of the soil microbes are influenced by their population Classen, (2015). Microbial population in forest soils are determined by both chemical and physical properties of the soil (Seeley, 1981). The results from table 4 and 5 showed the relationship between microbial loads of bacteria and fungi found in the study site. The study revealed that five (5) species of bacterial were found which are *Staph averus, Bacillus cereus, Pseudomonas spp, Bacillus subilis and E. coli.* Microbial load of *Pseudomonas spp*in the Neem hotspot recorded higher mean valueof 2.18 x10^6followed by Eucalyptus hotspot with loadof 1.48 x10^6.The grand mean of Neem hotspot was recorded to be 1.3 X 10^6 which is higher than Eucalyptus hotspot with valueof 1.24 X10^6. This implies that bacterial microbial load is prominent and active in the neem than Eucalyptus hotspot. There is significant difference between the bacterial microbial loads between the study sites at ($p \leq 0.05$).

Furthermore, there is similarity in the microbial load values of fungi recoded in the two study sites with values of1.45 x$10^6$and 1.50 x 10^6 respectively. *Aspergillus niger* is higher in Neem than Eucalyptus shelterbelt with the microbial load of 1.88 x 10^6 and 1.3 x 10^6 respectively while for *Penicillum spp*, the microbial load is higher in Eucalyptus (2.06 x 10^6) than Neem shelterbelt (1.38 x10^6). The weight of the fungi is lower in Eucalyptus hotspot due to the effect of allele-chemicals which is higher in eucalytus than neem hot. The results from table 4 and 5 revealed that fungi load was higher than bacteria load at both study sites. This is in accordance to (Barbour *et al,* 1987; Zhou *et al,*2018) who revealed that nature of physical properties of the forest soil determines the population and microbes in the soils. The dominant and structural organization of the sand textural class in the study provided a spatially heterogeneous habitat for fungal community because of smaller size fraction (silt and clay) host higher bacterial community than larger size particle (size). Ateh *et al.,* (2019) supported the study carried that microbial load of fungi was higher than bacteria with the value of 4.49 x10 ^{5}and 3.43 x10^5respectively at the same soil profile level (0-15cm) in Girea soil of Adamawa. This study also agrees with Nkereuwem *et al*., (2020) who reported that fungi did better than bacteria in adapting to drying rewetting stress across the different soil locations during the drying rewetting cycle. However, Adekunle *et al.* (2005), disagreed with the finding and reported that the amount of bacterial microbial load is higher than fungi microbial load in Akure Forest Reserve in southwestern, Nigeria with the range of (26.14 x10^6, 360x10^6MPNg^{-1}) and (2.50x10^6 to 23.34 x10^6MPNg^{-1}) respectively.

Conclusion and recommendations

The hotspots support better growth attributes of neem tree and fungi microbial load. Bacteria microbial load is not prominent unlike fungi. Therefore, neem tree is recommended for economic and ecological reasons; adaptive arable crops should also intercrop with tree crops for improve economic value of shelterbelt and land user. Therefore, this study gives a basis for further research especially on degree of allelo-chemicals characteristics on the growth of arable crops/plants between neem and eucalyptus shelterbelt since there is no documentation at Kiyawa Shelter belt.

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