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VARIABILITY OF ORGANIC CARBON WITH SOIL DEPTHS UNDER DIFFERENT LAND USE PRACTICES IN FEDERAL UNIVERSITY OF AGRICULTURE. ABEOKUTA, OGUN STATE, NIGERIA

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ABSTRACT

Role of soil in tree growth is invaluable. Soil accumulates more carbon when compared to atmosphere and terrestrial vegetation. The impacts of land use practices on soil organic carbon under different land use were determined in the study. The soil samples were obtained at three different depths (0-30 cm, 30-60 cm and 60-90 cm) in *Leucaena leucocephala*, secondary forest, *Gmelina arborea*, *Tectona grandis* and abandoned farmland. Samples collected were analyzed for SOC, LOC, DOC, MBC, SOM, soil textures, CEC, TN, BS%, chemical properties, and Na, K, Ca and Mg. following the standard laboratory procedures. Data obtained were subjected to one-way Analysis of Variance and Duncan's multiple Range Test were used for the separation of means at 5% level probability. Result obtained indicated significant differences in amounts of organic carbon with varying depths. Highest values of SOC (8.92±0.32) were recorded at depth 0-30cm. *Leucaena* plantation had the highest values of SOC (8.92±0.00), MBC (10.12±0.13) and SOM (13.98±0.72). Lowest values of SOC (4.76±0.00), LOC (5.11±0.02), DOC (4.92±0.10), MBC (3.92±0.03) and SOM (9.84±0.011) were obtained in abandoned farmland. The declined in organic carbon parameters in abandoned farmland might be the reflection of the agronomic activities that had been carried out.

Keywords: organic carbon, secondary forest, abandoned farmland, land use practices, soil health.

INTRODUCTION

Land use is one of the major drivers of the numerous processes of environmental change which affects essential resources within the lands landscape, such as the soil resources (González *et al.*, 2014). Land use management depend on interaction of human activities on natural environment and their usage by man in time and space. Many factors influence human activity, such as local culture, economics and environmental conditions. Soil carbon (SOC) is the organic matter constituent of soil, composed of plant and animal residues synthesized by soil organisms at different stages of decay (Esmaeilzadeh and Ahangar, 2014). Soil organic carbon (SOC) is significantly important in soils because it has high Cation Exchange Capacity (CEC) which of course influences plant nutrients availability, aggregate stability and microbial activity (Liao *et al.*, 2015). However, "the dynamics in soil organic carbon upon land use change may occur due to changes in the rates of accumulation, turnover and decomposition of soil organic carbon (Poeplau *et al.*, 2011). The land use type is an important factor controlling soil organic carbon levels since it affects the amount and quality of litter input, the litter decomposition rates and the processes of organic matter stabilization in soils (Römkens *et al.*, 1999). Many research findings have affirmed that soil organic carbon with various land use types varies significantly with depth in the soils per time in different locations. (Dengiz *et al.*, 2015). SOC is extraordinarily susceptible to environmental changes, particularly to vegetation cover changes (Lv and Liang, 2012). Soil microbial biomass carbon and soil dissolved carbon are generally used to portray the movement of soil organic carbon. Soil microbial biomass carbon is incredibly sensitive and reflects little changes in soil organic (Yang *et al.,* 2016). From the foregoing, it can be inferred that the availability of soil organic carbon, soil organic matter and soil microbial organic carbon are influenced by human activities and the land use practices in a given area. However, the extent of these influence on the soil is not yet known, most especially because most research works were carried only on soil surface. This study therefore analyzed the variability of soil organic carbon at different soil depths under different land use practices.

Materials and Method

The study was carried out in Ogun state located at southwest geopolitical zone of Nigeria. At Isolu Estate (N7^0 10' and 3^0 2' E), in Odeda Local Government. Abeokuta, Ogun State. Managed by Department of Forestry and Wildlife Management, Federal University of Agriculture Abeokuta. The university is lies between longitude 7.23''-7.58''N N and latitude 3.25''-3.43'' E approximately in Ogun state, Abeokuta. The research was carried out in different five land use practices namely; *Leucaena leucocephala*, secondary forest, *Gmelina arborea*, *Tectona grandis* and abandoned farmland.

Profile pits were dug to collect bulk soil samples from the center and four corners of different five land use practices at depths 0-30 cm 30-60 cm and 60-90 cm using soil auger (5 cm inner diameter). The samples collected were well labelled into samples bags. In each land use type fifteen samples were collected and total number of seventy-five (75) soil samples were collected for the studied in all the locations.

LABORATORY ANALYSES FOR SOIL SAMPLES

Determination of soil Organic Carbon (SOC): SOC was determined by the procedure of walkley and black (1934) using the dichromate wet oxidation method (Nelson and Sommers, 1996). Organic Carbon Content and organic Matter Content by Walkley and black (1934) using the dichromate wet oxidation method (Schumacher, 2002).

Determination of Labile Organic Carbon: LOC was determined by the chromic acid oxidation method (Walkley & Black, 1934).

Determination of Microbial Biomass Carbon: MBC was determined by using dichromate oxidation method (Kalembas and Jenkinson, 1973).

Determination of Dissolved Organic Carbon: The transferred of 4ml of the sample extract into a digestion tube was carried out. Addition of 1ml 0.0667M Potassium dichromate was also carried out after which 5ml concentration sulphuric acid was added.

Determination of Soil Properties: Exchangeable bases Ca, Mg, K and Na was determined by extracting with 1N Ammonium acetate (NH_4OAc) pH 7.0 Ca and Mg in the extract was titrated while Na and K was determined with flame photometric. (Jackson,1958). Cation Exchange Capacity (CEC) was determined by summation of exchangeable bases K, Na, H^+ and Mg. (Michigan warneke *et al.,* 1980) Soil pH was determined with an electronic pH meter in a 1:2.5 soil/water suspension. Total nitrogen (TN) was determined using semi micro-kjedahl method (Bremmer, 1965). Soil particle size distribution (silt, clay and sand) and physiochemical parameters was analyzed using hydrometer method (Bouyoucos, 1962).

Results: The results (table 1) indicated that Soil organic carbon (SOC) show no significant difference within the soil depth in the soils studied. Soil organic carbon had the highest values (8.92 ± 0.32^a) at depth (0-30 cm), while the lowest values (5.30 ± 0.09^c) was recorded for SOC at depth 60-90 cm. The values of labile organic carbon (LOC) (8.79 ± 0.60^a) was significantly higher at 0-30cm depth. The values recorded varied from 6.88 ± 0.01^c to 8.79 ± 0.60^a. The least contents of LOC (6.88 ± 0.01^c) was obtained at 60-90 cm depth. The values recorded for dissolved organic carbon (DOC) ranged from 7.69 ± 0.28^c to 9.23 ± 0.29^b. Dissolved organic carbon had the highest values (8.25 ± 0.02^a) at 30-60 cm depth, while the least values (7.69 ± 0.28^c) was observed at depth 0-30 cm. The concentration of soil organic matter at 0-30 cm, 30-60 cm and 60-90 cm depth within the soil depths shown in table 1 had a significant highest value (10.34 ± 0.03^a) at 0-30 cm depth followed by (9.28 ± 0.69^b) at depth 30-60 cm and the least soil organic matter 5.13 ± 0.16^c was recorded at 60-90 cm depth. Soil organic matter show a significance difference among soil depths in the study area. Microbial biomass carbon (MBC) was not significantly different within the depths in the study soils. The values obtained for MBC varied from 4.33 ± 0.48^c to 6.29 ± 0.19^a with the soil depth. The highest values of MBC (6.29 ± 0.19^a) was observed at 0-30 cm depth while the lowest MBC (4.33 ± 0.48^c) recorded at 60-90 cm depth within the study location.

Table 1: Distribution effect of dephts on soil organic carbon fraction in the study area.

SOC parameters	0-30 CM	30-60 CM	60-90 CM
SOC	8.92 ± 0.32^a	6.09 ± 0.34^b	5.30 ± 0.09^c
LOC	8.79 ± 0.60^a	7.18 ± 0.36^b	6.88 ± 0.01^c
DOC	7.69 ± 0.28^c	9.23 ± 0.29^a	8.25 ± 0.02^a
SOM	10.34 ± 0.03^a	9.28 ± 0.69^b	5.13 ± 0.16^c
MBC	6.29 ± 0.19^a	5.06 ± 0.17^b	4.33 ± 0.48^c

Mean values with the same superscripts in each column are not significantly different $p < 0.05$.

The results (Table 2) of soil organic carbon showed that Leucaena *leucocephala* plantation *had* the highest values(8.12 ± 0.00^a) of soil organic carbon when compared with *secondary* forest (7.34 ± 0.34^b), *Gmelina arborea* plantation (6.83 ± 0.21^c), *Tectona grandis* plantation (6.89 ± 0.23^c) and abandoned forest (4.76 ± 0.34^d). The least values of SOC (4.76 ± 0.34^d) was observed in abandoned farmland. Labile organic carbon (LOC) had the highest values (10.12 ± 0.51^a) in the soil under *Leucaena leucocephala* plantation. Meanwhile the least values (5.11 ± 0.02^d) of LOC was observed in abandoned farmland. The soil under secondary forest had a significant higher value (8.59 ± 0.24) of dissolved organic carbon (DOC), when compared with other land use for the study. The least values (4.92 ± 0.11^c) of DOC was recorded in abandoned farmland. DOC was significantly different among the five different land uses. The values (6.02 ± 0.21^a) of microbial organic carbon (MBC) was significantly high in secondary forest. The values recorded for MBC varied from 3.92 ± 0.03^d to 6.02 ± 0.21^a. However, the least values (3.92 ± 0.03^d) MBC was found in abandoned farmland in the soils studied. The results (Table 2) obtained for soil organic matter (SOM) ranged from 9.84 ± 0.11^a to 13.98 ± 0.72^c. The highest values (13.98 ± 0.72^c) of SOM was recorded in the soil under *Leucaena leucocephala*, while least values (9.84 ± 0.11^a) of SOM was observed in abandoned farmland. There was no significance difference in soil organic matter within the depth across all the locations.

Table 2: Distribution effect of land use on soil organic carbon under different land use.

Land use	SOC	LOC	DOC	MBC	SOM
Leucaena leucocephala	8.12 ± 0.00^a	10.12 ± 0.51^a	7.21 ± 0.13^b	5.13 ± 0.02^a	13.98 ± 0.72^a
Secondary forest	7.34 ± 0.34^b	9.64 ± 0.10^{ab}	8.59 ± 0.24^a	6.02 ± 0.21^a	12.55 ± 0.18^b
Gmelina arborea	6.83 ± 0.21^c	8.82 ± 0.00^b	6.52 ± 0.03^b	4.55 ± 0.01^{cd}	11.69 ± 0.01^c
Tectona grandis	6.89 ± 0.23^c	7.10 ± 0.03^c	6.82 ± 0.01^b	3.92 ± 0.03^d	11.84 ± 0.02^c
Abandoned farmland	4.76 ± 0.00^d	5.11 ± 0.02^d	4.92 ± 0.10^c	5.39 ± 0.10^b	9.84 ± 0.11^d

Mean values with the same superscripts in each column are not significantly different $p< 0.05$

The concentration of particles size distribution recorded (Table 3) showed that sand particles had the highest concentration of particles size distribution when compared to silt and clay particles. The soil pH obtained ranges from 5.67 ± 0.01^c to 7.08 ± 0.01^a at 0-30 cm with varying soil depth. The highest volumes of soil pH (7.08 ± 0.01^a) was recorded at 0-30 cm depth, while the lowest soil pH (5.67 ± 0.01^c) was obtained at 60-90 cm depth. The results recorded for Cation exchange capacity (CEC) with soil depths ranged from 1.12 ± 0.01^a to 0.78 ± 0.01^c. Highest CEC (1.12 ± 0.01^a) was obtained at 0-30 cm whereas CEC had the lowest values (0.78 ± 0.01^c) at 60-90 cm depth. The results of calcium (Ca) concentration obtained (Table 3) had the highest values (0.33 ± 0.13^a) at (0-30 cm) depth while the lowest values (0.17 ± 0.11^c) was recorded for Calcium content at (60-90 cm) depth. Mg, Na and K (0.18 ± 0.27^a, 0.32 ± 0.06^a and 0.44 ± 0.01^a) had the highest values at 0-30 cm depths respectively, whereas the least values of Mg (0.15 ± 0.01^c), Na (0.04 ± 0.02^c) and K (0.27 ± 0.14^c) was recorded at depths (60-90 cm). The concentration of total nitrogen (TN) and percentage of base saturation (BS%) followed the same trend with the highest values TN (0.16 ± 0.01^a) and BS% (86.84 ± 5.24^a) at 0-30 cm depths while the least content of TN and BS% ($0.04\pm0.02^c$and 0.04 ± 0.02^c and 81.16 ± 0.64^c) were observed at depth 60-90 cm. The results (Table 3) obtained for SOC (8.92 ± 0.06^a), MBC (15.34 ± 0.05^a), DOC (7.69 ± 0.40^a,), LOC (9.88 ± 0.60^a) and SOM (14.23 ± 0.05^a) had higher values at (0-30 cm) depth while the lowest values for SOC (5.07 ± 0.11^c), MOC (9.12 ± 0.02^C), DOC (4.25 ± 0.30^C), LOC (6.79 ± 0.71^C) and SOM (9.04 ± 0.15^C) respectively was observed at 60-90 cm depth in the study sites.

Table 3: Effect of depth on distribution of physicochemical in the study locations.

Soil properties	**Soil depth 0-30 (cm)**	**Soil depth 30-60 (cm)**	**Soil depth 60-90 (cm)**
Sand %	43.97 ± 0.55^c	66.41 ± 1.23^a	67.29 ± 1.07^a
Clay%	5.90 ± 0.58^b	5.53 ± 1.12^b	10.20 ± 0.21^a
Silt%	57.18 ± 2.31^a	28.55 ± 0.54^b	27.47 ± 3.48^c
pH(H_20) 1:2	7.08 ± 0.01^a	6.73 ± 0.02^b	5.67 ± 0.01^c

CEC (cmol/kg)	1.12±0.01^{a}	0.87±0.17^{b}	0.78±0.01^{b}
Ca (Cmol kg$^{-1)}$	0.20±0.30^{a}	0.33±0.13^{b}	0.17±0.11^{a}
Mg (Cmol kg^{-1})	0.18±0.27^{a}	0.17±0.10^{a}	0.15±0.01^{c}
Na (Cmol kg^{-1})	0.32±0.06^{a}	0.24±0.01^{b}	0.19±0.01^{c}
K (Cmol kg^{-1})	0.44±0.01^{a}	0.33±0.01^{b}	0.27±0.14^{c}
T.N%	0.16±0.01^{a}	0.09±0.01^{b}	0.04±0.02^{c}
BS%	86.84±5.24^{a}	84.78±1.15^{a}	81.16±0.04^{a}

Mean values with the same superscripts in each column are not significantly different $p< 0.05$.

DISCUSSION

This research work indicated that there was variation in distribution status of soil organic carbon fractions in *Gmelina arborea* plantation, *Tectona grandis* plantation, Secondary Forest, *Leucaena leucocephala* plantation and Abandoned farmland at varying soil depths. The highest Soil organic carbon was obtained at 0-30 cm depth. This implied that surface soil has tend to be richer in organic carbon. This could be due to the soil surface of the plantation which allowed accumulations of SOC fractions to gather at the surface of the soil (Oladoye *et al.,* 2020). LOC decreased with increased in depth whereas, the highest concentration of LOC was obtained at 0-30cm depth. This may due to the global climate change, The inconsistent changes in the subsoil layer affected by land-use change can probably be attributed to differences in the conversion duration and soil parent material. It is necessary to dynamically monitor the changes in SOC in the subsoil in future studies Hobley *et al.* (2016). DOC had the highest mean value at depth 0-30cm which shows a significant difference compared to depth other two depths which make the depth 0-30cm to be rich in DOC (Laik *et al.,* 2009). Litter and humus were the two important sources of Dissolved Organic Matter The composition of leaf litters and decaying roots is playing essential role in determining the mass of dissolved organic carbon in the soil (Yano *et al.,* 2005). SOM is higher at 0-30cm depth. This is because organic carbon storage below the soil surface is an attractive option in most soils in the tropical region (Senwo *et al.,* 1998).

MBC had the highest value at 0-30cm depth among the three depths. This is because Soils with more LOC tend to have a higher microbial biomass. Fresh plant residues and soluble compounds released into the soil by roots (root exudates) are important sources of energy for the microbial biomass. (Huang *et al.,* 2020). SOM fractions had the highest values at soil surface and diminished with increased in depths, displacing a clear stratification. (Guimarães *et al*. 2013).

Leucaena l. plantation had the highest amount of soil organic carbon compared to the other five land use practices. This could be attributed to the age of the plantation that can affect the rate of soil organic carbon (Jha *et al.,* 2010). Soil organic carbon content with increasing age in plantations and different geographical patterns of accumulation soil organic carbon (Ledo *et al.,* 2020). The highest amount of LOC was observed in *Leucaena l.* The quantity and characteristics of LOC fraction differ depending on the direction of land use change and fractionation approach used which means land use activities may determine the level of Labile organic carbon (Strosser *et al.,* 2012). Secondary f. has more DOC compared to other land use types. This could be attributed to the age and vegetation of the area as well as parent material of the soil in the locations. It could also be the high and low rate of microbial respiration (Don and Schulze, 2008). The highest MBC was recorded in Secondary Forest. This might be due to the different composition of leaf litter, there are different succession stages Secondary f. which showed increase in MOC in the secondary forest. (Medeiros *et al.* 2017). *Leucaena* plantation had the highest values of the SOM compared to other land use in the sites. SOM is a dynamic and large reservoir of carbon which is subject to change due to management practices as a result of different land use types (Post and Kwon, 2000).

The soil particles size distribution (sand, silt and clay), in the studied soils can be classified majorly as sandy soil (light-textured) as it constitutes majorly of sandy particles compared to silt and clay (Oladoye *et al.*, 2015). CEC diminished with increasing in depth. CEC is the measures of volume of cations which can be extracted from soil samples by a high amount of cation often dominated Ca, Na, K, and Al. (Asinwa *et al.*, 2021). The diminish in CEC, and TN with increasing in depth might be related to decrease in SOM values down the soil depth since SOM has been observed to influence the concentration of TN (Ewing and Singer 2012). The increase in Total N to improved organic matter content through leaf litter decomposition and mineralization in various land use types in forest ecosystem. %BS had the highest content at the surface soil this could be attributed to the higher amount of pH which determine the volume of BS% in the soil. (Guckland *et al.*, 2009).

CONCLUSSION AND RECOMMENDATIONS

The results of variability of SOC under different land use practices, indicated that the pattern in variations of organic carbon fractions with depth was not uniform in all the land use practices.

This study concluded that, land use types determine the volumes of SOC present in the soil per time. This study indicates that, since trees in this research work has shown a great potential to improve SOC by sustainable land use practices, trees planting should be encouraged to increase the concentration of soil organic carbon.

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HOUSEHOLD LEVEL ANALYSIS OF COSTS, RETURN AND BENEFITS OF AGROSILVOPASTORAL PRACTICES IN OGUN STATE, NIGERIA

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ABSTRACT

Agroforestry contributes to numerous benefits including provision of social, economic, and environmental values. Economic benefits of agroforestry have recently attracted increased interest from scientific communities, particularly in developing nations, as a result of ongoing food shortages and rising agricultural inputs prices. Hence, this study was conducted to analyze agrosilvopastoral costs, return and benefits to households in Ogun State, Nigeria. Multistage sampling procedure was used in selecting two hundred and forty (240) respondents within the agricultural zones [Ilaro (60), Abeokuta (60), Ikenne (60) and Ijebu (60)] of Ogun State Agricultural Development Program. Data obtained were processed and analysed for Descriptive statistics and Budgetary analysis (Net margin, Rate of Return on Investment, RORI). Results revealed that 31.7% of the household heads were in their active years ($\bar{x}$ = 54 years). Costs and return analysis showed that crops contributed the highest 51.8% of total revenue while piggery contributed the lowest (1.2%). Cost expended on labour covered 72.4% of the total production cost while cost of seedlings accounted for 0.2%. Profitability index value was 0.67, while the RORI was 2.01. Results further revealed that the households derived various benefits from agrosilvopastoral practices with mean scores of 1.70 (increase in farm income), 1.77 (prevention of erosion), 1.38 (provision of fruits and foods), 1.53 (provision of shelterbelt) and 1.85 (regulation of soil temperature) from agrosilvopastoral practices. The study recommends adoption of agrosilvopastoral practices as a strategy to boost rural income and livelihood.

Keywords: Costs, Agroforestry Benefits, Economic, Returns, Agrosilvopastoral practices

INTRODUCTION

The multiple perceived benefits and merits of agroforestry for providing environmental benefits, economic products and social goods are well known and widely recognized (Gao *et al.,* 2014). In rural households, trees can be used as sources of food, fuel, fodder, construction materials, medicine, to meet subsistence needs (Adekunle and Bakare, 2004; Kumar and Thakur, 2017; Jemal *et al.,* 2018). In light of recurring food shortages, and rising prices of fossil fuel-based agricultural inputs, economic benefits of agroforestry have recently experienced a surge in interest from the research communities, especially in developing countries (Amejo *et al.,* 2018). Furthermore, it increases farmers' incomes through the sale of extra staples, wood, and other tree products; provides wood for cooking; feeds cattle with greens, especially during natural disasters; and supports a number of ecosystems (Singh *et al.,* 2014).

Agroforestry would be crucial in the current situation for ensuring livelihood stability, especially for marginal and small-scale farmers. Agroforestry will help reduce the risk factor since perennial woody species can deal with the challenges of climate change (Prasad *et al.,* 2014). Agroforestry is used by smallholder farmers in Africa (Mbow *et al.,* 2013), and various traditional agroforestry techniques are also used in various regions of the continent. Rural communities should diversify their sources of income due to factors like more revenue, fewer risks, declining agricultural trade conditions, changes to the environmental resource base, climatic change, and natural disasters (Reardon *et al.,* 2006). Nevertheless, in several drylands of developing countries especially in the Sub-

Saharan Africa, studies addressing contribution of agroforestry to socio-economic status and rural livelihood are limited and therefore may be inconclusive. Therefore more studies on agroforestry adoption and socio-economic conditions are needed. The aim of this study is to analyze the costs, return and benefits of agroforestry adoption on the rural household income and livelihood in Ogun state, Nigeria.

MATERIALS AND METHOD

The study was carried out in Ogun State, otherwise known as the Gateway State, which was created out of the former Western State of Nigeria on February 3, 1976 and the State capital is Abeokuta. Ogun State is situated within the tropics and has an estimated population of 3,728,098 people (NPC, 2006) of which 67% were farmers (OGADEP, 1998). Its natural resources include extensive fertile soil suitable for agriculture, rivers, rocks, lagoons, mineral deposits and an ocean front.

Sample Collection

Based on the presence of agroforestry practices, a multistage sampling technique was used to draw out the sampling site and respondents. The sampling site was the agricultural zones of Ogun State ADP namely, (Ilaro, Abeokuta, Ikenne and Ijebu-ode) within the state which gave a total of two hundred and forty (240) respondents for this study (OGADEP, 2016). Structured questionnaire was used to obtain relevant data from the farmers.

DATA ANALYSIS

Costs and Return (Budgetary Analysis)

Costs and Return analysis was used to determine the profitability of agrosilvopastoral households in the study area.

$\boldsymbol{\pi}$ = TR – TC………………………… (i)

where, π = Profit (N),

TR = Total Revenue (N) given as P * Q,

where, P = Price, Q = Quantity.

TC = Total Cost in (N) is given as TFC + TVC …. (ii)

where, TFC = Total Fixed Cost, and TVC = Total Variable Cost (N).

Profitability Index (PI) = $\frac{\pi}{TR}$ ……………………………………...… (iii)

Rate of Return on Investment (RORI) = $\frac{\pi}{TC}$ ………………………….. (iv)

Benefits of Agrosilvopastoral Practices (Likert Scale Analysis)

This was chosen in order to assess both the challenges and various benefits of agrosilvopastoral practices in the study area. Respondents select from a pool of five options the one that most closely matches their perspective on this ordered one-dimensional scale. A common one in this analysis was ascertained, with which households may agree or disagree to varying degrees. For scoring, numbers (from 1–5) were assigned to each option. Class boundaries of the mean were used to draw the inferences (Del, 2010).

The options with their grading or scoring number are: Strongly agree = 5; Agree = 4; Undecided = 3; Disagree = 2; Strongly disagree = 1. For inferences, class boundaries are:

$0 \leq B \leq 1.4$ = Strongly disagree,

$1.5 \geq B \leq 2.4$ = Disagree,

$2.5 \geq B \leq 3.4$ = Undecided,

$3.5 \geq B \leq 4.4$ = Agree

$4.5 \geq B \leq 5.0$ = Strongly agree………….. (v)

Where, B = Benefits of agrosilvopastoral practices.

RESULTS

Cost and Return of Agrosilvopastoral Farmers

The result of the cost and benefits realized from agrosilvopastoral activities is presented on table 1. The result presents that the total revenue realized from the enterprise is ₦377,845.83 and income from crops contributed the most (51.81%) to the total revenue followed by trees (15.21%), poultry

(13.57%), employment activities (9.37%), other agricultural practices (8.82%) and piggery (1.22%) respectively. The total variable cost incurred was ₦108,078.75 and this constitutes 86.20% of the total production cost. Cost expended on labour covers the most (72.39%) of the total production cost, transport covers 7.13%, fertilizer covers 6.45% while cost of seedlings covers 0.23% of the total production cost. The total fixed cost incurred was ₦17,300.00 and this constitutes 13.80% of the total production cost. Depreciation on land covers 3.46%, implements (4.69%) and other fixed inputs covers 5.66%. The total cost incurred was ₦125,378.75 while the gross margin realized was ₦269,767.08. The profit realized from agrosilvopastoral activities was ₦252,467.08 which implies that the enterprise is a profitable one. The profitability index value of 0.67 shows that for every ₦1 incurred in the business, ₦1.67 will be returned back. The rate of return value of 2.01shows that for every ₦1 invested, ₦2.01 will be returned back to the enterprise. This implies that the business is a very profitable and bankable one.

Table 1: Costs and Return of Agrosilvopastoral Households

Variable	**Mean (₦)**	**% Total**
Revenue		
Crops	195,750.00	51.81
Poultry	51,262.50	13.57
Piggery	4,625.00	1.22
Trees	57,458.33	15.21
Other agricultural practices	33,333.33	8.82
Employment activities	35,416.67	9.37
Total revenue	**377,845.83**	**100.00**
Variable cost		
Seedling	283.75	0.23
Transport	8,937.50	7.13
Labour	90,765.83	72.39
Fertilizer	8,091.67	6.45
Total variable cost	**108,078.75**	**86.20**
Fixed cost		**0.00**
Land	4,333.33	3.46
Implements	5,875.00	4.69
Others	7,091.67	5.66
Total fixed cost	**17,300.00**	**13.80**
Total cost	**125,378.75**	**100.00**
Gross Margin	**269,767.08**	
Profit	**252,467.08**	
Profitability Index	**0.67**	
Rate of return	**2.01**	

Source: Data analysis, 2022

MULTIPLE BENEFITS OF AGROSILVOPASTORAL PRACTICES

The result of the multiple benefits of agrosilvopastoral practices is shown in table 2. The result shows that the majority of the agrosilvopastoralists agreed that the practices increase farm income. The majority agreed that the practices through the use of dung provide manure for plant growth. The agrosilvopastoralists agreed that leguminous crops improve soil fertility; the majority agreed that tree crops serve as shade for other crops as well as help to break wind effects. The majority agreed that tree crops provide shade for animals.

Table 2: Benefits of Agrosilvopastoral Practices

Variable	Mean Score	Decision
Multiple benefits of Agrosilvopastoral practices		
Increase in farm income	1.70	Agreed
Provision of manure	1.61	Agreed
Improvement in soil fertility	1.91	Agreed
Provision of shade to crops	1.63	Agreed
Shade to animal	1.79	Agreed
Regulation of soil temperature	1.85	Agreed
Prevention of soil erosion	1.77	Agreed
Provision of fruits and foods	1.38	Strongly agreed
Provision of shelterbelt	1.53	Agreed

Source: Data analysis, 2022

DISCUSSION

The results obtained from the socioeconomic characteristics of the respondents revealed that the mean age of the agrosilvopastoral household heads was 54 years which implies that the majority of the household heads were still in their active years. Male dominated the enterprise than female counterparts. This finding is consistent with those of Lutomia *et al.,* (2019) and Olumeh *et al.,* (2021). The mean household size of the agrosilvopastoral household heads was 6 persons which imply that the majority of the household heads had a fairly large household size which they could employ in their business when they are available. A larger portion of the agrosilvopastoral household heads had formal education and this might inform their decision to adopt innovative practices that will improve their production as well as their profitability.

The result of the cost and benefits realized from agrosilvopastoral activities by the different households shows that income from crops contributed the most to the total revenue followed by trees, poultry, employment activities, other agricultural practices and piggery respectively. The total variable cost incurred constitutes 86.20 % of the total production cost. Cost expended on labour covered the most of the total production cost, followed by transport and fertilizer while cost of seedlings constituted the least of the total production cost. The total fixed cost incurred constituted 13.80 % of the total production cost. Depreciation on land covered 3.46%, implements (4.69 %) and other fixed inputs covered 5.66 %. Results obtained from the study revealed that the total cost incurred was less than the profit realized from agrosilvopastoral activities which implies that the enterprise is a very lucrative and profitable one. The profitability index and the rate of return values both indicated that what is realized from the enterprise is more than what is invested and this implies that the business is a very profitable and bankable one. The necessity to boost earnings for the majority of the rural poor is one of the most significant causes that led economists to stress increasing agricultural production as an essential element of a successful rural development strategy (Maniriho and Nilsson, 2018).

The result of multiple benefits of agrosilvopastoral practices shows that the majority of the agrosilvopastoralists agreed that the practices increase farm income. The majority agreed that the practices through the use of dung provide manure for plant growth. The agrosilvopastoralists agreed that leguminous crops improve soil fertility; the majority agreed that tree crops serve as shade for other crops as well as help to break wind effects and also provide shade for animals. The majority also agreed that tree crops help to regulate soil temperature and prevent soil erosion. The majority strongly agreed that tree crops provide fruits and foods to animals and human and also provide shelterbelt to both animals and humans. According to Handayani and Prawito (2011), agroforestry systems offer an 80% better water conservation value than monoculture systems. According to a study by Tomer *et al.*, (2009), riparian buffers at first-order streams have the greatest potential to enhance water quality when compared to the bigger streams. According to a different study by Hasnol *et al.*, (2012), legumeous cover crops (LCC) have favorable effects on soil by fixing and providing nitrogen (N) to the primary crop, increasing palm development, and lowering competition from dangerous weeds. The integration of trees and crops may act as sources of carbon sinks and temporary carbon storage, increasing the possibility of sequestering carbon (C) compared to single-species agricultural production.

Conclusion and Recommendation

The profitability index and the rate of return values both indicated that what is realized from the enterprise is more than what is invested and this implies that the business is a very profitable one. The study also revealed that the integration of trees on farmland helps to improve soil fertility, prevent erosion, regulate soil temperature, provide shade for animals, etc. When fostering livelihood income diversification, policymakers and development organizations should adopt policies that are attentive to farmers' household-level characteristics and pay appropriate attention to expanding educational access, developing business skills, and improving market infrastructure.

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IMPACT OF WASTE WATER FROM FERMENTED CASSAVA (*Manihot esculentus* L.) ON SOIL PHYSICOCHEMICAL PARAMETERS IN ABRAKA DELTA STATE, NIGERIA

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ABSTRACT

This study was carried out to access the impacts of wastewater from fermented cassava on soil physicochemical properties in Abraka, Delta State. Different concentrations of treatment (control/water (0%), 20, 30, 40, 50 and 100% of cassava wastewater) were used in contaminating loamy soil. The soil pH was determined using a pH meter while the soil metal concentrations were determined using atomic adsorption spectrophotometer. The data obtained were subjected to statistical analysis and concentration mean differences were separated using Duncan multiple range test (DMRT). The results showed that cassava wastewater is toxic to plants in the soil as well as soil micro and macro organism as it increased the pH and the concentration of trace metals though significantly increased the concentration of the nutrients. Cassava farmers and cassava mill factory workers should be sensitive about the impacts of the improper disposal of the wastewater, so as to have a healthy soil for farming purposes.

Keywords: Cassava, Soil, Cassava wastewater, soil physicochemical properties

INTRODUCTION

Soil is the top layer of the lithosphere, which is formed from weathered rock that has been transformed by living organisms (Okunade and Adekalu, 2013). It is an important engineering material comprising of three phase materials of mineral particles (solid particles), water and air. A large portion of the earth's surface is covered by soil, and they are widely used as construction and foundation materials. Its mechanical behavior is largely dependent on the size of its solid particles and voids.

Cassava is the third major source of carbohydrate in the world with diverse uses depending on the community, and it serves as food security for millions of people in the developing countries (Akoroda and Ekanayake, 2005). It is an important staple crop, and in the tropical world it ranks fourth in importance after rice, wheat and maize (Agbogidi, 2023a). In Nigeria, cassava is extensively cultivated and classified into two kinds, namely: sweet cassava (*Manihot esculenta)* and bitter cassava (*Manihot utilissima*) which form hydrocyanic acid during processing (Okoye and Onuorah, 2023). Hydrogen cyanide can be removed by cooking or fermenting in water for specific period. In addition to cyanogenic glucoside, the tubers are quite rich in carbohydrate (85.9%) with very small amount of protein (1.3%) (Nawbueze and Odunsi, 2007). Cassava tubers are mainly harvested between 7 to 12 months based on the cultivars planted. All communities in Nigeria depend so much on cassava because of its wide usage when processed into garri, tapioca, akpu, fufu and starch. Starch is used in the production of textiles, paper and also serves as monosodium glutamate (MSG), an important flavouring agent in Asian cooking. Akpu, a grated, fermented and dehydrated cassava food product, is one of the most popular staple foods in Nigeria, which provides a major source of calories for families which consume it because of its high content (Agbogidi *et al.*, 2023a; Agbogidi *et al.*, 2023b). However, cassava is increasing in importance particularly in arid and semi-arid areas because it is a hard, drought-resistant crop that can give acceptable yields even in low-fertility soils. Cassava represents 57% of tropical root and tuber production, it is produced from stem cuttings and requires weeding until a canopy is established.

The processing plant of cassava also referred to as cassava mill was invented in 1919 and planted in 1934, and is extensively used in Nigeria, especially in the southern part where cassava is a major agricultural produce (Oyewole *et al.*, 1992; Aderiye and Laleye, 2003). Two liquid residues are generated in the production processes of cassava into food, feed, starch, garri and other products. These include, chemical oxygen demand (COD), which is produced from the washing and peeling of cassava tubers; and BOD which is produced from the sedimentation tank alongside with COD. Cassava effluent containing high concentration of BOD, COD and cyanide poses a serious threat to the environment and humans residing within the areas where the processing units are located. The production of starch and akpu usually involves simple technology, consuming an average of 23 m^3 of water per tonne of cassava. This also generates a contaminating load of about 180 kg of COD per tonne of tubers (Raddatz, 1986).

Currently, there is neither a specific method of disposing or treating cyanide-laden wastewater produced from cassava processing in neither Nigeria nor government policy regulating its disposal method. Cassava wastewater quality and quantity varies due to plant age, variety, time after harvesting, type of industrial equipment used in processing and its adjustment (Oliveria *et al.*, 2001). Most cassava processing industry discharges significant quantities of wastewater to the soil, rivers, lakes, sewage, canals, agricultural lands, and the environment, which eventually flows back to streams surface water locations (Oliveria *et al.*, 2001).

Akpu and starch processing industry has been one of the major threats to the environment. Hydrocyanic acid and unbroken down cyanogenic glycoside – linamarin and lotaustralin produces toxic and acidic effect. If not properly treated, they constitute potent toxicant to the soil, soil organisms, water, animals and plants. When leached into the soil, cassava wastewater could also change some soil properties, in addition to constituting breeding ground for disease vectors due to their improper disposal. Improper disposal of cassava wastewater (effluent) is becoming an increasing challenge to the environment and the populace, thus this study is aimed at accessing its impacts on soil physiochemical properties.

MATERIALS AND METHODS

Study Area

This experimental study was conducted in the Department of Botany Annex, Delta State. Abraka lies between latitude 05°47'N and longitude 06°06'E of the equator with an annual rainfall of 3,097 mm, annual relative humidity of 83% and annual mean temperature of 30.6 °C (Efe and Aruegodor, 2003). The topography, location factors and prevalence of the tropical rainy climate that is warm, humid and moist in most part of the year, encourages farming activities which is one of the major occupations of the dwellers (Agbogidi *et al.*, 2023a).

Collection of Samples

Soil samples were obtained from Site III, Delta State University Abraka, Nigeria with soil auger, and were put into a sterile polyethylene bag and transferred to the Chemistry Laboratory for analysis. Cassava effluents were collected from a cassava mill company at Umuno, Abraka, Delta State, Nigeria.

Sample Preparation and Analysis

The soil samples were air-dried for a period of three days in a clean and well-ventilated laboratory. They were homogenized by grinding with a 2 mm (10 mesh) stainless sieve, and stored in labeled plastic cans until analysis.

The soil samples were separated into six sterile polyethylene bags, each polyethylene bags weigh 5 kg. AAS machine (Agilent technology 55A) was used in determining the concentration of metals (Cn, Cd and Zn) in the soil. Digital pH meter was used in determining soil pH. Biological oxygen demand was determined using dissolve oxygen meter which was calibrated at 0% and 100%, and oxygen readings were taken at day 0 and day 4 of the study. Total dissolved solid was determined by measuring 100 ml of water sample, filtered through a pre-weigh filter paper, the filter paper was dried and weighed after drying, and the difference in weight was recorded as the total dissolved solid. Ca, K, P and Mg were determined by ammonium acetate (NH_4AOC) extraction method and cation exchange capacity (CEC) in meq/100 g. Total phosphorus was determined using HNO_3 digestion and spectrophotometric method and available phosphorus with the Bray-1 method. Electrical conductivity was determined using electrical conductivity meter calibrated with active standard solution. Organic nitrogen was determined using Kjedahl digestion flask. Total organic carbon was determined by dissolving 0.5 M of $K_2Cr_2O_7$:49.04 g in distill water and diluted to 1 Litre. Chemical oxygen demand was determined using potassium heptaoxochromate ($K_2Cr_2O_7$) solution, 0.125 M : dissolve 12.26 g previously dried at 103 °C for 2 hours in distilled water and diluted to 1000 cm^3.

Statistical analysis

Data obtained were subjected to one way analysis of variance (ANOVA) while significant treatment means were separated using the Duncan's Multiple Range Tests using SAS (2000).

RESULTS AND DISCUSSION

Table 1 shows the effects of cassava wastewater on the physical properties of soil. The highest pH value (6.60) was recorded in soil treated with 30% of cassava wastewater. pH values obtained in untreated soil, soils treated with 20, 50 and 100% differ significantly from those treated with 30 and 40% of cassava wastewater. Highest electrical conductivity (22.08 kgm^2) was recorded in soil treated with 50% of cassava wastewater. Significant difference was observed in the electrical conductivity of soil across the treatments. The highest total organic carbon (1.17%) was recorded in the untreated soil. There was no significant difference in the total organic carbon among the different treatments. The soil particle size, texture and colour remain the same across the treatments.

Table 1: Soil physical properties as affected by cassava wastewater

Parameters	**Soil Treatment Concentrations (%)**					
	Control	**20**	**30**	**40**	**50**	**100**
pH	5.20^b	5.60^b	6.60^a	6.10^a	5.00^b	5.10^b
EC kgm^2	21.40^b	20.00^c	21.60^b	21.08^b	22.08^a	21.60^b
TOC (%)	1.17^a	1.10^a	1.12^a	1.16^a	1.16^a	1.20^a
Particle Size	0.0025^a	0.0025^a	0.0025^a	0.0025^a	0.0025^a	0.0025^a
Soil Texture	Loamy	Loamy	Loamy	Loamy	Loamy	Loamy
Soil Colour	Brown	Brown	Brown	Brown	Brown	Brown

Results with the different superscript in the same row are different significantly using Duncan Multiple Range Tests (DMRT)

Table 2: Effects of cassava wastewater on soil nutrients

Parameters	**Soil Treatment Concentrations (%)**					
(mg/kg)	**Control**	**20**	**30**	**40**	**50**	**100**
Nitrogen	0.49^c	0.52^b	0.54^b	0.57^b	0.57^b	0.61^a
Phosphorus	17.78^c	20.74^b	17.90^c	17.63^c	17.63^c	22.40^a
Potassium	0.74^c	0.83^b	0.76^c	0.94^a	0.94^a	0.87^b
Calcium	0.24^c	0.24^c	0.26^b	0.26^b	0.26^b	0.28^a
Magnesium	0.94^b	1.00^a	1.04^a	0.97^b	0.97^b	0.97^b

Results with the different superscript in the same row are different significantly using Duncan Multiple Range Tests (DMRT)

Table 2 shows the effects of cassava wastewater on the concentration of soil nutrients. There was a significant difference between the concentration of nitrogen in the untreated soil and those treated with cassava wastewater. The smallest concentration of nitrogen (0.49 mg/kg) was recorded in untreated soil while the highest (0.61 mg/kg) was recorded in soil treated with 100% of cassava wastewater. The highest concentration of phosphorus (22.40 mg/kg) was recorded in soil treated with 100% of cassava wastewater while the lowest concentration (17.63 mg/kg) was recorded in soils treated with 40 and 50% of cassava wastewater. The highest concentration of potassium (0.94 mg/kg) was recorded in soils treated with 40 and 50% of cassava wastewater while the lowest (0.74 mg/kg) was recorded in the untreated soil. Significant differences in the concentration of potassium were observed across the treatments. The highest concentration of calcium (0.28 mg/kg) was observed in soil treated with 100% of cassava wastewater while the lowest (0.24 mg/kg) was observed in the untreated soil and soil treated with 20% of cassava wastewater. Significant differences in the concentration of calcium were observed across the different treatments. The highest concentration of magnesium (1.04 mg/kg) was recorded in soil treated with 30% of cassava wastewater while the lowest (0.94 mg/kg) was recorded in untreated soil. The concentration of magnesium in soils treated with 20 and 30% of cassava wastewater differ significantly from other treatments.

Table 3 shows the effects of cassava wastewater on the concentration of metals. Soils treated with 40 and 50% of cassava wastewater had the highest concentration (1.40 ppm) of cyanide while the least concentration (0.50 ppm) was recorded in the untreated soil. Significant difference was observed in the concentration of cyanide between the untreated soil and soils treated with cassava wastewater. The highest concentration (0.94 ppm) of cadmium was recorded in soil treated with 100% of cassava wastewater while the lowest concentration (0.84 ppm) was recorded in soil treated with 20% of cassava wastewater. The concentration of cadmium in soil treated with 30% of cassava wastewater differs significantly from soil with other treatments. The highest concentration (34.09 ppm) of zinc was recorded in soil treated with 100% of cassava wastewater while the lowest concentration (32.14 ppm) was recorded in untreated soil. The concentration of zinc in the untreated soil differs significantly from those treated with different concentration of cassava wastewater. The highest concentration (23.80 ppm) of manganese was recorded in soil treated with 20% of cassava wastewater while the lowest (22.00 ppm) was recorded in untreated soil. Significant difference in the concentration of manganese was observed among the different treatments.

Table 3: Metal concentration of soil contaminated with cassava wastewater

Parameters	**Soil Treatment Concentrations (%)**					
(ppm)	**Control**	**20**	**30**	**40**	**50**	**100**
Cyanide	0.50^b	1.30^a	1.20^a	1.40^a	1.40^a	1.37^a
Cadmium	0.87^b	0.84^b	0.90^a	0.86^b	0.86^b	0.94^b
Zinc	32.14^c	33.68^b	33.00^b	34.08^a	34.08^a	34.09^a
Copper	14.67^c	16.00^a	16.40^a	15.80^b	16.00^a	14.94^c
Manganese	22.00^b	23.00^a	22.80^b	22.74^b	23.60^a	23.40^a

Results with the different superscript in the same row are different significantly using Duncan Multiple Range Tests (DMRT)

DISCUSSION

Wastewater irrigation had both positive and negative effects on soil physicochemical properties. Soil pH value determines the availability of nutrients, the potency of harmful substances as well as the physical properties of the soil (Osakwe, 2012). This study showed an increase in the soil pH values contaminated with 20, 30 and 40% of cassava wastewater and a decrease at 50 and 100% concentration. This result is in line with the findings of Akpan *et al.* (2011) which showed an increase in the values of pH, organic carbon, phosphorus, sodium, potassium when they used fresh cassava processing wastewater to contaminate soil. Similar result has been reported by Shatanawi (1994) in his study, when crops were irrigated with wastewater, and in the study of Abegunrin *et al* (2016) who reported an increase in pH values at harvest of the two vegetables compared with their initial values thus making an initially slightly acidic soil becoming slightly alkaline. Though, this is contrary to the findings of Morji (2011) who reported an initial decrease in soil pH when irrigated with wastewater but subsequently increased. Increase in pH values in soils irrigated with wastewater can be attributed to decarboxylation and deamination processes consuming protons (Yan *et al.,* 1996). The increase in pH may also be attributed to the higher calcium and magnesium components of the effluent as reported by Asadu *et al,* (2007). Cation electrical conductivity is directly related to the soil capacity in absorbing or exchanging cations (Osakwe, 2012). A significant increase in electrical conductivity of the contaminated soil was observed in soils treated with 50% of cassava wastewater. This increase can be attributed to relatively high SOM obtained due to the addition of wastewater as opined by Abegunrin *et al*. (2016). A significant increase was recorded in the soil nutrients (potassium, nitrogen, magnesium and calcium) and trace metals (zinc, cyanide, cadmium, copper and manganese). This is in line with the study of Rusan *et al.* (2007) which showed an increase in the salt concentration, organic matter and plant nutrients in soil irrigated with wastewater. The increase in the concentration of nitrogen recorded in this study may be attributed to the nitrogen mineralization as a result of the breakdown organic matter as reported by Agbo *et al.* (2019). Magnesium was observed to vary across the different soil treatment and the control. According to Agbo *et al.* (2019), in low pH soils, the solubility of magnesium decreases and it becomes less available. The study of Mara *et al*. (2014) revealed that cassava wastewater is an efficient supplier of soil nutrients, and thus serving as an alternative fertilizer to the plants in their study. The increase in the concentration of metals in the cassava effluent treated soils could also be attributed to the abrasion of the cassava milling machine parts and emission of the metals through the exhaust of the machine as opined by Osakwe (2010).

CONCLUSION

The results of this present study show that the cassava wastewater effluent has significant effects on the soil physicochemical and nutrient composition. This is indicated by the increase recorded in the physicochemical and nutrient composition of the cassava waste water effluent impacted soil. It is therefore recommended that government enlighten farmers and factory workers on the deleterious effects of cassava effluent on the soil and how it may endanger the lives of plants and other soil micro and macro organism.

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ASSESSMENT OF THREATENED AND ENDANGERED FOREST TREES SPECIES AND THEIR BENEFITS IN WAMAKKO LOCAL GOVERNMENT AREA, SOKOTO STATE, NIGERIA.

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ABSTRACT

This study focused on assessment of threatened and endangered forest tree species and their benefits in Wamakko Local Government Area, Sokoto State, Nigeria. Random sample design was used, three (3) villages were purposively selected (Kalambaina, Gidan Yaro and Bado) for the study. Ninety (90) questionnaires were administered and thirty (30) structured questionnaires were distributed to each Village. Tree species identified include: *Tamarindus indica, Adansonia digitata, Parkia biglobosa, Vitex doniana, Hyphaene thebaica, Faidherbia albida, Guiera senegalensis* and *Borassus aethiopica* were the most commonly threatened and endangered forest tree species which were used either as fuel wood, timber, medicinal purpose, windbreaks, and thus, are considered to be a threat to sustainable environmental and ecosystem management in the study area. However, results show that Urbanization had high rate, followed by diseases and insect pest, flooding, uncontrol grazing, and lack of knowledge are identified as the major factors that are responsible for the destruction of these threatened and endangered forest trees species in the study area. Over-dependent on this resource (timber and fuelwood) lead to the depleting of some important tree species and also poorly management of forest trees leads to the species been threatened or endangered. Therefore, it is recommended that forest science and environmental education should be taught at different levels of formal learning; also, reliable and cheap sources of alternative energy must be provided, enforce the forest law and fine against the indiscriminate felling of trees and encourage tree planting campaign in the State.

Keywords: Threatened, Endangered, *Faidherbia albida*, Timber, Flooding

INTRODUCTION

There is a rapid decline of trees in Nigeria due to uncontrolled logging and clearing of forests for developments and agriculture (International Institute of Tropical Agriculture 2015). Vital commodities such as timber and medicinal plants affecting rural livelihoods and ultimately the economy. About 121 of Nigeria native trees were assessed by the IUCN Red list as threatened critically endangered (CR) endangered (EN), or vulnerable (VU) subsequently a further 17 species have been red listed bringing the total to 138. Nigeria has one of the highest rates of deforestation in the world and forest cover is now down to 4% as a result of forest clearance, illegal logging and habitat degradation, many trees' species are in rapid decline (IITA, 2015). Forest product of both the wood and non-wood forest products as well as their environmental is enormous through not completely quantification (Moormann *et al.*, 1975). Nigerian forest and woody vegetation resources include the high forest, woodland, bush land plantations and trees on farms. Forest trees contributes to production, protection and conservation functions (Alamu and Agbeja, 2011)

Nigeria shows strong inclination towards effective biodiversity monitoring to maintain and sustainably utilize their biological resources Nigeria is blessed with a plethora of biodiversity and biological resources including plants, animals and ecosystems to the extent that some of them are threatened to extinction and degradation resulting from the imbalance between economic development and biodiversity conservation. Some major threats to biodiversity conservation in Nigeria include poverty, economic development, incomplete or non-implementation and non-ratification by government of international treaties and conventions on conservation issues, ambiguous governmental laws on biodiversity, climate change, pollution, invasion by alien species etc.(BC, 2020)

Endangered species, is any species that is at risk of extinction because of sudden rapid decrease in its population or a loss of its critical habitat (FAO, 2002). Previously any species of plant or animal that was threatened with extinction could be called an endangered species. Endangered forest trees species can be found in all kind of forest in any and regions (FAO,2020). They have served as a major source of fuelwood by the rural people, particularly in area where there are lots of restrictions on felling of trees in the natural forest (Aju, 2012). Over two billion people depend on fuelwood for their energy needs, particularly those in developing countries. In Africa fuelwood is often the only available and affordable source of energy and accounts for almost 90 percent of primary energy consumption (FAO 2010).

Threatened species are any species (including animals, plants and fungi) which are vulnerable to endangerment in the near future (Martin 2001). threatened species is a population of organisms which is at risk of becoming extinct (Borokini, 2014a). They have served as a major source of fuelwood by the rural people, particularly in area where there are lots of restrictions on felling of trees in the natural forest (Aju, 2012). This research was conducted to identify the threatened and endangered species within the community and also their benefits derived from the species, and the challenges faced in managing the species.

MATERIALS AND METHODS

Study Area

The study area is Wamakko Local Government of Sokoto State and it is situated between the coordinates 13°16’N and 05°37’E. It falls within the Sudan savannah characterized by two seasons (wet and dry seasons) of varying duration and intensity, with prolonged dry season and short rainy season. The State is composed of scattered trees amongst dominating herbaceous layers and characterized by wet and prolong dry season. Fadama areas are the main sites for irrigation where tubers, spices, vegetables and moisture-loving crops such as rice are cultivated all year round while cereals and legumes are grown during the rainy season on rainfed croplands. (NMA, 2009).

SAMPLING TECHNIQUE

Preliminary survey was conducted in Wamakko Local Government of Sokoto State, observation and assessment was done for the forest trees species. Multi stage sampling was adopted for the study, Random sampling was employed at first stage to select three (3) wards in Wamakko Local Government Area from eleven wards (Arkilla, Bado/Kasarawa, Dundaye/Gumburawa, Gidan Yaro, Gidan Hamidu, Gumbi, Gwamatse, Kimba/Gedewa, Kalambaina, Kammata, Wamakko). Three (3) villages (Kalambaina, Gidan Yaro and Bado) from the identified wards were purposively selected based on distribution pattern of forest tree species cover. Snowball technique was adopted to select 30 respondents from each village, 30 (respondents from each village). A total number of 90 respondents were considered as a sample size for the study.

Data Collection

Data was collected from two main source; primary and secondary, the primary data was collected through the use of a well-structured questionnaire/interview schedule from the respondents, and secondary information was obtained from relevant literatures, textbooks, journals, past projects and internet.

DATA ANALYSIS

The data obtained was analyzed using descriptive statistics to achieve the stated objective. The statistical tools include frequency distribution and chart.

RESULT AND DISCUSSION

Identified Threatened and Endangered Forest Tree Species in the Study Area

The results showed that twenty-two (22) different species that are threatened and endangered were identified in the study area. This is in line with the findings of (Garba A, *et al.*, 2021) who identified *Tamarindus indica*, *Adansonia digitata*, *Faidherbia albida*, *Acacia nicotica*, as endangered species in Jigawa State, Nigeria

Table 1: Identified Threatened and Endangered Forest Tree Species in the Area under Study

Species	KALAMBAINA		GIDAN YARO		BADO	
	Threatened	Endangered	Threatened	Endangered	Threatened	Endangered
Anacardium occidentalis	✗	✓	✗	✓	✗	✓
Albizia lebbeck	✗	✓	✗	✓	✓	✗
Acacia nilotica	✗	✓	✗	✓	✓	✗
Adansonia digitata	✓	✗	✓	✗	✗	✓
Balanites aegyptiaca	✓	✗	✓	✗	✗	✓
Borassus aethiopum	✗	✓	✗	✓	✗	✓
Commiphora Africana	✗	✓	✗	✓	✗	✓
Detarium microcarpum	✓	✗	✗	✓	✓	✗
Diospyros mispiliformis	✓	✗	✗	✓	✓	✗
Ficus sycomorous	✗	✓	✗	✓	✗	✓
Ficus polita	✓	✗	✓	✗	✓	✗
Faidherbia albida	✓	✗	✓	✗	✓	✗
Guiera senegalensis	✓	✗	✓	✗	✓	✗
Hyphaene thebaica	✓	✗	✓	✗	✓	✗
Psidium guajava	✓	✗	✓	✗	✓	✗
Parinarium macrophyllum	✗	✓	✗	✓	✗	✓
Prosopis africana	✓	✗	✗	✓	✗	✓
Parkia biglobosa	✗	✓	✓	✗	✗	✓
Tamarindus indica	✓	✗	✓	✗	✓	✗
Vitex doniana	✓	✗	✗	✓	✓	✗
Ziziphus mauritiana	✓	✗	✓	✗	✓	✗
Ziziphus spina christi	✓	✗	✓	✗	✓	✗

Source; Field survey,2023

✓ **identified as Threatened or Endangered species**

✗ Not **identified as Threatened or Endangered species**

Perceived Benefits of Threatened and Endangered Forest Trees Species in the Study Area

The result from the study reveals that all the identified trees species in the study area are either threatened or endangered hence, they are either used for timber as local roofing materials, use the leaves, stem, back, or roots as medicinal as well as sources for fuel wood. Which agreed with (Borokini, 2014b) that forest tree was protected based on their medicinal values and food, Fire wood (fuel energy and heating) stand equally of importance, with the exception of *Adansonia digitata*.

Table 2: Perceived Benefits of Threatened and Endangered Forest species in the study Area.

Name of trees	***Uses***							
Species	*Medicinal*	*Timber*	*Fuel wood*	*Shade*	*Agro forestry*	*Wind break*	*Poles/stakes*	*Fencing /boundary*
Adansonia digitata	*82.2*	✗	*21.1*	✗	*47.8*	✗	✗	*41.1*
Acacia nilotica	*83.3*	*45.6*	*58.9*	*56.7*	*21.1*	✗	✗	*21.1*
Albizia lebbeck	✗	*57.8*	*78.6*	*57.8*	✗	*53.3*	*80.0*	✗
Anacardium occidentalis	*66.7*	*41.1*	*52.2*	*68.9*	✗	*51.1*	*62.2*	✗
Balanites aegyptiaca	*75.6*	*66.7*	*67.9*	*63.3*	*26.7*	*61.1*	*54.4*	✗
Borassus aethiopum	*62.2*	*63.3*	*32.2*	✗	*61.1*	✗	*74.4*	✗
Commiphora Africana	*60.0*	*24.4*	*44.4*	*46.7*	✗	✗	*62.2*	✗
Detarium microcarpum	*71.1*	*77.8*	*62.2*	*76.7*	✗	*58.9*	*68.9*	✗
Diospyros mispiliformis	*75.6*	*64.4*	*52.2*	*63.3*	✗	*63.3*	*61.1*	✗
Ficus polita	*45.6*	*45.6*	*54.4*	*88.9*	✗	*66.7*	*72.2*	✗
Ficus syccomorous	*51.1*	*61.1*	*53.3*	*60.0*	✗	*52.2*	*2.2*	✗
Faidherbia albida	✗	*71.1*	*67.8*	*46.7*	✗	*47.8*	*66.7*	✗
Guiera senegalensis	*81.1*	✗	*76.7*	✗	✗	✗	*46.7*	✗
Hyphaene thebaica	*68.9*	✗	*31.1*	✗	*48.9*	✗	✗	✗
Parkia biglobosa	*75.6*	*55.6*	*72.2*	*58.9*	✗	*57.8*	*73.3*	✗
Prosopis afiricana	*68.9*	✗	*74.4*	*55.6*	✗	*38.9*	*45.6*	✗
Psidium guajava	*76.7*	✗	*66.2*	*66.7*	*67.8*	*37.8*	✗	*45.6*
Parinarium macrophyllum	*74.0*	*71.1*	*64.2*	*55.6*	✗	*46.7*	*53.3*	✗
Tamarindus indica	*84.4*	*64.4*	*58.9*	*65.6*	✗	*57.8*	*61.0*	✗
Vitex doniana	*84.4*	*70.0*	*68.9*	*71.1*	✗	*54.4*	*60.0*	✗
Ziziphus mauritiana	*84.4*	✗	*24.4*	✗	✗	✗	✗	✗
Ziziphus spina Christi	***77.8***	***51.1***	***48.9***	***60.0***	✗	***52.2***	***51.1***	✗

Source: Field survey. 2023

Perceived Challenges in Managing the Forest Trees Species in the Study Area

The results showed the challenges faced in managing of forest trees species. The results showed that 22.9%, 9.6% and 15.6% of the respondents are from Kalambaina, Gidan Yaro and Bado respectively, perceived Urbanization as challenges faced in managing forest trees. , furthermore (figure 1) results revealed that flooding is also challenge faced by these trees 1.1%, 14.9%, and 10.7% of Kalambaina, Gidan Yaro and Bado respectively. This is in line with the findings of (Abubakar *et al.*, 2018) who stated that Loss in plant species is attributed to Urbanization, deforestation, expansion of agricultural activities and unsustainable collection of plants with a very few efforts of conserving or cultivating the species.

Challenges facing in managing forest trees

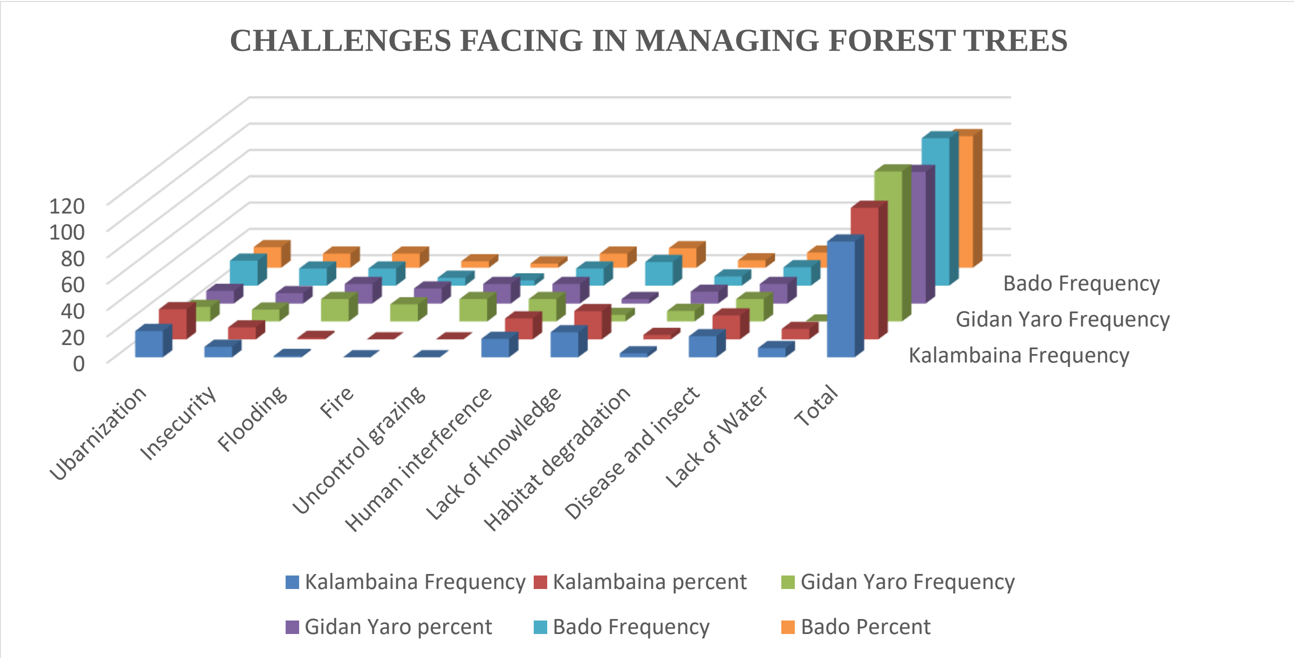

Figure 1; Challenges facing in managing forest trees

CONCLUSION AND RECOMMENDATION

This study focuses on threatened and endangered forest trees species and their benefits, Increase in human population and poverty call for the high demand of insufficient renewable resources like trees in the savannah region. Over-dependent on this resource (timber and fuelwood) lead to the depleting of some important tree species such as *Tamarindus indica*, *Adansonia digitata*, *Parkia biglobosa*, *Hyphaene thebaica*, *Farderbia albida*, and *Borassus aethiopicam* and also poorly management of forest trees leads to the species been threatened or endangered. It is therefore recommended that forest science and environmental education should be taught at different levels of formal learning; also, reliable and cheap sources of alternative energy must be provided, enforce the forest law and fine against the indiscriminate felling of trees and encourage tree planting campaign in the State.

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RECENT HONEY POLLEN ANALYSIS AS INDICATORS OF *APIS MELLIFERA* FLORAL PREFERENCE AND VEGETATIONAL HISTORY OF SHANI L.G.A., SOUTHERN BORNO STATE, NIGERIA

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ABSTRACT

Four samples of honey were sourced from Shani Local Government Area (LGA) of Southern Borno State, Nigeria. The study ascertained the species of plants that were utilized in the course of honey production, vegetational history, biogeographical origin of honey and taxa most preferred by *Apis mellifera* (honey bees).Samples were treated using standard palynological procedures. Pollen grains counts and fine morphological studies were made at x40 and x100 magnification respectively. Out of seventy-one pollen types belonging to thirty-six plant families of apicultural importance most foraged by *Apis mellifera* were encountered, two were identified to family level, fifty-six to generic level, twelve to species level, and one were unidentified. The identified species originated from numerous genera of trees, shrubs, grasses and herbs. Anguwan-audu, Labiri, Anguwan-babeto, and Lamot localities had pollen grain counts of 9,417, 9,055, 7,951 and 5,863 respectively. The predominant pollen types include those of *Borassus aethiopium*, Poaceae, *Mangifera indica*, *Hymenocardia acida*, *Phyllanthus* spp., *Tridax procumbens*, *Moringa oleifera*, *Combretum* spp., *Morellia senegalensis*, *Solanum melongena*, and *Mimosa pudica*. Indicators of Sudan savanna taxa: *Acacia dudgeoni*, *Adansonia digitata*, *Balanite orbicularis*, *Borassus aethiopium*, *Calotropis procera*, *Piliostigma thonningii*, Poaceae, *Senegalia mellifera*, and *Vitellaria paradoxa* were the highest pollen contributors (28.5 %) followed by human impact taxa (28.4 %). Pollen weight ranged from 0.40 - 0.45 g indicating that the honey samples were unadulterated. The honey samples were all multi-floral, which affirmed that they were of good quality. The season of honey production was between the period of the dry season and to early rainy season (October-April). Pollen assemblages reflected the vegetation of the study area which is largely Sudan savanna that is highly impacted by human activities. Adequate conservation of these indicator species is strongly recommended for health safety,natural resource availability and environmental sustainability using relevant biotechnological measures

Keywords: *Apis mellifera*,Floral preference, Pollen analysis, Vegetational history, Southern Borno.

INTRODUCTION

Pollen analysis is a technique for reconstruction of former vegetation by means of the pollen grains recovered from sediments (Essien *et al.*, 2023). Meo& Khan (2004) stressed that, pollen analysis has been significantly utilized as a means of tracing the history of cultivated and uncultivated plants. The use of pollen grains and spores in environmental studies is primarily in its application to the study of vegetational history (Traverse, 1988). Data gathered from pollen analysis could be useful to palaeoecologists, climatologists and oil explorationists among others (Moore & Webb, 1978).

The flora of an area provides a good reflection of the major climatic regime of the area. The influence of climate on other components of the environment is so great that every other climatic zone has its own characteristic vegetation type (Ige, 2017). Essien (2019) reported that the vegetation of an area is an integral and basic component of the ecosystem that is sensitive to changes in the ecosystem. He therefore opined that vegetation changes are themselves a response to and a reflection of variation in one or more of the factors of the environment, particularly climate. Thus, a close correspondence exists between vegetation and the rest of the environment, particularly climate and soil.

The study of vegetation and the way in which it has been altered and developed in the course of time indicates past changes that have occurred in our terrestrial environment. Variations in climate and in the intensity of human activities in historic and prehistoric times have made their mark upon the vegetation, and the plants themselves have left a record of these changes in the form of vast quantities of pollen grains which have survived in contemporary sediments (Roberts, 1989). In Quaternary, however, pollen grains can be directly referred to extant vegetation due to the proximity of Quaternary period with the present, proving "Present is key to the past". Ige (2017) opined that, pollen analysis is an extremely powerful tool for the investigation of floristic and climatic changes that took place in the recent past.

As a matter of urgency, plants foraged by honeybees must be conserved for continuity if honey production is to be sustained and one of the ways to determine these plants is through pollen analytical studies (Kayode & Oyeyemi, 2014; Byrant, 2018; Adekanmbi & Ogundipe, 2019). A combination of the insect and wind pollinated taxa found in a honey gives a unique understanding of the particular geographical location where the honey was produced and the plant communities in that region. This could shed more light on the important plants foraged by honeybees (Essien *et al.,* 2022a).

Findings from Neumann and Carreck, (2010) in Nnamani and Uguru (2013) revealed thatthe population of honeybee (*Apis mellifera* L.) has experienced serious decreasein Europe, North America and the world ingeneral. Theselosses highlight the potential risks for ournatural and agricultural biodiversity throughlack of pollination, and the repercussions onfood security and human nutrition (Ratnieksand Carreck, 2010).

It has been reported that lack of food and particularly scarcity ofpollen, within intensively farmed agriculturallandscapes and degraded environment as aresult of human impacted activities have actuallycontributed to the loss of plant species whichhoney bees foraged for pollen and nectar sources. Other biotic factorssuch as availability of plant genetic resources andtheir ability of these plant species to blossom,compete for resources, fight against pathogens,parasites, predators, and abiotic factors suchas climate and pollutants are all contributoryfactors to this decline (Gounari, 2006). Potts *etal*. (2010) opined that nutritional stress due tohabitat loss also played an important role in thecollapsed of honeybee colonies.

Recently, there are evident cultural, agricultural, unscientific and uncontrolled practices threatening the flora of several part of Shani, Southern Borno State. The report of a comprehensive and elaborate palaeoecological studies in Shani, Southern Borno State, Nigeria is almost non-existing and has not been given in any published literatures.The objectives of this study, therefore, are to ascertain the species of plants that were utilized in the course of honey production, vegetational history and biogeographical origin of honey as well as the taxa most preferred by *Apis mellifera* (honey bees).Knowing that the bee plants could be used as the basis for legalized protection and propagation of bee plants and farms. Pollen analytical studies have been found useful in deciphering such plants.

MATERIALS AND METHODS

Study Area: Lamot, Labiri, Anguwanbebeto and Anguwanaudu are localities within Shani Local Government Area of Borno State. Borno State lies in North Eastern Nigeria. Shani geographical coordinates- Latitude: 10° 25′ 59″ North, and Longitude: 12° 14′ 49″ East. It has an area of 2,098km² and altitude of 328 m (1,076 ft). Shani climate has a Tropical savanna climate and a population of about 120,000 as at the 2006 census. The land of Shani Local Government Area is covered with volcanic soil and the mean annual rainfall is 510-1150 mm, the dry season last 5 to 7 months. Increased seasonality and irregularity of rainfall impose semi-arid condition on the study area. The harmattan season between December and January is basically influenced by the North-East Trade winds. It has mean annual temperature of between 25 and 38^{o}C. There is extensive area of seasonal swamps. The vegetation is typically mixed Combretaceous woodland with *Vitellaria paradoxa*, *Acacia senegal*, *Acacia albida*, *Zizyphus* spp., *Adansonia digitata*, and *Piliostigmareticulatum* being the dominant trees. The common grasses in the zone, Aristida, *Brachiaria*, *Panicum*, *Chloris*, *Digitaria*, and *Eragrostis* are mostly short. Cultivation is intense and together with heavy grazing, bush burning and cutting for firewood/ charcoal, and browse, has contributed to extensive desertification in the study area.

Sample collection: Four honey samples were collected from vendors who sources from the wild at the study area between the months of September and December, 2022. The honeys were extracted by pressing and squeezing the combs, filtered into a bottle through fine mesh-copper gauze to avoid introduction of debris. Once collected the samples were labelled and transported to the Laboratory, Department of Biology, Nigerian Army University Biu, for pollen analysis.

Determination of pH: Honey (10 g) was dissolved in 75 ml of distilled water in a beaker and vigorously mixed using a glass rod, pH electric meter was immersed in the honey and values were taken.

Honey colour: The Munsell Soil Color Chart was used.

Pollen analysis: Three basic procedures were followed; honey quantification/dilution, pollen acetolysis and microscopy. All procedures followed the recommendation and techniques reported in Erdtman (1969); Louveaux*et al*. (1978), and Agwu *et al*. (2013).

M**ounting and microscopic examination**:On a 25.4 mm x 76.2 mm (1"×3") slide 1 mm- 1.2 mm thick, one drop of thoroughly shaken precipitates suspension was mounted and covered with 18mm x 18mm cover slip. To keep the precipitation from drying out, the mount was sealed off at the edges with colorless nail polish Counting was done using Olympus microscope at x400 magnification while detailed pollen morphological studies to aid identification was done using Leica microscope at x 1000 magnification. Reference slides, pollen atlas and photomicrographs (Sowunmi, 1978; 1995; Agwu & Akanbi, 1985; Agwu *et al.*, 2013; Shubharani*et al.*, 2013; Essien *et al.*, 2022b; Essien *et al*. 2023) was used for identification.

Weight of pollen grains: Honey (50 ml) and beaker (71.65 g) was weighed using the weighing balance. The honey was diluted with 1000 ml of distilled water and the formular below was applied

Weight of pollen x factor of 20 = weight of beaker/liter of honey samples.

Data analysis: Data generated from the study was presented in form of tablesand/ orgraphical representation (histogram). The classification for representation of pollen types followed was the one recommended by Louveaux*et al.* (1978) for expressing pollen grain frequencies: Very frequent (over 45%), frequent (16-45%), rare (3-15%) and sporadic (> 3%).

RESULTS AND DISCUSSIONS

Pollen Analysis

Pollen analytical examination of honey samples from four localities in Shani Local Government Area of Borno State, Nigeria was carried out to ascertain the different pollen types present in the honey samples, the botanical, ecological and geographical origin of the honey, the season of honey production in the study localities as well as the weight of the pollen grains which could be used to deduce between adulterated and pure honey and the results revealed great diversity in size, shape, aperture and sculpturing of pollen grains.

A total of thirty-two thousand three hundred and eighty-six (32,386) pollen grains were encountered. Result showed that out of seventy-one (71) pollen types belonging to thirty-six (36) plant families documented, two (2) were identified to family level, fifty-six (56) to generic level, twelve (12) to species level, and one (1) were unidentified. After dilution, the colours of the honey samples were observed and ranged from light-brown, dark-brown, brown and light-brown and the result are presented in table 1. The weight of pollen grains for the samples ranged from 0.40 g to 0.45 g per 10 g of honey. The weight of the sediment recovered per sample and the colour of the honey after dilution are given in Table 1.

The identified species originated from numerous genera of trees, shrubs, grass, and herbs. Anguwan-audu, Labiri, Anguwan-babeto, and Lamot each had pollen grain counts of 9417, 9055, 7951, and 5863 respectively. The predominant pollen types include those of *Borassus aethiopium*, Poaceae, *Mangifera indica*, *Hymenocardia acida*, *Phyllanthus* spp., *Tridax procumbens*, *Moringa oleifera*, *combretum* spp., *Morellia senegalensis*, *Solanum melongena*, and *Mimosa pudica*. Indicators of Sudan Savanna taxa: *Acacia dudgeoni*, *Adansonia digitata*, *Balanite orbicularis*, *Borassus aethiopium*, *Calotropis procera*, *Piliostigma thonningii*, Poaceae, *Senegalia mellifera*, *Vitellaria paradoxa* were the highest pollen contributors (28.5 %) followed by human impact taxa (28.4 %). The pollen weight was between 0.40-0.45 indicating that the honey samples were unadulterated. The honey samples were all multi-floral, which affirmed that they were of good quality

The classification recommended by Louveaux*et al.* (1970) for expressing pollen grains frequencies have been adopted: very frequent (over 45%), frequent (16-45%), rare (3-15%) and Sporadic (less than 3%). The pollen spectrum of the honey sample in percentage composition is presented in each of the Tables.

The highest number of pollen types (36) was recorded for Labiri, 33 for Anguwan-audu and Anguwan-babeto respectively and Lamot (26) had fewer pollen types. The detailed pollen count of each sample is presented in Table 2. All the plants (28.4%) recorded for human impact taxa. The predominant indicators species are presented Table 4.

identified were grouped into different phytoecological groups. Thus: Derived Savanna, Guinea Savanna, Sudan Savanna and Human impact taxa (Table 4). Indicators species of the Derived savanna taxa contributed 7,952 (24.4%), Guinea savanna taxa 5,863 (18.6 %), Sudan Savanna taxa 9,415 (28.5%) and 9,055 .

Figure 2 showed that the most abundant plant families in order of reducing percentage were Euphorbiaceae (19.92%), Rubiaceaeand Mimosaceae (17.82%), Myrtaceaeand Caesalpinaceae(15.92%), Meliaceae (14.67%), Phyllanthaceae (10.63%), Combretaceae (5.98), Cucurbitaceae (4.93%), Bombacaceae (3.75%), Anacardiaceae (2.64), Arecaceae (2.44) and Sapotaceae (1.9). While the least abundant were Loranthaceae, Lycytidaceae and Caprifoliaceae (0.01%), Balanitaceae, Labiatae and Cyperaceae (0.02%), Araliaceae (0.03), and Verbenaceae (0.04%), Asteraceae (0.05), Berberidaceae (0.08), and Boraginaceae (0.1).

Table 1: Physical properties of the four honey samples studied

Localities	Colour of honey after dilution	Honey Weight collected (g)	Weight of pollen (g)	Weight of honey (gram/litre)
Lamot	Dark-brown	10	0.40	1266
Labiri	Light-brown	10	0.43	1385
Anguwan- babeto	Brown	10	0.42	1286
Anguwan-audu	Light-brown	10	0.45	1395

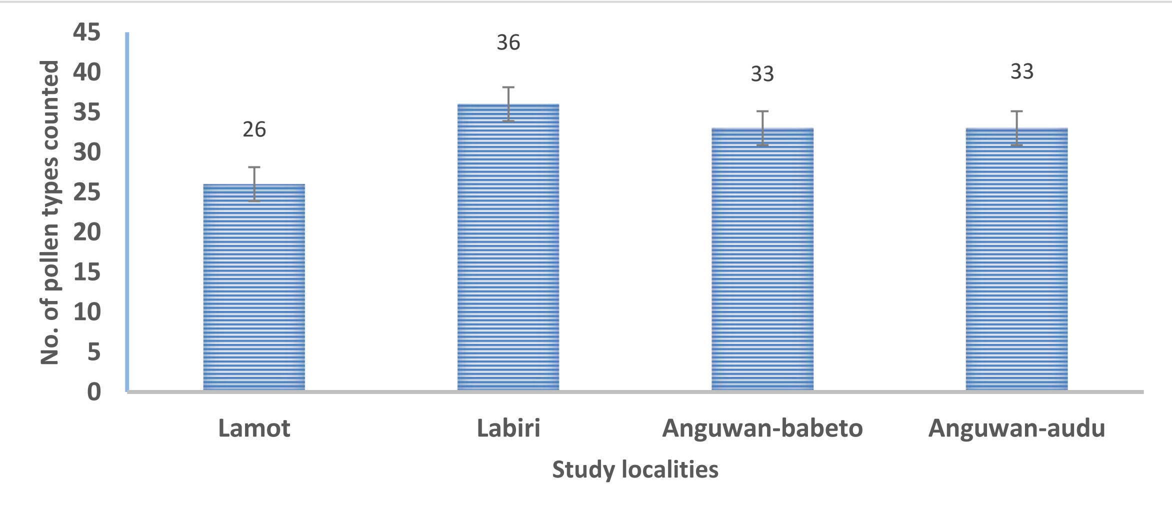

Figure 1: Histogram showing number of identified pollen types in the four honey samples from the study area clearly an indication of the high diversity of pollen in Shani Local Government Area, Borno State.

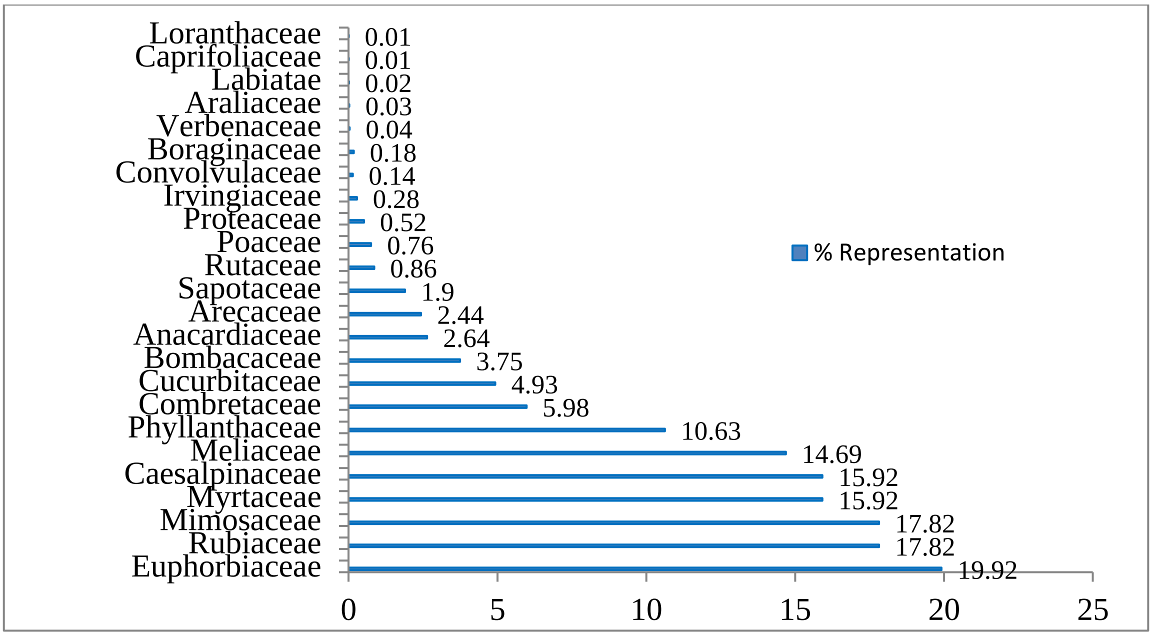

Figure 2: Relative abundance of the pollen types based on plant family

Table 2: Absolute pollen counts/ types recovered from recent honey samples in Shani, Southern Borno State

Pollen types/families	Localities in Shani									
	Lamot	%	Labiri	%	Angwan -babeto	%	Angwan -audu	%	Total	%
1. ACANTHACEAE										
Hypoestes spp.					412	5.1			412	1.2
Strobilanthes spp.					265	3.3			265	0.8
2. ANACARDIACEAE										
Herria reticulata			234	2.5					234	0.7
Mangifera indica	231	3.8	681	7.3	789	9.8	711	7.6	2412	7.3
3. ARECACEAE										
Borassus aethiopium	431	7.0	592	6.3	421	5.2	643	6.8	2187	6.6
Hyphaene spp.	120	2.0							120	0.4
4. ASCLEPIADACEAE										
Calotropis procera					146	1.8	397	4.2	543	1.6
5. ASTERACEAE										
Tridax procumbens	145	2.4							145	0.4
Ageratum conyzoides			235	2.5					235	0.7
6. BALANITACEAE										
Balanite orbicularis					321	4.0			321	0.9
7. BERBERIDACEAE										
Mahonia oiwakensis	123	2.0			121	1.5			244	0.7
8. BOMBACACEAE										
Bombax buonopozense			189	2.0	154	1.9	265	2.8	608	1.8
Ceiba pentandra			141	1.5	186	2.3	397	4.2	724	2.1
9. BORAGINACEAE										
Cordia africana			186	2.0					186	0.6
Cordia suckertii			125	1.3			111	1.2	236	0.7
10. CAESALPINACEAE										
Acacia rubida					178	2.2	432	4.6	610	1.8
Caesalpinia pulcherrima	412	6.7							412	1.2
Daniellia oliveri			198	2.1					198	0.6
Delonix regia					154	1.9	342	3.6	496	1.5
Piliostigma thonningii			145	1.5	176	2.2	254	2.7	575	1.7
Senegalia mellifera	354	5.8							354	1.1
Senna alata	476	7.7							476	1.4
11. CAPRIFOLIACEAE										
Knautia spp.					154	1.9	329	3.5	483	1.5
Viburnum taiwanianum					451	5.6			451	1.4
12. COMBRETACEAE										
Combretum spp.					187	2.3			187	0.5
13. CONVOLVULACEAE										
Ipomoea reptans					197	2.4	232	2.5	429	1.3
14. CUCURBITACEAE										
Momordica cymbalaria	132	2.1							132	4.0
Melothria maderaspatana			165	1.8					165	0.5
15. CYPERACEAE					312	3.9			312	0.9
16. EUPHORBIACEAE										
Alchornea cordifolia			276	2.9	186	2.3	265	2.8	727	2.2
Euphorbia hirta			167	1.8					167	0.5
Jatropha spp.			212	2.3					212	0.6
Ricinus communis	329	5.3	154	1.6					483	1.4
17. GESNERIANCEAE										
Hemiboea bicornuta					198	2.5	142	1.5	340	1.0
18. IRVINGIACEAE										
Irvingia gabonensis			143	1.5	176	2.2			319	0.9
19. LABIATAE										
Leonotis nepetifolia							421	4.5	421	1.2
20. LORANTHACEAE										
Hyphear owatarii			254	2.7					254	0.7
21. LYCYTIDACEAE										
Crateranthus letesturi					367	4.6			367	1.1
22. MALVACEAE										
Adansonia digitata			179	1.9	124	1.5	387	4.1	690	2.0
23. MAGNOLIACEAE										
Magnolia coco	321	5.2							321	0.9
24. MELIACEAE										
Trichilia prieureana	231	3.8			159	2.0	121	1.3	511	1.5
Trichilia emetica					238	3.0			238	0.7
25. MIMOSACEAE										
Acacia dudgeoni			276	2.9	189	2.3	153	1.6	618	1.8
Albizia zygia			198	2.1	178	2.2	132	1.4	508	1.5
Mimosa pudica	148	2.4					167	1.8	315	0.9

Table 3: Floral sources of the honey samples from the study area

Samples	Pollen type				Remark on floral origin	Pollen count/ Category
	Very frequent (> 45%)	**Frequent (16 – 45%)**	**Rare (3 – 15.9%)**	**Sporadic (< 3%)**		
Lamot	--	--	*Borassus aethiopium* (7.0), *Mangifera indica* (3.8), *Caesalpinia pulcherrima* (6.7), *Senegalia mellifera* (5.8), *Senna alata* (7.7), *Magnolia coco* (5.2), *Ricinus communis* (5.3), *Psidium guajava* (6.3), *Syzygium guineense* (4.2), *Trichillia prieureana* (3.8), *Moringa oleifera* (3.3), *Parkia biglobosa* (3.9), *Phyllantus* spp. (4.1), *Mitragyna inermis* (3.1).	*Hyphaene* spp. (2.0), *Tridax precumbens* (2.4), *Mahonia oiwakensis* (2.0), *Momordica cymbalaria* (2.1), *Eugenia* spp. (2.0), *Northia* spp. (2.0), *Eucalyptus camaldulensis* (2.0), *Mimosa pudica* (2.4), *Hymenocardia acida* (2.0), *Protea elliottii* (2.1), *Citrus* spp. (2.1).	Multifloral	6,152/ **I**
Labiri	--	--	*Borassus aethiopium* (6.31), *Mangifera indica* (7.3), *Hannoa klaineana* (3.0), *Psidium guajava* (6.2), *Syzygium guineense* (4.0), *Indigofera* spp. (3.3), *Citrus* spp. (3.1), *Vitellaria paradoxa* (3.0).	*Ageratum conyzoides* (2.5), *Herria reticulata* (2.5), *Tarenna graveolens* (2.6), Poaceae (1.3), *Hymenocardia acida* (1.84), *Parkia biglobosa* (2.09), *Combretum* spp. (1.9), *Saccocephalus latifolius* (2.9), *Tarenna graveolens* (2.1),	Multifloral	9,376/ **I**
Anguwan-babeto	--	--	*Borassus aethiopium* (6.5), *Moringa oleifera* (9.8), *Hypoestes* spp. (5.1), *Strobilanthes* spp. (3.3), *Balanite orbicularis* (4.0), *Cyperus* spp. (3.9), *Viburnum taiwanianum* (5.6), *Crateranthus letesturi* (4.6), *Trichilia emetic* (3.0), *Tephrosia* spp. (3.9), *Mimusops warneckei* (3.9).	*Calotropis procera* (1.8), *Mahonia oiwakensis* (1.5), *Bombax buonopozense* (1.9), *Ceiba pentandra* (2.3), *Piliostigma thonningii* (2.1), *Combretum* spp. (2.3), *Alchornea cordifolia* (2.3), *Hemiboea bicornuta* (2.5), *Moringa oleifera* (1.5), *Acacia dudgeoni.* (2.3), Poaceae (2.4).	Multifloral	8,051/ **I**
Anguwan-audu	--	--	*Mangifera indica* (7.5), *Borassus aethiopium* (6.8), *Calotropis procera* (4.2), *Ceiba pentandra* (4.2), *Delonix regia* (3.6), *Acacia rubida* (4.5), *Knautia* spp. (3.5), *Adansonia digitata* (4.1), *Leonotis nepetifolia* (4.5), *Psidium guajava* (4.4), *Syzygium guineense* (3.8).	*Bombax buonopozense* (2.8), *Cordia suckertii* (1.2), *Ipomoea reptans* (2.5), *Piliostigma thonningii* (2.7) *Alchornea cordifolia* (2.8), *Vitellaria paradoxa* (2.0), *Mitragyna inermis* (2.4), *Citrus* spp. (2.5), *Clausena anisata.* (2.5), Poaceae (1.7).	Multifloral	9,415/ **I**

***Floral origin:** selected based on most represented (very frequently and frequently occurring) plant species
Categories: **I** (<20,000), II (20,000 – 100,000), III (100,000 – 500,000), IV (500,000 – 1,000,000) and V (>1,000)

Table 4: Vegetation inference from pollen types recovered from honeys from the study area

Palaeoecological data		Vegetation type represented from absolute pollen counts				
		Derived savanna	**Guinea savanna**	**Sudan savanna**	**Human impact taxa**	**Suggestive inference on biogeographical origin of honey**
Selected pollen types		*Alchornea cordifolia, Bombax buonopozense, Ceiba pentandra, Clausena anisata, Daniella oliveri Irvingia gabonensis, Milettia pinnata, Mimusops warneckei, Morelia senegalensis, Parkia biglobosa Phyllanthus* spp.,	*Albizia zygia, Combretum* spp., *Gaertnera paniculata, Sarcocephalus latifolius Senna alata, Syzygium guineense, Trichilia prieureana, Trichilia emetica,*	*Acacia dudgeoni, Acacia rubida Adansonia digitata, Balanite orbicularis, Borassus aethiopium, Calotropis prosera, Cordia africana, Cordia suckertii Hannoa klaineana, Hyphaene* spp., *Magnolia coco, Northia* spp., Poaceae *Piliostigma thonningii, Senegalia mellifera, Vitellaria paradoxa,*	*Citrus* spp., *Delonix regia, Eucalyptus camaldulensis, Euphorbia hirta, Jatropha* spp. *Mangifera indica, Mimosa pudica, Moringa oleifera, Mitragyna inermis, Psidium guajava, Ricinus communis*	
Total pollen count		**7,951**	**5,863**	**9,417**	**9,055**	
Localities	Lamot (%)	40.65	30.60	17.52	26.20	-Sudan savanna/ Human impact
	Lambiri (%)	24.95	41.48	19.17	27.56	-Sudan savanna/ Human impact
	Anguwan-babeto (%)	14.17	16.40	18.09	21.70	-Sudan savanna/ Human impact
	Anguwan-audu (%)	20.23	11.52	45.25	24.54	-Sudan savanna/ Human impact
Total pollen indicator of the vegetation (%) of Shani		**24.4**	**18.6**	**28.5**	**28.4**	**Shani LGA in Southern Borno State is largely Sudan savanna that is highly impacted by human activities.**

Total pollen count = 32,386

Vegetation history and biogeographical origin of honey: The determination of a biogeographical origin of honey is based on the entire spectrum being consistent within the flora of that particular region (Louveaux *et al.*, 1978). The abundance of *Acacia rubida,Acacia dudgeoni*, *Adansonia digitata*, *Balanite orbicularis*, *Borassus aethiopium*, *Calotropis procera*, *Combretum* spp., *Cordia africana,Daniella oliveri*, *Parkia biglobosa*, *Sarcocephalus latifolius,Piliostigma thonningii*, Poaceae, *Senegalia mellifera*, and *Vitellaria paradoxa* reflects the vegetation of Sudan Savanna. The occurrence of the pollen of the above listed plants in the pollen spectrum of the studied samples confirms their biogeographical origin reflecting Sudan savanna ecovegetation type that is anthropogenically disturbed. Similar findings on other vegetation zones were reported by Agwu and Okeke (1997); Essien *et al*. (2022c), Essien *et al*. (2023) as well as Essien and Olaniyi (2023).

According to pollen analysis of these honey samples, Sudan Savanna taxa were the highest pollen contributor (28.5 %) followed by Human impact taxa (28.5 %). The suggestive vegetational inference inferred from this honey pollen analysis revealed that Shani in Southern Borno State is largely Sudan Savanna highly impacted by human activities. Similar findings were reported by Essien *et al*. (2023) who opined that the plant *Senegalia mellifera* whose pollen grains are present in the pollen assemblage of the honey samples studied is used as fencing, livestock feed and building material for huts. The wood is prized also for fuel and making charcoal. All these are predominant indigenous occupations/ cultural lifestyle and heritage of the inhabitant of the study area.

The pollen analysis shows a fairly similar floral composition for the entire honey samples studied which is in line with the work of Sowunmi (1976) in Southeastern Nigeria and the high floral diversity of the forested-savanna ecozone by Agwu *et al*.

(2013) in Northcentral Nigeria. The percentage of human impact indicator species could be attributed to anthropogenic activities in this region such as the activities of herdsmen (livestock grazing, annual bush burning, etc.), deforestation, urbanization, and agricultural activities in line with reports of Essien *et al*. (2022a). From Table 4, there were clear indications that the region ofShani in Southern Borno State is largely Sudan Savanna highly impacted by human activities with little variation with respect to the different study localities.

Season of honey production: Most plants flower during the dry seasons, allowing honeybees graze during those times. For instance, the flowers of *Senegalia mellifera* are sources of nectar for honey-producing bees. To produce honey in the study area efficiently, this study examined the numerous pollen types and their distinct flowering seasons. According to Dalziel (1937) and Keay (1959) studies, flowering seasons differ for different plants. For example, *Mangifera indica* (February-May), *Morellia senegalensis* (November to January; March to April), *Mimusops warneckei* (April to June), *Alchornea cordifolia* (October to November; June - August), *Bombax buonopozense* (January to March), *Brachystegiaeurycoma*(April to May), *Daniella oliveri* (November to January; March to April), *Delonix regia* (April to August),*Elaeisguineensis* (October-April), *Parkia biglobosa* (December to April),*Paullinia pinnata* December to January), *Trichilia prieureana* (January to March), *Tridax procumbens* (June to September), *Vitellaria paradoxa* (April to June). According to Sowunmi (1976) and Agwu & Akanbi (1985), *Parkia biglobosa*, and *Phyllanthus* spp. all have flowering periods between January and October. These flowering seasons can be used by beekeepers to maximize the production of honey in the study area.

Floral preference of honeybees (*Apis mellifera* var. *adansonii*): Pollen analysis of honey samples examined indicates the presence of pollen types of different plants species, most likely a reflection of more species diversity characteristics of Human impacted Guinean Savanna vegetation type. The determination of the floral origin of honey is based on the relative frequencies of pollen types of various nectar producing plants species in the honey samples. Generally, entomophilous plants were observed to be more abundant in the pollen spectrum of each honey sample studied and the honey from the source localities were rich in pollen types.

In terms of floral sources, this study revealed that all the honey samples were multifloral (Table 3); suggesting that honeybees (*Apis mellifera* var. *adansonii*) collected honey by gathering a variety of pollen and nectar that they found to be most appealing. According to Agwu *et al*. (2013), Kayode and Oyeyemi (2014), Adeonipekun *et al*. (2016), Adekanmbi & Ogundipe (2009), and Essien *et al*. (2022c), the majority of Nigerian honeys fall into the type I description of Parades and Bryant (2019). The pollen types from the least abundant families may not have been fully domesticated, or their pollen does not rank among the top choices for honeybees.

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Based on the relative frequencies of the various pollen types from nectariferous and polleniferous species in the honey samples, the botanical origin of the honey is identified. The predominance of plant families like the Fabaceae, Sapotaceae, Arecaceae, Euphorbiaceae, Anacardiaceae, Rubiaceae, and Combretaceae (Figure 2) has been reported in numerous other studies (Dukku, 2013; Kayode and Oyeyemi, 2014; Adekanmbi and Ogundipe, 2009), which is unmistakably a sign of the importance of these families in honey The least numerous families might not have been fully domesticated or their pollen may not be favoured by honeybees over the most numerous families.

The study showed that all honey samples were multifloral (Table 3), implying that honeybees (*Apis mellifera* var. *adansonii*) foraged for several preferred pollen and nectar sources to produce the honey. Agwu and Njokuocha (2004) reported that the differences which were observed in the number of contributing plant species in the honey samples may be attributed to the variation in edaphic factors, microclimate, lack of uniformity in the establishments of plants (including flowering period) and selective behaviors of bees during their foraging activities.

Originality of honey: Deciphering the botanical or ecological origin and the authenticity of honey samples from Shani, Southern Borno State, Nigeria was the focus of this study. Complimentarily, knowing the best times for apiculture by understanding the flowering seasons of the plant was another objective. Having seen evident impact of humans in the study location, pollen analytical study shed more light on the important bee plants that may require preservation for continuous supply of quality honey in Borno State. The study found that all honey samples were acidic in nature (Table 1) and pollen weight revealed that the honey sample were not adulterated. Cases of honey adulteration have been reported in many cities in Nigeria. For example, Agwu *et al*. (2013) from Dekina; Aina *et al*. (2014) from Kogi East; Anidiobu(2016) from Kabba; Essien *et al*. (2022a) from Ijumu has been reported to be good. This study confirms those from Shani, Southern Borno State; that were randomly sampled are also of good quality. Honey quality can be measured by its pollen diversity and count (Ige and Modupe, 2010; Oyeyemi, 2017; Essien *et al.*, 2022c). The high diversity of pollen types (Figure 1) further supports the originality of the honey samples (Bogdanov and Martin, 2002).

CONCLUSION

Pollen analysis is still an indispensable method for the determination of vegetational history and biogeographical origin of honey; major season of honey production; floral preference of honey bees, and purity status of honey based on its floral and geographical origin. It can to some extent, reflect the floristic characteristics of the area the honey was collected from. This study has revealed some important indicator species of vegetation types in Shani as well as honey bees (*Apis mellifera* var.*adansonii*) preferred pollen and nectar sources. These plants include those of *Syzygiumguineense, Psidium gaujava, Mangifera indica, Parkia biglobosa, Combretum* spp.*, Vitellaria paradoxa,* and *Trichillia prieureana* worthy of conservation and their sustainable exploitation managed in the apiculture to enhance large scale production of honey in Shani Local Government Area of Southern Borno State, Nigeria. The study further revealed that the vegetation of Shani in Southern Borno State is largely Sudan Savanna type and is currently being impacted by human activities of subsistence.

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The author declares that there is no conflict of interest.

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COMPARATIVE LEAF EPIDERMAL STUDIES OF SOME SPECIES IN THE FAMILIES ASCLEPIADACEAE AND APOCYNACEAE

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ABSTRACT

This study investigated leaf epidermal characters of 16 species in the family Asclepiadaceae and Apocynacneae with a view to enhancing the classification of the families in Nigeria following sstandard procedures. Elliptic stomata shape was common among the species studied except in *L. dulcis* with oval to circular stomata shape. Seven species were amphistomatic while others were hypostomatic. Anomocytic stomata type was observed in all the species except *C. roseus* and *H. floribunda.* Desmocytic stomata on coastal cells was diagnostic for *M. guineensis;* however, *F. elastica* had Diacytic stomata. *A. boonei* and *P. daemia* were unique in having cuticular ornamentation covering all the surfaces of the epidermal cells on the abaxial surfaces. Unicellular to multicellular non-glandular trichomes were present in most of the species studied except in *P. daemia* which had additional and different types of trichomes like biseriate bicellular, biseriate multicellular and multiseriate multicellular non-glandular trichome, which separated it from all the taxa studied. This study reported for the first time the presence of kinked uniseriate trichome-like structure which are multicellular and slender, with indefinite amoeboid shape which is common in almost all the species studied except in *A. barteri*, *F. elastica*, and *L. dulcis* on both surfaces but present only on the abaxial surfaces of *P. alba* and *P. rubra*. This unique feature can be used together with other characters like anomocytic stomata type and unicellular to multicellular trichomes as diagnostic tools for bringing the two families together.

Keywords: Apocynaceae, Asclepiadaceae, Epidermal, Trichomes, Stomata.

INTRODUCTION

The Apocynaceae Juss. family, is commonly known as the dogbane family according to Gill (1998), it comprises 200 genera and approximately 2000 species, as reported by Endress *et al*. (2000). In West Africa, this family is represented by 37 genera and 138 species, displaying a diverse array of life forms including trees, shrubs, perennial herbs, climbers, succulent stems, and vines, as noted by Gill (1988). Endress and Bruyns (2000) further categorized this family into five subfamilies: Secamomoidae, Apocynoidae, Rauvolfioidae, Periplocoidae and Asclepiadoidae. The family is characterized by the production of pod-like fruits, as reported by Koyuncu (2012). Many of these plants contain milky latex, and the leaves of various species can be toxic if consumed, as noted by Endress and Bruyns (2000). According to Keay *et al*. (1964), the leaves within the Apocynaceae family exhibit significant variability from one species to another. These leaves may be arranged in opposite or whorled patterns, with alternate arrangement being rare. They are typically simple and have entire margins. The structure of the leaf epidermis is a valuable trait for species and genera classification, as well as for addressing phylogenetic questions, as discussed by Stace (1984) and Jones (1986). Additionally, it’s worth noting that leaf epidermal characteristics have demonstrated greater stability compared to morphological features. Numerous scientists have documented the epidermal characteristics of various taxa within the Apocynaceae family. They utilized amphistomatic leaves as a means to differientiate *Wriohtia tinctoria, Ervatamia divaricata, and Catharanthus swere* from six other species in the same family. This differentiation was achieved through the examination of the foliar epidermis of ten Indian species representing nine distinct genera, as reported by Kannabiran and Ramassamy (1998). Bashir *et al*. (2020) differentiated *Nerium oleander* from other species by noting the presence of stomatal crypts. Onafeli and Kehinde (2021) characterize five tree species of Apocynaceae and identified various epidermal makers that can be used for the discrimination of the medicinal tree species of the taxa. Dalia *et al.,* (2015) investigated their study on 15 different types of trichomes from Apocynaceae and Asclepiadaceae using leaf morphological characters and considered the two families as one large family: the family Apocynaceae. Formerly, Apocynaceae and Asclepiadaceae exist as two separate families. This separation was based on morphological characters of androecium, pollen transfer system, gynoecium and more or less the presence of extra whorl of corona attached to the petal which was present in Asclepiadaceae and lacking in Apocynaceae (Brown 1810, 1811). Morphological and palynological evidences as well as the rapidly growing body of molecular information (Livshultz, 2010) suggests that Brown's delimitation does not reflect natural relationships and support the recognition of a single entity. Endress and Bruyns (2000) concluded that the Asclepiadaceae is an apomorphic derivative of the Apocynaceae, thus making it monophyletic and are better considered as a sub - family. Despite these significant contributions to the field, the taxonomic relationships within the Asclepiadaceae and Apocynaceae family remain in a state of uncertainty and incompleteness. This study therefore aimed at comparing the leaf epidermal characters of some species in the two families in order to ascertain their taxonomic relationships.

MATERIALS AND METHODS MATERIALS

Sixteen species belonging to 15 genera, 8 tribes and four sub - families were used for this study (Table 1:

Table 1: Species names, tribes and subfamilies of plants used for this study.

SPECIES	TRIBES	SUB-FAMILIES
Allamanda cathartica L.	Plumerieae	Rauvolfiodeae
Plumeria alba L.	Plumerieae	
Plumeria rubra L.	Plumerieae	
Thevetia neriifolia Juss. ex A. DC.	Plumerieae	
Alstonia boonei De Wild;	Alstoniae	
Catharanthus roseus (L.) G. Don.	Vincieae	
Rauvolfia vomitoria Afzel.	Vincieae	
Landolphia dulcis (R.Br.) Pichon	Willughbecieae	
Alafia barteri Olive.	Malouetieae	Apocynoideae
Funtumia elastica (Preuss) Stapf	Malouetieae	
Hollarhena floribunda (G. Don) Dur. & Schinz	Malouetieae	
Motandra guineensis (Thonn.) A.DC.	Apocyneae	
Gongronema latifolia Benth Hook	Marsdenieae	
Pergularia daemia (Forssk.) Chiov.	Asclepiadeae	Asclepiadoideae
Calotropis procera Br.	Asclepiadeae	
Parquetina nigrescens (Afzel.) Bullock	Undetermined	Periplocoideae

The procurement of plant samples and the Method for preparing Epidermal Peels: The plant specimens were collected from various locations in Obafemi Awolowo University in Ile-Ife, Osun state, Nigeria. To ensure the accuracy of the plant identification, the samples underwent validation at both the Obafemi Awolowo University Herbarium (IFE) and the Herbarium of the Forestry Research

Institute of Nigeria (FHI) in Ibadan. The leaves were initially preserved in a solution of 50% ethanol before they were prepared for epidermal characterization. Two distinct methods were employed for obtaining epidermal peels: manual peeling and acid peeling. For the manual technique, the adaxial and abaxial surfaces of well-expanded leaves were obtained by gently scraping off the tissues above the required epidermis using a sharp razor blade following the method of Odedeji and Adedeji (2015). As for the acid peeling method, mature leaves were chosen and soaked in concentrated nitric acid for a period ranging from 6 to 20 hours, depending on the leaf's texture. The appearance of air bubbles and the swelling of the leaf surfaces indicated that the epidermal layers were ready for separation. Once this occurred, the samples with swollen surfaces and air bubbles were transferred to clean glass Petri dishes filled with water, and the adaxial and abaxial layers were carefully separated using dissecting needles and forceps. The resulting epidermal peels were then cleaned using a camel-hair brush in water and subsequently preserved in storage containers filled with 50% ethanol, following the method described by Oyedapo *et al*. (2013).

Slides preparartion, evaluating epidermal characteristics and analysing data:

To prepare epidermal peels for analysis, they were initially rinsed with water, then stained with safranin O as described by Odedeji and Adedeji (2015). Excess staining was removed through two subsequent water rinses. Each epidermal peel was subsequently affixed to a clean glass slide using 25% glycerol to facilitate examination of its internal structure. An Olympus microscope, equipped with an Amscope digital camera, was employed for visual examination and photography of the adaxial and abaxial surfaces of the epidermis. Qualitative factors such as epidermal cell shape, anticlinal cell wall pattern, stomata, and trichome types were studied.

Additionally, quantitative measurements, including epidermal cell area, stomata area, stomata index, and guard cell area, were determined using the formulas proposed by Metcalfe (1960, 1989) and Arogundade and Adedeji (2016). The data obtained from this research underwent comprehensive multivariate statistical analysis. One-way Analysis of Variance (ANOVA) was employed to assess significant differences, with means compared at a significance level of $P < 0.05$ using the Duncan Multiple Range Test. Principal Component Analysis and Cluster Analysis were conducted to reveal relationships among the studied species.

RESULTS

The qualitative epidermal characters of the two families studied are shown in Tables 2 and 3. Stomata were present on both the abaxial and adaxial surfaces of all the taxa; Seven are amphistomatic. They include *Allamanda cathartica, Calotropis procera, Catharanthus roseus, Gongronema latifolia, Pergularia daemia, Plumeria alba* and *Plumeria rubra* while the remaining species are hypostomatic. It was also noted that there are similarities and differences at the generic levels and the specific levels between *Plumeria alba* and *Plumeria rubra.*

Anomocytic stomata type was observed in all the species of study on both surfaces except in *Catharanthus roseus* and *Hollarrhena floribunda* on the abaxial surface. Elliptic stomata shape was identified in all the taxa on the two surfaces except in *L. dulcis* on the abaxial surface which is oval to circular. Additional stomata complex types were encountered on both surfaces of the species studied. On the abaxial surface, tetracytic stomata was observed in some species: *Alafia barteri, Allamanda cathartica, Calotropis procera, Catharanthus roseus, Gongronema* *latifolia, Hollarrhena floribunda, Landolphia dulcis, Motandra guineensis, Parquetina nigrescens, Pergularia daemia* and *Plumeria alba*; Cyclocytic in *Calotropis procera, Landolphia dulcis* and *Motandra guineensis*; Anisocytic stomata was present in *Allamanda cathartica, Catharanthus roseus, Funtumia elastica, Hollarrhena floribunda* and *Pergularia daemia.* Diacytic stomata was encountered in *Funtumia elastica* only.

Brachyparacytic stomata type was present in *Funtumia elastica, Gongronema latifolia, Parquetina nigrescens, Plumeria alba, Plumeria rubra, Rauvolfia vomitoria* and *Thevetia neriifolia*; Paracytic stomata was found in *Hollarrhena floribunda* and *Motandra guineensis*; Desmocytic stomata was only encountered in *Motandra guineensis* only.

Also, stomata were found on the costal cells of *Motandra guineensis,* this was not encountered in the other species studied. On the adaxial surface, Anomocytic stomata was observed in *Allamanda cathartica, Calotropis procera, Gongronema latifolia, Pergularia daemia* and *Plumeria rubra*; Tetracytic stomata in *Allamanda cathartica, Catharanthus roseus, Gongronema latifolia, Pergularia daemia* and *Plumeria alba*. Anisocytic in *Allamanda cathartica, Catharanthus roseus* and *Pergularia daemia;* Brachyparacytic was found in *Calotropis procera* and *Plumeria rubra*; Paracytic stomata was only found in *Allamanda cathartica*; Diacytic was also only encountered in *Catharanthus roseus*.

The epidermal cell shape on the abaxial surface varies among the taxa studied (Table 2). It is irregular in *Alafia barteri, Hollarrhena floribunda, Landolphia dulcis, Motandra guineensis, Parquetina nigrescens, Pergularia daemia, Rauvolfia vomitoria* and *Thevetia neriifolia*; polygonal to irregular in *Allamanda cathartica* and *Gongronema latifolia*; rectangular to polygonal in *Calotropis procera*, *Catharanthus roseus, Funtumia elastica, Plumeria alba* and *Plumeria rubra* while on the adaxial surface (Table 3), it is irregular to polygonal in *Alafia barteri, Landolphia dulcis, Motandra guineensis, Pergularia daemia and Thevetia neriifolia,* as this groups the two families Apocynaceae and Asclepiadaceae together as one family.

It is polygonal in *Alstonia boonei* and *Funtumia elastica*; polygonal to sligthly irregular in *Allamanda cathartica;* polygonal to oval to circular in *Catharanthus roseus*; rectangular to polygonal in *Calotropis procera, Gongronema latifolia, Hollarrhena floribunda, Parquetina nigrecens, Plumeria alba, Plumeria rubra* and *Rauvolfia vomitoria*. On both surfaces, some of the species can be grouped at the generic - level because they share same types of epidermal cell shape. Anticlinal cell wall pattern also varies among the species studied.

On the abaxial surface (Table 2), it is wavy in *Alafia barteri*; wavy to undulating in *Gongronema latifolia,* wavy to undulating to straight in *Pergularia daemia, Funtumia elastica* and *Thevetia neriifolia*; straight in *Alstonia boonei* and *Calotropis procera*; straight to slightly undulating in *Catharanthus roseus*; undulating to sinuous in *Hollarrhena floribunda, Landolphia dulcis* and *Motandra guineensis*; undulating to wavy in *Rauvolfia vomitoria*; straight to undulating to slightly wavy in *Parquetina nigrescens*; straight to slightly wavy in *Plumeria alba* and *Plumeria rubra*; straight to undulating in *Allamanda cathartica*. On the adaxial surface (Table 3), the anticlinal wall pattern is wavy in *Alafia barteri*; straight in *Alstonia boonei, Calotropis procera, Funtumia elastica, Parquetina nigrescens, Plumeria alba, Plumeria rubra* and *Rauvolfia vomitoria*; straight to undulating in *Allamanda cathartica* and *Catharanthus roseus*; straight to slightly wavy in *Gongronema latifolia*; straight to wavy in *Hollarrhena floribunda*; undulating to sinuous in

Landolphia dulcis, undulating in *Motandra guineensis*; wavy to undulating to straight in *Pergularia daemia* and *Thevetia neriifolia*. Stomata were more distributed on the abaxial surface than the adaxial surface of all the taxa.

Pergularia daemia had the highest stomata size on abaxial while *Catharanthus roseus* had the highest on the adaxial surface. Stomata Index was higher in *Catharanthus roseus* on abaxial while it was higher in *Allamanda cathartica* on adaxial surface. Generally, the Stomata Index on the abaxial surface was higher than on the adaxial surface in all the species studied. Abnormal stomata can be employed as a diagnostic feature to distinguish the species of study. Contiguous stomata were present in *Allamanda cathartica*, *Landolphia dulcis* and *Thevetia neriifolia* on abaxial leaf surfaces while *Catharanthus roseus* had it on both surfaces. Some stomata were shrivelled as in *Allamanda cathartica, Funtumia elastica, Gongronema latifolia, Parquetina nigrescens, Rauvolfia vomitoria*, and *Thevetia neriifolia* all on abaxial surfaces.

There was also occurrence of only one guard cell as observed on both surfaces of *Allamanda carthatica* and on abaxial surface of *Gongronema latifolia*. Some (two to three stomata) shared the same epidermal cell as encountered in *Allamanda cathartica, Gongronema latifolia, Plumeria alba, Plumeria rubra* and *Rauvolfia vomitoria*. In this work, cuticular striations were found radiating from the stomata or guard cell or found on the epidermal surfaces. They were present in almost all the species, on abaxial surface except in *Alafia barteri, Catharanthus roseus*, *Landolphia dulcis*, *Motandra guineensis* and *Thevetia neriifolia*. On adaxial surface, it was absent in *Alafia barteri*, *Funtumia elastica*, *Landolphia dulcis*, *Motandra guineensis* and *Pergularia daemia. Alstonia boonei* and *Parquetina nigrescens* were unique in having cuticular ornamentation covering all the surface of the epidermal cells on the abaxial surfaces. Scales were only present on the abaxial surfaces of *Landolphia dulcis, Alafia barteri and Gongronema latifolia* (Plate 1A).

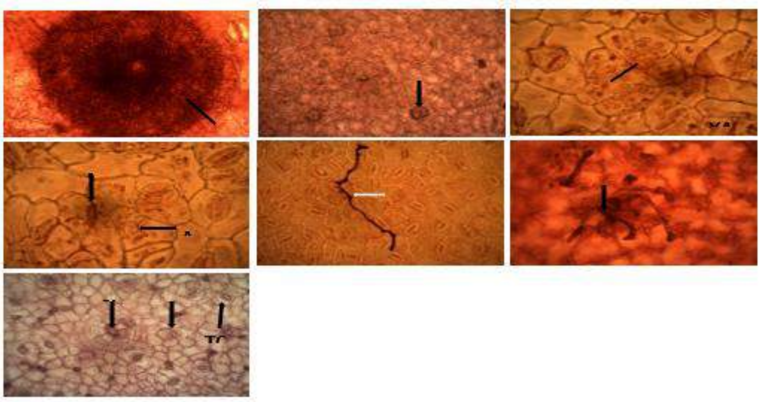

Plate 1: Diagnostic features of the abaxial surfaces of the species studied.
A &B – *A. barteri*, C, D &E – *A. cathartica*, F- *A. boonei*, G-C- *C. procera*
Legend: SC – Scale, DR – Druse, CS- contiguous stomata, AB – Abnormal stomat, KUT – Kinked uniseriate trichome, CL- Cyclocytic stomata, AN- Anomocytic stomata, TC –

Mostly, unicellular to multicellular non glandular trichomes was present in most of the species studied on both surfaces except in *Pergularia daemia* which had additional and different types of trichomes such as biseriate bicellular; biseriate multicellular and multiseriate multicellular non - glandular trichome (Plate 5 A-H). Kinked uniseriate trichome - like structure (Plate 1, E and F) which are multicellular and slender in nature were encountered in this study. Sometimes, it has an indefinite amoeboid shape. It was common in almost all the species studied except in *Alafia barteri*, *Funtumia elastica*, *Landolphia dulcis* on both surfaces but only on abaxial surface in *Plumeria alba* and *Plumeria rubra.*

This is the first report of this feature. Different types of calcium oxalate crystals were encountered in this study. These include druses (Plate 1C and 4F) which were found in *Gongronema latifolia*, *Landolphia dulcis* and *Thevetia neriifolia* on abaxial leaf epidermal surfaces while on adaxial leaf epidermal surfaces, druses were present in *Alafia barteri, Allamanda cathartica, Landolphia dulcis* and *Rauvolfia vomitoria;* prismatic crystals (Plate 3A) in *Alafia barteri, Plumeria alba* and *Rauvolfia vomitoria* only on adaxial surfaces while on adaxial surface, they were found in *Alafia barteri*, *Plumeria alba* and *Rauvolfia vomitoria*; styloid crystals (Plate 3A) were found in *Catharanthus roseus, Landolphia dulcis, Parquetina nigrescens* and *Thevetia neriifolia*. They were found on the adaxial surfaces of *Alafia barteri, Alstonia boonei, Calotropis procera*, *Catharanthus roseus*, *Landolphia dulcis, Motandra guineensis*, *Parquetina nigrescens* and *Thevetia neriifolia*; crystal sand (Plate 2I) was found on the abaxial surfaces of *Catharanthus roseus, Hollarrhena floribunda, Pergularia daemia* and *Thevetia neriifolia* while on adaxial surface, they were found in *Allamanda cathartica, Catharanthus roseus, Hollarrhena floribunda* and *Pergularia daemia*. It was generally observed that the crystals were more on the adaxial surfaces than the abaxial surfaces.

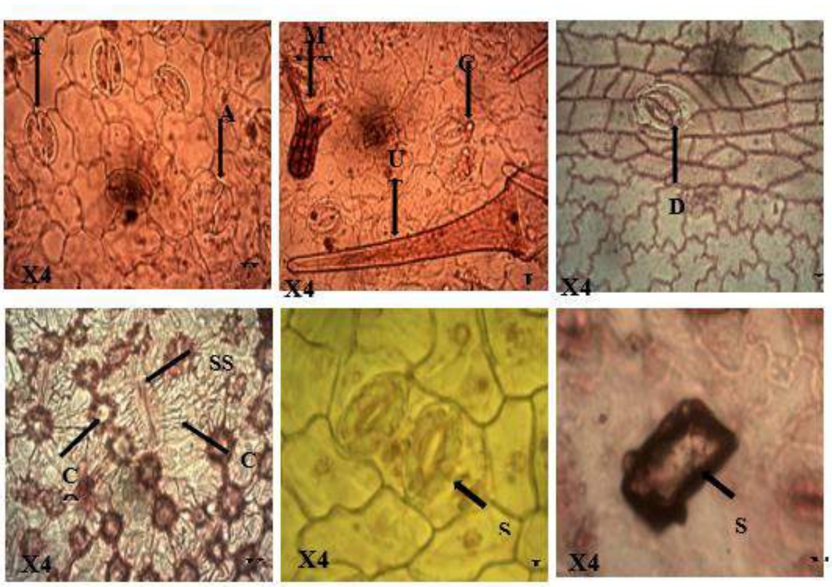

Plate 2: Diagnostic features of the abaxial surfaces of the species studied.
H&I- *C. roseus*, J-*M. guineensis*, K- *P. nigrescens*, L- *P. alba*, M- *T. neriifolia*
Legend: TC- Tetracytic stomata, ANI-Anisocytic stomata, MMTR- Multiseriate multicellular trichome, UTR- Unicellular trichome, CRS- Crystal sand, DC – Desmocytic stomata, CS-Cuticular striation, CO – Cuticular ornanmentaion, SSS-

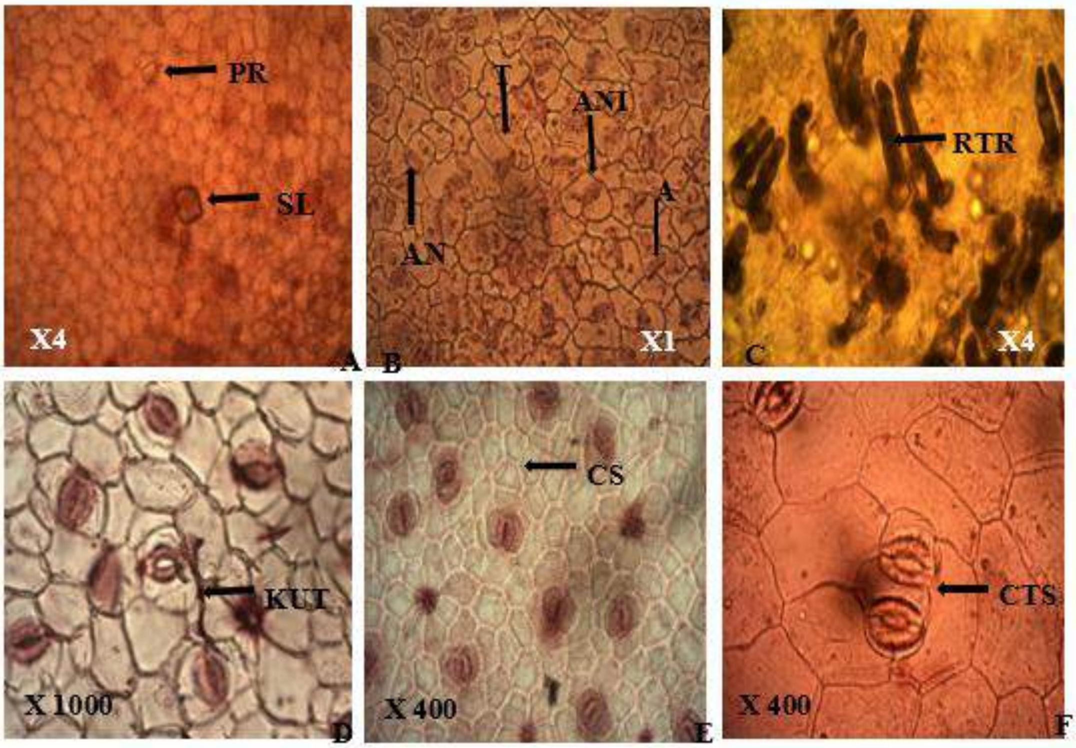

Plate 3: Diagnostic features of the adaxial surfaces of the species studied.
A- *A. barteri*, B- *A. cathartica*, C- *A. boonei*, D&E- *C. procera*, F- *C. roseus*
PC- Prismatic crystal, TC-Tetracytic stomata, ANI-Anisocytic stomata, AN-Anomocytic stomata, RTR- Rod shaped unicellular trichome, KUT- Kinked uniseriate trichome, CS-Cuticular striation, CTS- Contiguous stomata.

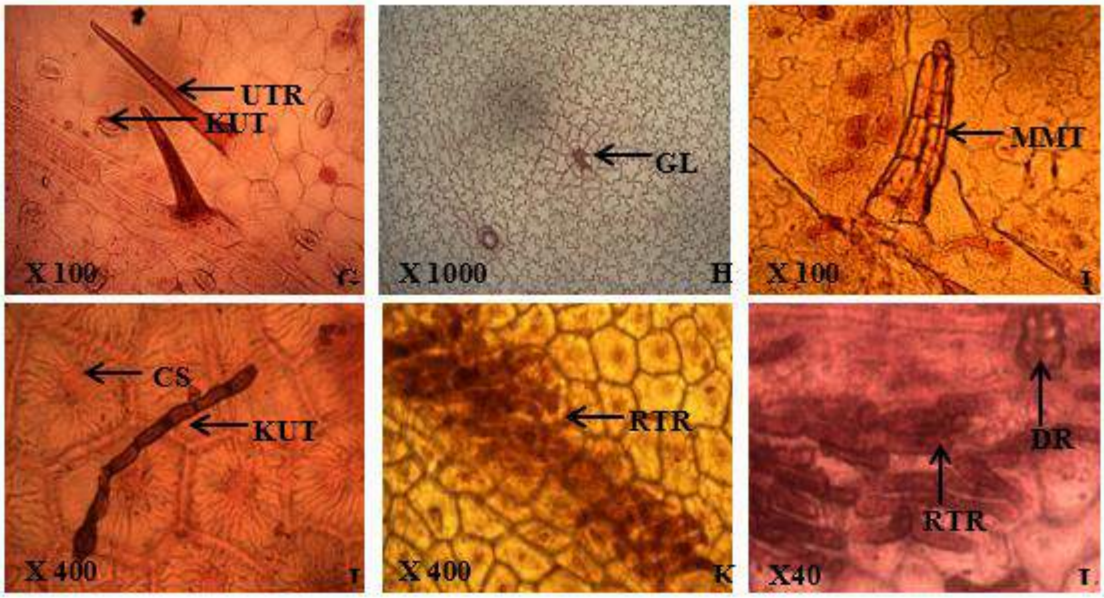

Plate 4: Diagnostic features of the adaxial surfaces of the species studied.

G- *C. roseus*, H- *M. guineensis*, I- *P. daemia*, J&K- *P. alba*, L- *T. neriifolia*, UTR-Unicellular trichome, GL- Gland, MMTR- Multiseriate multicellular trichome, KUT-Kinked uniseriate trichome, CS-Cuticular striation, RTR-Rod shape unicellular trichome.

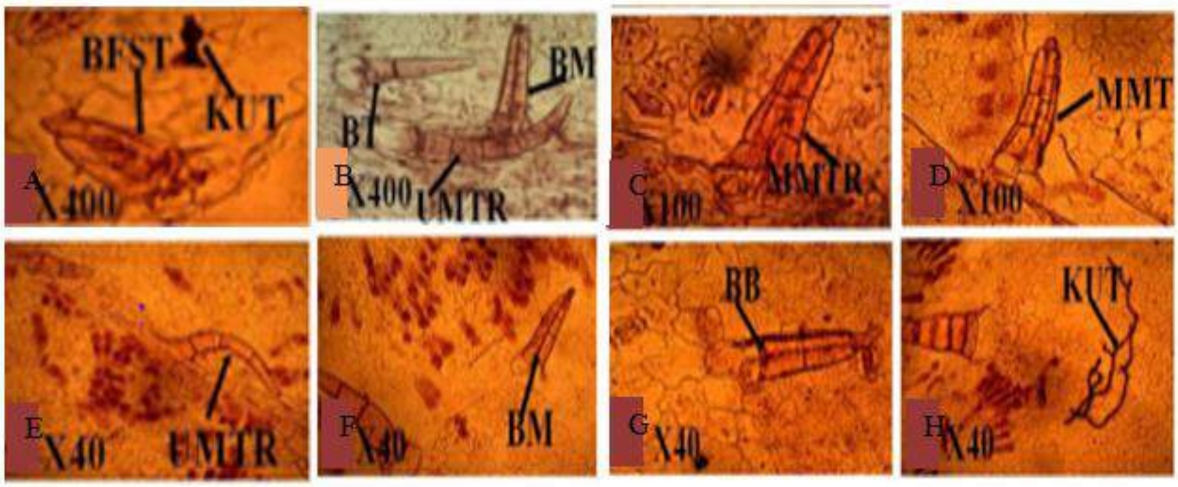

Plate 5: Leaf epidermal surfaces of *Pergularia daemia* showing different types of trichomes.

A, B & C. Abaxial epidermis of lamina of *P. daemia* showing kinked uniseriate trichome - like structure, bell or flower shaped trichome, bicellular trichome, biseriate multicellular trichome and multiseriate, multicellular trichomes.
D, E & F. Adaxial epidermis of lamina of *P.daemia* showing multiseriate, multicellular trichomes, Uniseriate, Multicellular trichome, biseriate multicellular trichomes.
G & H. Adaxial epidermis of lamina showing biseriate bicellular trichome, kinked uniseriate trichome - like structure, rod shaped trichome.

The Dendrogram result of the anatomical characters of the Apocynaceae species studied grouped the species into two main clusters (Fig. 1). The first cluster was separated into two, *Motandra guineensis* was separated from the other species because it had the highest number of epidermal cells on the abaxial surface but linked to *Allamanda cathartica* which was also standing on its own because it had the highest number of stomata on abaxial surface (Table 4) but joined to *Pergularia daemia* and *Gongronema latifolia* which were almost at the same similarity level because they have epidermal cell area value that were close (Table 4) with *Landolphia dulcis* and *Catharanthus roseus* because their values were not significantly different for trichome area (Table 4).

In the second cluster, *Funtumia elastica and Alafia barteri* were close together because of the absence of coastal cell and trichomes and separated from the other species in the second cluster but they were linked to *Rauvolfia vomitoria* which was standing on its own but linked to the two sub – clusters which include *Plumeria alba* and *Plumeria rubra* in the first sub cluster and *Parquetina nigrescens* and *Alstonia boonei* in the second sub cluster. All these were at the same similarity level which shows their level of closeness foliar anatomically (Fig. 1). Figure 2 shows the Principal Component Analysis showing the relationship of the Apocynaceae species based on their anatomical characters. This follows the pattern of the dendrogram by separating *Motandra guineensis* and *Allamanda cathartica* distinctly from all the other species; but the other species were closely grouped together.

DISCUSSION

Anatomical features or methods are important in delimiting or separating species; and this cannot be over-emphazied. Use of anatomical features has been found to be very valuable in the classification of plant species, the reason been that most anatomical features are not altered or affected by environmental factors.

According to Carlquist (1961), leaf anatomy provides a variety of features that could be used for taxonomic purposes. Quite a number of researchers have made use of leaf anatomy for taxonomic consideration in many species of plant. These include, Illoh (1995) on the genus *Celosia*, Adedeji (2004) on *Emilia*, Adedeji and Illoh (2004) on the genus *Hibiscus*, Oladipo (2011) on the genus *Jatropha*, Arogundade (2015) on some genera in Araceae family.

Foliar anatomical characters useful in the taxonomy of the families studied include epidermal cell shape, anticlinal wall pattern, stomata size, shape, type and index, presence of kinked uniseriate trichomes, cuticular striation and cuticular ornamentation. Seven out the species studied are amphistomatic. They include *Allamanda cathartica, Calotropis procera, Catharanthus roseus, Gongronema latifolia, Pergularia daemia, Plumeria alba* and *Plumeria rubra* while the remaining species are hypostomatic. It was also noted that there are similarities and differences at the generic levels and the specific levels between *Plumeria alba* and *Plumeria rubra* as shown in Table 2 and 3.

Table 2: Summary of Important Qualitative Foliar Epidermal Features of the Abaxial Surfaces of the Species Studied Characters

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A. barteri	IRR	WAVY	ELLIP	ANO,TETRA	+	+	+	-	-	-	-	-	-	-	-
A. cathartica	POLY to IRR	STR to UNDU	ELLIP to CIR	ANO, TETRA, ANI	+	-	+	+	+	+	+	-	+	-	-
A. boonei	POLY	STR	ELLIP	ANO	+	-	-	-	-	-	+	+	+	-	-
C. procera	REC to POLY	STR	ELLIP to CIR	ANO, CYCLO, TETRA	+	-	+	-	-	-	+	-	+	-	-
C. roseus	REC to POLY	STR to UNDU	ELLIP to CIR	ANI, TETRA	+	-	+	-	+	-	-	-	+	CRS, STY	-
F. elastica	REC to POLY	STR to WAVY to UNDU	ELLIP to CIR	ANO,DIA,ANI, TETRA, BRACHY	+	-	-	+	-	-	+	-	-	-	SC
G. latifolia	POLY to IRR	WAVY to UNDU	ELLIP to CYL	ANO, TETRA, ANI	+	-	+	-	-	+	+	-	+	DR, SO	-
H. floribunda	IRR	UNDU to SIN	ELLIP	PARA, TETRA, ANI	+	-	-	-	-	-	+	-	+	-	STG
L. dulcis	IRR	UNDU to SIN	CIR to OVAL	ANO,CYCLO, TETRA	+	-	+	-	+	-	-	-	-	STY, DR	SC
M. guineensis	IRR	UNDU to SIN	ELLIP	ANO, TETRA, CYCLO, PARA, DES	+	+	+	-	-	-	-	-	+	-	-
P. nigrescens	IRR	STR to UNDU to WAVY	ELLIP	ANO, TETRA, BRACHY	+	-	-	+	-	-	+	+	-	STY	-
P. daemia	IRR	WAVY to UNDU TO STR	ELLIP to OVAL to CIR	ANO, ANI, TETRA	+	-	+	-	+	-	+	-	+	CRS	-
P.alba	REC to POLY	STR to WAVY	ELLIP to CIR	ANO, TETRA, BRACHY	+	-	-	-	-	+	+	-	+	-	STG
P .rubra	REC to POLY	STR to WAVY	ELLIP	ANO, BRACHY	+	-	-	-	-	+	+	-	-	-	STG

Table 3: Summary of Important Qualitative Foliar Epidermal Features of the Adaxial Surfaces of the Species Studied Characters

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A. barteri	IRR	WAVY	-	-	-	-	-	-	-	-	-	-	-	PRIS,DR,STY	-
A. cathartica	POLY to IRR	STR to UNDU	ELLIP to CIR	ANO, TETRA,ANI,PARA	+	-	+	+	-	+	-	-	+	DR, CRS	-
A. boonei	POLY	STR	-	-	-	-	+	-	-	-	+	-	+	SO, STY	-
C. procera	REC to POLY	STR	ELLIP to CIR	ANO, BRACHY	+	-	-	-	-	-	+	-	+	STY	-
C. roseus	POLY, OVAL to CIR	STR to UNDU	ELLIP to CIR	ANI,TETRA	+	-	+	-	+	-	+	-	+	STY	-
F. elastica	POLY	STR	-	-	-	-	-	-	-	-	-	-	-	-	STG
G. latifolia	REC to POLY	STR to WAVY	ELLIP to CIR	ANO, TETRA	+	-	+	-	-	-	+	-	+	SO	-
H. floribunda	REC to POLY	STR to WAVY	-	-	-	-	-	-	-	-	+	-	+	CRS	-
L. dulcis	IRR	UNDU to SIN	-	-	-	-	-	-	-	-	-	-	-	STY, DR	-
M. guineensis	IRR	UNDU	-	-	-	-	+	-	-	-	-	-	+	STY	-
P. nigrescens	REC to POLY	STR	-	-	-	-	-	-	-	-	-	-	+	STY	-
P. daemia	IRR	WAVY to UNDU TO STR	ELLIP to OVAL to CIR	ANO, ANI, TETRA	+	-	+	-	-	-	-	-	+	STY	-
P.alba	REC to POLY	STR	ELLIP	TETRA	+	-	+	-	-	-	+	-	+	STY	-
P .rubra	REC to POLY	STR	ELLIP	ANO, BRACHY	+	-	-	-	-	-	+	-	+	-	STG
R.vomitoria	REC to POLY	STR	-	-	-	-	-	-	-	-	+	-	+	DR, PRIS	-
T.neriifolia	IRR to POLY	WAVY to UNDU to STR	-	-	-	-	+	-	-	-	+	-	+	SO, STY	-

Legend:1. Epidermal cell shape (IRR-Irregular; POLY – Polygonal; REC – Rectangular; OVAL; CIR - Circular)
2. Anticlinal wall pattern (WAVY; STR – Straight; UNDU – Undulating; SIN - Sinuous)
3. Stomata type (ELLIP – Elliptic; CIR – Circular, CYL – Cylindrical; OVAL)
4. Stomata shape (ANO – Anomocytic; ANI – Anisocytic; TETRA – Tetracytic; PARA – Paracytic; BRACHY – Brachyparacytic
Desmocytic; DIA – Diacytic; CYCLO - Cyclocytic) 5. Stomata 6. Gland 7. Trichomes 8. Abnormal stomata 9. Contiguous stomata 10. Stomata sharing the same cell 11. Cuticular striations 12. Cuticular ornamentations 13. Kinked uniseriate trichome 14. Crystal type (PRIS- Prismatic crystal; DR – Druse; STY – Styloid, CRS – Crystal sand; SO – Solitary crystal) 15.Cell inclusions (SC-Scale, STG- Starch granule) Key: Present = +; Absent = -

Table 4: Means and standard error of characters on the Abaxial surface of the foliar epidermis of the Apocynaceae species studied with Duncan Mutiple Range Test Values (contd.). (Means with the same alphabet along the same column are not significantly different)

Species	No of stomata (µm²)	Stomata length (µm²)	Stomata breadth (µm²)	Stomata Area (µm²)	No of Epidermal cells (µm²)	Stomata Index (%)	Epidermal cell length (µm²)	Epidermal cell breadth (µm²)	Epidermal cell Area (µm²)
A. barteri	89.1±2.58^{de}	22.6 ±0.82^{f}	14.6±0.37^{efg}	331.25±12.11^{ij}	532.4 ±12.66^{d}	14.41 ±0.42^{c}	25.9 ±1.83^{def}	24.8 ±1.90^{hij}	630.00±62.08^{ef}
A. cathartica	165.6±4.28^{a}	29.3±0.36^{b}	18.1±0.61^{d}	534.75±27.19^{de}	436.00±3.75^{i}	27.43±0.53^{a}	28.1±1.94^{cdef}	43.3±2.58^{ab}	1156.0 ±72.25^{a}
A. boonei	48.8±2.97^{l}	26.4±0.48^{cde}	15.4±0.37^{ef}	407.75±14.66^{gh}	478.5±12.44^{gh}	9.40±0.64^{fg}	25.3±1.04^{efg}	26,8±1.74^{ghi}	688.75±46.61^{ef}
C. procera	52.3±1.28^{kl}	26.1±0.43^{cde}	20.7±0.91^{b}	543.50±28.11^{cd}	504.8±5.92^{ef}	9.40±0.24^{fg}	30.1±1.69^{bcde}	31.5±1.77^{efg}	958.50±74.47^{bc}
C. roseus	145.2±2.71^{b}	24.9±0.26$_{e}$	19.0±0.25^{cd}	473.00±7.74^{ef}	372.4±8.83^{j}	28.25±0.74^{a}	39.9±1.99^{a}	21.5±0.94^{ij}	857.25±52.25^{cd}
F. elastica	67.2±1.22^{hi}	23.1±0.66^{f}	12.9±0.34^{h}	296.75±10.00^{j}	434.6±4.01^{i}	13.40±0.25^{cd}	30.6±2.97^{bcd}	35.3±2.86^{cdef}	982.00±79.30^{abc}
G. latifolia	57.7±4.05^{jk}	26.9±0.80^{cd}	13.8±0.50^{gh}	374.75±21.13^{ghi}	524.2±8.03^{de}	9.88±0.65^{f}	31.1±1.80^{cb}	36.9±2.01^{cde}	1150.75±84.68^{a}
H. floribunda	87.5±2.77^{e}	29.8±0.82^{b}	15.7±0.36^{e}	472.50±22.92^{ef}	435.3±9.20^{i}	16.83±0.55^{b}	26.9±1.92^{cdef}	37.9±2.43^{bcd}	984.75±76.01^{abc}
L. dulcis	95.9±4.34^{cd}	26.5±0.28^{cde}	22.8±0.54^{a}	604.5±16.43^{bc}	495.8±8.16^{fg}	16.19±0.70^{b}	35.1±2.03^{ab}	20.0±1.11^{j}	699.25±46.04^{def}
M. guineensis	40.1±1.60^{m}	25.5±0.47^{de}	12.7±0.45^{h}	326.75±15.66^{ij}	722±7.64^{a}	5.26±0.21^{h}	26.4±1.63^{cdef}	21.6±1.17^{ij}	533.00±33.32^{f}
P. nigrescens	71.4±1.72^{gh}	25.9±0.47^{cde}	13.9±0.32^{fgh}	360.25±11.19^{hij}	482.1±10.21^{fgh}	12.99±0.37^{de}	20.6±0.80^{gh}	29.9±1.48^{fgh}	613.00±36.88^{ef}
P. daemia	68.8±1.42^{hi}	32.1±0.94^{a}	20.5±0.093^{cb}	672.50±53.22^{a}	471.7±7.19^{h}	12.75±0.25^{de}	26.8±1.59^{cdef}	45.00±3.56^{a}	1143.75±72.25^{ab}
P. alba	76.5±1.62^{fg}	29.7±0.44^{b}	17.6±0.50^{d}	524.75±20.13^{de}	530.5±5.94^{d}	12.62±0.27^{de}	25.2±2.26^{efg}	31.3±1.84^{efg}	745.50±63.9^{de}
P. rubra	79.9±2.88^{f}	32.1±0.53^{a}	20.1±0.56^{cb}	648.50±24.92^{ab}	587.0±13.05^{c}	12.01±0.416^{e}	19.3±0.93^{h}	32.5±1.602^{defg}	622,50±40.93^{ef}
R. vomitora	62.0±1.74^{ij}	27.2±0.74^{c}	15.8±0.55^{e}	434.75±24.41^{fg}	671.3±4.70^{b}	8.45±0.22^{g}	23.2±1.99^{fgh}	33.5±1.782^{def}	767.25±63.20^{de}
T. neriifolia	102.2±1.72^{c}	26.3±0.41^{cde}	15.1±0.69^{efg}	397.50±20.37^{gh}	602.9±8.99^{c}	14.51±0.22^{c}	25.4±1.68^{efg}	41.2±3.78^{abc}	1034.50±115.77^{abc}

Table 4 contd: Means and standard error of characters on the Abaxial surface of the foliar epidermis of the Apocynaceae species studied with Duncan Mutiple Range Test Values (contd.). (Means with the same alphabet along the same column are not significantly different).

Species	Guard cell Length (µm²)	Guard cell breadth (µm²)	Guard cell Area (µm²)	Costal cell length (µm²)	Costal cell Breadth(µm²)	Costal cell Area (µm²)	Trichome length (µm²)	Trichome Breadth (µm²)	Trichome Area (µm²)
A. barteri	22.6±0.36^{f}	5.80±0.23^{h}	103.67±5.31^{kl}	0.00±0.00^{h}	0.00±0.00^{h}	0.00±0.00^{k}	0.00±0.00^{e}	0.00±0.00^{d}	0.00±0.00^{e}
A. carthartica	29.3±0.82^{b}	8.50±0.35^{c}	197.72±11.37^{cde}	32.1±1.07^{d}	74.5±6.59^{a}	2355.25±0.197.91^{a}	223.7±20.64^{a}	18.9±1.05^{c}	4252.25±478.88^{a}
A. boonei	26.4±0.48^{cde}	7.60±0.22^{de}	158.26±6.57^{ghi}	14.0±0.72^{fg}	17.5±1.05^{g}	247.50±21.92^{j}	0.00±0.00^{d}	0.00±0.00^{e}	0.00±0.00^{e}
C. procera	25.6±0.21^{cde}	10.80±0.23^{a}	217.16±5.16^{bc}	21.7±1.08^{e}	37.9±3.21^{de}	806.00±71.78^{def}	0.00±0.00^{d}	0.00±0.00^{d}	0.00±0.00^{e}
C. roseus	24.8±0.32^{e}	9.50±0.20^{b}	184.57±3.91^{def}	15.8±0.73^{efg}	62.8±4.71^{b}	985.25±81.82^{de}	151.9±15.11^{b}	17.7±0.87^{c}	2567.25±274.69^{b}
F. elastica	23.1±0.66^{f}	5.10±0.10^{h}	92.68±3.45^{l}	0.00±0.00^{h}	0.00±0.00^{h}	0.00±0.00^{k}	0.00±0.00^{d}	0.00±0.00^{d}	0.00±0.00^{e}
G. latifolia	26.9±0.80^{cd}	5.70±0.36^{h}	122.72±10.19^{jk}	65.7±5.11^{b}	13.2±0.39^{g}	837.50±56.56^{cde}	141.9±11.28^{bc}	21.6±0.67^{b}	3045.00±244.54^{b}
H. floribunda	29.4±0.76^{b}	7.20±0.26^{ef}	168.27±9.59^{fgh}	40.7±3.87^{c}	15.9±0.46^{g}	654.25±64.99^{efgh}	0.00±0.00^{e}	0.00±0.00^{e}	0.00±0.00^{e}
L. dulcis	26.4±0.32^{cde}	11.40±0.29^{a}	236.01±6.24^{b}	15.4±0.79^{g}	29.7±2.28^{f}	467.75±44.01^{hi}	129.3±21.66^{cb}	0.018±17.7^{c}	2665.00±656.74^{b}

Table 5: Means and standard error of characters on the Adaxial surface of the foliar epidermis of the Apocynaceae species studied with Duncan Mutiple Range Test Values (contd.). (Means with the same alphabet along the same column are not significantly different).

Species	No of stomata (µm²)	Stomata length (µm²)	Stomata breadth (µm²)	Stomata Area (µm²)	No of Epidermal cells (µm²)	Stomata Index (%)	Epidermal cell length (µm²)	Epidermal cell breadth (µm²)	Epidermal cell Area (µm²)
A. barteri	0.00±0.00^{g}	0.00±0.00^{e}	0.00±0.00^{f}	0.00±0.00^{f}	849.9±11.43^{a}	0.00±0.00^{f}	21.2±0.93^{fg}	24.4±1.33^{f}	520.00±36.28^{hi}
A. carthartica	147.9±3.18^{a}	29.00±0.61^{a}	16.80±0.88^{b}	493.50±31.02^{b}	477.1±3.98^{g}	23.45±0.44^{a}	30.2±2.61^{cd}	38.3±3.15^{ab}	1142.75±134.78^{bcd}
A. boonei	0.00±0.00^{g}	0.00±0.00^{e}	0.00±0.00^{f}	0.00±0.00^{f}	399.1 ±8.97^{h}	0.00±0.00^{f}	32.40±1.78^{bc}	31.2±1.96^{de}	1010.25±0.000^{de}
C. procera	47.7±0.66^{b}	27.50±0.40^{ab}	21.2±0.54^{a}	583.25±17.65^{a}	476.2±7.59^{g}	9.15±0.18^{b}	32.5±1.58^{bc}	31.4±1.33^{cd}	1025.75±66.63^{cd}
C. roseus	31.8±2.67^{c}	26.8±0.33^{ab}	22.1±0.51^{a}	593.00±17.61^{a}	323.80±4.99^{j}	8.88±0.75^{b}	43.1±2.89^{a}	30.7±1.85^{de}	1327.00±110.88^{b}
F. elastica	0.00±0.00^{f}	0.00±0.00^{e}	0.00±0.00^{f}	0.00±0.00^{f}	706.80±8.68^{b}	0.00±0.00^{f}	24.1±1.13^{efg}	25.6±1.34^{ef}	622.50±49.98^{ghi}
G. latifolia	4.80±0.72^{e}	24.7±0.72^{b}	13.90±0.50^{c}	347.25±19.08^{c}	615.80±4.64^{d}	0.77±0.12^{d}	22.8±1.18^{efg}	31.7±1.76^{cd}	707.50±41.39^{fgh}
H. floribunda	0.00±0.00^{g}	0.00±0.00^{e}	0.00±0.00^{f}	0.00±0.00^{f}	677.00±11.89^{c}	0.00±0.00^{f}	26.5±1.37^{de}	24.3±1.51^{f}	647.00±55.61^{ghi}
L. dulcis	0.00±0.00^{g}	0.00±0.00^{e}	0.00±0.00^{f}	0.00±0.00^{f}	734.8±7.92^{b}	0.00±0.00^{f}	25.4±1.47^{def}	24.0±1.24^{f}	608.75±49.02^{ghi}
M.guineensis	0.00±0.00^{g}	0.00±0.00^{e}	0.00±0.00^{f}	0.00±0.00^{f}	699.20±43.43^{c}	0.00±0.00^{f}	25.6±1.37^{g}	27.3±1.11^{f}	733.50±65.11^{i}
P. nignescens	0.00±0.00^{g}	0.00±0.00^{e}	0.00±0.00^{f}	0.00±0.00^{f}	294.80±4.54^{k}	0.00±0.00^{f}	36.00±1.99^{b}	42.6±2.88^{a}	1567.25±159.36^{a}

Table 5: Means and standard error of characters on the Adaxial surface of the foliar epidermis of the Apocynaceae species studied with Duncan Mutiple Range Test Values (contd.). (Means with the same alphabet along the same column are not significantly different).

Species	No of stomata (µm²)	Stomata length (µm²)	Stomata breadth (µm²)	Stomata Area (µm²)	No of Epidermal cells (µm²)	Stomata Index (%)	Epidermal cell length (µm²)	Epidermal cell breadth (µm²)	Epidermal cell Area (µm²)
A. barteri	0.00±0.00^{g}	0.00±0.00^{e}	0.00±0.00^{f}	0.00±0.00^{f}	849.9±11.43^{a}	0.00±0.00^{f}	21.2±0.93^{fg}	24.4±1.33^{f}	520.00±36.28^{hi}
A. carthartica	147.9±3.18^{a}	29.00±0.61^{a}	16.80±0.88^{b}	493.50±31.02^{b}	477.1±3.98^{g}	23.45±0.44^{a}	30.2±2.61^{cd}	38.3±3.15^{ab}	1142.75±134.78^{bcd}
A. boonei	0.00±0.00^{g}	0.00±0.00^{e}	0.00±0.00^{f}	0.00±0.00^{f}	399.1 ±8.97^{h}	0.00±0.00^{f}	32.40±1.78^{bc}	31.2±1.96^{de}	1010.25±0.000^{de}
C. procera	47.7±0.66^{b}	27.50±0.40^{ab}	21.2±0.54^{a}	583.25±17.65^{a}	476.2±7.59^{g}	9.15±0.18^{b}	32.5±1.58^{bc}	31.4±1.33^{cd}	1025.75±66.63^{cd}
C. roseus	31.8±2.67^{c}	26.8±0.33^{ab}	22.1±0.51^{a}	593.00±17.61^{a}	323.80±4.99^{j}	8.88±0.75^{b}	43.1±2.89^{a}	30.7±1.85^{de}	1327.00±110.88^{b}
F. elastica	0.00±0.00^{f}	0.00±0.00^{e}	0.00±0.00^{f}	0.00±0.00^{f}	706.80±8.68^{b}	0.00±0.00^{f}	24.1±1.13^{efg}	25.6±1.34^{ef}	622.50±49.98^{ghi}
G. latifolia	4.80±0.72^{e}	24.7±0.72^{b}	13.90±0.50^{c}	347.25±19.08^{c}	615.80±4.64^{d}	0.77±0.12^{d}	22.8±1.18^{efg}	31.7±1.76^{cd}	707.50±41.39^{fgh}
H. floribunda	0.00±0.00^{g}	0.00±0.00^{e}	0.00±0.00^{f}	0.00±0.00^{f}	677.00±11.89^{c}	0.00±0.00^{f}	26.5±1.37^{de}	24.3±1.51^{f}	647.00±55.61^{ghi}
L. dulcis	0.00±0.00^{g}	0.00±0.00^{e}	0.00±0.00^{f}	0.00±0.00^{f}	734.8±7.92^{b}	0.00±0.00^{f}	25.4±1.47^{def}	24.0±1.24^{f}	608.75±49.02^{ghi}
M.guineensis	0.00±0.00^{g}	0.00±0.00^{e}	0.00±0.00^{f}	0.00±0.00^{f}	699.20±43.43^{c}	0.00±0.00^{f}	25.6±1.37^{g}	27.3±1.11^{f}	733.50±65.11^{i}
P. nignescens	0.00±0.00^{g}	0.00±0.00^{e}	0.00±0.00^{f}	0.00±0.00^{f}	294.80±4.54^{k}	0.00±0.00^{f}	36.00±1.99^{b}	42.6±2.88^{a}	1567.25±159.36^{a}
P. daemia	10.00±0.75^{d}	27.2±0.39^{ab}	18.20±0.22^{b}	496.25±11.97^{b}	357.60±5.48^{i}	2.71±0.20^{c}	33.8±2.00^{bc}	41.4±2.81^{ab}	1365.5±97.27^{ab}
P. alba	0.90±0.40^{f}	5.60±2.28^{d}	3.30±1.35^{e}	0.03±0.01^{e}	503.8±10.29^{e}	0.21±0.90^{e}	25.6±0.93^{def}	36.6±2.16^{bc}	928.75±60.99^{def}
P. rubra	2.50±0.70^{ef}	12.50±3.18^{c}	8.40±2.11^{d}	263.25±67.67^{d}	593.30±8.73^{f}	0.42±0.12^{de}	23.8±1.01^{efg}	29.5±1.60^{def}	703.25±48.27^{fgh}
R. vomitoria	0.00±0.00^{g}	0.00±0.00^{e}	0.00±0.00^{f}	0.00±0.00^{f}	612.00±8.68^{d}	0.00±0.00^{f}	25.0±1.60^{ef}	30.9±2.05^{de}	788.50±70.07^{efg}
T. neriifolia	0.00±0.00^{g}	0.00±0.00^{e}	0.00±0.00^{f}	0.00±0.00^{f}	375.90±2.01^{h}	0.00±0.00^{f}	31.6±2.16^{bc}	41.9±2.48^{ab}	1251.75±68.88^{bc}

Table 6: Means and standard error of characters on the Adaxial surface of the foliar epidermis of the Apocynaceae species studied with Duncan Mutiple Range Test Values (contd.). (Means with the same alphabet along the same column are not significantly different).

Species	Guard cell Length (μm^2)	Guard cell breadth (μm^2)	Guard cell Area (μm^2)	Costal cell length (μm^2)	Costal cell Breadth(μm^2)	Costal cell Area (μm^2)	Trichome length (μm^2)	Trichome Breadth (μm^2)	Trichome Area (μm^2)
A. barteri	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{f}	0.00 ± 0.00^{f}	0.00 ± 0.00^{g}	0.00 ± 0.00^{c}	0.00 ± 0.00^{f}	0.00 ± 0.00^{d}	0.00 ± 0.00^{c}
A. carthartica	29.00 ± 0.61^{a}	7.60 ± 0.36^{b}	175.73 ± 11.00^{b}	25.4 ± 0.98^{c}	76.200 ± 5.50^{a}	1867.00 ± 120.37^{a}	226.1 ± 3.894^{b}	17.6 ± 1.15^{c}	4410.50 ± 833.45^{a}
A. boonei	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{f}	22.3 ± 1.17^{cd}	29.6 ± 2.02^{de}	765.09 ± 30.56^{c}	0.00 ± 0.00^{f}	0.00 ± 0.00^{f}	0.00 ± 0.00^{c}
C. procera	26.8 ± 0.33^{ab}	10.70 ± 0.27^{a}	225.41 ± 6.71^{a}	0.00 ± 0.00^{f}	0.00 ± 0.00^{g}	0.00 ± 0.00^{c}	0.00 ± 0.00^{f}	0.00 ± 0.00^{f}	0.00 ± 0.00^{c}
C. roseus	26.6 ± 0.37^{ab}	10.71 ± 0.27^{a}	223.64 ± 6.74^{a}	18.50 ± 0.84^{de}	62.30 ± 4.11^{b}	1157.25 ± 108.40^{b}	111.3 ± 13.6^{d}	17.7 ± 0.62^{c}	2036.00 ± 305.16^{d}
F. elastica	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{f}	0.00 ± 0.00^{f}	0.00 ± 0.00^{g}	0.00 ± 0.00^{ee}	0.00 ± 0.00^{f}	0.00 ± 0.00^{d}	0.00 ± 0.00^{c}
G. latifolia	24.7 ± 0.72^{b}	6.30 ± 0.25^{b}	123.31 ± 6.09^{c}	64.60 ± 4.93^{b}	14.30 ± 0.83^{f}	891.75 ± 69.87^{c}	301.00 ± 18.5^{a}	20.70 ± 0.46^{c}	6174.25 ± 381.03^{b}
H. floribunda	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{f}	16.60 ± 0.91^{e}	23.50 ± 1.11^{g}	393.25 ± 31.44^{d}	0.00 ± 0.00^{f}	0.00 ± 0.00^{d}	0.00 ± 0.00^{c}
L. dulcis	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{f}	13.10 ± 0.66^{a}	24.80 ± 1.34^{e}	323.25 ± 22.64^{d}	80.50 ± 3.70^{c}	82.80 ± 3.28^{a}	6946.50 ± 536.65^{ab}
M. guineensis	25.5 ± 0.47^{de}	0.00 ± 0.00^{d}	0.00 ± 0.00^{f}	16.85 ± 1.04^{e}	24.60 ± 1.52^{e}	462.50 ± 50.78^{d}	0.00 ± 0.00^{f}	0.00 ± 0.00^{d}	0.00 ± 0.00^{c}
P. nignescens	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{f}	25.4 ± 1.10^{c}	49.80 ± 2.72^{c}	1256.75 ± 85.26^{b}	0.00 ± 0.00^{f}	0.00 ± 0.00^{d}	0.00 ± 0.00^{c}
P. daemia	27.10 ± 0.40^{ab}	7.50 ± 0.24^{b}	160.02 ± 5.51^{b}	83.00 ± 5.38^{a}	16.30 ± 0.76^{f}	1327.75 ± 99.85^{b}	189.3 ± 16.18^{c}	36.1 ± 3.05^{b}	7734.50 ± 1395.61^{a}
P. alba	5.30 ± 2.18^{d}	2.60 ± 1.55^{c}	48.10 ± 25.633^{e}	23.2 ± 1.17^{cd}	34.50 ± 1.65^{d}	800.00 ± 53.37^{c}	0.00 ± 0.00^{f}	0.00 ± 0.00^{d}	0.00 ± 0.00^{c}
P. rubra	12.50 ± 3.18^{cc}	3.30 ± 0.83^{c}	82.27 ± 21.87^{d}	17.7 ± 0.66^{de}	28.80 ± 1.74^{de}	502.75 ± 31.60^{d}	0.00 ± 0.00^{f}	0.00 ± 0.00^{d}	0.00 ± 0.00^{c}
R. vomitoria	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{f}	16.7 ± 0.65^{e}	28.00 ± 2.14^{de}	466.00 ± 37.43^{d}	0.00 ± 0.00^{f}	0.00 ± 0.00^{d}	0.00 ± 0.00^{c}
T. neriifolia	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{f}	18.90 ± 1.01^{de}	48.9 ± 3.58^{c}	890.00 ± 73.15^{d}	0.00 ± 0.00^{f}	0.00 ± 0.00^{d}	0.00 ± 0.00^{c}

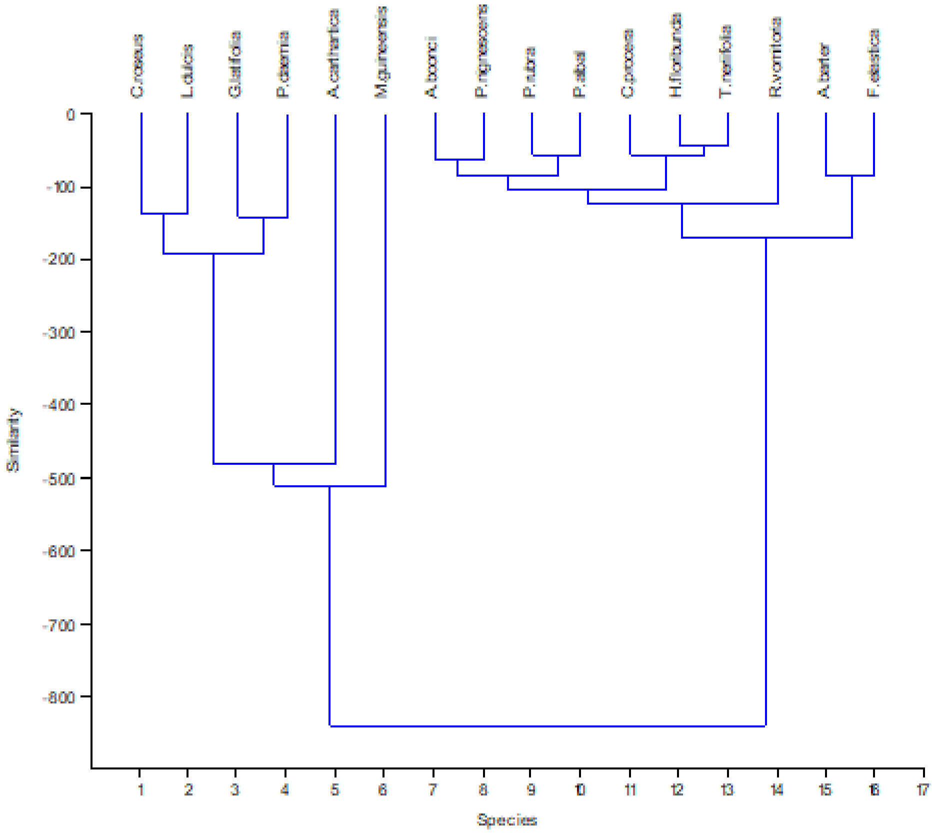

Fig. 1: Dendrogram showing relationship of the Apocynaceae species studied based on their quantitative and qualitative foliar epidermal Characters

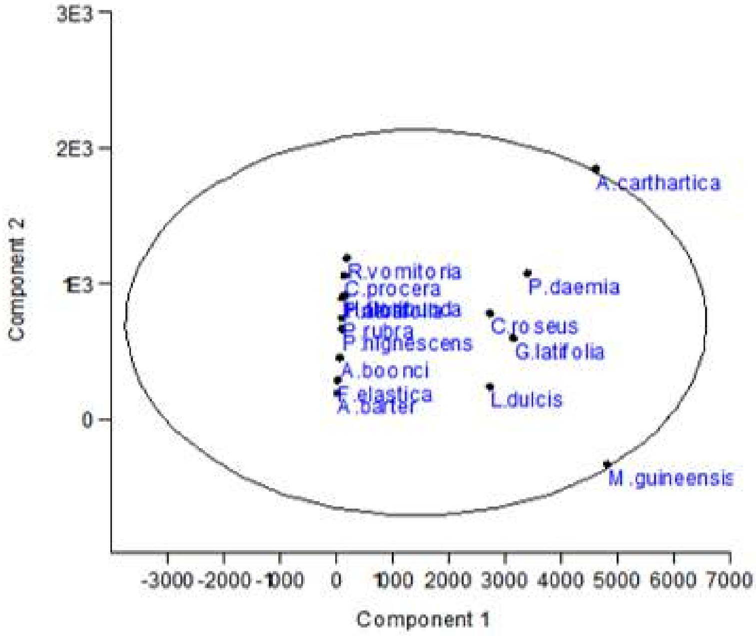

Fig. 2: Principal Component Analysis showing the relationship of the Apocynaceae species studied based on their Anatomical Characters.

Elliptic stomata shape is common among the species studied except in *Landolphia dulcis* which has oval to circular stomata shape on both the abaxial and adaxial surfaces. This character can be used to group the two families together as other researchers like Arogundade and Adedeji (2016) reported that elliptic stomata shape unifies all the *Aglaonema* species studied. Adedeji (2004) also emphasized stomata shape to be of taxonomic importance in leaf epidermal studies of some species of *Emilia*. Anomocytic stomata type on both surfaces was observed in all the species, except in *Catharanthus roseus* and *Holarrhena floribunda*.

This can be used as an inter-familial character that brings the two families together as one large family Apocynaceae. Mustafa *et al*. (2016) reported only anisocytic stomata in *Catharanthus roseus* and *Nerium oleander*; this was in agreement with this work but also contradicts this study as both tetracytic and anisocytic stomata were encountered in *C. roseus*. Tetracytic, Anisocytic, Cyclocytic and Paracytic stomata types were also observed to be present in some species, this can be useful in grouping them together.

However, some species have unique characters that can be used in delimiting them: diacytic and desmocytic stomata types in *Funtumia elastica* and *Motandra guineensis* respectively. *Motandra guineensis* was distinctly unique because it has demoscytic stomata present on the costal region on the abaxial surface; shrivelled stomata; stomata with one guard cell and two to three stomata sharing the same epidermal cell on abaxial surface. Sunken stomata also known as stomata crypts were only found in *A. boonei* and *P. nigrescens*.

This is a unique character too that has not been reported in Nigeria before except for Onafeli and kehinde (2021) that reported stomata crypts for *A. boonei*. Hassiotou *et al*. (2009) reported that sunken stomata are located in depressed portions of the epidermis, which forms a narrow-mouthed or deep longitudinal groove. The presence of sunken stomata in *A. boonei* and *P. nigrescens* can be linked to its wide range of ecological distribution, which occurs both in the savannah and wet regions as reported by Abu *et al*. (2016). The effectiveness of sunken stomata for apocynaceae taxa delimitation has been reported. Sharma *et al.* (2012) reported *Nerium indicum* to be taxonomically distinct from *Catharanthus roseus* and *Tabernaemontana divaricata* by having stomatal crypts or sunken stomata. *N. indicum* was the first species of apocynaceae to be reported with sunken stomata characteristics while in Nigeria, *A. boonei and P. nigrescens* were observed in the present study happened to be the second species with such traits. Metcalfe and Chalk (1979), reported that ridges or folds of the cuticle form ornamentations on them.

These ornamentations consist of striae; hence they are referred to as striated cuticle. Also, Solereder (1908) reported that striations are useful for specific diagnosis and are not always developed in the same way on the two surfaces of the leaf. He also reported that they are taxonomically stable. Adedeji and Illoh (2004), separated some species of *Hibiscus* using cuticular striations. *A. boonei* and *P. nigrescens* were unique by having cuticular ornamentation covering all the epidermal cells on abaxial surfaces, this can be used as a diagnostic anatomical character to delimit them and group them in the same tribe Alstonieae under the sub-family Rauvolfiodeae because the tribe of *P. nigrescens* is yet to be determined.

Also, epidermal characters like cuticular striations, stomata shape and type, presence of styloid crystal and kinked uniseriate trichome-like structure can be used to group them together. Scales were present on the abaxial surfaces of *A. barteri*, *L. dulcis* and *G. latifolia*; this trait separated them from all the other species studied. Quite a number of researchers like Adedeji and Illoh (2004); Adedeji *et al*. (2007) and Nwanko and Ayodele (2017) have separated groups of plants based on the presence or absence or type of trichomes, the presence of trichomes in some species of plant is of high taxonomic importance. The presence of biseriate, bicellular; biseriate, multicellular and multiseriate, multicellular non - glandular trichome types in *Pergularia daemia* separates this species from the other species which have simple, unicellular to uniseriate, multicellular, non - glandular trichomes. Kinked uniseriate trichomes are quite unique and diagnostic for the four sub-families studied. It is present on one or both surfaces of almost all the taxa studied and it can be used as a diagnostic character for bringing the two families studied together as one family. This is a novel report from this study, as no researcher as ever reported this unique character before.

CONCLUSION

From this study, it can therefore be concluded that anatomical field of evidence can be employed in grouping the two families Apocynaceae and Asclepiadaceae together as one family Apocynaceae. This is because of their overlaping characters. Notably, distinct features were observed in some species (*A. barteri* - Scale, *M. guineensis* - Desmocytic stomata on coastal cells, *A. boonei* and *P. nigrescens* - cuticular ornamentations on abaxial surface, *P. daemia* - biseriate, bicellular; biseriate, multicellular and multiseriate, multicellular non - glandular trichome) that could be subjected to further studies. This study reveals for the first time that Kinked uniseriate trichome - like structures are quite diagnostic for the four sub-families. Further research should be done on the DNA analysis of the selected species in Nigeria to provide more information on their unifying and discriminating features. More work should also be done on their Chemotaxonomy since most of them are medicinal plants and they contain different phytochemicals.

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MICROBIAL POPULATION UNDER DIFFERENT FOREST PLANTATION IN AREA J4 OGUN STATE, NIGERIA

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ABSTRACT

The population of microbes was determined for three different plantations in Omo Forest reserve (Area J4) of Ogun State with the aim of examining the microbial population and distribution with depth. The experimental design adopted was the Randomized Complete Block Design (RCBD), where the plantations (*Nauclea diderrichii, Pinus carribea* plantations and Natural Forest) constituted the treatments and the soil depths (0-30cm and 30-60cm) the blocks. Standard soil analytical procedures were followed for determination of (pH, H^+, Na $cmolkg^{-1}$, K $cmolkg^{-1}$, Ca $cmolkg^{-1}$, Mg $cmolkg^{-1}$, soil particle size, moisture content %, bulk density g/cm^3, organic carbon organic matter, total Nitrogen %, microbial biomass Carbon μgCg^{-1}, microbial biomass Nitrogen μgNg^{-1}, porosity, total bacterial count, total fungi count). Data collected were subjected to ANOVA and means separated using Duncan Multiple Range Test (DMRT). The result revealed that the soils had high microbial biomass carbon (MBC) content. The soil of *Pinus carribea* plantation has the highest MBC content (238.20 ± 3.310^a mg/kg), followed by Natural Forest (225.15 ± 1.987mg/kg) and *Nauclea diderrichii* (117.55 ± 1.103^e mg/kg). The soils had low microbial biomass nitrogen (MBN) content, the soil of Natural Forest had the highest MBN content (17.90 ± 0.744mg/kg) followed by *Nauclea diderrichii* (16.13 ± 0.568^b mg/kg) and *Pinus carribea* plantation (13.68 ± 0.150mg/kg). The population of total bacteria count and total fungal count were relatively low. The result for total bacteria count showed that Natural Forest soil at a depth of 0-30 cm has the highest value, followed by *Nauclea diderrichii* and *Pinus carribea* plantation soils both at 0-30 cm depth, while the least was Natural Forest at depth 30-60cm depth. The result for total soil fungi count occurred in the following order, *Pinus carribea* plantation, *Nauclea diderrichii* and Natural Forest. Proper soil management and silvicultural practices should be encouraged in Area J4 to improve availability of phosphorus and other nutrients.

Keywords: *soil microbes, forest plantation, natural forest, silvicultural practices, soil management*

INTRODUCTION

Plant physiologists observe that soil is a complex ecosystem that supports a variety of organisms, including mammals, bacteria, fungus, and protists, in addition to being an effective supply of nutrients for plants (Müller *et al.,* 2016). In general, three mechanisms underscore ecological functions of soil. They include the ability of microbes to promote plant growth manipulation of plants' hormonal signaling activity (Verbon and Liberman, 2016); inhibition of the growth of pathogenic microbes (Park *et al.*, 2015) and enhancing the availability of soil nutrients (Wagg *et al.,* 2014).

The method by which soil bacteria immobilized the bound forms of nutrients/elements and made them accessible to the plants was reviewed by Jacoby *et al.*, (2017). The biogeochemical processes in the soil, such as decomposition of organic matter, mineralization of nutrients, improvement of soil aggregation, sequestration of heavy metals (HMs), biodegradation of organic contaminants, and inhibition of the growth of plant pathogens, are all significantly influenced by microbes (Sun *et al.*, 2020; Cheng *et al.*, 2016; Pant *et al.,* 2016). In addition, macro and micro nutrients, including Sulfur, Phosphorus and Nitrogen, bind to organic molecules in the natural ecosystem, and are only accessible to plants at very low concentrations.

Plants completely rely on the interactions of soil microorganisms, collectively known as the soil microbiome, including bacteria, fungus, archaea, viruses, protozoa, and others, for acquiring essential nutrients (Jacoby *et al.,* 2017). These microorganisms have a variety of metabolic systems that they can use to mineralize and immobilize bound nutrients (Jacoby *et al.,* 2017). The microbial community known as the soil microbiome is found in the soil environment and has its own roles (Crecchio *et al.,* 2018).

In tropical environments, microbial populations and diversities are impacted by anthropogenic activities, such as logging and post-harvest regeneration fire, both of which have a variety of consequences on the soil environment. Anthropogenic pressures vary from location to location, for instance, anthropogenic forces threatening the microbial population in the soil beneath various forest plantations in the Area J4 continue to provide challenges despite the numerous benefits that microorganisms provide for improving plant development or growth, This is because they alter the microclimate, eliminates hosts for plant-microbe symbioses, increases soil erosion, and alters the inputs of soil organic matter, the removal of vegetation can have a detrimental effect on the abundance of fungal decomposers and mycorrhizae and, better yet, the population and diversity of microbes in the soil as Xu *et al.* (2018) observed. Therefore, the need to have a detailed study of soil microbial population and distribution with depth under plantations and natural forest in Area J4 Omo Forest Reserve, Ogun State is important because it will enable effective management of microbial population for sustainable forest management.

MATERIALS AND METHODS

The Study Area

The study was conducted in Area J4 of the Omo Forest Reserve in Ijebu-Ode, Ogun State, among natural forests, *Pinus carribea* plantations, and *Nauclea didderichi*. The Omo Forest Reserve is a protected section of tropical rainforest in the southwest of Nigeria, in Ogun State, Nigeria. It is geographically located about 80 kilometers east of Ijebu Ode and 135 kilometers northeast of Lagos. This area stretches North from latitudes 6^{o} 35^{1} to 7^{o} 05^{1} N and East 4^{o} 19^{1} to 4^{o} 40^{1} E.

Experimental Design

The experimental design adopted was Randomized Complete Block Design (RCBD),where the various plantations (*Nauclea diderrichii*, *Pinus carribea* plantations and Natural forest) constituted the treatments and the soil depths (0-30cm and 30-60cm) the blocks.

Soil Preparation

The soil samples were collected systematically from five auger point distributed within the plantations at 100 m intervals. Soil samples were collected at 0-30 cm and 30-60 cm depth from each plot using soil auger. The soil samples were bulk to form a composite sample per depth for each of the plantations and batched into three replicates per depth for each of the plantation making a total of thirty (30) samples. The soil samples were packed in a polythene bag and labeled appropriately for physical, chemical and soil microbial laboratory analyses.

Soil Analysis for Soil Microbial Population

The assessment of the microbial population in soil samples focused only on fungus and bacteria. To ensure precise counting, sterile water was used to make a suspension of the soil samples. Five factors were then serially diluted. Then, under suitable conditions at roughly 37ºC, 1 mL of the dilution was carefully transferred to sterilized Petri dishes containing sterile molten nutritional agar. It was blended and incubated for 24 hours. To obtain pure culture for identification, bacteria that are intended were sub-cultured to form pure colonies. Identification was conducted according to Bergey's manual of determinative bacteriology (Boone *et al.*, 2001). Serial dilution of the mixture will also be applied to petri dishes with sterile, molten malt extract agar for fungal growth under incubation for at 30ºC for 5 days. To create pure cultures for identification, fungi that have grown were sub-cultured for identification and microscopic characterization.

Data Analysis

Two-way analysis of variance (ANOVA) was used to examine if significant differences occurred among the various soil properties of the plantations and across the three soil depths. Mean separation was carried out using the Duncan Multiple Range Test (DMRT). Population values for bacteria and fungi (Most Portable Number-MPN) were logarithmically transformed -Ln (x+1) where, x=MPN g-1 dried soil x 106.

RESULTS

The means of the soil sand, clay and silt particles recorded in 0-30 cm and 30-60 cm were significantly different; sand particles (%) recorded 73.7±12.61 and 70.62±15.306 at 0-30cm and 30-60 cm respectively, clay particles (%) recorded 7.43±4.589 at 0-30 cm while, 11.27±10.094 was recorded at a depth of 30-60 cm (Table 1). Silt fractions (%) recorded in the soil at a depth of 0-30 cm and 30-60 cm were 18.87± 8.679 and 18.12±6.748 respectively. There was a significant difference in the mean of the pH recorded at both soil depths, 5.51±0.235 and 5.13±0.078 at a depth of 0-30 cm and 30-60cm respectively. The highest value recorded for soil pH is 5.51±0.235 at a depth of 0-30cm while the lowest value recorded for soil pH is 5.13±0.078 at a depth of 30-60 cm. Furthermore, the soil hydrogen (H^+) value recorded for both depths at 0-30cm and 30-60cm respectively were 0.13±0.012 and 0.39±0.546 which were not significantly different (Table 1).

The results for Na cmolkg^{-1}, K cmolkg^{-1}, Ca cmolkg^{-1} and Mg cmolkg^{-1} showed significant differences between *Pinus carribea*, *Nauclea diderrichii* and Natural forest, where *Pinus carribea* had the highest values of 0.28±0.10, 0.38±0.05, 0.20±0.03 and 0.23±0.03 respectively, while *Nauclea diderrichii* had the lowest values of 0.23±0.03, 0.27±0.04, 0.13±0.2 and 0.12±0.02 (Table 2). The result for soil organic carbon showed a significant difference in *Nauclea diderrichii* but there was no significant difference between *Pinus carribea* and Natural forest. *Pinus carribea* and Natural forest recorded the highest value of 6.11±0.81 and 5.98±0.89 while *Nauclea diderrichii* recorded the lowest value of 5.44±0.376 (Table 1).

The result for microbial biomass carbon showed there was no significant difference between *Pinus carribea*, *Nauclea diderrichii* and Natural forest. *Pinus carribea* recorded the highest value of 228.81±10.287 while the lowest value recorded was for *Nauclea diderrichii* is 165.10±50.860. The result for microbial biomass nitrogen showed there was a significant difference in Natural forest, but there was no significant difference between *Pinus carribea* and *Nauclea diderrichii*.

Natural forest recorded the highest value of 16.03±2.072 while *Pinus carribea* and *Nauclea diderrichii* recorded the lowest value of 14.86±1.311 and 14.65±1.654.

The result for porosity showed there was no significant difference between *Pinus carribea*, *Nauclea diderrichii* and Natural Forest. Natural forest recorded the highest value of 91.80±1.220, *Pinus carribea* recorded the lowest value at 78.61±5.606^{c}. The result for total bacterial count showed a significant difference in Natural Forest, while there was no significant difference between *Pinus carribea*, and *Nauclea diderrichii*. *Pinus carribea*, and *Nauclea diderrichii* recorded the highest values of 6.53±0.673 and 6.68±0.534 while Natural Forest recorded the lowest value of 5.69±2.4890. The result for total fungi counts shows that there was no significant difference between *Pinus carribea*, *Nauclea diderrichii* and Natural forest. However, *Pinus carribea* recorded the highest value of 1.94±0.670 while Natural forest recorded the lowest value of 1.28±0.306 (Table 2).

The results of correlation studies on the soils showed a negative significant correlation of pH with hydrogen (H^+) (r = -1.00). Also, pH showed positive significant correlation with sodium (Na $cmolkg^{-1}$) (r= 0.94), potassium (K $cmolkg^{-1}$) (r= 0.80), calcium (Ca $cmolkg^{-1}$) (r= 0.81), magnesium (Mg $cmolkg^{-1}$) (r = 0.81) (Table 4).

Microbial Biomass Carbon showed a positive significant correlation with pH (r= 0.63), Cation Exchange Carbon (CEC) (r= 1.00), while it showed a negative significant correlation with H^+ (r= -0.90). Microbial Biomass Carbon showed positive significant correlation with Cation Exchange Carbon (CEC) (r= 0.77) and Microbial Biomass Nitrogen (r = 1.00). Microbial Biomass Nitrogen showed positive significant correlation with Cation Exchange Carbon (CEC) (r= 0.58) and Microbial Biomass Carbon (r = 0.56). Microbial Biomass Nitrogen showed positive significant correlation with Cation Exchange Carbon (CEC) (r= 0.58) and Microbial Biomass Carbon (r = 0.56). Microbial Biomass Phosphorus showed positive significant correlation with Cation Exchange Carbon (CEC) (r= 0.78), Microbial Biomass Carbon (r = 0.76) and Microbial Biomass Nitrogen (r= 0.66). Total Bacteria count showed a positive significant correlation with Microbial Biomass Carbon (r = 0.10), Microbial Biomass Nitrogen (r= 0.63) and Microbial Biomass Phosphorus (r= 0.20). Total Fungi count showed a positive significant correlation with Microbial Biomass Carbon (r = 0.39), Microbial Biomass Nitrogen (r= 0.51) and Microbial Biomass Phosphorus (r= 0.26) (Table 4).

Table 1: Effect of Depth on the Physiochemical, Properties and Distribution of Microbial Population

Soil properties	Depth (cm)	
	0-30	**30-60**
Sand	73.70 ± 12.610 [a]	70.62 ± 15.306 [b]
Clay	7.43 ± 4.589 [b]	11.27 ± 10. 094 [a]
Silt	18.87 ± 8.679 [a]	18.12 ± 6.748 [b]
Ph	5.51 ± 0.235 [a]	5.13 ± 0.078 [b]
H^+	0.13 ± 0.012 [a]	0.39 ± 0.546 [a]
Soil organic carbon	6.47 ± 0.559 [a]	5.21 ± 0.159 [b]
Soil organic matter	11.15 ± 0. 963 [a]	9.07 ± 0.351 [b]
Total Nitrogen	0.05 ± 0.007 [a]	0.04 ± 0.007 [b]
Moisture content	7.53 ± 0.393 [a]	6.48 ± 0.397 [b]
Bulk density	0.15 ± 0.012 [a]	0.14 ± 0.008 [b]
Na $cmolkg^{-1}$	0.30 ± 0.0394 [a]	0.21 ± 0.011 [b]
K $cmolkg^{-1}$	0.35 ± 0.051 [a]	0.28 ± 0.051 [b]
Ca $cmolkg^{-1}$	0.18 ± 0.031 [a]	0.13 ± 0.028 [b]
Mg $cmolkg^{-1}$	0.20 ± 0.056 [a]	0.16 ± 0.028 [b]
Total Nitrogen %	0.05 ± 0.008 [a]	0.04 ± 0.008 [b]
Nitrate %	0.04 ± 0.004 [a]	0.02 ± 0.005 [b]
Microbial Biomass Carbon μgCg^{-1}	225.33 ± 11.143 [a]	184.947 ± 49.792 [b]
Microbial Biomass Nitrogen μgNg^{-1}	16.69 ± 1.048 [a]	13.67 ± 0.523 [b]
Porosity %	87.29 ± 3.109 [a]	80.56 ± 9.162 [b]
TBC	7.41 ± 0.544 [a]	5.18 ± 1.38 [b]
TFC	2.05 ± 0.440 [a]	1.21 ± 0. 189 [b]

Values of the same alphabets horizontal are not significantly different at (p<0.0001)

Table 2: Effect of Forest plantation on the Physiochemical Properties and Distribution of Microbial Population in the Study Area

Soil particles	***Pinus carribea*** **Plantation**	**Natural forest**	***Nauclea diderrichii*** **Plantation**
Silt %	27.20 ± 3.338 [a]	9.95 ± 0.886 [c]	18.334 ± 2.900 [b]
Sand %	53.83 ± 3.159 [c]	84.45 ± 2.188 [a]	78.20 ± 3.586 [b]
Clay %	18.98 ± 6.435 [a]	5.60 ± 1.512 [b]	3.48 ± 0.83 [c]
pH	5.46 ± 0.34 [a]	5.35 ± 0.17 [b]	5.15 ± 0.12 [c]
H^+	0.14 ± 0.02 [b]	0.14 ± 0.01 [b]	0.50 ± 0.65 [a]
Na $cmolkg^{-1}$	0.28 ± 0.10 [a]	0.25 ± 0.04 [b]	0.23 ± 0.03 [c]
K $cmolkg^{-1}$	0.38 ± 0.05 [a]	0.31 ± 0.15 [b]	0.27 ± 0.04 [c]
Ca $cmolkg^{-1}$	0.20 ± 0.03 [a]	0.15 ± 0.02 [b]	0.13 ± 0.2 [c]
Mg $cmolkg^{-1}$	0.23 ± 0.03 [a]	0.20 ± 0.03 [b]	0.12 ± 0.02 [c]
Moisture Content %	7.17 ± 0.44 [a]	6.71 ± 0.85 [b]	7.14 ± 0.60 [a]
Bulk Density g/cm^3	0.15 ± 0.01 [a]	0.13 ± 0.00 b	0.15 ± 0.01 [a]
Soil Organic Carbon %	6.11 ± 0.81 [a]	5.98 ± 0.89 [a]	5.44 ± 0.37 [b]
Soil Organic Matter %	10.53 ± 1.40 [a]	10.44 ± 1.44 [a]	9.37 ± 0.628 [b]
Total Nitrogen %	0.05 ± 0.009 [a]	0.04 ± 0.011 [b]	0.05 ± 0.009 [a]
Microbial Biomass Carbon μgCg^{-1}	228.81 ± 10.287[a]	221.51 ± 4.231 [b]	165.10 ± 50.860 [c]
Microbial Biomass Nitrogen μgNg^{-1}	14.86 ± 1.311 [b]	16.03 ± 2.072 [a]	14.65 ± 1.654 [b]
Porosity %	78.61 ± 5.606 [c]	91.80 ± 1.220 [a]	81.41± 6.513 [b]
TBC	6.53 ± 0.673 [a]	5.69 ± 2.490 [c]	6.68± 0.534 [a]
TFC	1.94 ± 0.670 [a]	1.28 ± 0.306 [c]	1.68 ± 0.413 [b]

Values of the same alphabets horizontal are not significantly different at (p<0.0001)

Table 3: **Interactive Effect of Depth and Forest plantation on the Physiochemical Properties and Distribution of Microbial Population**

Soil particles	Natural forest (0-30cm)	Natural forest (30-60cm)	Nauclea *diderrichii* (0-30cm)	Nauclea *diderrichii* (30-60cm)	*Pinus carribea* (0-30cm)	*Pinus carribea* (30-60cm)
Silt %	10.70 ± 0.578 ^{e}	9.20 ± 0.000 ^{f}	15.70 ± 0.578 ^{d}	20.95 ± 0.957 ^{c}	30.20 ± 1.414 ^{a}	24.20 ± 0.000 ^{b}
Sand %	82.95 ± 1.500 ^{b}	85. 95 ± 1.709 ^{a}	81.45 ± 0.957 ^{b}	74.95 ± 0.957 ^{c}	56.70 ± 0.577 ^{d}	50.95 ± 0.957 ^{e}
Clay %	6.35 ± 0.957 ^{c}	4.85 ± 1.709 ^{a}	2.85 ± 0.500 ^{e}	4.10 ± 0.578 ^{de}	13.10 ± 1.915 ^{b}	24.85 ± 0.957 ^{a}
pH	5.50 ± 0.115 ^{b}	5.20 ± 0.000 ^{c}	5.30 ± 0.058 ^{c}	5.05 ± 0.058 ^{d}	5.78 ± 0.056 ^{a}	5.15 ± 0.056 ^{c}
H^{+}	0.13 ± 0.006 ^{b}	0.15 ± 0.000 ^{b}	0.15 ± 0.003 ^{b}	0.86 ± 0.805 ^{a}	0.12 ± 0.003 ^{b}	0.15 ± 0.003 ^{b}
Na cmolkg^{-1}	0.29 ± 0.015 ^{b}	0.21 ± 0.021 ^{d}	0.26 ± 0.010 ^{c}	0.21 ± 0.012 ^{d}	0.35 ± 0.010 ^{a}	0.22 ± 0.013 ^{d}
K cmolkg^{-1}	0.33 ± 0.012 ^{cb}	0.28 ± 0.028 ^{d}	0.31 ± 0.020 ^{cd}	0.23 ± 0.014 ^{e}	0.42 ± 0.020 ^{a}	0.34 ± 0.023 ^{b}
Ca cmolkg^{-1}	0.17 ± 0.015 ^{b}	0.13 ± 0.012 ^{c}	0.15 ± 0.012 ^{b}	0.11 ± 0.006 ^{d}	0.21 ± 0.020 ^{a}	0.17 ± 0.010 ^{b}
Mg cmolkg^{-1}	0.22 ± 0.021 ^{b}	0.17 ± 0.012 ^{d}	0.13 ± 0.012 ^{e}	0.10 ± 0.000 ^{f}	0.25 ± 0.010 ^{a}	0.20 ± 0.005 ^{c}
Moisture Content %	7.36 ± 0.641 ^{a}	6.06 ± 0.398 ^{c}	7.68 ± 0.222 ^{a}	6.60 ± 0.183 ^{b}	7.56 ± 0.189 ^{a}	6.78 ± 0.096 ^{b}
Bulk Density g/cm^{3}	0.14 ± 0.002 ^{d}	0.13 ± 0.001 ^{e}	0.17 ± 0.004 ^{a}	0.14 ± 0.002 ^{c}	0.16 ± 0.003 ^{b}	0.15 ± 0.002 ^{c}
Soil Organic Carbon %	6.82 ± 0.110 ^{a}	5.15 ± 0.058 ^{d}	5.73 ± 0.174 ^{b}	5.14 ± 0.221 ^{d}	6.86 ± 0.073 ^{a}	5.35 ± 0.098 ^{c}
Soil Organic Matter %	11.76 ± 0.189 ^{a}	9.13 ± 0.451 ^{c}	9.89 ± 0.299 ^{b}	8.86 ± 0.381 ^{d}	11.83 ± 0.126 ^{a}	9.23 ± 0.098 ^{c}
Total Nitrogen %	0.05 ± 0.000 ^{b}	0.03 ± 0.000 ^{c}	0.06 ± 0.000 ^{a}	0.04 ± 0.005 ^{c}	0.05 ± 0.012 ^{b}	0.05 ± 0.006 ^{b}
Nitrate %	0.004 ± 0.001 ^{ba}	0.002 ± 0^{c}	0.04± 0 ^{a}	0.002 ± 0.001 ^{c}	0.04 ± 0.001 ^{ba}	0.03 ± 0 ^{b}
Microbial Biomass Carbon µgCg^{-1}	225.15 ± 1.987 ^{b}	217.89 ± 1.595 ^{c}	212.65 ± 2.263 ^{d}	117.55 ± 1.103 ^{e}	238.20 ± 3.310 ^{a}	219.42 ± 0.830 ^{c}
Microbial Biomass Nitroge µgNg^{-1}	17.90 ± 0.744 ^{a}	14.15 ± 0.300 ^{c}	16.13 ± 0.568 ^{b}	13.18 ± 0.506 ^{d}	16.05 ± 0.480 ^{b}	13.68 ± 0.150 ^{dc}
Porosity %	90.75 ± 0.620 ^{b}	92.85 ± 0.387 ^{a}	87.35 ± 1.353 ^{c}	75.38 ± 1.245 ^{e}	83.78 ± 0.888 ^{d}	73.45 ± 1.215 ^{f}
TBC	7.98 ± 0.613 ^{a}	3.40 ± 0.365 ^{d}	7.15 ± 0.191 ^{b}	6.20 ± 0.163 ^{c}	7.13 ± 0.222 ^{b}	5.93 ± 0.222 ^{c}
TFC	1.55 ± 0.129 ^{c}	1.00 ± 0.000 ^{e}	2.05 ± 1.000 ^{b}	1.30 ± 0.115 ^{d}	2.55 ± 0.129 ^{a}	1.33 ± 0.171 ^{d}

Values of the same alphabets horizontal are not significantly different at (p<0.0001*)*

Table 4: Correlation between Physicochemical properties and Microbial population

	PH	*H+*	*Na cmolkg-1*	*K cmolkg-1*	*Ca cmolkg-1*	*Mg cmolkg-1*	*Av. P mgkg-1*	*Total P mgkg-1*	*Total Nitrogen %*	*CEC*	*MBC*	*MBN*	*MBP*	*TBC*
PH	1													
H+	-1.00	1.00												
Na cmolkg-1	0.94	-0.94	1.00											
K cmolkg-1	0.80	-0.81	0.78	1.00										
Ca cmolkg-1	0.81	-0.82	0.78	0.97	1.00									
Mg cmolkg-1	0.81	-0.82	0.69	0.84	0.85	1.00								
Av. P mgkg-1	0.87	-0.87	0.95	0.73	0.77	0.61	1.00							
Total P mgkg-1	0.86	-0.85	0.89	0.76	0.77	0.61	0.92	1.00						
Total Nitrogen %	0.30	-0.30	0.47	0.40	0.43	0.07	0.60	0.56	1.00					
CEC	0.89	-0.90	0.86	0.97	0.97	0.91	0.81	0.81	0.37	1.00				
MBC	0.63	-0.64	0.53	0.78	0.76	0.79	0.50	0.66	0.18	0.77	1.00			
MBN	0.66	-0.65	0.71	0.50	0.53	0.46	0.71	0.80	0.46	0.58	0.56	1.00		
MBP	0.77	-0.78	0.63	0.68	0.70	0.89	0.54	0.65	-0.05	0.78	0.76	0.66	1.00	
TBC	0.50	-0.50	0.65	0.39	0.43	0.27	0.71	0.55	0.76	0.46	0.10	0.63	0.20	1.00
TFC	0.74	-0.75	0.87	0.69	0.70	0.42	0.89	0.77	0.65	0.70	0.39	0.51	0.26	0.65

- ** Correlation is significant at the 0.01 level (2-tailed).
- *. Correlation is significant at the 0.05 level (2-tailed).

DISCUSSION

When sand fraction over silt and clay particles, the soil texture of the examined regions between the depths of 0-30 cm and 30-60 cm can be mostly sandy soil (light textured). The outcomes of the soil's physical characteristics are consistent with (Oyelowo *et al.,* 2019) and Isikhuemen (2015). Similar trends in particle size distribution have been reported by Muoghalu *et al.*, (2014).

The soil pH measurements made in this investigation for both depths are comparable to those made by (Salim *et al.,* 2018). The pH of the soil is slightly acidic. The fact that all the soils were acidic and that tropical soils typically have acidic soils coincides with (Igwe, 2011). Also, as depth increases, soil organic carbon decreases. The greatest value for soil organic carbon was 6.470.559[a] at depths of 0–30 cm, and the lowest value was (5.210.159[b]) at depths of 30-60cm, which was caused by the deposition of leaves. Nitrogen, calcium, sodium, magnesium, and potassium results concur with those of (Oyelowo *et al.,* 2019). As depth, the total nitrogen drops. Among the cations, potassium (K) is the most important nutrient for plants. It strengthens drought resistance while promoting root growth. Reduces wilting and water loss while maintaining turgor, helps avoid energy losses by reducing respiration and assisting in the production of food. (Qiwen *et al.,* 2021).

The result for soil organic matter reveals that the maximum value for soil organic matter was (11.15±0.963[a]) at a depth of 0-30cm, while the lowest value was (9.07±0.351[b]) at a depth of 30-60cm. Isikhuemen (2015) asserts that carbonates' ability to alter soil pH can have an impact on soil production. The quantities of nitrogen, organic carbon, exchangeable calcium, and magnesium in the top soil may have been dramatically influenced by the tree leaves and other plant components. Sand particles make up the majority of the soil in every plantation, followed by silt and clay particles. The pH recorded in all the plantations are slightly acidic and nearly neutral, while *Nauclea diderrichii* soil reveals a more moderately acidic soil because its pH reading is a little lower than the others. Leaching of base elements may be the cause of a significant pH change. In the tropical rainforest, Onyekwelu *et al.,* (2016) found that heavy precipitation quickly leaches nutrients. Organic debris in the soil decomposes, releasing organic acids that lower the pH of the forest (Killham, 2014).This may be one of the reasons for having low soil pH under *Nauclea diderrichii* as it produces large components of litter as compared to the other plantations. Similar observation was also made by (Hann *et al.,* 2017) where they mentioned that the reduction in pH can be attributed to accumulation and subsequent slow decomposition of organic matter, which releases acids in the forest soil.

The result for total nitrogen reveals that *Pinus carribea*, and *Nauclea diderrichii* has the highest value of soil total nitrogen recorded 0.05±0.007[a] at a depth of 0-30cm, while the lowest is Natural forest with a value of (0.04±0.007[b]) recorded, at 30-60cm depth.

The low content in soil organic carbon in *Nauclea diderrichii* could be associated to the tree species constituents. The exchangeable concentrations of Ca, Mg, and K in the various plantations are noteworthy. Baillie and Aghton (2013) suggested that Ca and Mg should be more variable than K in forest soils. In the three plantations, exchangeable magnesium (Mg) tends to be more abundant, followed by calcium (Ca) *Pinus carribea* plantation recorded the highest exchangeable magnesium (0.23 ± 0.03 [a]) and calcium (0.20 ± 0.03 [a])

According to the results for soil organic matter, *Pinus carribea* and Natural forest had the highest values of soil organic matter of any 10.53 ± 1.40 [a] and 10.44 ± 1.44[a] While Natural forest and *Pinus carribea* have similar values and Nauclea *diderrichii* has the lowest value (9.37 ± 0.628 [b]), there appears to be a considerable difference in Nauclea *diderrichii*. The outcome is comparable to that of (Opeyemi *et al.,* 2020).

The result of the total bacteria count on the study area reveals that Natural forest 7.41 ± 0.544[a] at a depth of 0–30 cm had the highest value recorded according to the result discovered on the total bacteria count, and Natural forest had the lowest value recorded according to the result discovered on the total bacteria count (3.40 ± 0.365 [d]) at a 30 to 60 cm depth. The total number of fungus found in the study region revealed that *Pinus carribea* had the maximum depth value, measuring 0–30 cm with a value of (2.55±0.129 [a]), while Natural forest had the lowest value, measuring 30–60 cm with a value of 1.00±0.000[e]. This finding contrasts with that of (Opeyemi, *et al.,* 2020), which found that the total number of bacteria and fungi is found in the natural forest. But in the upper soil depth, there were more microorganisms and microbial activities than in the lower. This is comparable to the outcome obtained by Piriyaprin *et al.,* (2012).

Pinus carribea has the highest value ever found for microbial biomass carbon, according to the results for microbial biomass carbon that were identified (238.20 ± 3.310 [a]) while *Nauclea diderrichii* has the lowest value yet measured, at a depth of 0–30 cm (117.55 ± 1.103 [e]) at a depth of 30-60cm. The results for the nitrogen-containing microbial biomass showed that *Nauclea diderrichii* at a depth of 30-60 cm recorded the lowest value of (13.18 ± 0.506 [d]) and Natural forest at a depth of 0-30 cm recorded the greatest value of (17.90 ± 0.744 [a]). Nonetheless, there were noticeable variations in the microbial biomass nitrogen and carbon across the research area's plantation and at different depths. The microbial biomass Carbon and Nitrogen varied significantly between sampling sites and different depths. The *Pinus carribea* plantation had the highest levels of microbial biomass carbon (238.20 ± 3.310 to 117.55 ± 1.103 gNg-1) compared to *Nauclea diderrichii* soils (17.90 ± 0.744 to 13.18 ± 0.506 gNg-1) at the soil depths of 0-30cm and 30-60cm. This finding is consistent with that of Han *et al.* (2017), who found that different tea stands' microbial biomass carbon levels decreased relative to forests. The three plantations' soil microbial biomass varied significantly from one another.

CONCLUSION

The population of microbes present in the soil samples gotten from the natural forest, *Pinus carribea and Nauclea diderrichii* plantations was soil organic carbon, soil organic matter, microbial biomass carbon, microbial biomass nitrogen, bacteria and fungi. It was also discovered from the study that microbial population in *Pinus carribea* soils was higher compared to Natural forest and then *Nauclea diderrichii* plantation which may be due to degradation in the former. Total microbial population decreases down the depth in all the area of study. *Pinus carribea* has the highest population of microbes, followed by Natural forest plantation and the least is *Nauclea diderrichii* plantation. The total microbial population is low when compared with other previous research work. In the soils studied, total nitrogen and nitrate was relatively low, but microbial biomass carbon proves to be relatively high. Findings of this study are also recommended for proper soil management and silvicultural practices in the study area to improve availability of phosphorus and other nutrients.

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A SURVEY OF GAME BIRDS ABUNDANCE IN FADAMA AREA OF SANAGI VILLAGE IN JEGA LOCAL GOVERNMENTOF KEBBI STATE, NIGERIA

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ABSTRACT

This study was carried out to assess the distribution, abundance and to identify the dominant species of game bird species at Fadama area of Sanagi village, Jega Kebbi State, Nigeria. Morning observation was made between the hours of 0600 and 1000 hours, while the evening visit was from 1630 to 1830 hours when the temperature was relatively cool and bird activities were high. A total of 14 birds were identified from nine (9) species of birds in the study area. It was observed that speckled pigeon has the dominant game bird species (41) and the least was White face duck (8). More studies should be carried out so as to determine composition of game birds in the study area.

Key words: Avian survey, Game birds, Distribution, Avian abundance, Fadama.

INTRODUCTION

Game birds

The concept of game birds distribution and abundance is very important in biodiversity conservation (Ajiboye, 2012). The distribution and abundance are dependent on many abiotic factors of continuous interaction of vegetation, and also includes the effects of continuous interaction of different species of wildlife (Ajiboye, 2012). Populations of all species are naturally dynamic and change over time. The degree to which they change depends on a complex interaction between the biology of the species and the ecosystem in which they live. Some changes in environmental conditions can be beneficial and lead to an increase in population size (Alarrape, 2002). At the other end of the spectrum, extreme circumstances can result in a disaster decrease in numbers leading to a species becoming locally extinct. Both species abundance and species distribution are closely linked to measures of factors that affect the status of species whether positively or negatively (Ajiboye, 2012). These include changes in the extent of habitat, habitat fragmentation, water quality, invasions by alien species, coverage of protected areas and harvesting by humans.Very much the same, tropical forests support the highest quantity of native birds' areas and are home to the best range-restricted bird types on the planet (Alarape, 200 Game birds are birds that are hunted in the wild legally according to the laws as well as kept in captivity where they are raised often with some difficulties. Birds are feathered, winged, egg-laying vertebrates. These vertebrates survive in a variety of environments across the globe but mostly forests and wetlands. Birds are social animals that communicate with visual signs, calls and songs (Ajiboye, 2012). They display social behaviors such as cooperative breeding hunting, flocking and mobbing of predators. Birds live and breed in most terrestrial habitats and on all the seven Continents. As with any natural habitat, wetlands are important in supporting bird species diversity. A survey is a research method use for collecting data from a predefined group of respondents to gain information. Nigeria is blessed with many species of birds scattered throughout the different ecological regions. The avifauna of Nigeria include a total of 940 species, of which four are endemic (*Ibadan malimbe*, Jos plateau indigo, Rock fire finch and Anambra waxbill) and five are rare or accidental (species that rarely or accidentally occur in Nigeria). Over 10,000 varied species of birds reside presently on the Earth. Out of which about (83%) dwell in the continental regions while the remaining in islands (Baker *et al.,* 2008) Despite the considerable interest shown in the conservation of Nigerian ecosystems in recent years, little attention has been focused on the associated bird life, its inventory monitoring, distribution, and abundance. Although, bird life resources continue to sustain the rural dwellers in Kebbi State, the danger in it is the destruction of these valuable resources almost at the point of extinction. The ecosystems in Nigeria support a larger diversity of biomass of birds which is traditionally exploited and largely unmanaged. Illegal hunting is the major problem of game birds in Nigeria through the birds are killed to reduce their number (Gonzale, 2016).

Scientific Classification of Game Birds

Kingdom:	Animalia
Phylum:	Chordata
Class:	Aves
Sub-Class:	Neornithes
Super Order:	Carinatee
Order:	Galliformes
Sub-Order:	Galli and Opisthocome

(Atiku *et al.,* 2020)

2.6 Economic Importance of Birds

1. Source of protein food

2. Source of feather and oil especially around breeding area

3. Source of feather for beautification

4. Provide mutton birds

5. Source of income

6. They are kept as pets

7. They are also used in shooting reserve

8. Dispersal for seed

9. For research and education

10. For recreational purpose. (Atiku, *et al.,* 2020)

Under proper management, birdlife is an important resource to mankind's existence through the roles it plays in the balance of ecosystems, as a preferred material for research and a major base for the recreation and tourism industry. They also serve as raw material for several purposes such as provision of feather for the purpose of beautification of human environment, source of animal protein for human consumption. They also play important roles in scientific research work. Biodiversity loss of game bird distribution also threatens the structure and proper functioning of the ecosystem (Donald *et, al.,* 2006) Although all ecosystems are able to adapt to the stresses associated with reductions in biodiversity to some degree, biodiversity loss r educes an ecosystem’s complexity, as roles once played by multiple interacting species or multiple interacting individuals are played by fewer or none. The effects of species loss or changes in composition, and the mechanisms by which the effects manifest themselves, can differ among ecosystem properties, ecosystem types, and pathways of potential community change. At higher levels of extinction (41 to 60 percent of species), the effects of species loss ranked with those of many other major drivers of environmental change, such as ozone pollution, acid deposition on forests and nutrient pollution. Finally, the effects are also seen on human needs such clean water, air and food production over-time. For example, studies over the last two decades have demonstrated that more biologically diverse ecosystems are more productive (Balenger and phill, 2019). As a result, there has been growing concern that the very high rates of modern extinctions due to habitat loss, overharvesting and other human-caused environmental changes – could reduce nature’s ability to provide goods and services like food, clean water and a stable climate. (Fuller, 2019).

Study Area The study was conducted in Sanagi Village within Jega Local Government Area Kebbi State. Jega is a Local Government Area in Kebbi state, Nigeria. Its headquarter are in the town of Jega. It is situated in extreme kebbi central, it has an area of 891 Km^2 and a population of 193352 at 2006 National Population Census. It has a Geographical Coordinates 12.2258˚N, 4.3822˚E. and between latitude:12.3667, longitude: 4.6333. The mean annual temperature was between 35˚C and 40˚C, annual rainfall range of 450-1050mm and relative humidity ranged from 51-79% and 10-25% during rainy and dry seasons (Atiku, *et al.*, 2014).

Climate The climate condition of Kasar Jega is synonymous with that obtain in Kebbi and Sokoto region. Rainfall which is an important of climate in so far as agriculture is concerned, occupies the period starting mid-May to mid-September in which generally known as wet season. This attains mean annual rainfall of between 500 mm to 1,300 mm with a heavy concentration in the month of august which is locally known as *malka*. The wet season is followed by dry season which is commences from September to April. The dry season is characterized few or new absence of vegetation cover and non-incidence of rainfall. It is a period of low agricultural activities mainly restricted to fadama (flood plain) lands (Dicks *et al.*, 2016).

Vegetation The vegetation is Sudan savannah type and the soil is semi-arid type, characterize by frequent weathering and leaching due to poor soil structure and low organic matter content. (Atiku, 2019).

Occupation The main economic activity is agriculture and business/trading. And over 70% of the people practice one form of agriculture or the other (Atiku, 2019).

MATERIALS AND METHODS

Sampling Procedure and Data Collection

A reconnaissance survey was carryout in the study area, the topography of the area was observed in three different habitats (farmland, fadama and human habitat). In the study area, morning observation was made between the hours of 0600 and 1000 hours while the evening visit was from 1630 to 1830 hours when the temperature was relatively cool and the birds activities were high. On every site we recorded all birds seen or heard during 15 minutes, the first five minutes were used to wait until game bird species were settled due to arrival disturbances and the remaining ten minutes were used to record all species observed or heard on every occasion.

Sampling Materials

1 A field guide books: which was used to identify the birds sighted in the field. (Atiku *et al.*, 2020).

2. Binocular: which was used to sight birds from distance.

3. Recording book: for recording the features of the birds sighted.

Data Analysis

The data collected was subjected to descriptive statistics such as frequency, table, and percentage and statistical package for the social sciences (SPSS) was used.

RESULTS AND DISCUSSION

The result (Table 1.) showed that nine (9) game bird species were identified in the Fadama area, the morning visit has 137 numbers of game bird species and the evening visit has 116 numbers of game bird species, which consisted of a total of 243 game bird in the Fadama area. It was also found that speckled pigeon has the dominant numbers of birds (41) in the Fadama area. From the study, it was observed that the game bird species with the highest numbers in morning and evening visits were speckled pigeon with total abundance of 41 (16.87%). While White face tree duck species has the least numbers of game bird species 8 (3.29%). This is because, speckled pigeon is respected in the Islamic religion, and which is the dominant religion in the study area.

Similar research forms, Bradley (2014) shows that they are genetically varied with some forms of interaction between them.

Table 1. Abundance and proportion of game bird species in Fadama area of Sanagi Village, Jega Kebbi State, Nigeria

Scientific Name	Common Name	Local Name	Morning Visit	Evening Visit	Total	Percentage
1. *Bubulcus ibis*	Cattle Egret	Belbela	18	13	31	12.76
2. *Threskiornis aethiopicus*	African Sacred Ibis	Cilakku	12	18	30	12.34
3. *Columbia guinea*	Speakled Pigeon	Hasbiya	33	18	41	16.87
4. *Centropus senegalensis*	Senegal coucal	Ragon Maza	17	12	29	11.93
5. *Dendrocygna viduata*	White-Face Tree Duck	Kirinjijiya	5	3	8	3.29
6. *Spizastur melanoleucus*	Black and White Hawk Eagle	Shirwa	14	8	22	9.05
7. *Lamprotornis caudatus*	Long Tail Glossy Starling	Kila-Kilai	8	11	19	7.82
8. *Zenaida macroura*	Morning Dove	Kurciya	18	19	37	15.23
9. *Passer luteus*	Golden Sparrow	Bankwalo	12	14	26	10.69
TOTAL			**137**	**116**	**243**	**99.98**

Source; Survey Field (2021)

CONCLUSION AND RECOMMENDATION

The Fadama area of Sanagai Village area ecologically supported species diversity and relative abundance of game birds. The protection of the ecosystem will preserve the birds' diversity. More studies should be carried out obtain clearer picture of ecological preferences of game birds in the study area.

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EVALUATION OF THE DISTRIBUTION OF VEGETAL COVER USING INTEGRATED VEGETATION INDICES AND LANDSAT 8 IMAGERY

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ABSTRACT

This study uses methodologies unique to remote sensing and geographic information systems to critically examine the state of vegetation health over a brief period. Therefore, the Normalized Difference Vegetation Index (NDVI), Normal Literature Vegetation Moisture Index (NDMI), and the Structure Insensitive Pigment Index were used to measure the health of the forest ecosystems (SIPI). 2014 to 2023 was the time frame taken into account for this study. The utilised data were pre-processed according to industry standards (resize data, radiometric calibration, atmospheric correction). The Top of the Atmosphere was used to modify the satellite photos. The quantified-spatial findings of the overlayed vegetation indices derived from the analysis showed that in 2014, 25402.05 ha of the studied area had a concentration of "Low" vegetation, whereas 23913.36 ha of the region had a concentration of "High" vegetation. With 19078.83 hectares covered in "High" vegetation in 2023, there was a noticeable drop in the vegetation.

Keywords: Vegetal cover, Spectral analysis, Radiometric calibration, Remote sensing, Vegetation health

INTRODUCTION

Over the past few decades, the strain from anthropogenic and natural stress factors has steadily increased in the forest areas. It manifests as changes in how the land is utilized, fires, unsustainable management, air pollution, climatic changes, droughts, and a greater tendency for pests and pathogenic agents in many literary works (Andronache *et al.,* 2019; Lausch *et al.,* 2016; Romocea *et al.,* 2018; Herman *et al.,* 2019). Although cultural, spiritual, and social aspects are also crucial for an all-around healthy forest, they are not as significant as physical forest health (McAllister *et al.,* 2019). This fact naturally leads to the idea of "forest health," which was initially introduced by Aldo Leopold (1949). It was carefully examined in the 1990s (Kolb *et al.,* 1991), thereby giving a shared rationale for the wide range of research and methodologies that attempted to evaluate, measure, and monitor the health of forest ecosystems.

Even while the concept's meaning and implications may be viewed from many economic, social, and environmental perspectives (Tuominen *et al.,* 2008), they are all interrelated and founded on the same basic idea: the typical processes that occur in a forest setting. Furthermore, due to the issue's significance, the condition of forests is currently evaluated using hierarchically organized, unitary, and coherent working structures and fluxes. Among other techniques, vegetation indices have proven effective at tracking vegetation change. The Normalized Difference Vegetation Index is one of the most used indices for monitoring vegetation (NDVI). Data on plant biophysical features may be extracted from electromagnetic spectrum measurements in the visible, near-infrared, and mid-infrared ranges (EMS). The NDVI method is based on the observation that healthy vegetation has high reflectance in the NIR owing to internal reflection by the mesophyll spongy tissue of green leaves and poor reflectance in the visible region of the EMS due to Chlorophyll and other pigment absorption (Varghese *et al.*,2021).

Red and NIR bands of a sensor system may be compared to determine NDVI. Due to the strong reflectance in the NIR section of the EMS, NDVI values vary from -1 to +1. Because of this, healthy vegetation has high NDVI values between 0.1 and 1. The electromagnetic absorption properties of water, on the other hand, lead non-vegetated surfaces like lake bodies to have negative NDVI readings. Multi-temporal satellite data significantly enhance the temporal characteristic and reliability of multi-data. The approaches for detecting changes in plant cover using multitemporal remotely sensed data are discussed in this research. This research's specific goal is to evaluate the health of the vegetation utilising the study region as a case study.

MATERIALS AND METHODS

Description of the study area

In 1976, the Oluyole Local Government Area (LGA) was created. Its borders are shared with Ona-Ara, Ido, Ibadan South-West, and Ibadan South-East LGAs. It is a significant industrial area in Ibadan. The elevation is typically 200 meters above mean sea level. Four river basins drain it. Its vegetation includes grasslands as well as secondary rainforests (Figure 1). It is situated in latitudes 7°19'10” and 7°23'36” north and 3°50'36” and 3°55'33” east, respectively. It is one of Oyo state's most industrialized LGAs (Fidelix, 2021). The selection of this LGA is based on the presence of a state-owned Forest Reserve there (Onigambari Forest Reserve).

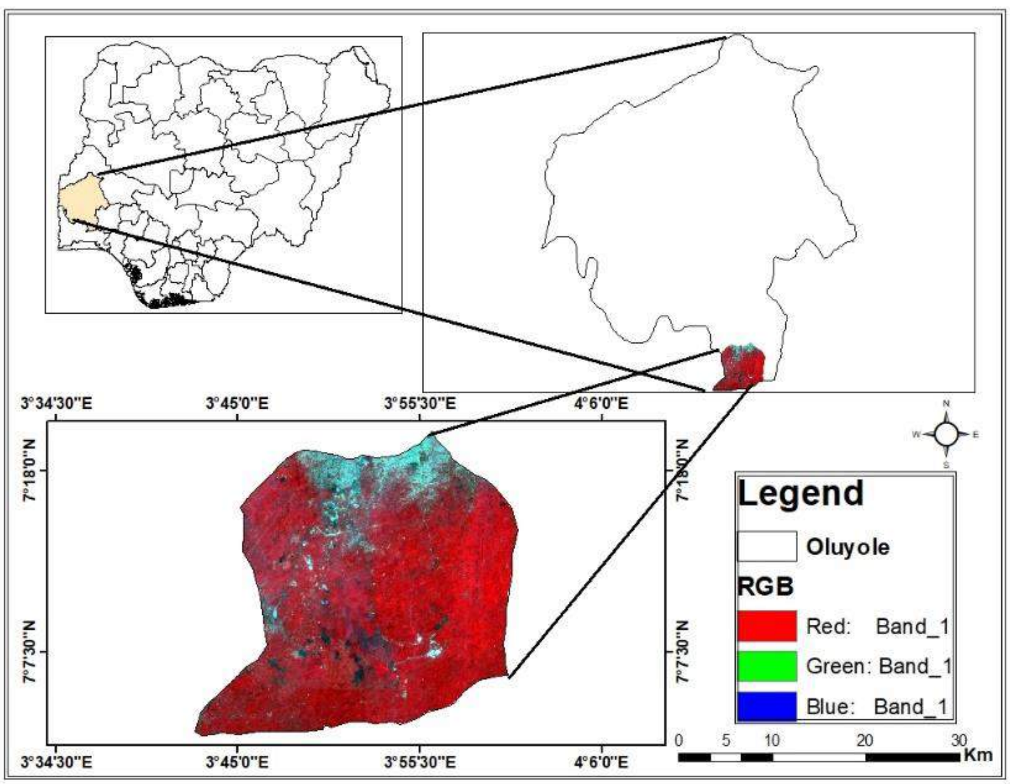

Figure 1: Map of the study area showing bands Red, Green and Blue (RGB) composite.

Radiometric calibration, which is mostly reserved for the FLAASH module (Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes) of the Envi program, was used to convert data from a DN format (Digital Number) in radiation values with a scale factor of 0.1. In many works that either provide a synthesis (Chen, 1996; Xue *et al.*, 2017) or are devoted to particular investigations, the description and applicability of the various indexes can be discovered (Heiskanen *et al.*, 2013; Avola *et al.*, 2019). The Normalized Difference Vegetation Index (NDVI), the Normalized Vegetation Moisture Index (NDMI), and the Structure Insensitive Pigment Index were chosen as the two spectral indices for the current investigation (SIPI). The most well-known and often used spectral index for the evaluation of the typological, physiological, and phenological characteristics of green vegetation is the NDVI, which belongs to the Broadband Greenness class (Jiang and Huete, 2010; Xu and Guo, 2014). Based on the idea that green plants with chlorophyll absorb light in the red spectrum (Red) and reflect radiation from the near-infrared spectrum (Near Infrared), Rouse et al. (1973) have demonstrated that through the combination of RED and NIR channels:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

While for the vegetation, the numbers are typically between 0.3 and 1, its values vary from +1 to -1. The vigour and health of the vegetation increase as we move closer to 1. Studies like the one in this one commonly employs the NDVI as a measure of defoliation and chlorophyll content since it does so correctly (Pettorelli *et al.*, 2005; Xiao and McPherson, 2005; Reid *et al.*, 2016).

Normalized Difference Moisture Index (NDMI)

The NDMI scale ranges from -1 to +1, and it measures the water stress of plants. According to the mapping of the examined region, each number obtained corresponds to a certain agronomic scenario. When utilizing Landsat 8 satellite images, the following calculation formula for NDMI is used:

$$NDMI = \frac{NIR - SWIR}{NIR + SWIR}$$

where:

NIR = near-infrared;

SWIR = shortwave infrared.

NDMI has been used successfully in various aspects of vegetation assessment (Taloor *et al.*, 2021),

Structure Intensive Pigment Vegetation Index (SIPI)

Based on the idea that both chlorophyll and carotenoids absorb radiation from the red spectrum, Penuelas et al. (1995) emphasized a particular type of measure called the Structure Intensive Pigment Vegetation Index (SIPI). Under situations of medium and high plant pigmentation concentration, he showed the association between the values of the differences (NIR - Blue) and (NIR - Red) from the radiation spectrum reflected by the plants, on the one hand, and that between carotenoids and chlorophyll, on the other:

$$SIPI = \frac{NIR - BLUE}{NIR + RED}$$

Its readings vary from 0 to 2, whereas the typical range for healthy, green vegetation is between 0.8 and 1.8.

RESULTS AND DISCUSSION

Normalised Difference Vegetation Index (NDVI) Spectral Analysis

The 2014 NDVI measurements had a spectral value range of -0.0269 to 0.9299 with an average of 0.8137. The study area's vegetation was particularly lush and luxuriant, which was shown by the high NDVI values. The eastern and western portions of the research region, which includes the Onigambari forest reserve, were dominated by the lush green vegetative cover. The NDVI values were modified in 2017. The range of the results, with 0.5521 serving as the mean spectral value, was between 0.0190 lowest and 0.7523 maximum.

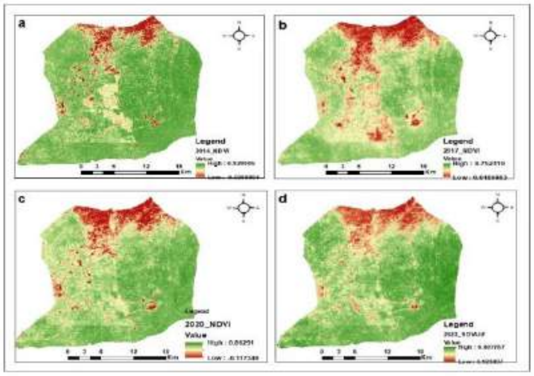

Figure 2: NDVI images of 2014, 2017, 2020 and 2023 showing the spectral values.

The decrease in the NDVI maximum value from 2014 to 2017 may be related to anthropogenic activities changing the vegetative cover. The NDVI maximum value saw some noticeable rises in 2020, rising from 0.7523 in 2017 to 0.8629 in 2020. The highest NDVI value decreased from 0.8629 in 2020 to 0.8076 in 2023. This explains why all parties must collaborate to lessen human activity inside the research area's vegetated areas (Figure 2 and Table 1). Figure 3 displays a visual depiction of the NDVI spectral statistics.

Table 1: Spectral Statistics of Normalised Difference Vegetation Index (NDVI)

Year	**Minimum**	**Maximum**	**Mean**	**St. Deviation**
2014	-0.0269	0.9299	0.8137	0.1092
2017	0.0190	0.7523	0.5521	0.1088
2020	-0.1173	0.8629	0.6598	0.1361
2023	0.1237	0.8076	0.6060	0.1167

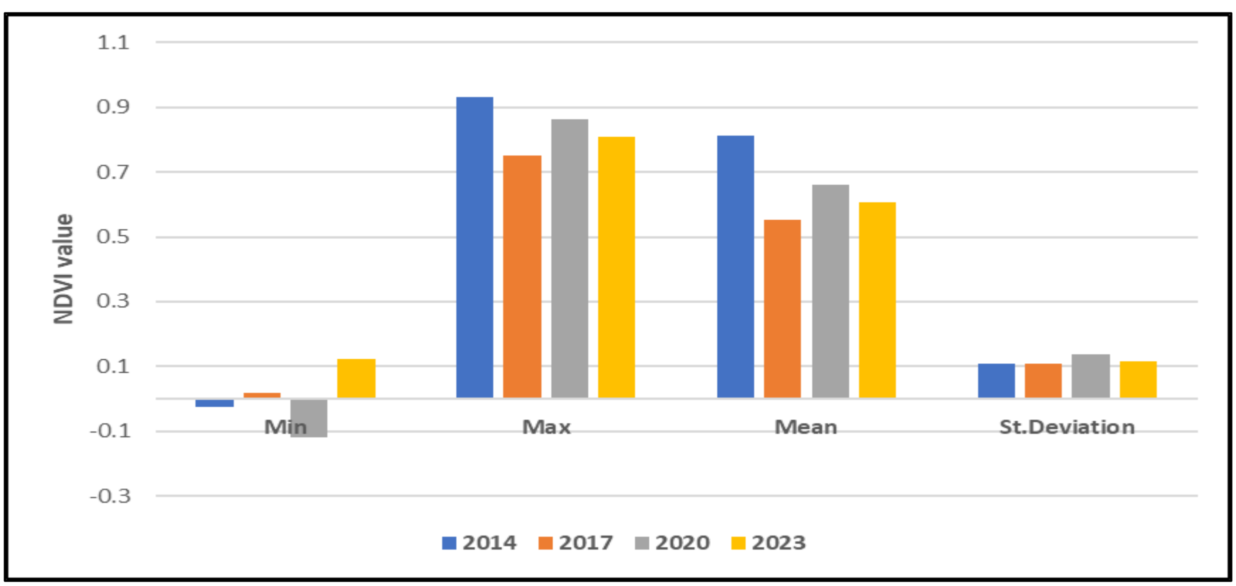

Figure 3: Visualisation of NDVI Statistics of 2014, 2017, 2020 and 2023.

Normalised Difference Moisture Index (NDMI) Spectral Analysis

This measure looks at how much moisture is held in a particular area of a plant at a specific period. 2014 saw an average NDMI spectral value of 0.0682. It significantly decreased in 2017, going from 0.0682 in 2014 to -0343. (Table 2). These alterations could be related to climate variations or other stress-producing factors. The vegetation's moisture content increased significantly in 2020, with an average NDMI value of 0.0602. With an average NDMI value of 0.0682 in 2023, there were no notable changes (Figures 4 and 5)

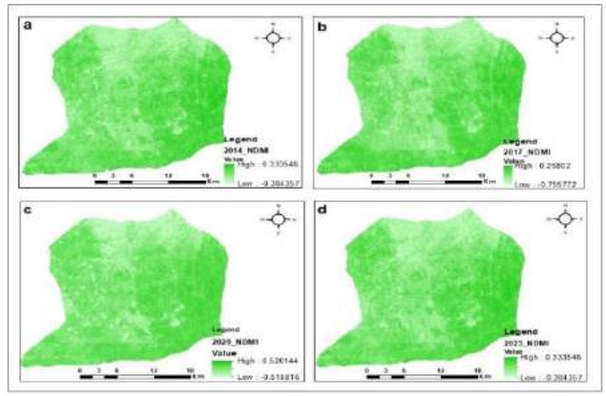

Figure 4: NDMI images of 2014, 2017, 2020 and 2023 showing the spectral values.

Table 2: Spectral Statistics of Normalised Difference Moisture Index (NDMI)

Year	Minimum	Maximum	Mean	St. Deviation
2014	-0.3844	0.3335	0.0682	0.1144
2017	-0.7558	0.2580	-0.0343	0.1128
2020	-0.5188	0.5261	0.0602	0.1240
2023	-0.3844	0.3335	0.0682	0.1144

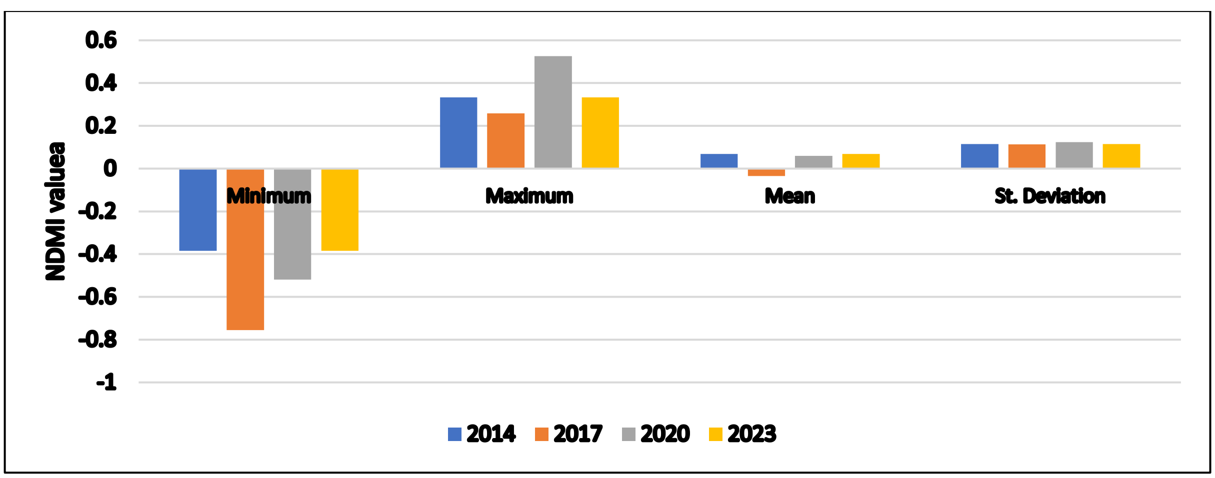

Figure 5: Visualisation of NDMI Statistics of 2014, 2017, 2020 and 2023

Structure Intensive Pigment Vegetation Index (SIPI) Spectral Analysis

The SIPI readings for 2014 varied from a low of 0.1405 to a maximum of 0.9267. (Table 3). The maximum SIPI fell to 0.7479 in 2017 and rose to 0.8591 in 2020. In 2023, there was a modest decline (Figures 6 and 7). The closeness between the indexes suggests that the vegetation indicators share certain characteristics.

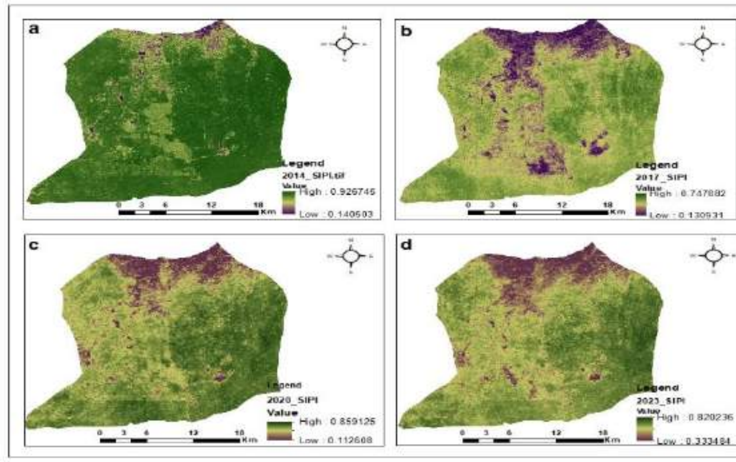

Figure 6: SIPI images of 2014, 2017, 2020 and 2023 showing the spectral values.

Table 3: Spectral Statistics of Structural Intensive Pigment Vegetation Index (SIPI)

Year	Minimum	Maximum	Mean	St. Deviation
2014	0.1405	0.9267	0.8310	0.0777
2017	0.1309	0.7479	0.5887	0.0697
2020	0.1126	0.8591	0.7029	0.0935
2023	0.3335	0.8202	0.6669	0.0771

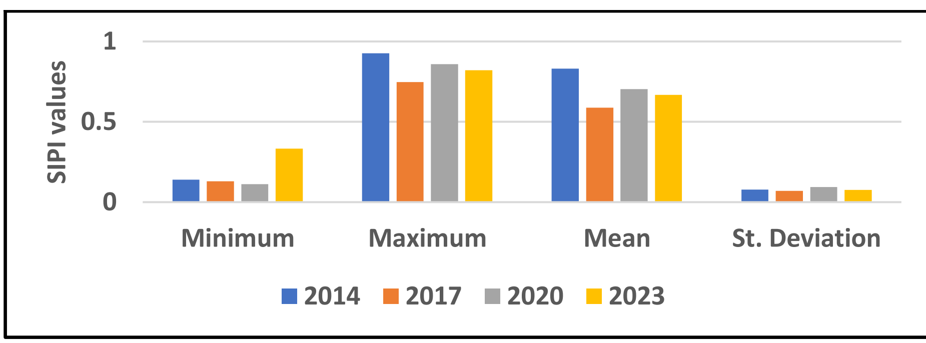

Figure 7: Visualisation of SIPI Statistics of 2014, 2017, 2020 and 2023.

Fused Vegetation Indices (FVI) Spectral Analysis

The three vegetation indexes have been combined to create this. To merge the three indices, the overlay procedure in ArcGIS software was used. Each vegetation indicator has advantages and disadvantages. Thus, to increase the strengths of the resulting index, it is essential to combine the three vegetation indices (FVI). Figure 8 demonstrated that during the research periods, the healthy vegetation predominated in the eastern part of the study region.

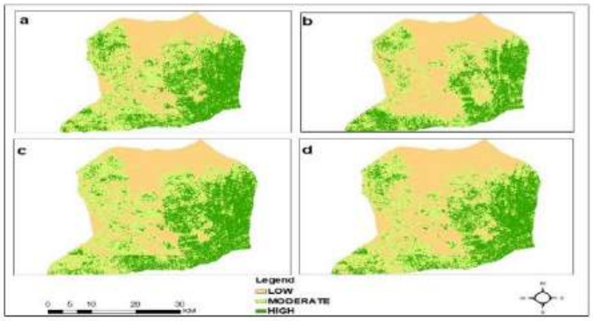

Figure 8: Fused Vegetation Indices (FVI) images of 2014, 2017, 2020 and 2023 showing spectral classes.

The maps of the fused vegetation indices were divided into three categories: "Low," "Moderate," and "High" for better analysis. In 2014, there were 25402.05 areas with "Low" vegetation, whereas there were 23913.36 hectares with "High" vegetation concentration (Table 4). With 19078.83 hectares covered in "High" vegetation in 2023, there was a noticeable drop in the vegetation.

Table 4: Spectral Statistics of Fused Vegetation Indices (FVI) Analysis

	2014		**2017**		**2020**		**2023**	
Class	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%
Low	25402.05	33	33694.29	44	27608.67	36	32041.80	42
Moderate	26838.72	35	23573.16	31	27043.65	36	25033.50	33
High	23913.36	32	18886.68	25	21501.81	28	19078.83	25

CONCLUSION AND RECOMMENDATION

The study revealed that the healthiest vegetation is also located in areas that have 'High' vegetation distribution. According to the NDVI Spectral Analysis conducted in 2014, NDVI values varied from -0.0269 to 0.9299 with an average spectral value of 0.8137. the three vegetation indices were combined, and the results revealed a considerable decline in vegetation in 2023, with 'High' vegetation covering 19078.83 hectares of the study area. Last but not least, future studies may entail developing a unique index for evaluating the health of plants and tracking changes over time. This might be created using a variety of pre-existing indices and customized to the particular situation. Governmental organizations and other parties involved in forest management must strive tirelessly to raise awareness of the need to preserve and safeguard our vegetative ecology.

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BIODIVERSITY CONSERVATION AWARENESS AND LIVELIHOODS IN SELECTED ILAJE LITTORAL COMMUNITIES, ONDO STATE, NIGERIA

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ABSTRACT

The Ilaje study location in lower Gulf of Guinea is part of the littoral zone in Ondo State, Nigeria. Several studies have been reported on coastal ecosystem and its biodiversity scenarios due to its' conservation priorities and sustainable livelihood in parts of Niger Delta region. Neither of these studies nor similar research on biodiversity conservation in coastal environment has been carried out in parts of Ilaje. Hence, the aim of this study is to evaluate the coastal biodiversity scenarios, livelihood and conservation efforts in selected Ileja communities (Odonla, Ikorigho, Molutehin, Odun-Igo and Awoye). Gradient – directed transect sampling and Wetland Ecosystem Dynamic Plot (WEDP) method was used to access the flora diversity, Participatory Rapid Appraisal (PRA) method was used for questionnaires and interviews and a hand-held geographic positioning system (GPS - *Garmin Dakota 10 model*) was adapted for direct observational and ground-truthing, sampled point coordinates and data collection. Data analysis was by descriptive analytical tools (frequency count, percentages and charts and levels of response anchors using the Likert –Type scale 7-point level of agreement and 5-point level of agreement). Result of biodiversity awareness of natural resources was high for the fishes; with 84% awareness in Odonla, Molutehin (84%) and Odun-Igo (84%); Ikorigho (88%) and Awoye (92%). The least known resources include: Pig, Mudskipper, and Tortoise respectively with 4% awareness in Odonla, 4% of Snail in Molutehin, and 8% for Cray fish and Periwinkle respectively in Odun-Igo and Awoye. The level of awareness for community protection effort was 24% in Ikorigho and Odun-Igo respectively and 44% in Awoye. Government protection efforts were 36% in Odonla and 76% in Molutehin. The choice for government effort than traditional effort in flora (mangrove) protection were 88%, 56%, 100%, 84% and 48% in Odonla, Ikorigho, Molutehin, Odun-Igo, and Awoye, respectively. Conservation policy support was highest (96%) in Molutehin and least (44%) in Odun-Igo. In the absence of groves recorded 16%, 76% 92% and 68% presence in Ikorigho, Molutehin, Odun-Igo and Awoye, respectively. It can be highlighted that the condition of the coastal biodiversity scenarios of Ilaje can be assessed as this may assist the government in executing the legislation at its disposal.

Key words: Ilaje Communities, natural resources, government protection areas and biodiversity conservation

INTRODUCTION

The Ilaje coastal landscape in southern parts of Ondo State is incredibly parts of a well-endowed wetland ecosystem in lower Gulf of Guinea supporting the highest concentration of biodiversity on Earth. Biodiversity entails degree of natures' variety and variability including the number and frequency of genes, species and ecosystems in their totality among living organisms (plant, animals and microorganism) from all ecosystems, and ecological complexes of which they are part of (Soule and Wilcox, 1990). It constitutes the resource base of human survival and economic well-being of families, communities, nations and future generations. It can be described as the diversity of life forms on Earth, variety of all living things, the places they inhabit, and the ecological interaction between them. The concept of biodiversity came into full emergence following the declaration and adoption of Agenda 21 at the Convention on Biological Diversity (CBD) during the Earth Summit at Rio de Janeiro, Brazil, in 1992 (McNeely and Scherr, 2001).

Biodiversity is among the important feature of major biomes of ecosystems with increasing recognition from the scientific community on Earth. It is directly responsible for about 40% of the world's economy and greater percentage (70%) of the rural poor in the world depends directly on biodiversity for their survival and well-being (CBD, 2010). Biological diversity can be measured in terms of different components (landscapes, ecosystems, communities, species / populations and genes), each of which has structural, compositional and functional attributes (Sandy *et al*., 2001).

Several studies have been carried out and documented on coastal biodiversity for conservation priorities and sustainable livelihood in parts of Niger Delta (John *et al*., 2013; Onwuteaka, 2014; Anthony and Adeleke, 2014; Ajibola *et al*., 2015; Ayansina and Ulrike, 2015; WIA, 2015; John *et al*., 2016). Similarly, there are many traditional conservation practices of indigenous communities in many parts of the world, which contributed to the conservation and protection of biodiversity. In traditional societies, sustainable natural resource and environmental management is driven by the intimacy between the human communities and behaviours, belief systems and local cultures (Rist *et al*., 2003). Despite the characteristics and importance of Ilaje coastal biodiversity ecosystem, the area and its ecosystem have been subjected to enormous pressures upon it sustainable livelihood and benefits for several decades. This informed the reason for the initiation of this project, to ascertain the conservation awareness by the inhabitants of the littoral region in salvaging the area by preventing further declining and threat to biodiversity scenarios thus, projecting future directions and initiatives for sustainable development planning and restoring biodiversity for conservation priorities, investment and sustainable livelihood.

MATERIALS AND METHODS

Description of study area, location and site:

Ondo State (AKA: Sunshine State) with its' capital in Akure is situated between longitudes 4"30" and 6" East of the Greenwich Meridian, 5"45" and 8" 15" North of the Equator (Fig. 2.1). State shares boundary with Ekiti, Kwara, and Kogi States in the North; Edo State in the East; Oyo, Ogun and Osun States in the West; Delta and the Bight of Benin of the Atlantic Ocean in the South.

It has a tropical climate environmental condition with two distinct seasons (rainy and dry seasons), maximum temperature annually ranging from 21^{o}C to 29^{o}C, relatively high humidity, and maximum rainfall varying from 2000mm - 1150mm. The vegetation system is luxuriant with both heterogeneous and homogenous discrete structural formation and composition. The State comprises 18 Local Council Areas, including **Ilaje - study location (**with headquarter at Igbokoda). The study location is known for its major five Kingdoms: Ugbo, Mahin, Etikan, Aheri and Igbotu consisting of over 100 communities including such sampled sites as: Odonla, Ikorigho, Molutehin, Odun-Igo and Awoye (Fig. 2.1).

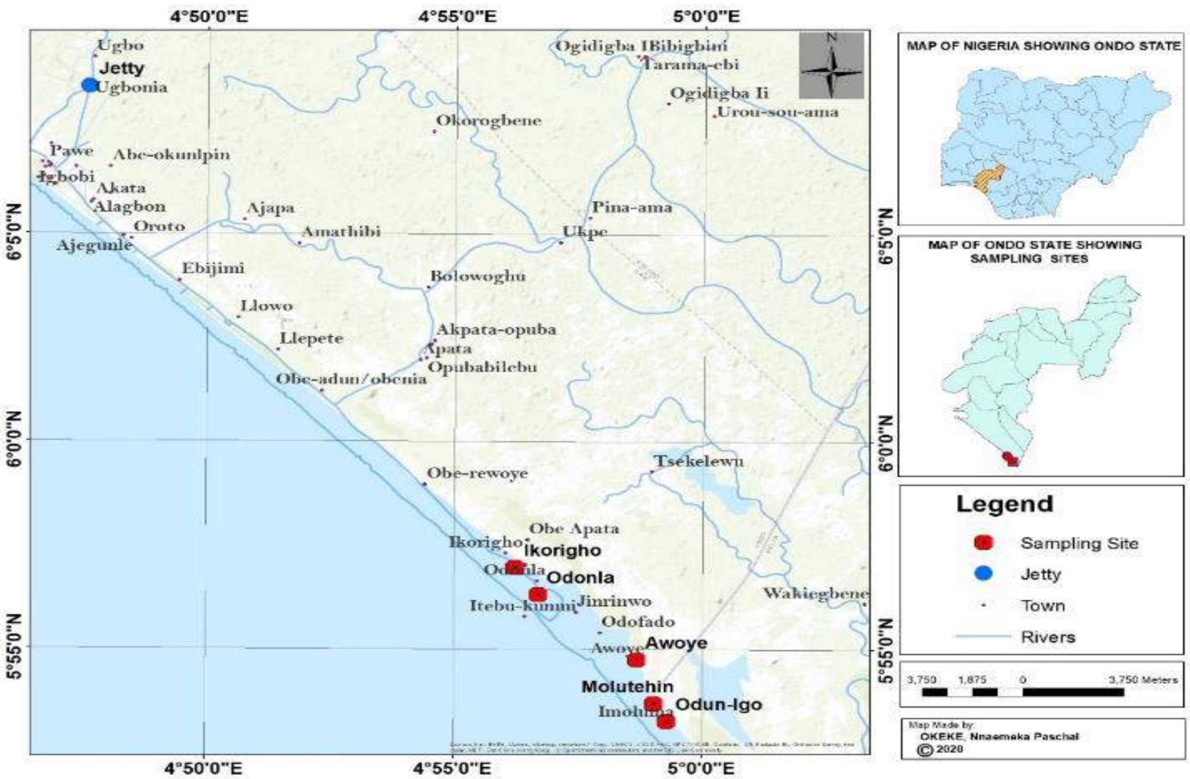

Fig. 2.1: Nigeria indicating Ondo State (the study area), location and sampled site

Field Sampling, Data Collection and Analysis

A Participatory Rapid Appraisal (PRA) and a purposive and random sampling technique was adapted for the administration of well-structured questionnaires and focused group discussions and interviews with key informant (Edet *et al*., 2017; Edwin-Wosu and Anaele, 2018) at the selected sampled sites (**Odonla, Ikorigho, Molutehin, Odun-Igo and Awoye**).

Gradient – directed transect sampling and Wetland Ecosystem Dynamic Plot (WEDP) method (Andy, 2004) for assessing: the biodiversity composition based on field direct observational and ground-truthing to acquire information on the livelihood natural resource capital assets and conservation awareness of the study area.

The ground-truthing was adopted to validate the sampled site using a hand-held Garmin geographic positioning system (GPS - *Garmin Dakota 10 model*) for georeferencing of exact sampled point (Table 2.1) of the sampled sites (Odonla, Ikorigho, Molutehin, Odun-Igo and Awoye).

Data was subjected to descriptive analytical tools such as: frequency count, percentages and charts (Edet *et al*., 2017). Levels of response anchors using the Likert –Type scale 7-point level of agreement and 5 point level of agreement (Vagias, 2006) was adapted to ascertain the capital assets (natural resources) of the respondents and biodiversity conservation status of the coastal environment at study area.

Table 2.1: Coordinates of Sampled Site in parts of Ilaje Coastal Ecosystem, Ondo State

Latitude (N)	Longitude (E)	Altitude	Community / Sampled site
			Igbokoda
06^{o}08.543’	004^{o}47.618’	17ft	Jetty
			Odonla
05^{o}56.407’	004^{o}56.768’	9	Jetty
05^{o}56.391’	004^{o}56.743’	28	Sampled site
05^{o}56.387’	004^{o}56.737’	21	Sampled site
			Ikorigho
05^{o}57.042’	004^{o}56.241’	27	Sampled site
05^{o}57.035’	004^{o}56.222’	43	Sampled site
			Molutehin
05^{o}53.816’	004^{o}59.048’	30	Jetty
05^{o}53.802’	004^{o}59.025’	15	Jetty
05^{o}53.782’	004^{o}59.034’	15	Jetty
05^{o}53.817’	004^{o}59.054’	10	Sampled site
05^{o}53.743’	004^{o}59.021’	4	Sampled site
05^{o}53.743’	004^{o}59.017’	7	Sampled site
05^{o}53.774’	004^{o}59.046’	-15	Sampled site
			Odun-Igo
05^{o}53.433’	004^{o}59.231’	7	Jetty
05^{o}53.427’	004^{o}59.226’	13	Jetty
05^{o}53.404’	004^{o}59.237’	14	Jetty
05^{o}53.446’	004^{o}59.250’	14	Jetty
05^{o}53.297’	004^{o}59.287’	-1	Sampled site
05^{o}53.300’	004^{o}59.287’	4	Sampled site
05^{o}53.324’	004^{o}59.288’	15	Sampled site
05^{o}53.299’	004^{o}53.302’	24	Sampled site
05^{o}53.444’	004^{o}53.189’	59	Sampled site
			Awoye

05°54.838’	004°58.766’	9	Sampled site
05°54.901’	004°58.737’	4	Sampled site
05°54.904’	004°58.693’	12	Sampled site

RESULTS

The results of the study have enumerated the biodiversity scenarios of conservation priorities in parts of Ilaje coastal ecosystem with the known species of coastal littoral flora, aquatic faunas and patches of sacred groves of natural resources. Various trend of conservation awareness with regards to the environmental data based on the known livelihood natural assets in parts of Ilaje coastal communities (Figs. 3.1.-3.6) have also been revealed. The level of awareness of biodiversity resources of sustainable livelihood by the respondents has indicated fishes as a well-known resource capital among other natural resources with 84% awareness in Odonla, Molutehin and Odun-Igo respectively; 88% in Ikorigho and 92% in Awoye. The least known resources include: Pig, Mudskipper, and Tortoise with 4% awareness respectively in Odonla, 4% Snail in Molutehin, and 8% Cray fish and Periwinkle in Odun-Igo and Awoye respectively (Fig 3.1). The level of awareness in community versus government protection effort has recorded 24% in Ikorigho and Odun-Igo respectively and 44% in Awoye for community protection effort, while 36% and 76% for government protection effort in Odonla and Molutehin respectively (Fig. 3.2).

The level of respondents’ preference for flora (mangrove) protection by government effort against traditional effort recorded 88%, 56%, 100%, 84% and 48% preference in Odonla, Ikorigho, Molutehin, Odun-Igo, and Awoye respectively (Fig. 3.3). Direct support for conservation policy among inhabitants has recorded a greater level of positive response with the following percentages of agreement: 92%, 84% 96% 44% and 72% in Odonla, Ikorigho, Molutehin, Odun-Igo, and Awoye respectively for mangrove conservation (Fig. 3.4). The presence and absence of conservation area indicated greater level of absence with 92%, 84%, 80%, 64% and 28% in Odonla, Ikorigho, molutehin, Odun-Igo and Awoye respectively, with few preserves of 4% in Ikorigho and Odun-Igo respectively and 36% in Awoye (Fig. 3.5). Sacred groves (shrine) have shown 16%, 76% 92% and 68% presence in Ikorigho, Molutehin, Odun-Igo and Awoye respectively, 88% and 56% absence in Odonla and Ikorigho respectively (Fig. 3.6).

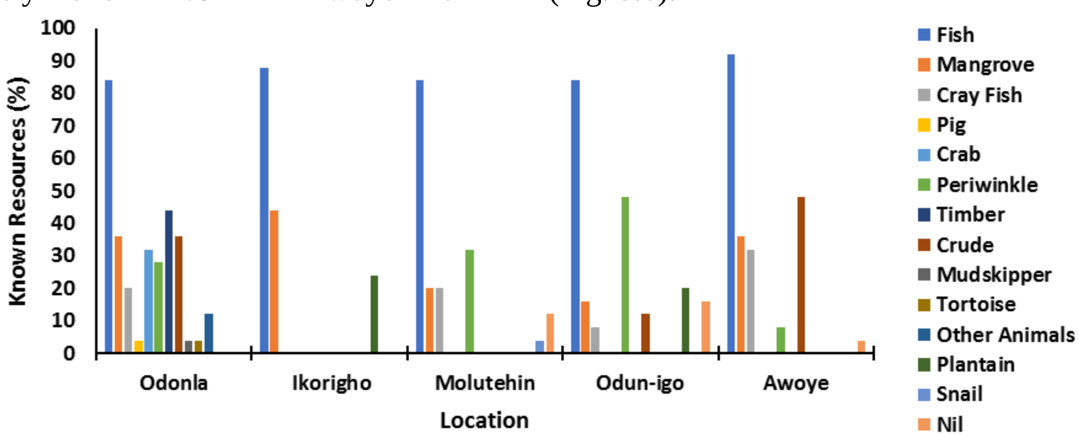

Fig. 3.1: Biodiversity awareness of Respondents in parts of the sampled

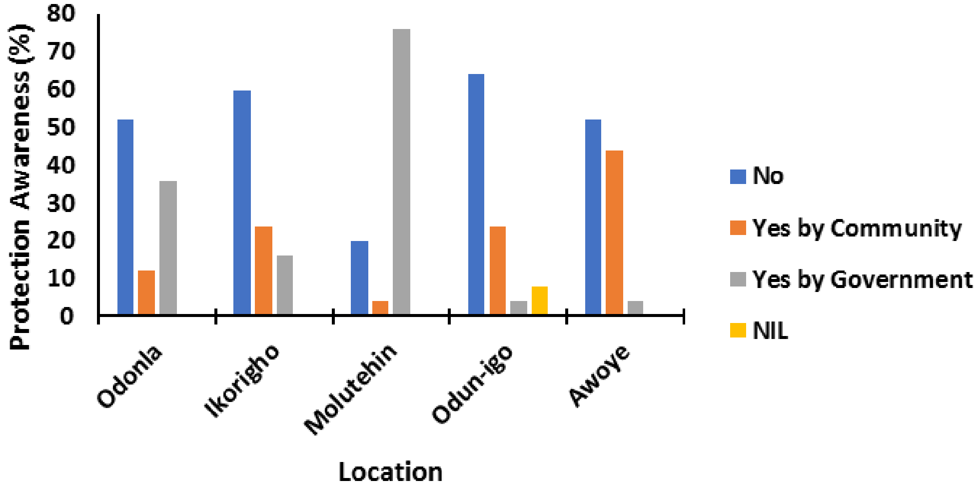

Fig.3.2: Awareness of Community versus Government protection effort in parts of the sampled Communities in Ilaje study location

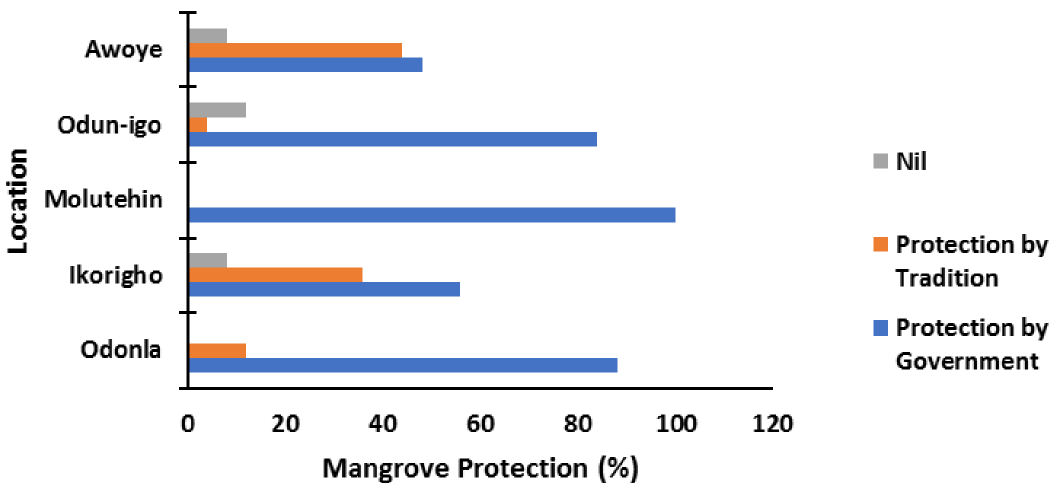

Fig.3.3: Flora protection effort in parts of the sampled Communities in Ilaie studv location

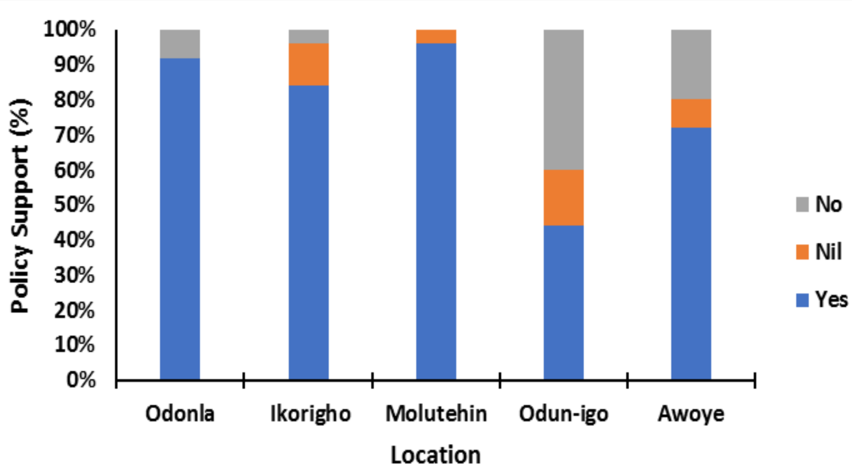

Fig. 3.4: Community support for conservation policy in parts of the sampled site in Ilaje study location Ilaje Coastal

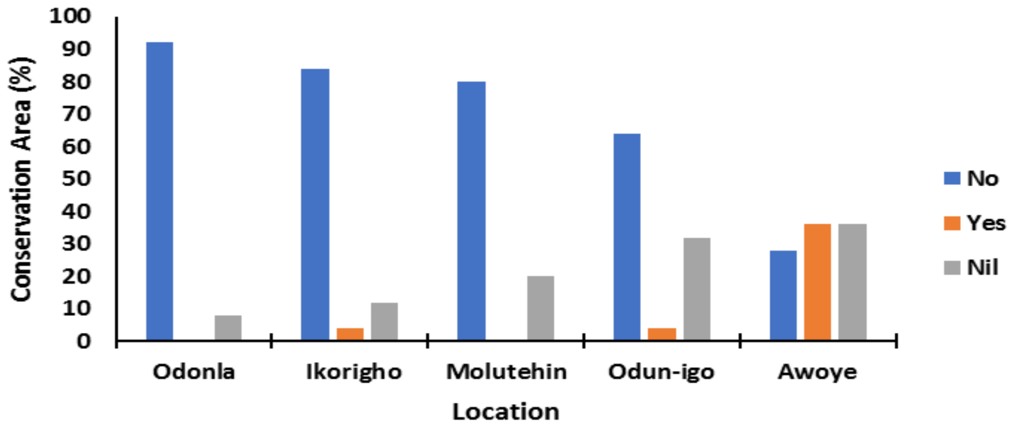

Fig.3.5: Frequency of Conservation Area in parts of the sampled Communities in Ilaje study location

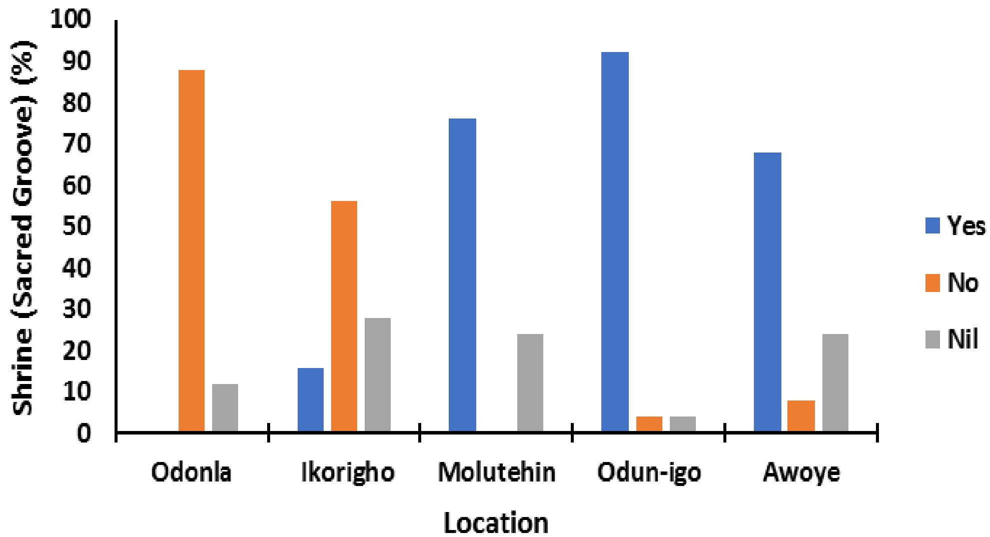

Fig.3.6: Percentage Composition of Sacred Grove in parts of the sampled Communities in Ilaje study location

DISCUSSION

The assessment of the conservation profile of the coastal biodiversity ecosystem has revealed levels of agreement and responses among inhabitants in terms of: biodiversity awareness, protection awareness, flora (mangrove) protected areas, policy support for protected areas, conservation areas and sacred groves. The Ilaje sampled sites were characterized by diverse resources of the coastal ecosystem for the sustainable livelihood of the community members. The major resources are the aquatic lives of both fresh and marine water fishes among other resources, with the inhabitant of Awoye having the highest level of awareness in biodiversity resources in the order: *Awoye>Ikorigho> Odonla= Molutehin= Odun-Igo.* Though a greater proportion of inhabitants were not at all aware of any protection effort, the awareness of government and community efforts were respectively noted. The level of awareness based on Likert 5-point scale was in the order: *extremely aware> moderately aware> somewhat aware> slightly aware* correspondingly in *Molutehin> Odonla> Ikorigho> Odun-Igo> Awoye* for government protection awareness and vice-versa in the order: *Awoye> Ikorigho> Odun-Igo> Odonla>Awoye> Molutehin* for community protection awareness.

Protected areas (PAs) are fundamental tool to conserve the biodiversity and natural ecosystems of the earth (Laurance, 2013). They are socio-ecological systems whose management and sustainability heavily influence and are influenced by people (Cumming and Allen, 2017). A number of empirical studies have estimated the effects of PAs on poverty alleviation as well as on the livelihoods of local community (Canavire-Bacarreza and Hanauer, 2013; Bennett and Dearden, 2014; Niedziałkowski *et al*., 2014; Heagney *et al*., 2015; Chao *et al*., 2018). In light of the above several government effort have been made toward protected areas; the International Union for Conservation of Nature (IUCN) has developed a set of guidelines that define what constitutes a protected area and categorise PAs into six management types and four governance types (Dudley, 2008; Day *et al*., 2012). Today, about 15% of the world's land and inland water areas outside of Antarctica, 10% of the coastal and marine areas within national jurisdictions, and 4% of the world's oceans are part of PAs (UNEP-WCMC and IUCN, 2016).

Research on coastal wetland has identified the need for increased awareness on the use of wetland resources that are neglected or unused because of a lack of indigenous knowledge about their economic value (Thapa and Dahal, 2009). Several studies have earlier proposed a community-based conservation approach for better wetland resource use and conservation. For successful conservation and management, the participating local communities should understand and be fully aware of the importance of wetlands (Williams, 2002). From a socio-ecological perspective of the present study the level of agreement in the order of inhabitants respondence has indicated *Molutehin>Odonla>Odun-Igo>Ikorigho>Awoye* in their preference for government against traditional protection effort. The implementation of community forest programs, which also incorporate the community-based conservation approach along with many other pro-poor aspects (equal access and equitable resource distribution) in the lake complex, can be a good option because they empower the poor and disadvantaged resource-dependent communities and improve their livelihoods in the long run (Andrianandrasana *et al*., 2005, Bajracharya *et al*., 2006).

The support for conservation policy has recorded a greater agreement among inhabitants in the order: *Molutehin> Odonla> Ikorigho> Awoye> Odun-Igo* and vice- versa in disagreement among the inhabitants of the community in the order: *Odun-Igo> Awoye> Odonla>Ikorigho>Molutehin.* Legislation, policies, and programs that accommodate local people in the decision-making process make resource conservation cost-effective and sustainable (Lamsal *et al*., 2015). To assist managers and policy makers, research must: understand the interlinkages between societal, environmental and ecological processes that underpin coupled human-ecosystem interactions (Marchant, and Lane, 2014); and identify and value the mix of economic, social and ecological benefits received by stakeholders from the protected ecosystems (Silvestri *et al*., 2013). Community based conservation is a better alternative compared to central level handling of natural resources and is an effective tool in solving conflict and engaging community participation for resource conservation, including wetlands (Trisurat 2006). It has opined that decentralized participatory conservation programs could help resource-dependent developing countries minimize obstacles between conservation and sustainable development if they are implemented carefully. (Baral and Heinen, 2007).

This present report has also revealed the absence of conservation areas (Protected Areas), despite non-significant patches of conservation areas observed in just three communities (Ikorigho, Odun-Igo and Awoye) as well as sacred groves across the respective communities. Sacred grove is an ecosystem biome endowed with whole lots of biodiversity, and natural resource potential that needs to be harnessed through its ecosystem services vis-à-vis; Provisioning, Regulating, Cultural and Supporting / habitat services. Therefore, the biodiversity-rich sacred groves are of immense ecological significance. Sacred groves play important role in the conservation of flora and fauna. Besides, several rare and threatened species are found only in sacred groves, which are perhaps, the last refuge for these vulnerable species among the ecosystem services. Based on the conservation status of the ecosystem the respondence of the inhabitants were in agreement for the protection of conservation areas by both government and traditional efforts which is in tandem with the level of awareness and support policy for protection.

CONCLUSION

The assessment of the conservation profile of the coastal ecosystem biodiversity has revealed levels of agreement among inhabitants in terms of biodiversity awareness, protection awareness, flora (mangrove) protected areas, policy support for protected areas, conservation areas and sacred groves. The biodiversity scenarios though at variance have recorded in the respective community diverse species of coastal littoral plant, and animals including aquatic faunas and patches of sacred grove. Based on the conservation status of the ecosystem the respondence of the inhabitants was in agreement for the protection of conservation areas by both government and traditional efforts which is in tandem with the level of awareness and support policy for protection. The results obtained shall widen the knowledge on biodiversity scenarios; livelihood and conservation scenarios associated with the interaction between the inhabitant of the area and natural resource capital assets of the environment.

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IMPACTS OF ENVIRONMENTAL STATISTICS ON ECOSYSTEM HEALTH

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ABSTRACTS

Ecosystem deals with the complex of living organisms, their physical environment and all their interrelationship in a particular unit of space. Cumulative impacts of chronic stress from human activities such as releasing of waste residual like release of contaminant to the air, water as well as land among others has led to serious unhealthy ecosystem. Recovery of ecosystem health has become societal goals' today. Ecosystem health is of paramount importance for maintaining biodiversity and ensuring ecological stability. This paper explores the crucial role of environmental statistics in understanding and assessing ecosystem health. By analyzing various statistical approaches and their applications in monitoring and managing ecosystem health, we shed light on the multidimensional impact that statistics has on environmental science and policy. The findings suggest several statistical methods but employed multivariate statistical analysis. The results from PCA and CCA provide valuable insights into the ecosystem health of Lake EcoClear. PC1, primarily related to water quality, indicates that variations in water quality parameters play a significant role in shaping the overall health of the lake. These results demonstrate the utility of multivariate statistical techniques in assessing the health of freshwater ecosystems. The use of PCA and CCA provides a holistic view of the complex relationships between environmental variables and biological communities.

Keywords: Ecosystem, contaminant, ecosystem health, environmental statistics

INTRODUCTION

Ecosystems are the foundation of life on Earth, encompassing complex interactions between living organisms and their physical environments. Ecosystem also deals with the complex of living organisms, their physical environment and all their interrelationship in a particular unit of space. They vary widely in size, from tiny microcosms in a pond to vast tropical rainforests or the entire planet itself. Ecosystems are complex, dynamic systems, and their health is integral to the well-being of both natural environments and human societies. Understanding and quantifying ecosystem health has gained prominence in recent decades, with the concept extending beyond traditional ecological assessments. This paper delves into the holistic concept of ecosystem health and the impacts of environmental statistics in its assessment. Understanding ecosystems is crucial for addressing ecological challenges and promoting conservation efforts.

MATERIALS AND METHODS

Ecosystem health

Ecosystem health can simply be described as the capacity for maintaining biological and social organization on the one hand and the ability to achieved reasonable and sustainable human goals on the other hand. This implies that ecosystem health is as much about sustaining human communities, economic opportunity, human and animal health as it is about sustaining the biological functions of ecosystems. Its concepts and definition is a multidimensional and evolving concept. It encompasses the vitality, resilience and overall integrity of ecological system. Seminal works by Rapport et al. (1998) and Chapin et al. (2000) underscore the holistic nature of ecosystem health, emphasizing the significance of biodiversity and habitat quality in assessing and managing it. Ecosystem health reflecting a growing awareness of the need to protect and restore natural systems. Numerous studies have contributed to our understanding of ecosystem health, including the development of indices and indicators that serve as proxies for overall ecosystem condition (costanza *et al.*, 1992; rapport *et al.*, 1998). Environmental statistics play a crucial role in quantifying these indicators, enabling rigorous assessment of ecosystem health.

In addition to traditional ecological indicators, environmental statistics allows for more nuanced evaluations. For instance, spatial statistics can assess the distribution of species within an ecosystem (Legendre and Legendre, 1998), and time series analysis can reveal long-term trends and potential disruptions (Zuur *et al.*, 2007). This interdisciplinary approach is essential for comprehensively understanding and managing ecosystem health.

Causes of Unhealthy Ecosystem:

Cumulative impacts of chronic stress from human activities include the release of waste residual like releasing of contaminant to the air, water as well as land; overharvesting and physical restructuring of both terrestrial and aquatic ecosystem such as dams, water diversions, roads, and utility corridors which fragment the landscape; and the introduction of exotic (species not native to the ecosystem). Climate change and depletion of the protective stratospheric ozone layer. The general effects of acute and chronic stress result in Ecosystem Distress syndrome (EDS). It manifests inform of enhanced volatility of fluctuations in components population number, reductions in biodiversity, simplification of food webs through elimination of key species, relative depletion of the larger and longer – lived biotic components, declining yields or harvests, increasing disease prevalence (within both plant and animal species), and increases in dominance by exotic species. Also, most terrestrial ecosystem (e.g forest grasslands), as damaged system, show reduces secondary productivity and altered rates of nutrient cycling. These changes, in turn, result in impairment of ecosystem services such as portable water.

Environmental Statistics in Ecosystem Health:

Environmental statistics offers indispensable tools for the quantification and assessment of ecosystem health. It can help in describing environmental problems in terms of mathematical modeling to understand the impacts of the chosen variables understudy and show the direction of change – increase or decrease – or the nature of the relationship – positive or negative. Statistics generally is an important field because it helps us understand the general trends and patterns in a given data set. It involves in analyzing data and drawing conclusion from it. This help in making prediction about the future and behavior of the variables understudy. This section reviews the role of environmental statistics, including the quantification of biodiversity (Shannon and Weaver, 1949; Simpson, 1949) and habitat quality (Forman, 1995). Spatial statistics (Legendre and Legendre, 1998) are fundamental in analyzing species distribution patterns, while time series analysis (Box and Jenkins, 1970) provides insights into ecosystem dynamics.

Recent Developments:

Recent research developments have expanded the application of environmental statistics in assessing ecosystem health. Environmental economics and ecosystem services valuation (Costanza *et al.,* 1997; Daily *et al.*, 1997) offer economic perspectives in evaluating ecosystem health. Advances in multivariate statistical techniques (ter Braak, 1986) and generalized linear models (McCullagh and Nelder, 1989) have strengthened our ability to interpret complex ecological data. Having shown several statistical methods which can be used for the analysis of the ecological health data. But Multivariate Statistical Analysis which consists of Principal Component Analysis (PCA) and Canonical Correspondence Analysis will be used here.

Multivariate Statistical Analysis:

Principal Component Analysis (PCA):

PCA is used to reduce the dimensionality of data and identify underlying patterns in ecosystem health indicators Jolliffe (2002). The central idea of principal component analysis (PCA) is to reduce the dimensionality of a data set consisting of a large number of interrelated variables, while retaining as much as possible of the variation present in the data set. This is achieved by transforming to a new set of variables, the principal components (PCs), which are uncorrelated, and which are ordered so that the first few retain most of the variation present in all of the original variables. Principal component analysis is the oldest and best-known technique of multivariate data analysis. It was first coined by Pearson (1901), and developed independently by Hotelling (1933). Like many other multivariate methods, it was not widely accepted nor used until the advent of electronic computers, but it is now well entrenched in virtually every statistical software packages. Principal Component Analysis (PCA) is the general name for a technique which uses sophisticated underlying mathematical principles to transforms a number of possibly correlated variables into a smaller number of variables called principal components. The origins of PCA lie in multivariate data analysis; however, it has a wide range of other applications. PCA has been called one of the most important results from applied linear algebra and perhaps its most common use is as the first step in trying to analyze large data sets. Some of the other common applications include; denoising signals, blind source separation and data compression. In general terms, PCA uses a vector space transform to reduce the dimensionality of large data sets. Using mathematical projection, the original data set, which may have involved many variables, can often be interpreted in just a few variables (the principal components).

(i) **Canonical Correspondence Analysis (CCA):** CCA helps establish relationships between environmental variables and species composition, offering insights into the drivers of ecosystem health ter Braak (1986). Canonical Correspondence Analysis (CCA) using secondary data. CCA determines the relationship between the species and the environment. CCA is unusual among the ordination methods used in community analysis in that the ordination of the community data matrix (species) is constrained by a multiple regression on its relationships to environmental variables.

(ii) **Regression Analysis**:

Generalized Linear Models (GLMs): GLMs allow for modeling relationships between ecosystem health indicators and environmental factors (McCullagh and Nelder, 1989). Generalized Linear Modeling (GLM) unifies several statistical techniques, providing a stable and modular foundation on which to build a useful knowledge of statistical modeling. GLM enable a re- Generalized Additive Models (GAMs): GAMs provide a flexible framework for capturing non-linear relationships between variables (Hastie and Tibshirani, 1986).

(iii) **Spatial Statistics**:

- Spatial Autocorrelation Analysis: This method examines the spatial patterns of ecosystem health indicators and identifies areas with similar values, helping to detect spatial trends and dependencies (Cliff and Ord, 1973).

- Geostatistics: Geostatistical techniques, such as kriging, are used to interpolate and predict ecosystem health values in unmeasured locations (Cressie, 1993).

(iv) **Time Series Analysis**:

Autoregressive Integrated Moving Average (ARIMA) Models: ARIMA models are used to analyze temporal trends and cyclical patterns in ecosystem health data (Box and Jenkins, 1970).

Spectral Analysis: Spectral analysis helps in identifying periodic patterns or frequencies in time series data, revealing long-term trends and seasonality (Chatfield, 1989).

(v) **Species Abundance Models**:

Species-Area Relationship (SAR): SAR models examine the relationship between the area of a habitat and the number of species it can support (Rosenzweig, 1995).

Species Abundance Distributions (SAD): SAD models describe the distribution of individuals among species in a community, shedding light on community structure and diversity (Preston, 1962).

(vi) **Indicator Species Analysis:**

Indicator Species and Biotic Indices: Indicator species analysis involves the identification of species that are sensitive to environmental changes, often used in habitat-specific assessments (Camargo and Kapos, 1995; Carignan and Villard, 2002).

Hypothetical Dataset:

For the purpose of this work, we will consider a simplified dataset for assessing the ecological health of a small forest ecosystem. We have measured two variables, "Biodiversity" and "Habitat Fragmentation," at several locations within the forest. The dataset is shown on the table below:

Location	Biodiversity	Habitat Fragmentation
A	0.75	0.20
B	0.90	0.30
C	0.60	0.40
D	0.85	0.60
E	0.70	0.60

Statistical Analysis:

With the given data in the table above we will perform a Principal Component Analysis (PCA) to reduce the dimensionality of the data and identify underlying patterns in the ecosystem's ecological health. PCA is a technique often used for assessing complex datasets, like those in ecology.

Python Code for PCA (using SciPy and NumPy):

pythonCopy code

import numpy as np from scipy import linalg

Hypothetical data data = np.array([[0.75, 0.2], [0.90, 0.3], [0.60, 0.4], [0.85, 0.5], [0.70, 0.6]]) # Center the data (subtract the mean) mean = np.mean(data, axis=0) centered_data = data - mean # Calculate the covariance matrix cov_matrix = np.cov(centered_data, rowvar=False)

Perform PCA eigenvalues, eigenvectors = linalg.eigh(cov_matrix)

Sort eigenvalues and eigenvectors in descending order sorted_indices = np.argsort(eigenvalues)[::-1] eigenvalues = eigenvalues[sorted_indices] eigenvectors = eigenvectors[:, sorted_indices]

Calculate the percentage of variance explained by each principal component explained_variance_ratio = eigenvalues / sum(eigenvalues) print ("Eigenvalues:", eigenvalues) print ("Explained Variance Ratio:", explained_variance_ratio)

Calculate the principal component scores scores = np.dot (centered_data, eigenvectors) print ("Principal Component Scores:") print(scores)

This code snippet will perform PCA on the hypothetical ecological health dataset. The output will provide eigenvalues, explained variance ratios, and the principal component scores, which indicate the relationship between the "Biodiversity" and "Habitat Fragmentation" variables and the underlying patterns in the data.

Keep in mind that this is a simplified example, and in a real-world scenario, you would need a larger and more diverse dataset, as well as a more comprehensive ecological assessment. The choice of statistical technique and the interpretation of results would depend on the specific research objectives and the nature of the ecosystem being studied.

RESULTS

Findings from PCA: Principal Component Analysis (PCA) was applied to the dataset collected from Lake EcoClear. The eigenvalues and variance explained by the principal components are as follows:

Eigenvalue of PC1: 3.45 (explaining 75% of the variance)

Eigenvalue of PC2: 1.20 (explaining 25% of the variance)

The PCA results suggest that the first principal component (PC1) is strongly related to water quality variables (e.g., dissolved oxygen, pH) and serves as a composite indicator of water quality in Lake EcoClear. The second principal component (PC2) appears to be linked to phytoplankton and zooplankton species composition.

Findings from CCA: Canonical Correspondence Analysis (CCA) was conducted to investigate the relationships between environmental variables (water quality) and the composition of phytoplankton and zooplankton species in Lake EcoClear. The results indicate the following significant relationships:

Dissolved oxygen is positively correlated with the abundance of certain zooplankton species (e.g., Daphnia spp.).

pH levels are negatively correlated with the dominance of specific phytoplankton taxa (e.g., cyanobacteria).

Nutrient levels, such as phosphorus and nitrogen, influence the overall structure of phytoplankton and zooplankton communities.

CONCLUSION

The results from PCA and CCA provide valuable insights into the ecosystem health of Lake EcoClear. PC1, primarily related to water quality, indicates that variations in water quality parameters play a significant role in shaping the overall health of the lake. High dissolved oxygen levels are indicative of good water quality and are associated with diverse and abundant zooplankton communities. Conversely, lower pH levels can promote the growth of certain phytoplankton, potentially harmful to the ecosystem.

CCA highlights the ecological significance of nutrient levels in driving variations in phytoplankton and zooplankton communities. The findings underscore the importance of managing nutrient inputs to maintain a balanced and healthy aquatic ecosystem in Lake EcoClear.

These results demonstrate the utility of multivariate statistical techniques in assessing the health of freshwater ecosystems. The use of PCA and CCA provides a holistic view of the complex relationships between environmental variables and biological communities. Managers and conservationists can use these insights to inform strategies for maintaining and enhancing ecosystem health in Lake EcoClear.

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THE NEXUS OF ANTHROPOGENIC FACTORS, ECOSYSTEM DESTRUCTION AND ENVIRONMENTAL SUSTAINABILITY IN NIGERIA: A GENERAL VIEW

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ABSTRACT

Generally, human factors affect environmental sustainability. The use of natural resources has been an important aspect of human existence. In the struggle for survival and development, man creates a lot of negative impacts on the environment. This paper examines the impact of anthropogenic factors on environmental sustainability in Nigeria, with a particular focus on ecosystem destruction. Utilizing selected articles from online databases, it was discovered that, urbanization and population growth were the key drivers of ecosystems destruction in Nigeria. Factors such as pollution, fossil fuels consumption, and deforestation were explored. It is important that a different kind of human involvement is required for an ecosystem survival, whether through knowledge, behavior, or the use of different types of capital formation in addressing sustainability issues in Nigeria. Conclusively, there is urgent need to address gaps in advocacy and funding before any meaningful impact can be made in our quest to effectively maintain Nigeria's environment and ensure long-term sustainability.

Keywords: Natural resource management, Ecological disturbance, Environmental sustainability, Urban development, human economy

NTRODUCTION

Throughout human history, the use of natural resources has been an important aspect of human existence; people used natural materials to create the products needed to support the masses. This is mainly about food production and economic development, but many other areas are also drawn from the natural environment. Natural resources are important resources for the sustainable development of the natural and human economy and can be divided into two groups: exhaustible: such as food; inexhaustible: like forest and grass. With the development of industrialization and urbanization, people's great need for natural resources and their large-scale use and consumption have led to the weakening of people, the extinction and disappearance of this resource. In the struggle for survival and development, humans have caused many adverse effects on the environment, including overuse, destruction of ecosystems and pollution. There is a growing concern that nature is often used non-profitably because the inefficient use of natural resources creates problems for people's lives. The Nigerian environmental system is characterized by a combination of natural factors that make it particularly vulnerable and very fragile. From an ecological point of view, Nigeria is a country at risk for many years and the amount of environmental damage has increased with recent events of global warming. Some special features of developing countries are that they provide the sustainability of natural resources with the lowest environmental cost, while also providing economic and social development (Aina and Salau, 1992).

Anthropogenic factors constitute the primary deterministic causes of species declines, endangerment and extinction: land development, over-exploitation, species translocation and introductions, and pollution. The primary anthropogenic factors produce ecological and genetic effects contributing to extinction risk. Scientists use the word "anthropogenic" in referring to environmental change caused or influenced by people, either directly or indirectly. Humans impact the physical environment in many ways: overpopulation, pollution, burning fossil fuels, and deforestation. Changes like these have triggered climate change, soil erosion, poor air quality, and undrinkable water in Nigeria (Primack, 2006).

Nigeria's Deteriorating Environment

The forces of natural and man-made factors have combined to make Nigeria one of the most stressful regions in the world. The combination of these factors has resulted in a visible and alarming rate of degradation in our environment and caused misery and poverty for many of people (Primack, 2006). Nigeria's deteriorating environment could be seen in;

(a) Deforestation

Ongoing deforestation or clearing of large areas of forest cover has resulted in high levels of environmental damage and loss of biodiversity. It also causes soil erosion and possibly desertification on poor soils. Among other countries such as Brazil, Nigeria currently has perhaps the highest rate of primary deforestation in the world and has lost more than half of its primary forests in the last five years (Primack, 2006). In 2006, the United Nations Environment Program estimated that Nigeria's annual deforestation area was 663,000 hectares and the country's annual deforestation rate was 0.76%. The deforestation rate in the southwest is as high as 1.36%, which is twice the national average. Data on vegetation and land use change between 1976 and 1995 show a 53% reduction in pristine forests in Nigeria. 5%, from 25,951 km^2 in 1976 to 12,114 km^2 in 1991 (FORMECU, 1998). The main driver of deforestation in Nigeria today is population growth with increasing demand for farmland, livestock production, urbanization and firewood. Unfortunately, these needs will continue to increase as the population grows unless significant measures are taken. The old practice of farming ("slash and burn") will also exacerbate this threat because farmers are still migrating and plundering our forests as farmland is less productive. Deforestation due to uncontrolled fire and neglect by farmers and hunters, as well as the reliance of rural people and the urban poor for food, are depleting much of our forests. With the increasing global demand for hardwood, many hardwood species have been removed from large natural forest areas and sold in local and international markets, helping to control the destruction of our forests. For example, in Ondo Province, more than 44 percent of the 3,075 km^2 forest reserve has been lost in the last 30 years due to the above activities (Omofonwan and Osa, 2008).

(b) Desertification

Between 50% and 75% of Bauchi, Borno, Gombe, Kano, Jigawa, Katsina, Kebbi, Sokoto, Zamfara and Yobe states are threatened by desertification. These 10 states have a population of over 27 million and make up about 38% of the entire country. Populations in these areas suffer from overgrazing, overuse of marginal lands for firewood, and severe droughts due to global warming, accelerating desertification. In the climatic zone of Katsina, Sokoto, Jigawa, Borno and Yobe states, entire villages and highways are buried in sand dunes. In fact, the total area of lost dunes increased from 812 km^2 in 1976 to 4,829 km^2 in 1995 (FORMECU, 1998).

(c) Soil Erosion

In many parts of Nigeria, people are bewildered by flooding and erosion, some streams that exceeded one foot about 30 or 40 years ago are now so large as to expose the foundation of their own houses and causing gorges in their communities. Although erosion is one of the biggest environmental problems affecting many parts of the country, especially the areas below the country's sand layer. Classical erosional features are found in the states of Edo, Anambra, Imo, and Enugu. For example, in the state of Anambra, more than 70% of the state's land is affected in form of sheet and gully erosion. In fact, more than 550 gullies have been mapped in the state of Anambra alone, causing massive soil erosion and threatening agriculture, homes and other infrastructure. Erosion-related disasters are occurring at an increasing and alarming rate in Nigeria with factors such as increased agriculture, infrastructure development, deforestation, forest burning, overgrazing, clogged drainage systems, poor water quality management, urbanization and increased population pressure (Primack, 2006).

(d) Pollution

Urban and industrial pollution is a major environmental problem in Nigeria due to the lack of waste management plans in many cities and ineffective monitoring and industrial waste management. Despite the low level of industrial activity, waste management is still a serious problem in Nigeria. Generally, effluents from industrial processes are only allowed to flow into public waterways and rivers, thereby entering water or groundwater. The oil industry has had a significant impact on Nigeria's environmental pollution. Between 1976 and 1997, even till date, more than 2,676 separate oil pipelines spills were reported in the country. Equipment failure, corrosion of old pipelines and destruction of oil facilities by militants and oil thieves are the main causes of this phenomenon. Perhaps the biggest pollution associated with the oil industry is gas flare-ups, which, despite many attempts at regulations, are yet to be stopped. Nigeria extracts more natural gas from its oil fields than any other country in the world, and about 80 percent of the oil found in Nigerian oil fields are flared. International estimates also show that the Nigerian oil flare-up is having a significant impact on global CO_2 emissions (Aina and Salau, 1992).

(e) Solid waste

Solid waste management has become a major threat to cities in countries around the world. In a study published by the United Nations Development Program in 1997, 151 mayors from around the world identified waste disposal as the second largest urban problem after unemployment and urban poverty. Today waste management has gained notoriety in Nigeria due to the visibility and the embarrassment it brings to the country's image. Only a few state capitals are able to implement municipal solid waste management programs. As a result, even with air and groundwater risks, it is not uncommon to see mountains of garbage in our city for weeks or months without a clear solution.

(f) Mining lands

In many parts of the country, mining lands have now become very dangerous for people in mining communities. When mining pits are filled with water, they turn into ponds and become breeding grounds for mosquitoes and other insects, posing a threat to the environment (Adekoya, 2003). In Plateau State, for example, thousands of heaps of mine wastes which are now found to be radioactive were abandoned after tin mining failed years ago. State health officials said an inspection of 1,100 abandoned mines at five sites contained radioactive materials that are dangerous to human health, putting residents at risk of developing skin, lung and long-term cancers. This radioactive waste can cause eye damage but are still being neglected.

Environmental Issues

The environmental issues we face today are multifaceted and interrelated. However, some problems are bigger than others. According to Barbault and Sastrapradja, (1995) One of the most common environmental problems is waste disposal, the discharge of unwanted or harmful products into the environment. The volume of litter itself is an issue that needs to be managed, the real damage comes from chemicals that seep into the soil when dumped in the landfill and are released into the air when incinerated. Some of the main sources of pollution are batteries, engine oil, electronic products, detergents and fluorescent lamps. Even organic waste can cause problems, rotting materials in landfills are responsible for a third of all methane emissions from human sources. Recycling efforts aim to reuse these materials, leading to reduce toxins and conserve energy. Related to waste issues are air and water pollution, often associated with large business products, heavy chemicals used in factories, water runoff from mining operations, smoke from power plants, oil spills, fertilizers, pesticides and herbicides.

Worst of all is the radiation from nuclear power plants that poses a double threat. The first is the safe disposal of radioactive waste, which is still dangerous to humans and animals for up to a million years. There is no way to destroy it and no way to protect it from long-term damage (Scholes and Biggs, 2004). Other problems related to ecosystem shrinkage is population growth and industrialization. Habitat destruction occurs when an area is unable to support the plants and animals that normally live in that area.

The expansion of agriculture and the construction of new roads are the cause of deforestation; an example of this is the depletion of rainforests in developing countries such as Brazil (Scholes and Biggs, 2004). The biggest consequence of habitat destruction is species extinction – the more we enter ecosystems, the greater the risk that species will die. This is especially true of rainforests, which have a disproportionately large number of plant and animal species. Genetic diversity is essential to the continuation of an ecosystem in which species are dependent on each other for certain nutrients. Eliminating some of the key links in the food supply can have far-reaching consequences. Genetic diversity is also important in ensuring species survival during environmental changes in temperature and precipitation. While some species will not survive these natural changes, others can. As diversity increases, so does the chance of some species to survive during a period of environmental change (Ravenga *et al.,* 2000).

One of the most common causes of environmental damage is the depletion of the earth's ozone layer. All of the ozone on earth is not compressed in one area, but spread 10 to 50 miles upstream. If extruded in one layer, it is only two cents thick. The ozone layer plays an important role in absorbing more than 97% of the sun's ultraviolet rays, a spectrum that is particularly damaging to DNA, and full exposure to UV rays can damage animal tissue. Therefore, animal life on the earth's surface depends on the ultraviolet filtering of the ozone layer.The ozone layer has been thinning over the past few decades, mostly due to chlorofluorocarbon gases (CFCs) released into the atmosphere that destroy ozone (McKee *et al.,* 2003).

The biggest environmental challenge today is global warming, which threatens to raise sea levels, turn hot regions into deserts and leave many animal species extinct; this has become a reality today. Global temperature has increased in the last 100 years and is expected to increase further. Scientists agree that global warming is caused by humans. It is produced by the burning of fossil fuels, which produces a lot of carbon dioxide, which causes heat from the sun and causes temperature to continually rise. The cycle begins with fossil fuels such as oil, gas, and coal, which produce carbon dioxide. The dependence of modern society on fossil fuels exacerbates the problem. This happens with gasoline in cars and natural gas in heaters. But even electricity comes mostly from fossil fuels, and more than half from coal alone in United states (MEA,2005). Hence, the main cause of global warming is the burning of non-renewable fuels, and the solution is to use other energy sources that are not fossil fuels. But now there is another problem: fossil fuels like oil, gas and coal are cheap and there are so many that there is no other energy source that are cost effective or surplus. Hydroelectric power requires a large amount of water, high pressure. Wind energy requires a constant source of air movement. Solar panels are expensive, inefficient and, in their current form, require a large amount of space to meet the country's electricity needs. Geothermal energy requires underground heat sources such as geysers or volcanoes, and they are not easy. Nuclear power is also an option: although technically non-renewable (we cannot make more uranium), nothing is burned to produce carbon dioxide in the process. The heat generated by the nuclear reaction is converted into electricity. But nuclear power is getting more and more expensive, and there are other environmental risks mentioned above. While no other energy source alone can meet the world's energy needs immediately, policy makers and environmentalists generally advise on the use of any of these ways, with the expectation that technological advances will make them affordable and available (White *et al.,* 2000).

Anthropogenic Threats

In addition to environmental threats from the natural environment in Nigeria, there are many other threats related to human activities that make the country vulnerable to environmental damage and ecosystem destruction (Omofonwan and Osa, 2008). Currently, Nigeria has a population of over 200 million, or 20% of Africa's total population. The population has increased significantly since the 2006 census, when it was over 140 million. We currently have a total fertility rate (TFR) of 5.7 children per woman, a birth rate of 42 per thousand births, a child mortality rate of 13 percent, and the population is growing at a rate of 2.9 percent per year. The United Nations expects the country's population to reach 289 million by 2050.

Another threat is urbanization; Nigeria has experienced urbanization over the past 50 years, in addition to population growth. The proportion of the population living in urban areas increased from 15% in 1960 to 43.3% in 2000 and is expected to increase to 60% by 2030 (National Population Council, 2004). One of the main effects of urbanization is the generation of large amounts of waste (liquid, petroleum, commercial and domestic) and waste problems, thus affecting the quality of the air we breathe and the water we drink. Overall, there is a clear cycle of population growth, poverty and ecological degradation. Nigerian towns and cities are often dire examples of unplanned population, poor urban planning, misery and environmental degradation that need to be addressed urgently. As farmers grow in search of more land for a livelihood, population growth is putting more pressure on our forests.

Inappropriate agricultural practices cannot be over emphasized**.** In the tropics, the old practice of crop rotation ("slash and burn") still applies. As soil fertility declines after a few years, farmers move to other fields, destroying vast tracts of land that would otherwise be untouched. Unfortunately, we don't have enough farmers to train and encourage them to switch to modern technology on a large scale.

Over-exploitation for Firewood; Firewood is now the main source of cooking oil for more than 76 percent of Nigeria's population.1993 UNDP data shows that Nigeria consumed 262,783 tons of oil, South Africa 7,210 tons and Thailand 35,313 tons of oil. Nigeria's dependence on wood fuel has increased, while in the other two countries it has reduced completely. At the current price of fossil fuels, logging will soon turn our forests into savannahs and grasslands. Also, uncontrolled Logging is increasing the demand for wood in the world. High logging and illegal logging continue to pose a serious threat to the country's forest resources and environment. The use of modern machinery such as tractors and trucks has made logging faster and easier, leading to increased logging and cutting costs. Today, illegal loggers often take up arms against forest rangers who dare to stop them. More so bushfire has become a major hazard in many parts of Nigeria. Forest fires are started by recreational farmers, smokers and hunters. Due to these inevitable practices, we lose thousands of hectares of forest every year, especially in the dry season. Unfortunately, our fire department is in most cases not capable of managing large fires.

Extensive oil exploration and production in Nigeria's sedimentary rocks, particularly the Niger Delta, has led to the spread of these areas. Contamination threats, such as leaks from pipelines and production facilities, often arise from exploration and production. The recent labor dispute in the Niger Delta region has increased the threat as oil thieves are now raiding pipelines killing thousands of people, with buckets of oil flowing into rivers and streams (Effley and Matthew, 2004).

Overgrazing is a herbivorous practice that takes an unsustainable amount of floral biomass from the ecosystem. However, this extreme practice is used for livestock or native species. Herbivores include cattle, sheep and goats. It is estimated that one-third of the world's pastures are overgrazed (William and Barbara, 1990). Overgrazing can lead to reduced species richness, loss of biodiversity, desertification, loss of natural topsoil and increased surface runoff. The most common practices leading to overgrazing are: high animal density on land; (b) no rotation or residence time for herbivores in small areas of land; due to overgrazing, there is no time for flora production (William, 1992).

Sustaining the Nigerian Environment:

Eminent Nigerian environmentalists, researchers, pressure groups, threatened communities, government departments, agencies, and Non-Governmental Organisations (NGOs) including Nigerian Conservation Fund (NCF) have been drawing attention to the perilous path along which Nigeria is threading with regards to the environment. In response, federal and state governments have enacted various policies, regulations and enacted various laws to prevent environmental threats and bring Nigeria back from the brink of the abyss (Omofonwan and Salau, 2008).

Environmental Laws and Regulatory Actions in Nigeria:

There are many regulatory agencies at the state and federal level to deal with environmental issues affecting the country. In addition, Nigeria has signed many international conventions, protocols and agreements in order to cooperate with other countries in the solution of environmental problems. More importantly, while preserving ecosystem functions and services, ecosystem functions exist in nature beyond human organizations (such as water cycle, or primary biomass production) human decisions can greatly affect them. On the other hand, maintaining ecosystem services are viewed as beneficial by the socio-economic system. They focus on human interest, i.e. peoples giving choices for each ecosystem services and therefore have a view of their development. A different kind of human involvement is required for an ecosystem survival, whether through knowledge, behavior, or the use of different types of capital formation.

Sustainable development is a dynamic process that must be constantly adjusted to economic and environmental changes. It is suggested that, to have an environmental safety and sustainable development in Nigeria, a material stewardship concept should be adopted and implemented in order to ensure sustainable use of natural resources. It is important to ensure continuous monitoring of natural resources by government and social groups and encourage citizens to participate in activities aimed at developing natural resources such as recycling, waste reduction, afforestation, pollution control, biological remediation and forest conservation areas.

The issue of protecting the environment and ecosystem is everyone's concern, government must play an important role in policy, strategy, planning and financing. The government must muster sufficient political will to ensure the effective implementation of appropriate plans and programme. Also, given the level of threats and disasters facing Nigeria's environment, significant financial resources are required to manage, monitor and repair projects.

CONCLUSION

This study has established that humans impact the physical environment in many ways: overpopulation, pollution, burning of fossil fuel, and deforestation. Changes like this have led to climate change, soil erosion, undrinkable water and poor air quality. Urbanization and population are the key drivers of environmental impacts in Nigeria. Human impact on biodiversity, direct or indirectly involves over exploitation of natural resources, habitat modification, the introduction of exotic species and conversion and fragmentation. These impacts mentioned has always led to more demand of exploration and extraction in the world of which Nigeria is not exempted and has increased the use of natural resources. Using natural resources faster than they can be recovered can cause environmental damage, ecological degradation, extinction of nature and animals, global warming and desertification. Everything on our planet is interconnected, and although nature provides us with valuable environmental services without which we cannot survive, we are all dependent on each other's actions and use of our natural resources. Sometimes we need to take a closer look at the situation, thinking that it is not different from us, that we are a part of it, and we need to deal with sustainability properly by generating good ideas and producing policies. We can strike a balance between the use of resources and conservation, only in this way we can solve environmental problems and the destruction of ecosystems.

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USE OF NEPHROLEPIS CORDIFOLIA (L.) C. PRESL IN PHYTOREMEDIATION OF SPENT ENGINE OIL POLLUTED SOILS

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ABSTRACT

This study was conducted to phytoremediate heavy metals in soil contaminated with spent engine oil using *Nephrolepis cordifolia*. Eighteen rectangular biocells were constructed using cement blocks and filled to the brim with top soil. The soil was treated with 0mL, 200mL, 400mL, 600mL, 800mL and 1000mL of spent engine oil in triplicates. The concentration of heavy metals in the soils were analysed before and after treatment application. *Nephrolepis cordifolia* of approximately the same size were transplanted into the soils two weeks after the treatment. The experiment was terminated after 52 weeks of planting and the plants were analysed for copper, cadmium, lead, chromium and cobalt using Flame atomic absorption spectrophotometer. Growth parameters such as frond length and number of fronds were also measured. Data generated were analysed using SPSS. The results showed that mean concentrations of heavy metals in the plants increased with increase in the volume of spent engine oil used. The roots of the plants accumulated more heavy metals than the shoots. The highest concentration of heavy metals recorded was copper>cadmium>lead>cobalt>chromium. Growth parameters were also affected by reduction in size and number of fronds.

Keywords: Heavy metals, Hyperaccumulators, *Nephrolepis cordifolia*, Spent engine oil, Soil Contamination

INTRODUTION

Spent engine oil is engine oil that has undergone changes when subjected to oxygen, combustion gases, and high temperature and now contains chemical and physical impurities (Ayandele, 2018). It contains metals and polycyclic aromatic hydrocarbons that pose a risk to humans, plant and animal health, resulting in serious health problems such as anemia, tumors including mutagenicity and carcinogenicity (Boonchan *et al.,* 2000). Due to the rise in the use of automobiles and machineries, Nigeria is seeing a surge in the use of engine oil (Dike *et al.,* 2013). According to Adegoroye (1997), around 20 million gallons of spent engine oil is collected from mechanic workshops throughout the country and disposed of carelessly in the environment. According to USEPA (1996), a single litre of used engine oil is enough to pollute one million gallons of freshwater (Adelowo *et al.*, 2006). Pollution from spent oil is more widely spread than crude oil especially in urban centres where there are more automobiles and generators using petroleum products (Odebode *et al.,* 2021, Odjegba and Sadiq, 2002).

Some of the metals present in spent engine oil can dissolve in water and move through the soil easily and may be found in surface water and groundwater (Mohd *et al.,* 2011). These heavy metals may be bound with organic matter in the soil and are retained in the form of oxides, hydroxides, carbonates, and exchangeable cations (Yong *et al.,* 1992). Soil biochemistry, microbial communities, pH of the soils, oxygen diffusion inhibition and nutrient availability are all affected by these contaminants. (Merkl *et al.,* 2004). Thus, metals such as lead, tin, manganese, nickel, chromium, copper found in spent engine oil can build up in plants, animals, soil and non-flowing surface water (Abdulsalam *et al.*, 2012). The use of chemical methods like filtration, adsorption, and ion exchange to clean up heavy metals is expensive and may have adverse environmental effects.

Phytoremediation is a biological technique for decontaminating or removing contaminants from the soil using plants. Plants suitable for phytoremediation must possess the ability to generate biomass, endure extreme conditions, and absorb significant quantities of contaminants from the soil (Nerlekar *et al.*, 2023). Certain lower green plants have the ability to be hyper accumulators, they can take up more than half of their weight in pollutants from the polluted soils. Some fern species are significant bio indicators of contaminated soils or have been identified to have the extraordinary capability to hyper accumulate some heavy metals (Kachenko *et al.*, 2007). *Nephrolepis cordifolia* also known as erect sword fern belongs to the family Nephrolepidaceae. It is more tolerant of low humidity than most other ferns. This fern has extensive root system that absorbs water well in deep soil, hence, it could grow well in dry areas. Banks *et al.*, (2007) found that species of *Nephrolepis* such as *N. falcata* have been used to remediate soil contaminated with creosote and found it to be tolerant to the contaminants. Sonphueak (2007) also found *Nephrolepis cordifolia* to be the best to remediate fuel oil contaminated soil amongst two other species of *Nephrolepis*; *N. exaltata* and *N. biserrata.* This study was carried out to investigate the potentials of *Nephrolepis cordifolia* to remediate heavy metals in soil polluted with spent engine oil.

MATERIALS AND METHODS

Study Area

This research was carried out in the Botanical nursery, University of Ibadan, Ibadan, Oyo State (Longitude 07°26`35.1 N and Latitude 03°53`47.1 E). Eighteen (18) open rectangular biocells were constructed using cement blocks with dimensions 0.7m x 0.85m each.

Collection of Spent Engine Oil

The spent engine oil was collected from an automobile mechanic workshop opposite Trans Amusement Park (Longitude 07°43`73.6 N and 03°90`86.2 E) in the Ibadan metropolis.

Collection of plant samples

Nephrolepis cordifolia of approximately the same size were harvested from the surrounding vegetation of the University of Ibadan. Identification was done at the University of Ibadan, Department of Botany Herbarium.

Soil Preparation and Planting

The constructed biocells were filled to the brim with topsoil (0-15 cm depth), that was obtained from the botanical nursery, University of Ibadan, Ibadan.

The experimental setup of the biocells had the following treatments:

1. Treatment 1: 200mL spent engine oil + *Nephrolepis cordifolia.*
2. Treatment 2: 400mL spent engine oil + *Nephrolepis cordifolia*
3. Treatment 3: 600mL spent engine oil + *Nephrolepis cordifolia*
4. Treatment 4: 800mL spent engine oil + *Nephrolepis cordifolia*
5. Treatment 5: 1000mLspent engine oil + *Nephrolepis cordifolia*
6. Treatment 6: 0mLspent engine oil + *Nephrolepis cordifolia* (Positive control)
7. Treatment 7: 600mL spent engine oil without *Nephrolepis cordifolia* (Negative control).

The experimental setup was replicated three times and continued for 52 weeks.

Determination of growth parameters of plants

Growth parameters such as frond length and number of fronds of the ferns in each biocells were measured every four weeks till the end of the experiment. Frond length was determined by measuring the length of ten fronds with a tape rule and the mean value was recorded. Number of fronds was determined by visually counting the ferns in the biocells.

Heavy Metals Analysis

Soil samples were collected from the biocells and 1.0g of each sample was weighed into digesting tubes, with 8 ml of concentrated HNO_3, 4 ml of concentrated HCl and 2 mL of diluted H_2O_2, ratio 4:2:1 added to the samples. The content was heated on a hot plate in a fume cupboard till brownish fume is expelled. The solution was cooled for 5 minutes. After cooling, 10 ml of distilled water was added and filtered using Whatman No. 42 filter papers. The filtrate was made up separately with distilled water to 50 ml of the standard flask. The digested soil samples were transferred separately into plastic sample bottles for heavy metals analyses.

The plant samples were separated into shoots and roots and grinded, 0.5g of the ground plant sample was weighed into a digesting tube. Acid mixture of concentrated HNO_3 (15mL) and concentrated HCl (5mL), ratio 3:1 were added to the digesting tube. The content was heated on a hot plate in a fume cupboard till brownish fume was expelled. The solution was cooled for 5 minutes. After cooling, 10 ml of distilled water was added and then filtered using Whatman No. 42 filter papers. The filtrate was made up separately with distilled water to 100 ml of the standard flask. The digested soil and plant samples were analyzed for the concentration of heavy metals: Copper (Cu), Lead (Pb), Cadmium (Cd), Chromium (Cr) and Cobalt (Co) using an Atomic Absorption Spectrophotometer, Buck Scientific 210 VGP.

Determination of Biomass

The ferns were harvested from each biocell, washed with deionized water and weighed immediately to determine the fresh weight and then taken to the laboratory and oven dried for 24 hours at 80°C to attain constant weight. It was reweighed to attain the dry weight and the biomass was calculated as:

$$\text{Total Biomass} = \frac{\text{Dry weight of the plant}}{\text{Plot area}}$$

(Roberts *et al.*, 1985)

Translocation factor and Bioaccumulation factor

These were used to assess the feasibility of the plant species for phytoremediation purposes. A translocation factor (TF) value greater than 1 means the plant is an accumulator and a value less than 1 means the plant is an excluder. The translocation factor is also used to know in which part of the plants the pollutants are stored. It was calculated as:

$$\text{TF} = \frac{\text{Metal concentration in the plant shoots}}{\text{Metal concentration in the roots}}$$

(Ng *et al.*, 2016).

Bioaccumulation factor (BAF) values more than 1 demonstrate the potential success of a plant species for phytoremediation. Bioaccumulation factor was calculated as:

$$\text{BAF} = \frac{\text{Metal concentration in the plant tissues}}{\text{Metal concentration in the soil}}$$

(Zhuang *et al.*, 2009).

Statistical Analysis

All analytical data collected from the experiment were evaluated in relation to the Positive control to determine statistical difference. Mean of all the parameters were subjected to One-Way Analysis of Variance (ANOVA) and means separated by Duncan Multiple Range Test at $p<0.05$.

RESULTS

Growth parameters of *Nephrolepis cordifolia*

The frond length of *Nephrolepis cordifolia* grown in the different biocells throughout the sampling period is present in Figure 1. At the end of the experiment, *Nephrolepis cordifolia* from the positive control biocell recorded the highest mean value of 72.80cm compared to the treated biocells which decreased with significant increase in the volume of spent engine oil used.

The number of fronds of *Nephrolepis cordifolia* in the different biocells throughout the sampling period is shown in Figure 2. At the end of the experiment, *Nephrolepis cordifolia* from the positive control biocell recorded the highest number of fronds with the mean value of 110 compared to that of the treated biocells, the lowest number of fronds was recorded for *Nephrolepis cordifolia* grown in the soil treated with 800ml spent engine oil with a mean value of 62.

Heavy metals concentration of soil from the biocells

The heavy metals concentration in the soil before and after treatment with spent engine oil is shown in Table 1. There was no cadmium, lead, cobalt and chromium recorded in the soil before treatment, however, the concentration of copper was 2.49mg/kg. There was an increase in the concentration of heavy metals in the treated soils collected from the biocells with increase in the volume of spent engine oil. The highest concentration of heavy metals recorded in the treated soils was copper>cadmium> lead >cobalt>chromium. At the end of the experiment, significant reduction was observed in the concentration of heavy metals in the soil from all the biocells.

Heavy metals concentration in the plants

The concentrations of copper in the plant tissues at the end of the experiment is shown in Figure 3. The highest concentration of copper in the roots was recorded for *Nephrolepis cordifolia* grown in the biocells treated with 1000ml spent engine oil with the mean value of 123.45mg/kg, while the lowest mean value 2.55mg/kg was recorded for *Nephrolepis cordifolia* grown in the positive control biocells. The concentration of copper in the roots was significantly different across the treatments except for the positive control and the 200ml treatment. The highest concentrations of copper in the shoots was recorded for *Nephrolepis cordifolia* grown in the soil treated with 1000ml spent engine oil with a mean value of 81.60mg/kg, while the lowest mean value 3.50mg/kg was recorded for the shoots of *Nephrolepis cordifolia* grown in the positive control soil. The concentration of copper in the shoots was significantly different across all the treatments.

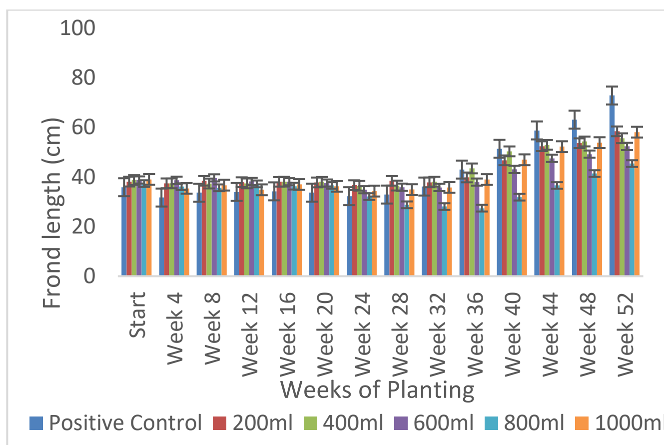

Figure 1: Length of *Nephrolepis cordifolia* fronds from the biocells.

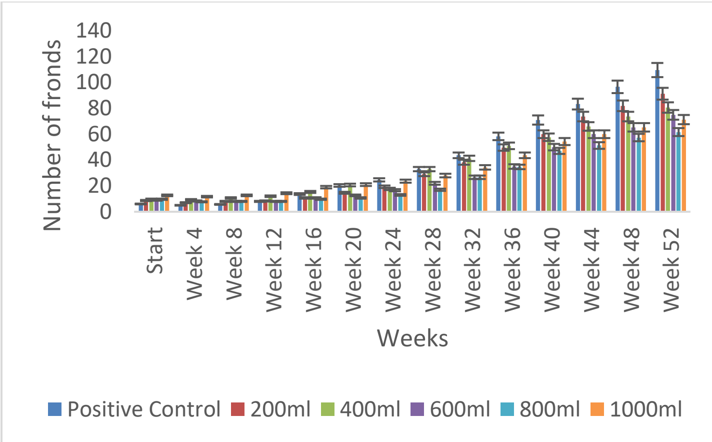

Figure 2: Number of fronds of *Nephrolepis cordifolia* from the biocells across the weeks.

Table 1: Heavy metal concentrations (mg/kg) of the soil before and after spent engine oil treatment pre - planting.

Oil Treatment	Copper	Cadmium	Lead	Cobalt
200ml	8.08 ± 0.12	3.72 ± 1.20	4.38 ± 1.11	4.19 ± 0.08
400ml	9.70 ± 0.10	4.93 ± 0.45	5.07 ± 0.91	6.41 ± 1.31
600ml	11.44 ± 0.18	6.61 ± 0.22	7.20 ± 0.02	7.56 ± 0.55
800ml	13.76 ± 0.29	8.66 ± 1.64	8.54 ± 0.78	8.52 ± 0.47
1000ml	17.04 ± 1.51	9.80 ± 0.84	9.92 ± 0.23	10.89 ± 1.89
Positive control	2.49 ± 0.05	0.00	0.00	0.00

Values presented are mean ± standard deviation in three replicates.

Table 2: Heavy metal concentrations (mg/kg) of the soil post planting.

Oil Treatment	Copper	Cadmium	Lead	Cobalt
200ml	5.82 ± 0.25	3.37 ± 0.87	3.96 ± 0.96	3.95 ± 1.06
400ml	6.72 ± 0.06	4.12 ± 1.26	4.68 ± 0.87	6.21 ± 0.30
600ml	8.41 ± 0.65	6.18 ± 1.11	6.70 ± 1.02	7.4 ± 0.16
800ml	10.26 ± 0.41	8.26 ± 0.92	6.59 ± 0.11	8.35 ± 0.41
1000ml	10.75 ± 0.36	9.37 ± 0.54	9.57 ± 0.36	10.59 ±0.26
Positive control	0.5 ± 0.02	0.00	0.00	0.00

Values presented are mean ± standard deviation in three replicates.

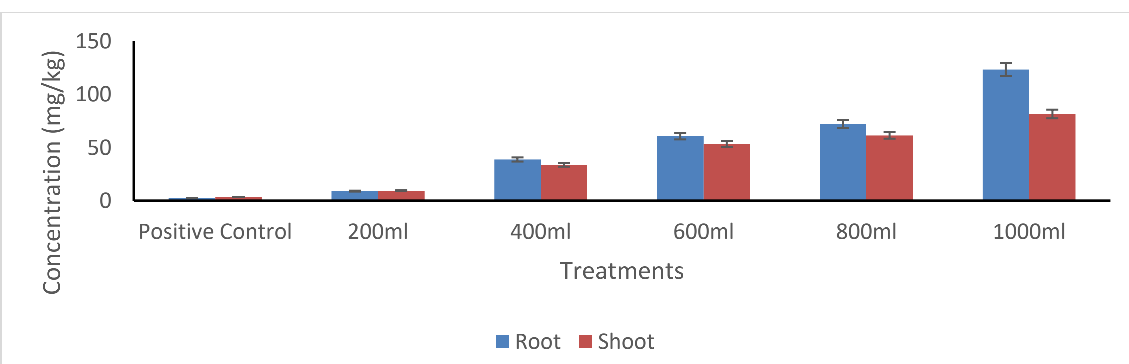

Figure 3: Copper concentrations in the tissues of *Nephrolepis cordifolia* in the biocells.

The concentrations of cadmium in the plant tissues after 52 weeks shows the highest concentration of cadmium in the roots was recorded for *Nephrolepis cordifolia* grown in the biocells treated with 1000ml spent engine oil with the mean value of 1.42mg/kg, which decreased with decrease in the volume of spent engine oil in the biocells (Figure 4). There was no cadmium in the roots of *Nephrolepis cordifolia* grown in the Positive control biocells. The concentration of cadmium in the roots grown in the biocells treated with 600ml and 800ml were not significantly different. The shoots of *Nephrolepis cordifolia* from the biocells treated with 1000ml spent engine oil recorded the highest mean value of 0.87mg/kg compared to the treated biocells which decreased with significant increase in the volume of spent engine oil used. (Figure 4).

The concentration of lead in the roots of *Nephrolepis cordifolia* grown in the biocells is shown in Figure 5. The highest concentration of lead in the roots was recorded for the *Nephrolepis cordifolia* grown in the biocells treated with 1000ml spent engine oil with a mean value of 4.56mg/kg. The lowest mean value 2.90mg/kg was recorded for the *Nephrolepis cordifolia* grown in the biocells treated with 200ml spent engine oil. There was no lead detected in the roots and shoots of *Nephrolepis cordifolia* grown in the Positive control biocells. The concentration of lead in the shoots of *Nephrolepis cordifolia* grown across the treated biocells was below detectable limit.

Biomass, Translocation and Bioaccumulation factor

The biomass for *Nephrolepis cordifolia* collected from the Positive control biocells and the biocells treated with 200ml spent engine oil recorded the highest mean value of 672.27g/m^2 while the lowest mean value of 336.14g/cm^2 was recorded for the biocells treated with 800ml and 1000ml spent engine oil (Table 2).

The translocation factor for copper recorded the lowest value for the biocells treated with 1000ml spent engine oil with a mean value of 0.68 while the highest value for the translocation factor of copper was recorded for the positive control biocells with a mean value of 1.37 (Table 3). The lowest value for the translocation factor of cadmium was recorded in the biocells treated with 800ml and 1000ml spent engine oil with the mean value of 0.62 while highest value was recorded for the biocells treated with 200ml spent engine oil with the mean value of 0.74 (Table 3).

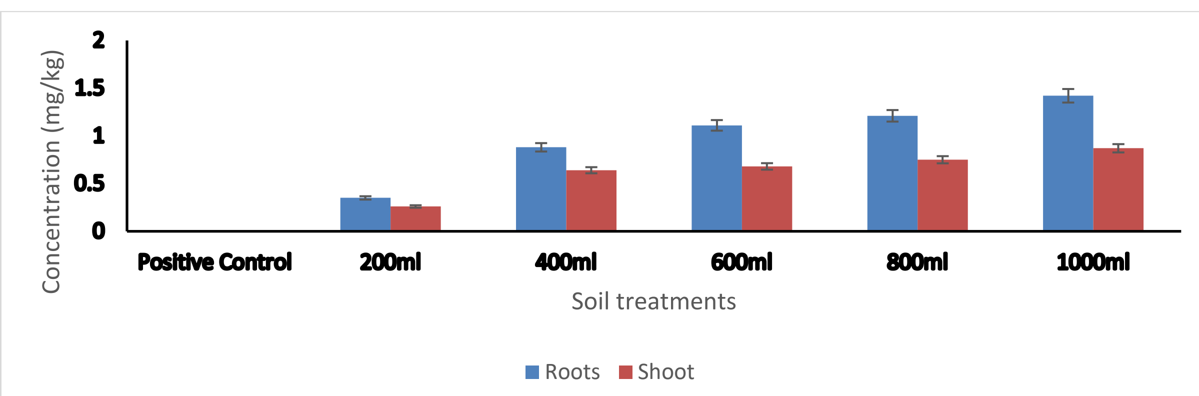

Figure 4: Concentration of cadmium in the roots and shoots of *Nephrolepis cordifolia* in the biocells.

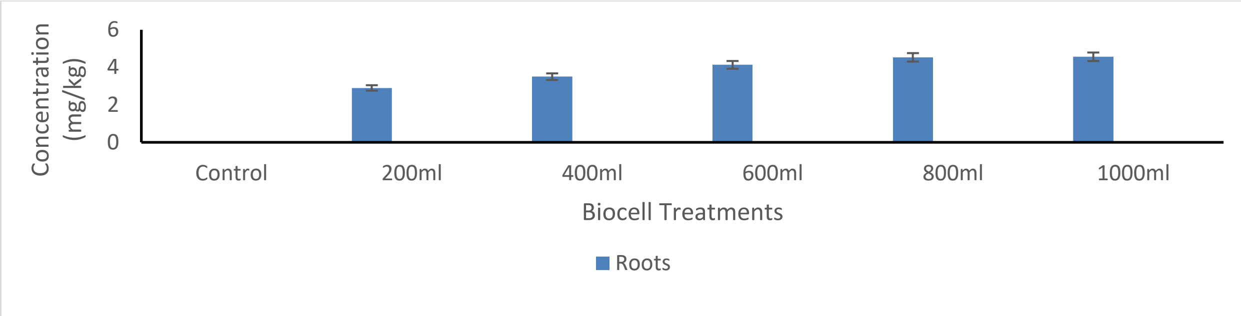

Figure 5: Concentration of lead in the roots of *Nephrolepis cordifolia* grown in the biocells.

Table 3: Biomass of *Nephrolepis cordifolia* grown in the different biocells.

Samples	Biomass (g/m^2)
Control	672.27 ± 475.37
200ml	672.27 ± 475.37
400ml	588.24 ± 356.52
600ml	378.15 ± 178.26
800ml	336.14 ± 118.84
1000ml	336.14 ± 118.84

Values presented are mean ± standard deviation in three replicates.

Table 4: Translocation factor of *Nephrolepis cordifolia* grown in different soil treatments.

Samples	Copper	Cadmium
Positive control	1.37 ± 0.68	0.00
200ml	1.06 ± 0.28	0.74 ± 0.26
400ml	0.87 ± 0.06	0.73 ± 0.14
600ml	0.88 ± 0.04	0.68 ± 0.05
800ml	0.85 ± 0.09	0.62 ± 0.05
1000ml	0.68 ± 0.06	0.62 ± 0.12

Values presented are mean ± standard deviation in three replicates.

The bioaccumulation factor for cadmium recorded the lowest value for the biocell treated with 200ml spent engine oil with the mean value of 0.18, followed by 0.24 recorded for the biocells treated with 800ml and 1000ml spent engine oil. This was followed by the mean value of 0.29 for the biocell treated with 600ml spent engine oil, the highest mean value was 0.37 recorded for the biocell treated with 400ml spent engine oil. The bioaccumulation factor for lead recorded in the treated biocells was 1000ml <800ml <600ml <200ml < 400ml.

Table 5: Bioaccumulation factor of *Nephrolepis cordifolia* grown in the different soil treatments

Samples	Copper	Cadmium	Lead
Positive control	5.93 ± 0.08	0.00	0.00
200ml	2.75 ± 0.12	0.18 ± 0.26	0.73 ± 0.02
400ml	12.47 ± 0.06	0.37 ± 0.14	0.75 ± 0.14
600ml	13.55 ± 0.05	0.29 ± 0.05	0.62 ± 0.12
800ml	13.02 ± 0.11	0.24 ± 0.05	0.69 ± 0.03
1000ml	19.07 ± 0.06	0.24 ± 0.12	0.48 ± 0.06

Values presented are mean ± standard deviation in three replicates.

DISCUSSION

The plant height and number of fronds of *Nephrolepis cordifolia* recorded in this study showed significant difference between the Positive control biocell and the treated biocells. The highest value for the plant height and number of fronds was recorded for the plant grown in the Positive control biocell while the lowest value was recorded for the biocell treated with 800ml spent engine oil. The plant height and number of fronds reduced with an increase in the volume of spent engine oil. This agreed with the findings of Odebode *et al.,* (2021) who reported a reduction in plant height of *Helianthus annus* that was treatment dependent. This reduction could be as result of inadequate nutrients uptake by the plants due to poor aeration of soil. Similar results were reported for maize by Okonokhua *et al.,* (2007).

The concentration and site of accumulation of heavy metals in plants vary in plant species. Absorption of heavy metals from the soil by plants occurs either passively with the mass flow of water into the roots or through active transport across the plasma membrane of root epidermal cells (Okonokhua *et al.,* 2007). The accumulation of copper by the plants was higher than that of cadmium and lead, and it increased with an increase in the volume of spent engine oil in the soil. This could be because copper is a micro nutrient needed for photosynthesis in plants. The bioaccumulation factor of copper was greater than 1 which indicates the plants ability to absorb and accumulate the metal and its suitability for phytoextraction. The translocation of lead from the roots to the shoots was low resulting in higher concentrations in the roots while the concentration in the shoots was below detectable limit. This explains low bioaccumulation factor for lead that was observed in this study. This result agreed with Testa *et al.,* (2023) who reported low concentrations of lead in the roots and low translocation of lead from roots to the aboveground biomass in hemp plants.

CONCLUSION

The results of this study has revealed the ability of *Nephrolepis cordifolia* to absorb copper, cadmium and lead from soil contaminated with spent engine oil. The results suggest that *Nephrolepis cordifolia* has the ability to hyperaccumulate copper from contaminated soils. Furthermore, the study highlights the plants tolerance to varying concentrations of spent engine oil.

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ASSESSMENT OF HEAVY METALS POLLUTION OF ROAD-SIDE SOILS IN OSOGBO, SOUTHWEST NIGERIA

ABSTRACT

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ABSTRACT

The study assessed the effect of vehicular emission on heavy metal loads of roadside soils along four roads in Osogbo. Three locations were selected depending on the traffic density. The locations were designated as very busy (Ayetoro with an average traffic density of 1,960 vehicles per hour), busy (Oja Oba with an average traffic density of 1,055 vehicles per hour), Less busy (Ilesa-Garage with an average traffic density of 883 vehicles per hour) and control (Ibokun road with an average traffic density of 132 vehicles per hour). Soil samples were collected done using a randomized technique at six different points in each location. The results showed that while pH ranged between 8.3 and 9.06; conductivity was between 39.8 and 342.9µS/cm conductivity; and organic matter content fell between 4.72% and 6.93%. The pH of the soil sample from Ayetoro Road and Oja – Oba Road was strongly alkaline while that of Ilesa Garage Road was moderately alkaline and the control sample was neutral (Cations exchange capacity ranged from 4.88 to 5.37 meq/100g and the result for the control site was 4.65 meq/100g). The test of significance of means was carried out by Duncan's Multiple Range Test (DMRT). The results obtained showed the significant differences in the mean concentration of Fe, Zn and Cu, but not in the mean concentration of Cd and Pb across the location (while Fe has higher mean concentration than other metals found in the samples), also, mean concentration of heavy metals found in Ayetoro road and Oja-Oba Road was slightly higher than other locations. Based on this study, the concentration of heavy metals in the study areas are within the permissible limit, but their accumulation overtime can pollute the soils of Osogbo if not controlled.

Key words: Pollutant accumulation, Heavy metal pollution, Traffic density, Vehicular emission,

INTRODUCTION

Heavy metals include lead (Pb), cadmium (Cd), zinc (Zn), mercury (Hg), arsenic (As), silver (Ag) chromium (Cr), copper (Cu) iron (Fe), and the platinum group elements (Duruibe, 2007). Although heavy metals are naturally occurring elements that are found throughout the earth's crust, nearly all environmental pollution and human contact result from anthropogenic activities such as mining and smelting operations, industrial production and use, and domestic and agricultural use of metals and metal-containing compounds (ZL *et al.*, 2005). Recently it has been recorded that human activities increases daily, and these activities (like burning of fossils, vehicular emission, industrial emission etc.) are refers to as primary sources of pollution (Amusan *et al.*, 2003).

Nevertheless, these metals are leached out, dissolved and carried away into water bodies through runoff by heavy rainfall or storm and settle down at underground water, causing water pollution (Duruibe, 2007). Transportation is as an essential activity of human structures, the center of all socioeconomic connections (Nwafor and Onya, 2019). It facilitates the progress of communities by easy the movement of people to be able to access the available resources in the area (Ezeife and Bolade 1984). Transportation by road take higher percentage in urban areas of Nigeria, 90% of goods and passengers are transported by Road (Nwafor and Onya, 2019). Transportation service is a major pollution source of heavy metals in surroundings soils close to the highways, which are produced by vehicles and dust, entering the soil through natural sedimentation (Rajneesh *et al.*, 2019). Pollutants emission from gasoline powered vehicles is one of the causes of road side soil pollution due to their production of volatile organic compounds (VOC), carbon monoxide (CO), and oxides of nitrogen (NO_x), while emission from vehicles using diesel are fine particles matter ($PM_{2.5}$) and NO_x, (Sawyer, 2010). These pollutants from different sources released and spread to the environment affect soil, vegetation, water, and other natural resources. (Shafat *et al.*, 2020).

Moreso, car traffic has excessive effect on the urban localities due to the toxic factor generated through the fume emission (Clarlesworth *et al.*, 2003). Meanwhile, automobiles are the major vital contributors of Cr, Pb, Zn, Cu and As, on road side soils, while Cu and Zn contained higher concentration in street soil from both vehicular and mechanical areas (Humayun *et al.*, 2021).

Fatoki and Ayodele, 1991 reported that Zn and Cu contributed to the atmospheric pollution in Nigeria, through traffic mass. Also, Ademoroti (1996) gave details on organometallics like tetraethyl lead $[(C_2H_2)_4Pb]$ which is an additive to petrol (gasoline) and source of Pb in vehicular exhaust emission. Numerous cars, inappropriate vehicle servicing, inadequate rigorous regulations for traffic management, low-quality exhaust emission monitoring during yearly vehicle inspections, lack of parking spaces and low-grade fuels, lack of more helpful traffic regulations on existing highways, and an inadequate mass transportation network are all factors that contribute to emissions from traffic sources. (Hossain *et al.*, 2020)

Dust is another area of concentration, it evolves from the exhausts of the vehicles during movement on the roads, it is a particulates that contain topsoil, anthropogenic metallic element, and biological components from nature (Manikandan *et al.*, 2021). About 1.5 to 2 million mortality is recorded yearly base on this dusts pollution, while 33% of total air pollution in the results resulted from suspended dust or re-suspended dust caused by vehicles (Odediran *et al.*, 2021).

Every road-side plant is susceptible to dust especially particles from automobiles emission, these emissions are known as particulate Matter (PM2.5) and (PM10) which are very toxic to both plants and animals (Manikandan *et al.*, 2021). Also, particle sizes with its distinctiveness affects plants, because plants vary in their capability to obtain particles from air and larger dust are easily filtered than fine particles. Meanwhile, plants located near an untarred road absorb more dust because untarred road with vehicular traffic produce more dust than tarred one (Manikandan *et al.*, 2021). However, lots of damages have been done to the road-side plants by vehicular emission and dust. Previous researches have shown that leaf area and chlorophyll content of some road-side plants were reduced (Hussain *et al.*, 1994). Also, radiation absorption is being reduced causing energy disparity of leaves (Eiler, 1997). Depositions of trace elements generated from gaseous discharges from road traffic on leaf surfaces can affect plants by reduce the growth and morphological characteristics (Ahmad *et al.*, 2012).

The occurrence of these metals in soils can cause it to become greatly toxic to human beings. (Osama *et al.*, 2020). Though many people are primarily exposed to these contaminants in their place of work, while others contact it through the diet (food and water) (ATSDR 2005). Inhalation of these elements through ingestion or direct dermal contact be it intentional or not intentional can cause breathing problems and skin irritation, and long-term exposure can leads to kidney damage, lung or skin cancer (Humayun *et al.*, 2021). Soil-to-plant transfer of heavy metals is a very important stride in the trophic transfer of metals in food chains, when these metals are taken up by plants from polluted soil and transferred to herbivorous animals along the food chain (Nica *et al.*, 2012). The chains of these heavy metal pollutants always follow a cycle order; industry, atmosphere, soil,water, foods, and human (Simone *et al.*, 2012).

MATERIALS AND METHODS

To access the effects of vehicular emission in Osogbo, this research was focused on three locations in Osogbo metropolis with considerable amounts of traffic consisting of

(i) Very busy, Ayetoro area
(ii) Busy, Oja-Oba area
(iii) Moderate traffic movement, Ilesa Garage area

Ibokun road was used as control because of its low traffic movement.

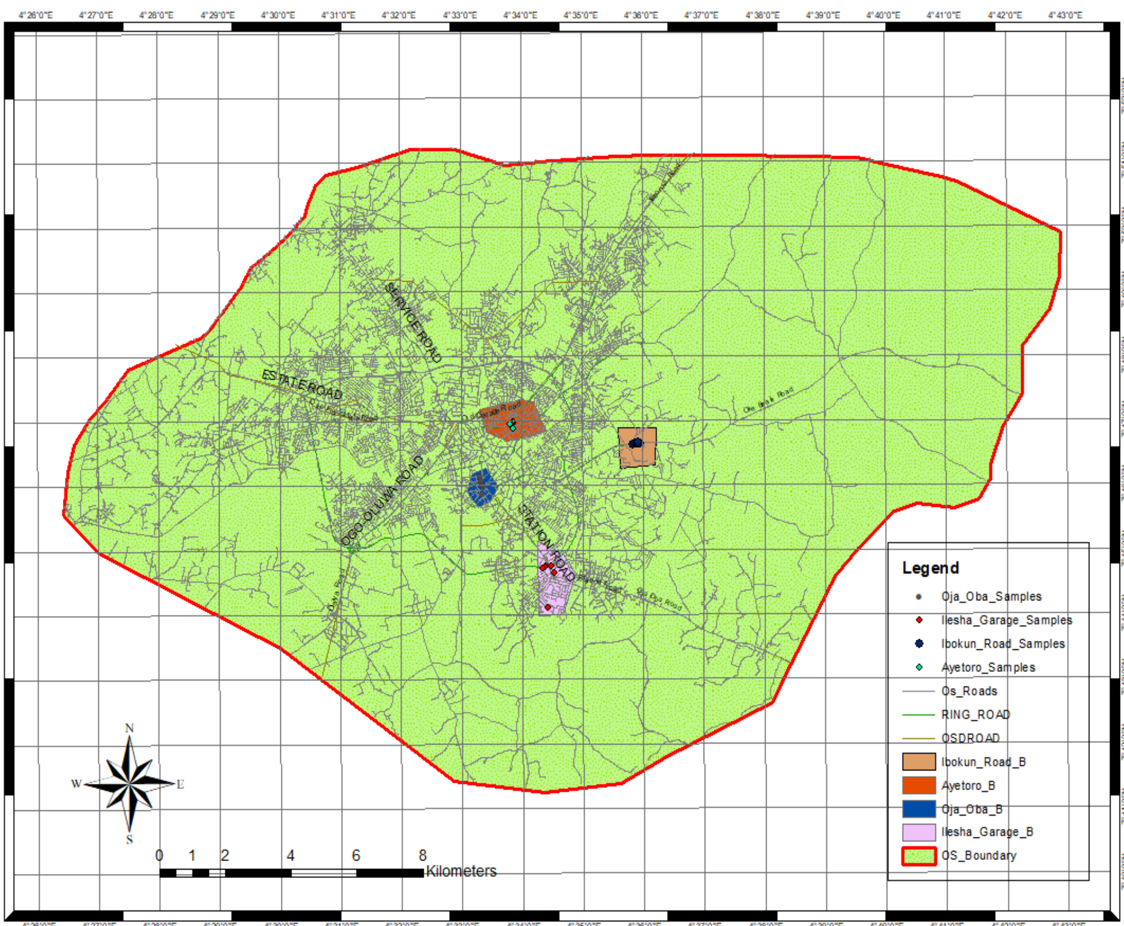

Figure 1: Sampling locations for heavy metal pollution of road sides in Osogbo, Osun State, Nigeria

EXPERIMENTAL DESIGN AND PLOT SELECTION

Road-side soil samples were taken at each sampling site by using randomize method for samples collection with $1m^2$ quadrant at 50 m away from each point. The debris was removed and soil samples collected at 0–15 cm depth using soil auger at 5 m distance from the edge of the main road at each location

SAMPLE PREPARATION

The samples were put the labeled polythene bags and brought to the laboratory for further analysis. The soil samples were spread and air-dried in the laboratory for 5 days in order to remove the moisture, then it was sieved through 2 mm mesh size, thoroughly mixed and the gravel was also removed. The powdered samples were stored for subsequent laboratory analysis.

CHEMICAL ANALYSIS

pH, Organic matter content, and conductivity was carried out on the samples collected. Also, cations exchange capacity was carried out according to Miroslav & Vladimir, (2000) and American Standard Test Methods (ASTM), 2015. Analysis of Cd, Pb, Cr, Zn, Cu, and Fe was detected using Atomic Absorption Spectrophotometer (Bulk .211VGP).

STATISTICAL ANALYSIS

The data obtained was subjected to analysis of variance using ANOVA (one way ANOVA), and test of significance of means was done by Duncan's Multiple Range (DMR) test using Statistical Package for Social Sciences (SPSS) .

RESULTS AND DICUSSION

The results of vehicular counting carried at each location were recorded, Ayetoro has 1,960 vehicles per hour**,** Oja Oba was 1,055 vehicles per hour**,** Ilesa-garage has 883 vehicles per hour**,** while Ibokun road (Control) was 132 vehicles per hour.

The pH, electrical conductivity (EC), organic matter content (OM) and cations exchange capacity (CEC) analysis of the samples collected from Ayetoro, Oja-Oba, Ilesa garage and Ibokun road are presented in Table 1. The results obtained indicates that there were significant differences ($p<0.05$) in the pH, EC, OMC and CEC properties across the study area (Table1). The concentrations of pH ranged between 8.3 and 9.06; while conductivity is between 39.8 and 342.9µS/cm conductivity; and organic matter content falls between 4.72% and 6.93%. The pH of soil sample from Ayetoro road and Oja – Oba Road was strongly alkaline (8.75 – 9.06) while the one collected from Ilesa garage road was moderately alkaline and control sample was neutral. Alkalinity of these samples may be due to presence of soluble salts and calcium magnesium sodium carbonates, giving a predominance of hydroxyl ions over hydrogen ions in the solution as reported by Isreal and Mira, 2021. Also, according to United States Department of Agriculture National Resources Conservation Service group (2011), nutrients availability of pH greater than 8.0 like phosphorous or micronutrients can be low meanwhile, the pH of soils samples collected were greater than 8.3, this indicates the presence of sodium or sodic problems, with high calcium carbonate content which prevents plants from absorbing most essential nutrients according to USDA, 2011. Standard Operating Procedure for soil determination by (FAO 2021) reported that the desirable soil pH range for optimum plant growth varies among crops, but soil pH between 6.0 –7.5 is acceptable for most plants. Cations exchange capacity ranged from 4.88 to 5.37 meq/100g and the result for control site was 14.65 meq/100g. These results was significantly lower than control, low CEC may be due to development in magnesium (Mg^{2+}), potassium (K^+) deficiencies according to (CUCE, 2007). Also, low CEC may be due to their texture because samples collected were all sandy soils and these can cause the pH to decrease with time according to Rayment and Higginson (1992), reported that sandy soils usually low in CEC because of loss of nutrients via leaching.

The results of organic matter content of all the location were very low compared to control site 13.76%, Ayetoro road had OM 6.3 %, Oja Oba Road had 4.72%, while Ilesa garage road had 6.36%. The state of these soils is not healthy enough because Sullivan *et al.,* (2019) reported that the higher the organic matter of the soil the more the nutrients that are available for the usefulness of the soil. According to Marno, (2019), Sullivan *et al.,* (2019), the organic matter of the soils is very important because it also determine the structure, texture, colour, fertility state, ability to resist the wind and water erosion, and ability to respond to tillage. The heavy metal concentration varied across the study sites such that Fe > Zn > Cd > Cu > Pb > Cr (Table. 2). Iron (Fe) had the highest concentration irrespective of the study sites when compare with other metals, while there was no trace of Cr in all the sites.

The concentration of Fe in Ayetoro (349.83) was higher than that of Oja Oba (280.95), Ilesa garage (291.50) and Ibokun with (348.29). Zinc (Zn) concentration at Ibokun area was significantly lower than concentration obtained in other study area.

The concentration of Cu at Ilesa garage was significantly higher than that of Oja oba and Ayetoro, which are not significantly different from each other (Table 2). Although there was no significant different in the Cd concentration across the study sites. The Cd concentration at Ilesa garage was slightly higher than that of Oja-Oba and Ayetoro. The Cd concentration at Ilesa garage was slightly higher than that of Oja-Oba and Ayetoro. The non-carcinogenic assessment result in Table 3 showed that hazard quotient (HQ) for the metals whose assessment parameters are available in this study were below the threshold value of 1.0 for adult. Likewise, the estimated index (HI) was also below 1.0 suggesting that no adverse effects would be expected to occur from human exposure to either individual toxic metals or their combination in the soils. Only Fe and Zn indicate the chances of carcinogenic risk (greater than 1) as shown in Table 3.

Table 1: Soil Chemical properties across the soils of roads in Osogbo, Nigeria

	Chemical Properties of the Soil					
Properties	**Ayetoro Road**	**Oja Oba road**	**Ilesa garage road**	**Ibokun road (control)**	**f-value**	**p-value**
pH	8.85[a]	9.06[a]	8.32[a]	7.22[b]	10.780	0.000
Oganic Matter Content (%)	6.93[b]	4.72[b]	6.36[b]	13.76[a]	3.057	0.052
Conductivity (µS/cm)	235.25[a]	342.93[a]	39.8[b]	48.48[b]	3.467	0.036
CEC (meq/100g)	5.37[b]	4.96[b]	4.88[b]	14.65[a]	0.427	0.736

Footnote: Values with the same letters in a column are not significantly different at P=0.05.

Table 2: Average concentration of heavy metals (mg/kg) in soil of roads in Osogbo, Nigeria

Locations	Zn	Fe	Cu	Cd	Pb
Ayetoro	35.51 ± 1.11[a]	349.83 ± 2.12[a]	0.012 ± 0.002[b]	0.150 ± 0 .134[b]	0.161 ± 0.081[b]
Oja-Oba	35.57 ± 1.23[a]	280.95 ± 3.10[c]	0.004 ± 0.105[a]	0.109 ± 0.107[b]	0.134 ± 0.088[b]
Ilesa Garage	28.86 ± 0.12[b]	291.50 ± 2.12[b]	0.023 ± 0.020[a]	0.167 ± 0.166[b]	0.138 ± 0.042[b]
Ibokun	13.36 ± 0.21[c]	348.29 ± 1.47[a]	0.003 ± 0.001[b]	0.076 ± 0.068[b]	0.093 ± 0.016[b]
f-value	**0.417**	**8.770**	**4.168**	**0.655**	**1.159**
p-value	**0.743**	**0.001**	**0.019**	**0.589**	**0.350**

Footnote: Values with the same letters in a column are not significantly different at P=0.05.

Table 3: Non carcinogenic HQ and THI of metals in soil of roads in Osogbo, Nigeria

Locations	HQZn	HQFe	HQCu	HQCd	HQPb
Ayetoro	1.8	49.29	0.0013	0.094	0.0003
Oja-Oba	0.1	51.29	0.0001	0.13	0.0005
Ilesa Garage	2.2	61.29	0.0035	0.18	0.0006
Ibokun	0.9	61.57	0.0073	0.20	0.0006
THI	**5.0**	**223.44**	**0.012**	**0.604**	**0.002**

Spatial analysis of heavy metals pollution distribution across the sites were under permissible limit except in Ayetoro and Oja Oba where Zn concentration was beyond the permissible limit. These two sites possessed higher traffic density than others. Higher concentration of Zn in these sampling points may be due to tear and wear of vehicular parts, most of the vehicle parts are protected with Zn because of corrosion while some engines are using zinc oil additives like ZDDP (Zinc dialkyl dithiophosphate) which creates a protective coating on metal surfaces in order to withstand the load put on the engine by camshaft (www.rislone.com). Moreso, previous researches shows that tire emitted more Zn because of its high concentration resulted from addition ZnO and ZnS to the tire during vulcanization, according to Ozaki *et al.*, (2004) tires contained 0.4 and 4-3% of Zn, while Baekken 1993; Lee *et al.*, 1997; Legret and Pagtto 1999, reported the emissions range of Zn by tire between 16 and 90 mg/tire/km.

CONCLUSION

It was established that the soil has been polluted with heavy metals. From this study, Zn, Fe, Cu, Cd, and Pb were all presents in the soil samples collected. Although, all the metals were within the permissible limit but the result of other chemical parameters (pH, EC, CEC, OMC) carried out indicated that the soils were alkaline and low in nutrients availability, the results also indicated that adverse effect would be expected to occur from human exposure, it poses no threats to human health. However, inhalation of heavy metals present in this emission contributes to an increased risk of death, particularly from cardiopulmonary causes. It increases the risk of respiratory symptom and accumulation of these metals in the body system can be cancerous.

Meanwhile, accumulation of these metals beyond the permissible limit can occur in the future, if the vehicular emission is not monitor or controlled.

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MITIGATING POTENTIAL HAZARDS ASSOCIATED WITH THE USE OF INSECTICIDES ON HUMAN HEALTH AND THE ECOSYSTEM: A REVIEW

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ABSTRACT

Agriculture plays a pivot role in the nation's economy and one of the things Nigerian farmers consider as an enhancement bullet to increase farming efficiency with robust output is the use of agrochemicals. This review was conducted to find practicable means of mitigating the potential hazards associated with the use of insecticides on human health and the ecosystem. This was achieved by reviewing selected existing documents on the effects and management of various agrochemicals used on farmland. These agrochemicals are chemical substances used for agricultural activities to protect plants, such as pesticides, fertilisers, liming and acidifying agents, plant growth hormones and soil conditioners. The most commonly used among these agrochemicals pesticides which are formulated to control the infestation of pests on plant. Ideally, pesticides are supposed to be biodegradable and act against the target pest without leaching into the soil. Unfortunately, most of them vaporizes into the air, consequently leading to air pollution while others pollute the water bodies through runoff. In order to mitigate the negative impact of pesticides on human and the ecosystem, it was suggested that Government (through Agricultural Extension Workers) and NGOs should make deliberate effort in educating the farmers on the characteristics and proper handling of chemicals to avoid direct contamination. Also, a variety of environmentally friendly management strategies, including bioremediations to address pesticide issues by creating green alternatives. More awareness should be created towards the acceptance of alternative protocols to further prevent the indiscriminate use of agrochemicals.

Keywords: Agrochemicals, Contamination, Pesticide use, Management

INTRODUCTION

Before industrial revolution, human totally depends on organic farming system which protects human and his habitat. The industrial revolution however, introduced the use of chemicals to agriculture (called agrochemicals) in order to protect crop and enhance food production to cater for population growth. These agrochemicals are chemical substances used for agricultural activities to protect plants, such as pesticides, fertilisers, liming and acidifying agents, plant growth hormones and soil conditioners (Mandal *et al.,* 2021). The most consumed among these agrochemicals is pesticides. Pesticides according to the food and agricultural organization (FAO) of the united nation defined it as a substance or mixture of substances intended to control, prevent, destroy pest, animal, or human disease-causing vectors, undesirable plants, or animal species affecting food production, management, sales, storage and transportation (World Health Organization, 2015).

Boxall *et al.,* (2009) reported that about 25% of world's crop production were lost to pest attacks and other pathogenic microbes. Meanwhile, the world's total population is 7.2 billion with a projection of 9.3 billion by 2050 which implies that there would be increased demand for food and by implication, there will also be an increased demand for pesticides to sustain the growth (FICCI, 2016). These chemicals were reported by several Researchers of their adverse effect on both aquatic and terrestrial ecosystems (Jayasumana *et al.,* 2015; Parks *et al.*, 2016). For these reasons, it is pertinent to pay attention to the menace posed by the use of agrochemicals in agriculture to human, and the ecosystem in order to prevent from associated hazards.

Methodology

This study is a summary of selected existing documents on the effects and management of various agrochemicals used on farmland. These literatures include both local, international and standard regulatory organisation records.

Types of agrochemicals

Agrochemicals are categorized based on their uses. These includes pesticides (for eliminating pest from the soil, plants and produce), fertilizers (for enhancing plant growth), liming and acidifying agents (for regulating soil pH) and soil conditioner (Pal *et al.*, 2006).

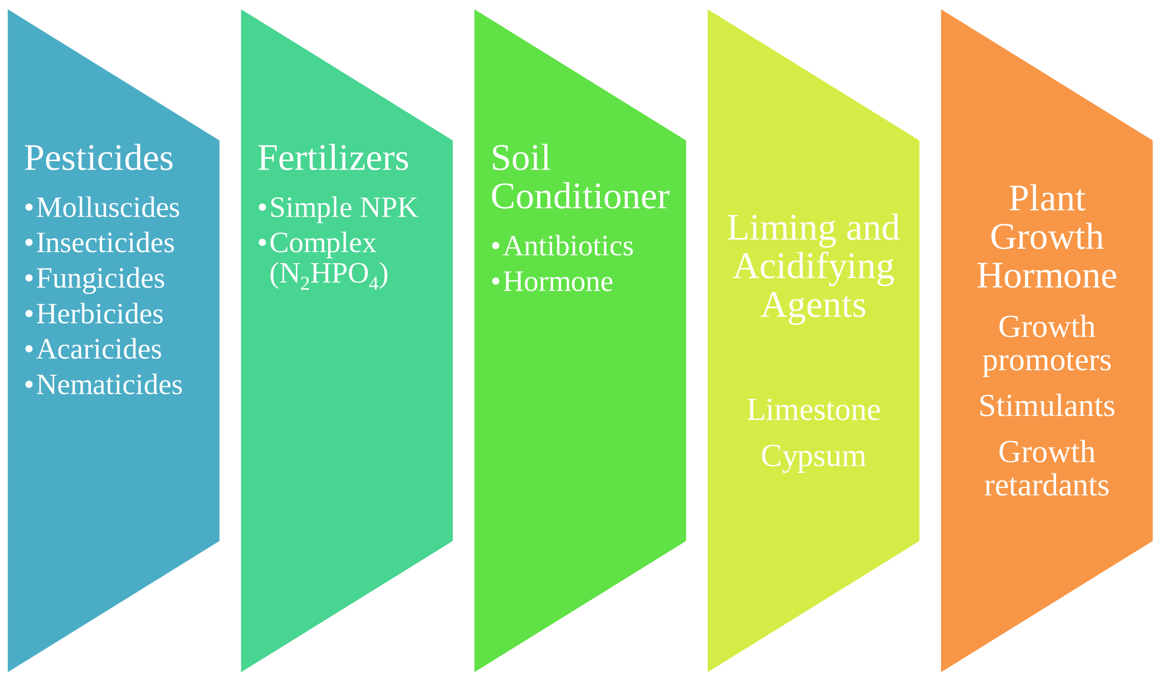

Figure 1: Types of agrochemicals used in agriculture practices.
Source: Mathur, S.C. (1999).

Pesticides

Pesticides are complex chemical substances designed to control, retard or eliminate pest form plants (Johnsen *et al.*, 2001). Ideally, pesticides are supposed to be biodegradable, they are supposed to act against the target pest and remain on the soil surface. However, most agrochemicals will vaporize to pollute the air, leach into the soil through runoffs and thereby affecting the ecosystem severely (Agnihotri *et al.*, 1996). Pesticides are classified based on several factors. The mode of entry, chemical constitution and target pests are the factors often used in classifying pesticides (fig. 2). However, WHO and Global Harmonized System (GHS) classified insecticides based on their toxicity on health basis. Pathak *et al.*, (2022) reported that herbicide is the most toxic pesticide known. It constitutes 47.5% toxicity, while insecticides take 29.5%, fungicides accounts for 17.5% and other pesticides contribute just 5.5% (Gill and Garg, 2014; Zhang, 2018; Sharma *et al.*, 2019; Pathak *et al.*, 2022).

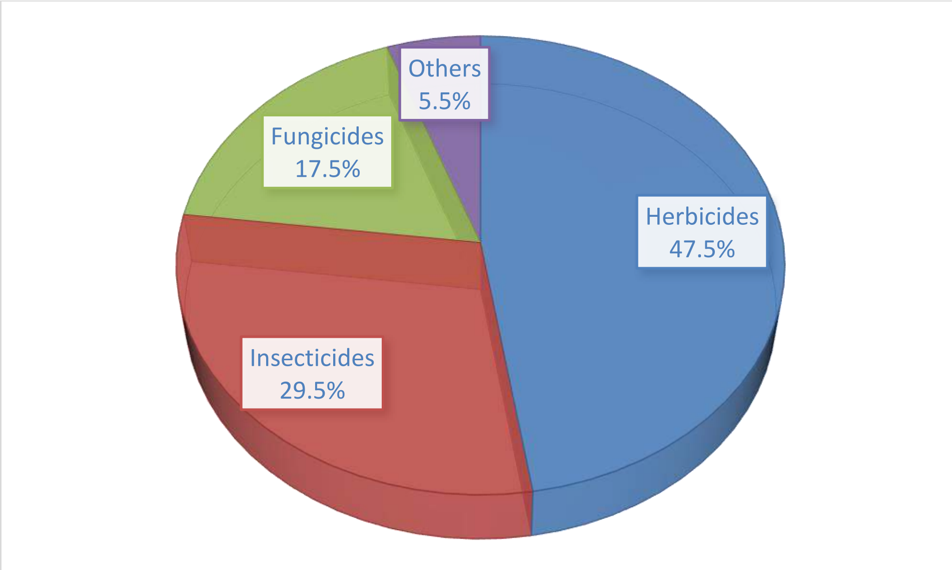

Figure 2: Percentage distribution of pesticides
Source: Gill and Garg, 2014; Zhang, 2018; Sharma *et al.*, 2019; Pathak *et al.*, 2022

Pesticides interaction with soil

Recently, farmers depend largely on the use of pesticides to kill insects and protect plant unfortunately, they can contaminate the soil when handlers lack information their usage (Pathak *et al.*, 2022). Zhang *et al.*, (2011) reported that one third of agricultural produce are made with the aid of pesticides. It was reported in another study that only 0.1%of insecticide applied is used up by plant while the remaining goes to contaminate the soil and water bodies (Pathak *et al.*, 2022; Carriger *et al.*, 2006). The degree of contamination depends on the degradability, toxicity, concentration, frequency, bioactivity and absorption and desorption of chemical used coupled with the soil factor or properties such as fertility, texture and tillage system as well as application strategy (Marino, 2022; Ram *et al.*, 2020).

Impact of Pesticides on Water Ecosystem

Water constitutes about 71% of the earth surface, of which the groundwater covers 30%. Water is the most essential element for all forms of life be it agriculture, domestic, industrial and transportation (Marsala *et al.*, 2020). But human activity has placed water quality under threat as urbanization, industrialization and agriculture strives to satisfy the population growth (Jayaraj *et al.*, 2016; Wagh *et al.*, 2020).

The environmental protection agency (EPA) identifies pesticide runoff as a major source of water pollution. It constitutes a major pollutant which degrades the environment. The fertilizer and pesticides used on farm lands are leached into the soil while some are washed over the soil surface to the surrounding lakes and streams. Studies revealed that when fertilizer containing high amount of phosphorus is washed into the water, it eliminates the available algae, as this happens, bacteria begin to breakdown the organic material (Pathak *et al.*, 2022). Overtime, this gets to an extent that bacteria begin to make use of the available dissolved oxygen. By implication, the organisms in the water begins to die off. When this occurs, the lake becomes inhabitable for any organism survive and thereby denies human access to drinking water. Unfortunately, human cannot do without water, but the presence of pesticides in water calls for serious concern as most populace depends on groundwater for drinking. For instance, a study conducted by Bassi *et al.,* (2016) on the agrochemical use and associated risk factors in Fadan Daji district of Kaura local government area, Kaduna State, Nigeria examined of their source of their drinking water. It was discovered that most local dwellers consume ground waters without treatment. According to report (Table 1), only 19.6% of farmer drink pipe borne water; 55.2% rinks well water, 6.4% takes river/stream water; 0.8%-rain water while the remaining 18% consumes get their water from the borehole. This is a clear indication that humans especially those living around the farmlands indirectly consume these chemicals in their water through agricultural runoffs.

Table 1: Sources of Drinking Water

Source of drinking water	Percentage
Well	55.2
Borehole	18
Pipe borne	19.6
River/Stream	6.4
Rain	0.8

Source: Bassi *et al.,* (2016)

Identified risk factors to human health

The toxicity of pesticides on human are numerous and are dependent on their chemical composition with respect to the amount utilized and mode of utilization. There are broad categories of pesticides products ranging from insecticide, fungicides, rodenticides, antiseptics, herbicides and disinfectants (Garcia *et al.*, 2012; Pathak *et al.*, 2022). Therefore, the health implication of these chemical on human depends on their constituent. Tables 2, 3, and 4 presents few classes of insecticides and their corresponding effects on human health.

Table 2: effect of herbicides on human body

Herbicides	Effect on body
Glyphosate	Nervous system
Metribuzin	Organ weight
Decthal	Liver damage
Sethoxydim	Tremors
Trifluralin	Dermal irritation

Source: Nicolopoulou-Stamati *et al.,* 2016; Alengebawy *et al.,* 2021; Pathak *et al.,* 2022

Table 3: Effect of insecticides on human body

Insecticides	Effect on body
DDT	Carcinogenic
Dieldrin	Dizziness
Endosulfan	Diarrhoea
Dicofol	Headache
Methoxychor	Nervous system

Source: Nicolopoulou-Stamati *et al.,* 2016; Alengebawy *et al.,* 2021; Pathak *et al.,* 2022

Table 4: Effect of fungicides on human body

Fungicides	Effect on body
Benonyl	Cirrhosis
Metiram	Thyroid glands
Nabam	Nerve damage
Zineb	Diarrhoea
Dichloran	Kidney

Source: Nicolopoulou-Stamati *et al.*, 2016; Alengebawy *et al.*, 2021; Pathak *et al.*, 2022

Bassi *et al.*, (2016) examined the general farming practices on farmlands with respect to the use of Personal Protective Equipment (PPE) and farmers' mode of chemical handling. The study reported that the problems emanating from the use of agrochemicals are not only limited the chemicals alone rather there is lack or inadequate information on the use of PPE, handling methods and disposal management by the farmers. For instance, while examining the use of PPE, it was discovered that only 21.6% of the farmers interviewed wear mask while spraying while 54.4% do not wear any PPE as presented in Figure 3. The study also reported that 4.8% of the farmer wear cap during application but were found to do so ignorantly because wearing caps is part of their tradition.

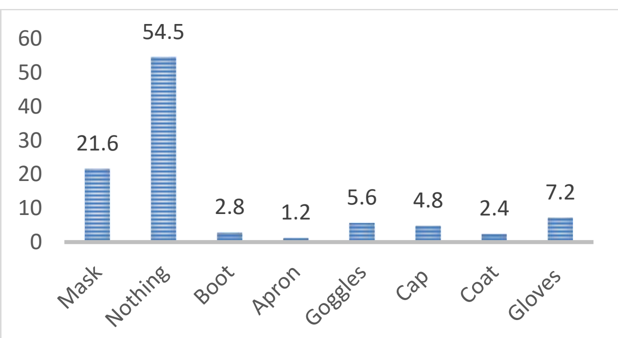

Figure 3: Use of Personal Protective Equipment (%) Source: Bassi *et al.*, 2016

Aside the inadequate use of PPE, Bassi et.al., (2016) also investigated how the chemicals are being applied. It was discovered that 19.6% (Fig. 4) of the farmers do engage in other activities while spraying the chemicals which include smoking, eating drinking and exchange of pleasantries which can cause direct contamination. However, it should be noted that this practise is not limited to the people of Fadan-Daji alone rather to most local farmers in Nigeria.

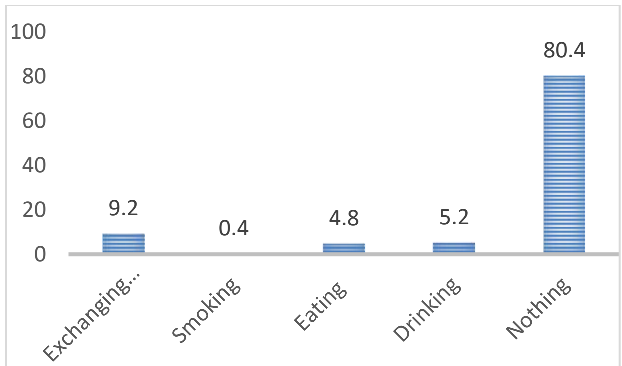

Figure 4: Habit of farmers while applying insecticides
Source: Bassi *et al.*, 2016

Mitigating Strategy

Since the advent of agrochemicals, remarkable studies were conducted on the long-term impacts on soil and natural ecosytem through the innovation of reliable analytical techniques. These techniques pave way for better understanding of their destructive mechanism (Ram *et al.*, 2020). As a result, there is a growing interest in using environmentally friendly approach to tackle this problem.

An effective removal of pesticides and heavy metals can be achieved using microalgae as biosorbent. This is achieved by converting light energy to chemical energy. The process leads to the production of oxygen that preserves the environment, help recover nutrient and remove contaminants (Pathak *et al.,* 2022). "Bacteria have been widely reported to degrade and

remove pesticides as compared to other remedial approaches. Pseudomonas, Azotobacter, Flavobacterium, and Arthrobacter are the major bacterial genus involved in the removal of

pesticides from polluted environments. The discovery of pollutant-degrading bacteria aided by advances in genetic engineering methods. These microbes use the pesticide for nutrients, generate H_2O and CO_2, and overcome the environmental risk associated with pesticides. In the soil system, such pesticides accumulate and act as electron donors and carbon sources for soil microorganisms" (Pathak *et al.,* 2022).

CONCLUSION

The industrial revolution introduced the use of chemicals in agriculture called agrochemicals. This was formulated to protect crop and enhance food production to satisfy population growth. These agrochemicals are chemical substances used for agricultural activities to protect plants, such as pesticides, fertilisers, liming and acidifying agents, plant growth hormones and soil conditioners. Pesticides are the mostly consumed these agrochemicals. Pesticides are complex chemical substances constituted to control the infestation of pests on plant. ideal pesticides are supposed to be biodegradable and act against the target pest without leaching into the soil. Unfortunately, most of them vaporizes into the air which would consequently lead to air pollution while some pollutes the water bodies through runoff. In order to mitigate the negative impact of agrochemicals on human and the ecosystem, Government (through Agricultural Extension Workers) and NGOs should make deliberate effort in educating the farmers on the characteristics and proper handling of chemicals to avoid direct contamination. However, pesticide pollution reduction has been a long-standing goal of the scientific community. There are variety of environmentally friendly management strategies, including bioremediations and servers to address pesticide issues by creating green alternatives. Therefore, more developments for the acceptance of alternative protocols to further prevent the indiscriminate use of agrochemicals, more attempts should be made to increase the adoption of alternative protocols such as biopesticides, organic pesticides, novel biocontrol agents, and nanopesticides.

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EFFECT OF MACRONUTRIENTS DEFICIENCIES ON FOLIAR NUTRIENT CONTENT OF *Adansonia digitata* L. (AFRICAN BAOBAB)

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ABSTRACT

Adansonia digitata L. (African baobab) is a tree species with significant socio-economic and ecological values. Evaluating the its regeneration and nutrient requirements for successful domestication is important. This study examined the effect of macronutrients deficiencies on foliar nutrient content of *A. digitata* for 12 weeks under seven treatments (Complete Nutrient Solution (CNS), Complete Nutrient Solution minus Nitrogen (CNS-N), Complete Nutrient Solution minus Phosphorus (CNS-P), Complete Nutrient Solution minus Potassium (CNS-K), Complete Nutrient Solution minus Calcium (CNS-Ca), Complete Nutrient Solution minus Magnesium (CNS-Mg) and Complete Nutrient Solution minus Sulphur (CNS-S)) in five replicates in a Completely Randomized Design. Data collected were subjected to two-way analysis of variance and where significant difference ($P \leq 0.05$) occurred among the means at $P \leq 0.05$, Fisher's Least Significant Difference was used for separation. Macronutrients deficiencies significantly ($P \leq 0.05$) influenced foliar nutrient contents of *A. digitata* seedlings. Seedlings grown with complete nutrient solution had normal concentrations of all the macronutrient elements in their foliage. CNS-N showed lower concentration of nitrogen (2.97 mg/100g) but improved sulphur (234.86 mg/100g) and magnesium (13.89 mg/100g) in their leaves. Also, in CNS-P, it was observed that there were lower concentrations of nitrogen (4.32 mg/100g), potassium (32.70 mg/100g) and phosphorus (47.81 mg/100g) in the foliage. CNS-K also reduced foliar concentration of sulphur (226.73 mg/100g) and potassium (15.61 mg/100g) but slightly improved nitrogen (4.35 mg/100g) compared to CNS-P. CNS-C, CNS-Mg and CNS-S seedlings were observed to have lower foliar concentration of each of their respective particular nutrient with slightly improved nitrogen and potassium. Complete nutrient solution is required for optimum growth of *A. digitata* seedlings as it produced normal concentrations of all the macronutrients in their foliage.

Keywords: Deficiency, Foliage, Forest regeneration, Growth, Macronutrient

INTRODUCTION

Adansonia digitata (Linn) is a tree species with significant socioeconomic and ecological value. The tree is one of the nine species of baobab that make up the Malvaceae family, Bombaceae subfamily, and the genus *Adansonia* (Venter and Witkowski, 2010; Salami and Lawal, 2018). The species is primarily found in the arid and savanna regions of Africa, where it is abundant and show the existence of watercourse from a distance (Wickens and Lowe, 2008). Due to its shape, the baobab, a tree species that is frequently utilized for many purposes in Africa, is formally known as the "Africa upside-down tree". *Adansonia digitata*, among other things, makes significant contributions to human survival in the form of food, medicine, and fodder (Wickens and Lowe, 2008; Venter and Witkowski, 2010). Almost all of the tree's parts are utilized because of its versatility. While the baobab's leaves and fruits are valuable and nutrient-rich food sources, other portions of the tree are also utilized for food, medicine, handicrafts, shelter, fertilizer, and fodder. Baobab frequently has cultural or spiritual value. Along with other ecosystem services like carbon sequestration, soil enrichment, improved air and water quality, and biodiversity preservation, it also provides habitat for a variety of wild species (Wickens and Lowe 2008; Gebauer and Luedeling 2013). This species mostly generate income when there is a dry spell or a drought (Sidibe and Williams, 2002; Duvall, 2007). It is a symbolic, culturally significant, and physically magnificent sub-tropical tree (Salami and Lawal, 2018).

Overharvesting of non-timber forest products (NTFPs) has harmed natural ecosystems, leading to a shortage and rising commercial value in sub-Saharan Africa (Ticktin, 2004). A major challenge to seed crop species is posed by the fact that people have constrained the variety and evolution of their non-timber products in a hostile physical environment. Managing valuable tree species reproductive biology and adaptation capacity is necessary for successful domestication and large plantation programs in order to maintain the complex co-evolution in which humans and plant species are involved in a global context of faster-growing human populations (Scheldeman *et al.,* 2007).

Adequate understanding of the nutritional relationships of trees, especially at the seedling stage, is one of the conditions for a successful plantation operation. The development of plantation forestry and its expansion into regions with relatively infertile soil have increased knowledge of the nutritional requirements of forest trees and the application of fertilizer to address nutrient issues. However, an accurate diagnosis of soil nutrient deficiencies is essential for the success and value of fertilization programs for forests. In higher plants, deficiencies of the majority of the essential elements result in visible symptoms that serve as crucial warning signs of a nutritional disorder. In order to determine the best nutritional management strategy and assess the impact of nutrient deficits on seedling morphology and physiology, nutrient deficiency studies with tree seedlings are frequently utilized (Jeyanny *et al.,* 2009). The study's main objective is to assess the effects of macronutrients deficiencies on foliar nutrient content of *A. digitata* seedlings.

MATERIALS AND METHODS

The study was conducted at the Centre of Excellence in Agricultural Development and Sustainable Environment (CEADESE) Screenhouse at the Federal University of Agriculture Abeokuta, which is located northeast of Abeokuta in Odeda Local Government Area of Ogun State at latitude 7°13'57" N and longitude 3°26'17" E.

Procedure for Experimentation

Two weeks old seedlings of *A. digitata* with uniform size, height, and high vigour were transplanted into polypots filled with river sand that had been sterilized. There were seven (7) treatments with five (5) replicates each, the complete nutrient solution (CNS) and the complete nutrient solution lacking each of the macronutrient N, P, K, Ca, Mg, and S and labelled as CNS-N, CNS-P, K, CNS-Ca, CNS-Mg, and CNS-S, respectively. The macronutrient breakdown of the applied nutrition solutions is presented in Table 1. A basal micronutrient solution containing, in ppm, the following elements: Fe (Fe-EDTA) 0.54, boron 0.54, Mn 0.55, Cu 0.064, Zn 0.065, Mo 0.048, and Co 0.012 were added to each solution. All the reagents salt used in preparation of the solutions were of analytical reagents grades. Each solution's pH was adjusted to 6.5 (Ajekigbe, 2014). The solutions were prepared using distilled water. The nutrient solution was applied at the rate of 50 mL per seedling at three (3) times per week. The experiment was set up in a completely randomized design (CRD). The experiment was terminated after twelve (12) weeks of data collection.

Table 1: Summary of the Macronutrient Composition of the Solution Applied (G/Liter)

Nutrient	KNO_3 (202)	$Ca(NO_3)$ (326)	$CaCl_2$ (222)	K_2SO_4 (174)	$MgSO_4$ ($7H_2O$) (184)	Na_2SO_4 ($10H_2O$) (301)	$NaNO_3$ (340)	$Mg(NO_3)_2$ $8H_2O$ (340)	NaH_2PO_4 $2H_2O$ (208)
Complete	+	+			+				+
-N			+	+	+				+
-P	+	+			+	+			
-K		+				+		+	+
-Ca	+				+		+		+
-Mg	+	+				+			+
-S	+	+						+	+
1 ml of stock per liter of treatment solution									

Source: Kareem *et al.* (2019)

Data Analysis

Data collected on growth parameters were subjected to descriptive statistics and inferential statistics. Analysis of variance (ANOVA) was adopted using the statistical package Statistical Analysis System (SAS vs 9.1.2) and where significant difference occurs among the means at $P \leq 0.05$, Fisher's Least Significant Difference (LSD) was used for separation.

RESULTS AND DISCUSSION

The foliar nutrient content of *A. digitata* seedlings grown in complete nutrient solution treatment was significantly different ($P \leq 0.05$) from those of other treatments. Seedlings grown with complete nutrient solution had normal concentrations of all the macronutrient elements in their foliage. The deficiency of each of the macronutrient in the rooting medium led to significant reduction in the concentration of that element in the foliage of the seedlings. Nitrogen deficient seedlings (CNS-N) showed lower concentration of nitrogen (2.97 mg/100g) but improved sulphur (234.86 mg/100g) and magnesium (13.89 mg/100g) in their leaves. Also, in phosphorus deficient seedlings (CNS-P), it was observed that there were lower concentrations of nitrogen (4.32 mg/100g), potassium (32.70 mg/100g) and phosphorus (47.81 mg/100g) in the foliage. The deficiency of potassium (CNS-K) also reduced foliar concentration of sulphur (226.73 mg/100g) and potassium (15.61 mg/100g) but slightly improved nitrogen (4.35 mg/100g) compared to phosphorus deficient seedlings. Calcium, magnesium and sulphur deficient seedlings were observed to have lower foliar concentration of each of their respective particular nutrient with slightly improved nitrogen and potassium (Table 2).

Analysis of Variance (ANOVA) revealed that there were significant differences ($P \leq 0.05$) in foliar nutrient content across the various treatments (Appendix).

Table 2: Effect of Macronutrients Deficiencies on Foliar Nutrient Content of *A. digitata* seedlings (mg/100g)

Treatments	N	Mg	K	Ca	P	S
CNS	6.66^{a}	14.24^{a}	38.12^{a}	196.32^{a}	114.92^{a}	258.48^{a}
CNS-N	2.97^{e}	13.89^{c}	36.26^{c}	191.33^{f}	108.74^{d}	234.86^{b}
CNS-P	4.32^{c}	13.46^{e}	32.70^{f}	192.36^{c}	47.81^{f}	231.47^{c}
CNS-K	4.35^{c}	13.63^{d}	15.61^{g}	191.44^{e}	106.12^{e}	226.73^{d}
CNS-Ca	4.27^{d}	13.92^{c}	34.84^{e}	89.93^{g}	110.93^{c}	220.63^{e}
CNS-Mg	4.67^{b}	13.37^{f}	36.82^{b}	193.15^{b}	112.95^{b}	201.70^{f}
CNS-S	4.68^{b}	14.04^{b}	36.13^{d}	191.69^{d}	106.09^{e}	92.47^{g}

Means with different superscript in columns are significantly different (*P≤0.05*)

According to the study, compared to other nutrient-deficient treatments, *A. digitata* seedlings raised in complete nutrient solutions exhibited normal concentrations of all the macronutrient elements in their leaves. Each nutrient's deficiency resulted in a notable decrease in the amount of that nutrient in the seedlings' leaves. Additionally, each nutrient's shortage led to either abnormal or subnormal levels of one or more other nutrients. This supports the findings of Ugese *et al.* (2012) in *Vitellaria paradoxa* seedlings. Similar results were achieved by Bessa *et al.* (2019), who observed a significant loss of a specific nutrient in the foliage of *Eugenia dysenterica* seedlings under various macronutrient omission treatments. Veígas *et al.* (2012) also reported that individual omissions of N, P, K, Ca, Mg and S reduced the leaf content of these nutrients, when compared to the control treatment in *Swietenia macrophylla* seedlings. However, Ugese *et al.* (2012) indicated that foliar nutritional imbalances as a result of certain shortages highlight the need for balanced nutrition for tree seedlings, which could promote physiological efficiency and higher growth performance.

CONCLUSION AND RECOMMENDATION

The study has revealed that the deficiency of macronutrients can significantly influence the foliar nutrient content of seedlings of *A. digitata*. The complete nutrient solution seedlings exhibited normal concentrations of all the macronutrient elements in their leaves. This shows that all the macro nutrient elements are essential and needed in appropriate amount for optimum development and growth, deficiency of any can result in growth impairments which can adversely affect the overall development of the plant. However, it is recommended that prior to seedlings establishment, appropriate nutrient deficiency diagnoses should be performed on the soil in order to identify the deficient nutrient for appropriate fertilizer to be applied to the soil.

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APPENDIX

Analysis of Variance (ANOVA) for the Effect of Macronutrients Deficiencies on Foliar Nutrient Content of *A. digitata* Seedlings

Variable	SV	Df	SS	MS	F	Pr > F
N	Treatment	6	21.45	3.57	15398.0	<.0001*
	Error	14	0.00	0.00		
	Total	20	21.45			
Mg	Treatment	6	1.79	0.30	917.23	<.0001*
	Error	14	0.00	0.00		
	Total	20	1.79			
K	Treatment	6	1100.88	183.48	667199	<.0001*
	Error	14	0.00	0.00		
	Total	20	1100.88			
Ca	Treatment	6	27219.38	4536.6	1.65	<.0001*
	Error	14	0.00	0.00		
	Total	20	27219.38			
P	Treatment	6	10129.84	1688.31	4502150	<.0001*
	Error	14	0.00	0.00		
	Total	20	10129.84			
S	Treatment	6	53108.37	8851.39	2.17	<.0001*
	Error	14	0.00	0.00		
	Total	20	53108.37			

*Significant at ($P \leq 0.05$)

ASSESSMENT OF CRUDE EXTRACT OF *PLEUROTUS PULMONARIUS* FOR LARVICIDAL EFFICACY AGAINST FEMALE *ANOPHELES* MOSQUITO LARVAE

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ABSTRACT

Anopheles mosquitoes are important vectors that spread diseases such as malaria and lymphatic filariasis. The abundance and distribution of adult Anopheles mosquitoes are based on the presence and productivity of larval breeding habitats. In other to control larvae development, breeding sites must be eradicated. This study is aimed to determine the larvicidal efficacy of *Pleurotus pulmonarius* methanol extract on *Anopheles* mosquito larvae. Five grams of grounded *Pleurotus pulmonarius* was extracted with 100mLof methanol. Phytochemical contents of the crude extract were determined, functional groups in the extract were identified with Fourier transform-infrared spectroscopy (FTIR), and Gas chromatography-mass spectral (GCMS). *Anopheles* mosquito larvae werecollected from breeding sites and larvicidal efficacy of the extract was determined by introducing 10 larvae to 500 ppm, 1000 ppm, 1500 ppm, 2000 ppm, and 2500 ppm of the crude extract. The phytochemical revealed phenol, flavonoids, saponins, alkaloids, tannins, sterols and steroids, terpenoids, and phytate in the extract. The FTIR showed alcohol, amines, amides, alkenes, amines, aromatic amines, aliphatic amines, amines, and alkyl halides. The GCMS showed a total of 41 compounds in the extract and the most prominent compound was identified as 7-anti-hydroxy bicycle [2,2,2] oct-5-en-2-one. The 2500 ppm crude extract exhibited 100% mortality rate on the larvae at 60 hours of exposure, whereas 2000, 1500, 1000, and 500 ppm exhibited 80%, 60%, 40%, and 10% mortality rates of the larvae respectively. This study suggests that compound 7-anti-hydroxy bicycle [2,2,2] oct-5-en-2-onein combination with other compounds not prominent in the methanol extract may be responsible for the mortality of *Anopheles* larvae and it can be scaled up in the pharmaceutical industry for the production of liquid antilarvicides and mosquitocides to reduce the spread and development of mosquitoes in developing country.

Keywords: *Anopheles* mosquito larvae, *Pleurotus pulmonariu*s, Fourier transform-infrared spectroscopy, Gas chromatography-mass spectral, Larvicidal efficacy, Female mosquitoes

INTRODUCTION

Anopheles mosquitoes are important vectors that spread diseases such as malaria and lymphatic filariasis. The abundance and distribution of adult Anopheles mosquitoes are predicated on the presence and productivity of larval breeding habitats (Hinne *et al.,* 2021). Species of the *Anopheles gambiae* prefer to breed in shallow water collections that are open to sunlight. Their breeding habitats may include various sizes ofwater bodies that are natural or man-made, temporary or permanent saline or freshwater. The availability of larval habitats and larval productivity may also be impacted by variations in rainfall patterns or seasonal changes (Hinne *et al.*, 2021).

The end of vector-borne diseases like lymphatic filariasis and malaria depends on vector control. Long-lasting insecticide nets (LLINs) and indoor residual spraying (IRS), the two most popular vector control strategies, have decreased malaria transmission in Africa, but they have not been able to completely eradicate the disease due to the emergence and rapid spread of insecticide resistance in mosquitoes (Emidi *et al.*, 2017; Ondiba *et al.*, 2019; Hinne *et al.*, 2021).

Additionally, the *Anopheles* mosquito's behavior has changed from interior, late-night biting to early biting hours when humans might be unprotected outside as a result of the usage of LLINs and IRS, which target indoor-biting and indoor-resting mosquitoes, respectively. To combat malaria vectors, larval source management or source control could provide an additional valuable tool (Emidi *et al.,* 2017; Ondiba *et al.,* 2019; Hinne *et al.,* 2021).

Hence, developing biologically active natural chemical constituents that act as larvicidal and potential to reduce the risk to humans and harmful accumulated residues is essential. It is necessary to develop indigenous vector control methods that are low-risk for the environment, biodegradable, and affordable to the people communities (Kumar *et al,* 2014).

Mushrooms are fungi fruiting bodies bearing spores that grow above the soil or on their substrates, and forms a major group of smaller plant kingdom. Due to their characteristic fruiting bodies and size, mushrooms are large enough to be visible to the naked eye. Some mushrooms are edible due to their nutritional components, while others are heavily used in traditional medicines (Karaman *et al.,* 2012; Nwobodo *et al,* 2021). Mushrooms have medicinal properties especially due to their abundance of physiologically active chemicals with antioxidant and antibacterial qualities that boost the immune system and protect against carcinogens (Nwobodo *et al,* 2021). Mushroom species are known to produce several bioactive compounds like flavonoids, terpenoids, alkaloids, polysaccharides, and tannins (Fakoya *et al.,*2020; Nwobodo *et al,* 2021). Even with the abundance of bioactive molecules that mushrooms possess, their natural compounds have not been extensively researched. The bioactive compounds found in various cellular components and secondary metabolites have been extracted and identified from the mushroom fruiting bodies as secondary metabolites (Gebreyohannes *et al.,* 2019; Nwobodo *et al.,* 2021).

Pleurotus pulmonarius is a North American macro fungus that can be found worldwide in temperate and subtropical climates. This fungus typically develops on hardwood and conifers in the summertime in the United States. A pileus on *P. pulmonarius* can have a diameter of 5 to 25 cm. The fruit bodies might be light, dark, or gray in color. The stipe often varies in thickness, is white, and is hard. The gills are either cream or white. This fungus often produces white or, onrare occasions, purple spore prints. The stipe of the fungus is thick and short (Gbolagade*et al.,* 2020). A study by Wasonga *et al.,* (2008)indicates that the extracts of *P. pulmonarius* may reduce replication of cancer cells. *P. pulmonarius* extract was added to the food of mice and was found to delay carcinogenesis, suggesting that the extracts could be used as adjuvants in the treatment of cancer (Gbolagade *et al.,* 2020). Despite the acclaimed medicinal potential of *Pleurotus pulmonarius* as an antibacterial and antifungal agent in literature, determination of larvicidal efficacy of *Pleurotus pulmonarius* would be of great help in the control of larval development. Therefore, the aim of this study was to investigate the larvicidal activity of methanolic extracts of *Pleurotus pulmonarius* on *Anopheles* mosquito larvae.

MATERIALS AND METHODS

Sample Collection

Mushroom (*Pleurotus pulmonarius*) spawn was collected from Ofatedo, Osun State, Nigeria. Sawdust and rice bran used as substrates for mushroom cultivation were obtained from Sawmill, and purchased from market in Oke-Baale Osun State, Nigeria respectively.

Cultivationof *Pleurotus pulmonarius*

The cultivation of mushrooms was done with slight modification to the method of Ogidi *et al.*, (2020); Balaji *et al.*, (2020); Dawidowicz (2021); and Ahmed *et al.*, (2022). Fine sawdust and rice bran were used as the substrate for the mushroom cultivation. The substrates were pasteurized in hot water for 15 minutes for effective soaking, drained, and allowed to cool. Sawdust (280 g) and 120 g of rice bran (70:30) were mixed evenly. Spawn (100 g) was inoculated into the substrate and carefully mixed to allow even spawn distribution before being packed in a sterile bag. The bag was slightly tied at the top with holes punched around the bag and incubated in a dark covered box until they were fully colonized with the fungal mycelium. The fully colonized substrate was watered twice per day for 23 days to aid mushroom fruit production. The matured fruiting mushroom was harvested for further processing.

Extraction of metabolites

With slight modification to methods of Nwobodo *et al.*, (2021); Assemie and Gemeda, (2023), matured fruits of *Pleurotus pulmonarius* were oven-dried at 70˚C for 6 hours. The dried mushrooms were grinded into fine powder and stored in a dry place at room temperature. The mushroom powder (5g) was dissolved in100mL solvents (methanol) and mixtures were periodically agitated for 72 hours. It was then filtered using Whatman No. 1 filter paper. The collected filtrates (50,000ppm stock solution) were stored in sterile amber screw cap bottles at room temperature.

FT-IR Analysis

Functional groups of compounds present in the stock solution of the *Pleurotus pulmonarius* methanol extracts of *Pleurotus pulmonarius* were determined with infrared spectral analysis using Shimadzu FTIR 8300 instrument. The spectra range wasrecorded from 400 to 4000cm^{-1} according to the report of (Vairavan *et al.*,2018; Baranitharan *et al.*, 2019; Ogidi *et al.*, 2020).

Gas Chromatography-Mass Spectrometry (GC-MS) of Extract

The Perkin - Elmer Clarus 680 system (Perkin Elmer Inc. USA) was utilized from the GC-MS analysis of methanol extract of *Pleurotus pulmonarius* which was carried out using equipped with a fused silica column, packed with elite -5MS) capillary column (30m in length *250 nm in diameter *0.25nm in thickness). The carrier gas used was unalloyed helium gas (99.99%) at a constant flow rate of 1ml/min. An electron ionization energy method was used with high ionization energy of 70 eV (electron Volts) with 0.2s of scan time and fragments ranging from 40 to 600m/z for the detection of the GC-MS spectral 1 uL of the extract were injected and the injector temperature was maintained at 250^{0}C(constant). The column oven temperature was set at 50^{0}C for 3 min raised at 10 degree per min up to 280^{o}c and final temperature was increased to 300^{0}C for 10 min. The phytochemicals present in the methanol extracts were identified by comparing their retention time (min), peak area peak height, and mass spectral patterns with the spectral database of authentic compounds stored in the National Institute of Standards and Technology (NIST) library (NIST Chemistry web book,2008).

Qualitative and Quantitative Phytochemical Screening

Qualitative and quantitative screening of the phytochemical constituent of methanol extracts of *Pleurotus pulmonarius* were carried out according to the report of Assemie and Gemeda, (2023), to determine the presence of phenol, tannins, saponins, flavonoids, sterols and steroids, phytate, terpenoids, alkaloids, cyanogenic glycoside.

Collection of Mosquito Larva

With some modifications to the methods of Kumar*et al.,* (2014); Vairavan *et al.,* (2018);Assemie and Gemeda, (2023),*Anopheles* mosquito larvae were collected from stagnant water in a bucket at Osun State University, Osogbo, Nigeria. The larvae were kept ina plastic container containing sterile water. The larvae were maintained at 25-29°C and 75-85% relative humidity and taken to the laboratory. The larvae were identified with the help of a Zoologist in the Department of Zoology, Osun State University, Osogbo, Nigeria.

Biolarvicidal activity of extract

With slight modification to the method of Kumar*et al,* (2014); Vairavan *et al*, (2018); Assemie and Gemeda (2023), ten (10)healthy*Anopheles* mosquito larvaewere distinctly placed in 15 mL of methanol extracts of *Pleurotus pulmonarius* in sterile Petri dishes at varying concentrations of 500, 1000, 1500, 2000, and 2500 ppm for 72 hours. Methanol (99.9%) was used as a positive control 5% methanol was used as a negative control. The experiment was carried out in triplicate and the mortality rates were calculated and recorded every 6 hours using this formula.

$$\text{Percentage mortality} = \frac{\text{Number of dead larvae}}{\text{Number of larvae introduced}} \times 100\%$$

Statistical analysis

Experimental values are represented as means ± standard deviation (SD). Statistical significance was determined by one-way variance analysis (ANOVA), with significant differences considered at $P<0.05$. Microsoft Excel (2016) and SPSS version 20software were used for analysis. All experiments were conducted in duplicate.

RESULT

Plate 1: Young fruiting *Pleurotus pulmonarius* mushroom

The extract from *Pleurotus pulmonarius* showed that methanol was able to extract the chemical contents present in the extract. The extract was observed to be odorless and yellow in color as shown in**Plate 2.**

Plate 2: Methanol extract of *Pleurotus pulmonarius* (Mushroom). PpE (*Pleurotus pulmonarius* extract)

Fourier-transform infrared spectroscopy (FTIR) of the*Pleurotus pulmonarius*extracts

The FTIR spectrum of the extract wascarried out to identify the functional groups. The spectrum is shown in **Plate 3.** The broad and long peak at 3421 cm^{-1} is due toDimeric O-H stretch. The peak at 2928 cm^{-1} and 2854 $cm^{-1}$is due to N-H stretching of amine salt. Also, the peak at 2360 cm^{-1} is due to O=C=O stretching of carbon dioxide. The peak at 1998 cm^{-1} is due to O=C=O stretching of carbon dioxide. The peak at 1635 cm^{-1} is due to C=C stretching of alkene. The peak at 1508 cm^{-1}, and 1458 cm^{-1} is due to N-O stretching of nitro compound. The peak at 1404 cm^{-1}, and 1338 cm^{-1} is due to O-H bending of alcohol. The peak at 1238 cm^{-1} is due to C-O stretching of alkyl aryl ether. The peak at 1076 cm^{-1} is due to C-O stretching of primary alcohol, and the peak at 1037 cm^{-1} is due to S=O stretching of sulfoxide. The peak at 933 cm^{-1}, and 767 cm^{-1} is due to C=C bending of alkene. While the peak at 609 cm^{-1}, 536 cm^{-1}, and 466 cm^{-1} is due to C-Br stretching of halo compound (Table 1).

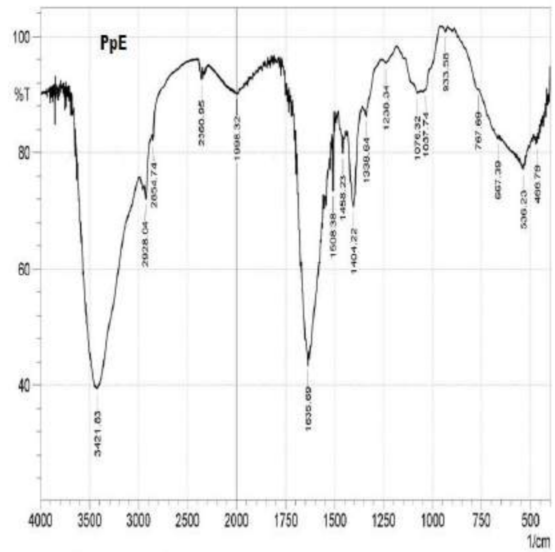

Plate 3: FTIR spectra of *Pleurotus pulmonarius* extract.PpE (*Pleurotus pulmonarius* extract)

GCMS result of compoundspresent in the mushroom methanol extract

The gas chromatography-mass spectroscopy analysis of the compounds present in the mushroom (*Pleurotus pulmonarius*) methanol extract revealed a total of 41 compounds Table 2 and Plate 4. Among the compounds identified, the structure and the characteristics of the six compounds with percentage peak area>5%, were described in Plate 5& Table 3. The most prominent compound in the extract was identified as 7-anti-hydroxy bicycle [2,2,2] oct-5-en-2-one (m/z 139.0678) at a retention time of 7.218minwhich account for 46.46% peak area from the total 108.56% peak area. The GCMS spectra is shown in Plate 6andthe structure of some other compounds identified with percentage peak area<5% is shown in Plate 7 and Table 4.

Table 1: Spectrum range of FTIR result for *Pleurotus pulmonarius* methanol extract

Absorption (cm^{-1})	Group	Compound Class
600-500	C-I stretching	Halo compound
690-515	C-Br stretching	Halo compound
840-790	C=C bending	Alkene
895-885	C=C bending	Alkene
1070-1030	S=O stretching	Sulfoxide
1085-1050	C-O stretching	Primary alcohol
1275-1200	C-O stretching	Alkyl aryl ether
1420-1330	O-H bending	Alcohol
1450	C-H bending	Alkane
1550-1500	N-O stretching	Nitro compound
1648-1638	C=C stretching	Alkene
2400-2000	O=C=O stretching	Carbon dioxide
3000-2800	N-H stretching	Amine salt
3550-3200	O-H stretching	Alcohol

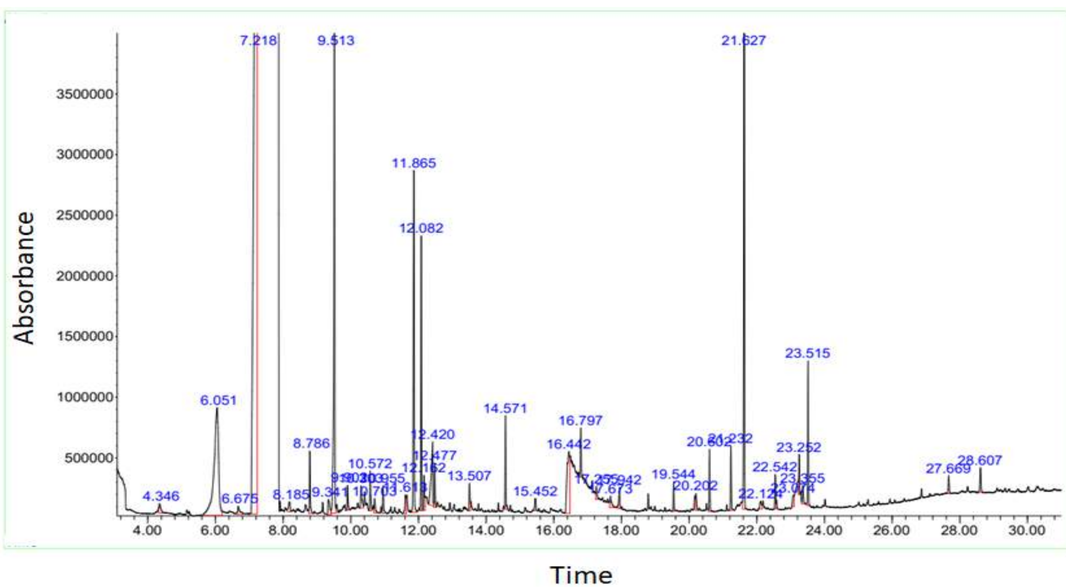

Plate 4: Spectra scan of the compounds identified in the GCMS analysis of the extract

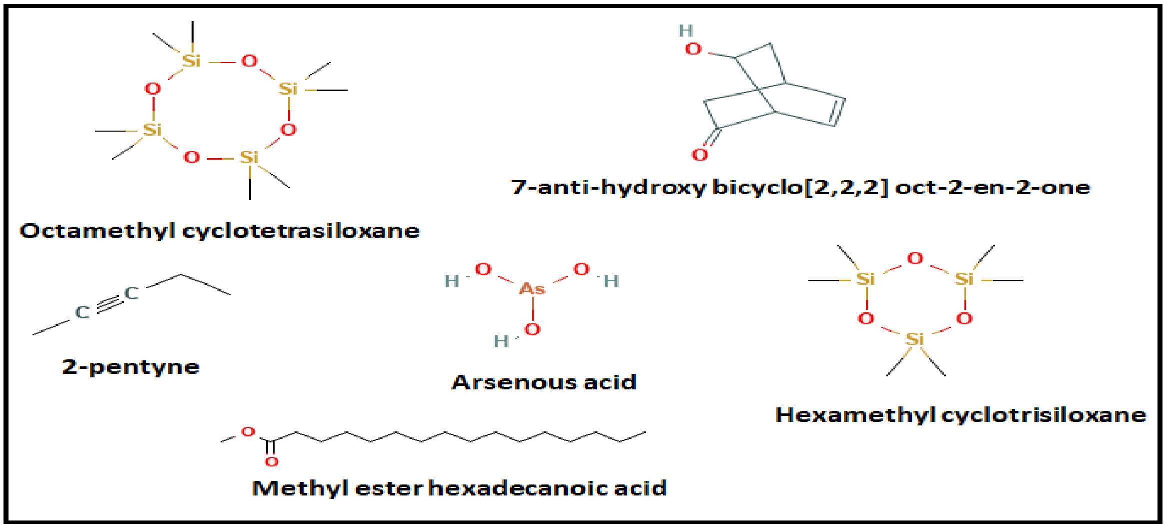

Plate 5: Structure of the compounds with percentage peak area >5%

Table 2: Compounds present in the methanol extract of mushroom (*Pleurotus pulmonarius*)

S/N	COMPOUND	RT	AREA (%)
1.	2-pentanethiol	4.346	0.3
2.	Hexamethyl cyclotrisiloxane	6.051	8.56
3.	Arsenous acid	6.051	8.56
4.	1,4-dimethyl pyrazole	6.675	0.3
5.	7-anti-hydroxy bicyclo[2,2,2] oct-5-en-2-one	7.218	46.46
6.	6-(methylamino)phenathren-3-ol	8.185	0.29
7.	N-methyl-2-furan carboxamide	8.786	0.85
8.	5-methyl-2-furan carboxylaldehyde	9.341	0.47
9.	Octamethyl cyclotetrasiloxane	9.513	8.23
10.	5-methyl isothiazole	9.902	0.35
11.	Dimethyl este but-2-enedioic acid	10.303	0.43
12.	Dimethyl-3-oxoadipate	10.572	0.53
13.	2-propenyl cylcopentane	10.703	0.28
14.	4-(phenylsulfanyl)-6-(pyrrolidin-1-yl)-2,1,3-benzoxadiazole	10.955	0.4
15.	1,3-butadiene-1-carboxylic acid	11.613	0.43
16.	2-pentyne	11.865	5.09
17.	Decamethyl cyclopentasiloxane	12.082	2.83
18.	Dimethyl dl-malate	12.162	0.58
19.	Monomethyl ester 2-butenedioic acid (E)	12.42	1.83
20.	Methyl-4-pentynoate	12.477	0.53
21.	1-beta,d-ribofuranosyl-1,2,4-triazole-3-carboxylic acid	13.507	0.43
22.	Dodecamethyl cyclohexasiloxane	14.571	1.05
23.	Methyl ester benzenesulfonic acid	15.452	0.25
24.	5-(hydroxymethyl)-2-pyrrolidinone	16.442	2.97
25.	5-oxo methyl ester L-proline	16.797	0.66
26.	2-piperidinecarboxylic acid	17.255	0.24
27.	2-methyl-3-(1-methylethyl) trans aziridine	17.673	0.29
28.	7-hexadecene	17.942	0.35
29.	Methyl tetradecanoate	19.544	0.34
30.	3-[2-[3-[1-phenyl-1H-tetrazol-5-yl]oxy]propyl]amino] ethyl ester thiosulfuric acid	20.202	0.29
31.	Methyl ester pentadecanoic acid	20.602	0.71
32.	3-(naphthalene-1-ylmethyl0-1-pentyl-1H-indole	21.232	0.83
33.	Methyl ester hexadecanoic acid	21.627	8.66
34.	Dihydropyrimidine-2-methyl thiosulfuric acid	22.124	0.23
35.	4-methoxy-N-(2-phenyl ethyl)-N-pentyl benzamide	22.542	0.44
36.	Dihydropyrimidine-2-methyl thiosulfuric acid	23.074	0.3
37.	Methyl ester-9,12-octadecadienoic acid	23.252	0.55
38.	Methyl ester-11-octadecenoic acid	23.355	0.35
39.	Methyl stearate	23.515	1.64
40.	3,5-bis(1,1-dimethylethyl)-1,2-benzenediol	27.669	0.27
41.	Methyl ester tetracosanoic acid	28.607	0.41
			108.56

Table 3: GCMS result of compoundspresent in theextract with percentage peak area >5%

S/N	Identity	RT	Area %	Molecular weight (g/mol)	Molecular formal
1	7-anti-hydroxy bicyclo[2,2,2] oct-2-en-2-one	7.218	46.46	138.07	$C_8H_{10}O_2$
2	Methyl ester hexadecanoic acid	21.627	8.66	270.5	$C_{17}H_{34}O_2$
3	Hexamethyl cyclotrisiloxane	6.051	8.56	222.46	$C_6H_{18}O_3Si_3$
4	Arsenous acid	6.051	8.56	125.944	AsH_3O_3
5	Octamethyl cyclotetrasiloxane	9.513	8.23	296.61	$C_8H_{24}O_4Si_4$
6	2-pentyne	11.865	5.09	68.12	C_5H_8
Grand total			**85.56**		

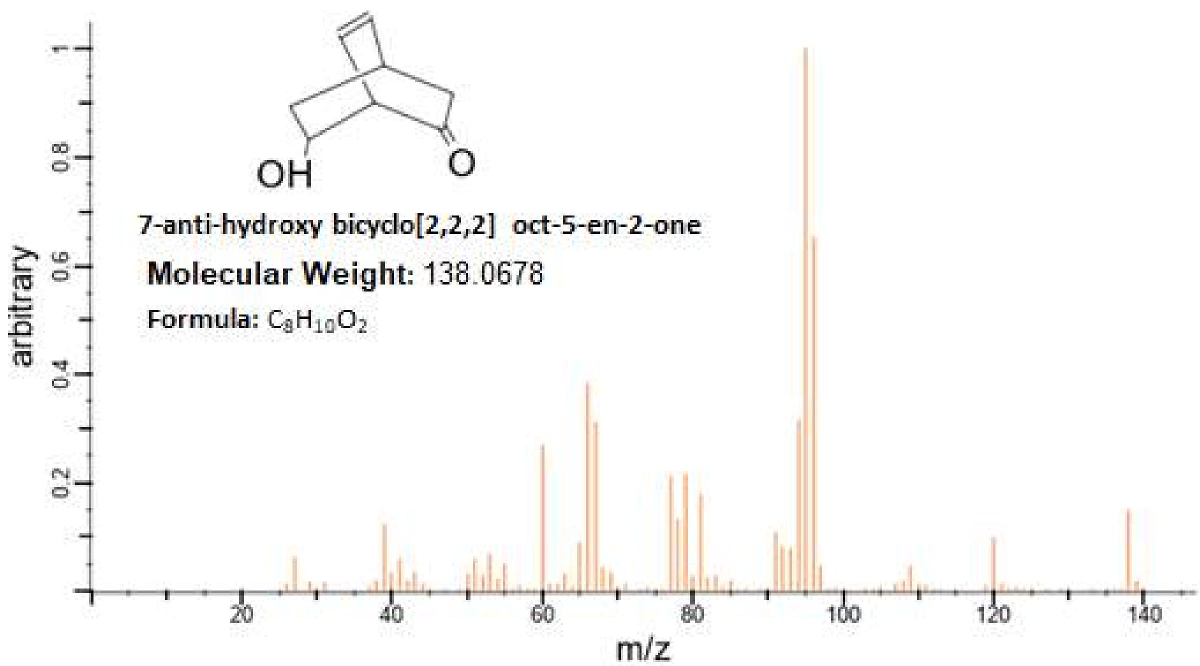

Figure 6: Gas chromatography-mass spectrometry analysis of the most prominent compound (7-anti-hydroxy bicyclo[2,2,2] oct-5-en-2-one)

Table 4: GCMS result of some compounds present in theextract with percentage peak area<5%

S/N	Identity	RT	Area %	Molecular weight (g/mol)	Molecular formal
1	Decamethyl cyclopentasiloxane	12.082	2.83	370.77	$C_{10}H_{30}O_5Si_5$
2	Monomethyl ester 2-butenedioic acid (E)	12.42	1.83	30.1	$C_5H_6O_4$
3	Dodecamethyl cyclohexasiloxane	14.571	1.05	444.92	$C_{12}H_{36}O_6Si_6$
4	5-(hydroxymethyl)-2-pyrrolidinone	16.442	2.97	115.13	$C_5H_9NO_2$
5	Methyl stearate	23.515	1.64	298.5	$C_{19}H_{38}O_2$
Grand total			**10.32**		

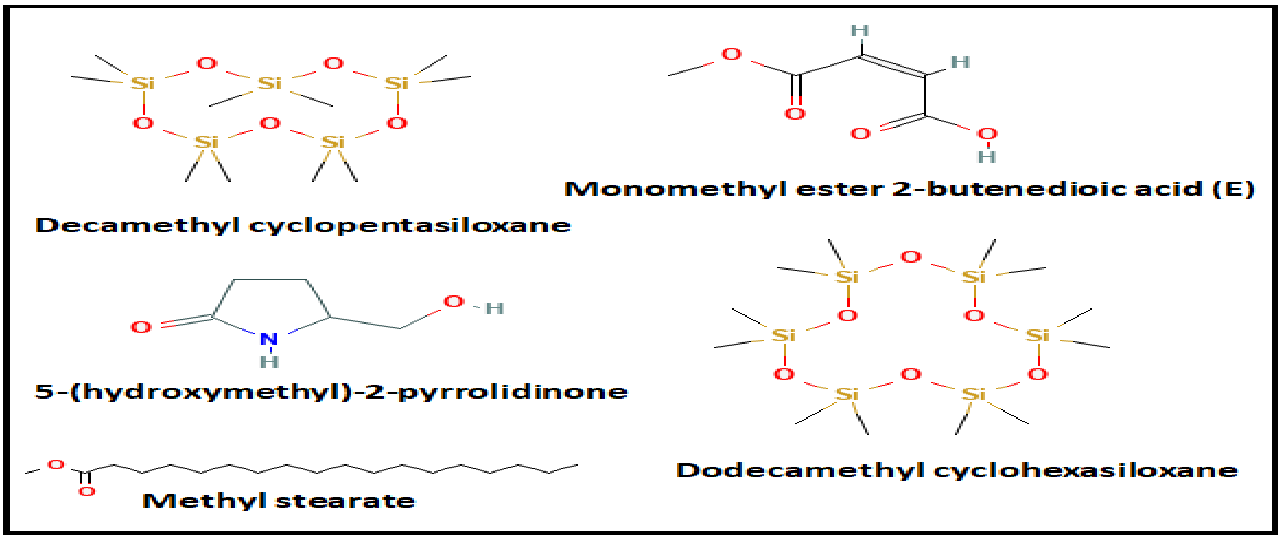

Figure 7: Structure of some compounds' percentage peak area<5%

Qualitative and quantitative phytochemical screening of *Pleurotus pulmonarius* extracts

The result of the qualitative phytochemical screening of the methanol extracts of *Pleurotus pulmonarius* revealed the presence of phenol, flavonoid, saponins, alkaloids, tannin, sterols, steroids, terpenoids, and phytate. The quantitative screening showed high concentrations of alkaloids (109.42mg/g), saponins (89.25mg/g), phenol (65.32mgGAE/g), Sterols and Steroids (62.04), terpenoids(58.08mg/g), phytate(30.01mg/g), and tannin (14.39 mg/g) in the extract. However,low concentration of flavonoid 0.95mgQE/g was detected in the extract**(Table 5).**

Biolarvicidal activities and effect of *Pleurotus pulmonarius* methanol extract concentrations

The result of the Larvicidal activity of methanol extract of *Pleurotus pulmonarius* is shown in Plate 8**.** It was observed that at an initial concentration of 2500 ppm of the extract, no mortality of the larval was observed at 0 hours of exposure. As the period of exposure progressed, 20% of mortality was recorded at 12 hours, 50% at 24 hours, 80% at 38 hours, 90% at 48 hours, and 100% at 60 and 72 hours of exposure. The positive control exhibited 100% mortality rate of the larva while no larva mortality was observed in the negative control.

Table 5: Qualitative and quantitative phytochemical composition of methanol extract of *Pleurotus pulmonarius*

Phytochemicals	Qualitative screening	Phytochemicals	Quantitative screening
Phenol	+	Phenol (mg GAE/g)	65.32±0.15
Saponin	+	Saponin (mg/g)	89.25±0.21
Tannin	+	Tannin (mg/g)	14.39±0.10
Flavonoid	+	Flavonoid (mg QE/g)	0.95±0.00
Alkaloids	+	Alkaloid (mg/g)	109.42±0.25
Sterols and Steroids	+	Sterols and Steroids	62.04±0.05
Terpenoid	+	Terpenoid (mg/g)	58.08±0.17
Phytate	+	Phytate (mg/g)	30.01±0.012

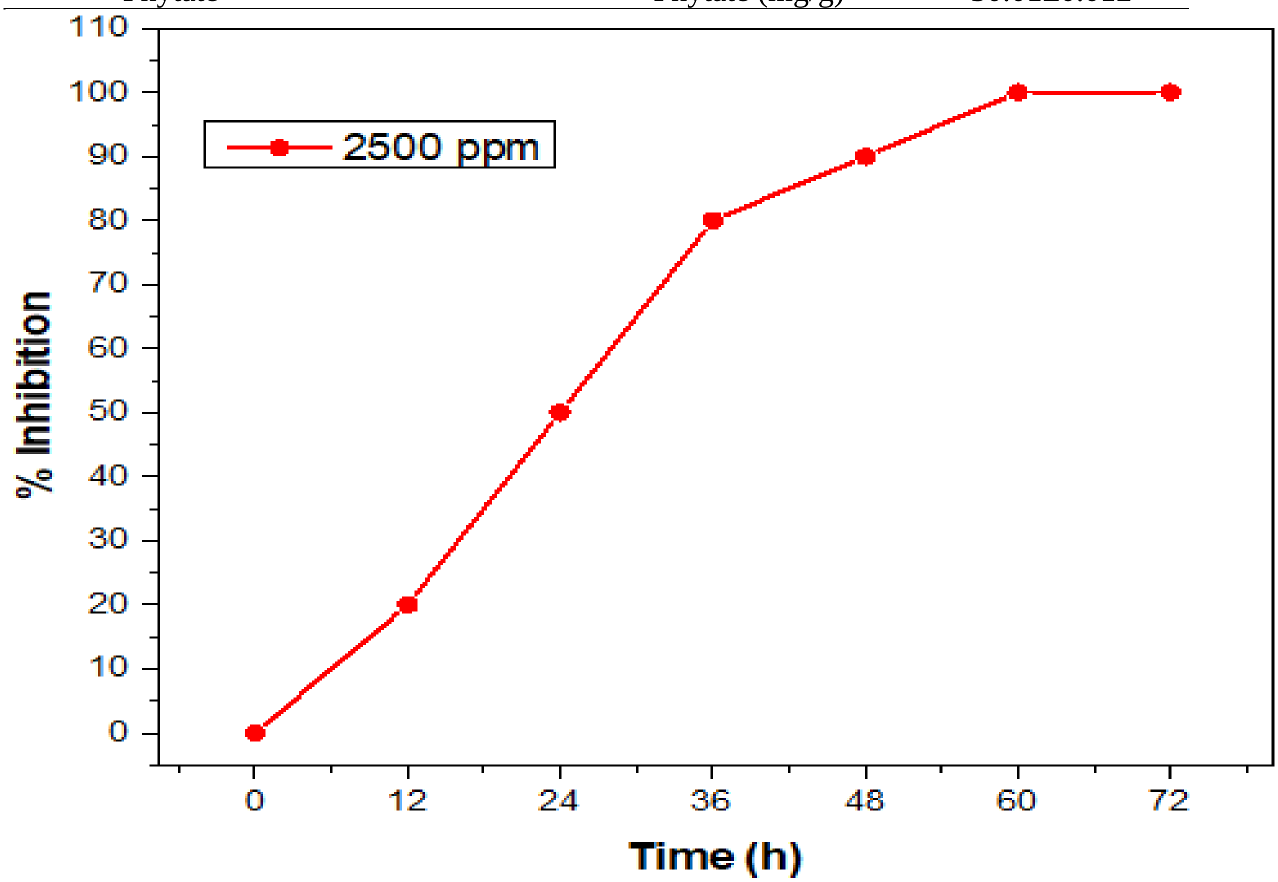

Plate 8: Percentage inhibition of methanol extract of *Pleurotus pulmonarius* against *Anopheles* mosquito larva. Ppm (part per million)

Various concentrations of the extract were tested against *Anopheles* mosquito larvae. The result showed that exposure of the larva to 2000 ppm of the extract, no mortality was seen at 0 hours, 20%, 30%, 50%, 60%, 80%, and 100% mortality rate was recorded at 12, 24, 36, 48, 60, and 72 hours of exposure to the extract. When the larvae were exposed to 1500 ppm of the extract, no larva mortality was observed at 0 and 12 hours of exposure. However, 10% at 24 hours, 30% at 36 hours, 40% at 48 hours, and 60% at 60 and 72 hours of exposure. The extract exhibited no larval mortality at 0, 12, and 24 hours of exposure whereas, 10%, 30%, 40%, and 50% larval mortality was observed at 36, 48, 60, and 72 hours of exposure to 1000 ppm concentration respectively. A weak larva inhibition was observed in exposure to a concentration of 500 ppm as there was no mortality of larva at 0, 12, 24, and 36 hours of exposure to the extract. However, 10% mortality at 48 and 60 hours and 30% mortality were seen at 72 hours of exposure (Plate 9).

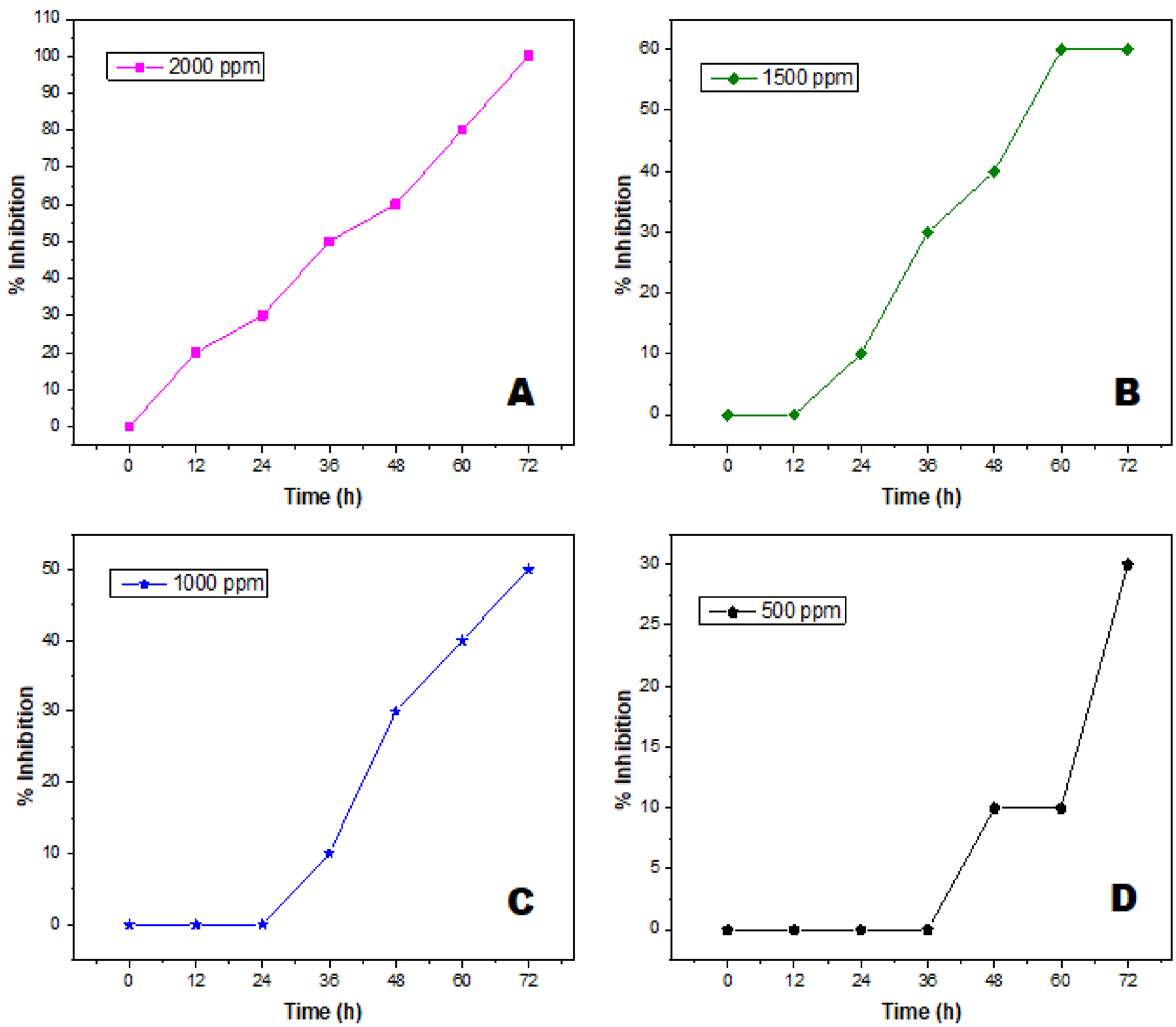

Plate 9: Percentage inhibition of *Anopheles* mosquito larval at different concentrations of *Pleurotus pulmonarius* methanol extract. ppm - part per million

DISCUSSION

The obtained mature *Pleurotus pulmonarius* grown on the substrates is as a result of the nutrients present in the substrates required for its growth. This correspondsto the report of Dawidowicz, (2021), on the growth of *Pleurotus pulmonarius* (Fr.) Quel on substrates based on cereal straw and various types of organic waste, including agricultural, horticultural, textile, and forestry in Poland. In another finding by Ahmed *et al.*, (2022), used paddy straw as a substrate for the cultivation of oyster mushrooms (*Pleurotus ostreatous)*. This showed that the growth of mushrooms could be achieved with the use of waste as substrate.

Our study revealed the presence of phenol, flavonoids, saponins, alkaloids, tannins, sterols and steroids, terpenoids, and phytate in the *Pleurotus pulmonarius* extract. The quantitative screening showed an abundance of alkaloids, saponins, Phenol, Sterols and Steroids, terpenoids, phytate, and tanninin high concentrations respectively. These findings correlate with the report of Nwobodo *et al.*, (2021) who detected the presence of alkaloids, terpenoids, flavonoids, and glycoside in *Pleurotus ostreatus* and *Agaricus bisporu s*and evaluated the antimicrobial activity against pathogenic bacterial strains; *Staphylococcus aureus*, *Bacillus subtilis*, *Escherichia coli*, and *Pseudomonas aeruginosa*, and the yeast *Candida albicans*. Tannic acid mainly produces maximum damage to the midgut epithelium of some dipterian larvae. Tannins also have various physiological effects like antiparasitic anti-irritant, antiscretolytic, and antimicrobial activities (Vairavan *et al.*, 2018). The alkaloids possess antioxidant activity. Terpenoids and essential oilshave membrane disruption characteristics (Vairavan *et al.*, 2018). Quinines and polyphenols inactivate the enzymes, bind to adhesions, and forma complex with cell wall. Flavonoids inhibit gastrointestinal tract releasing acetylcholine. Saponin possesses membrane permeabilizing properties, leading to vacuolization and disintegration of integuments. Some of the characteristics of saponins include formation of foamsin distilled water solutions, cholesterol binding properties, and hemolytic activity which affects mosquito larvae (Vairavan *et al.,* 2018). Alkaloids inhibit the metabolic processes in mosquito larvae, interfere with growth hormones, and digest the protein in the larval body and turn it into peptone derivatives (Vairavan *et al.*, 2018).

The FTIR analysis confirmed the presence of phytochemicals belongs to the functional groups such as alkyl halides, aliphatic amines, alcohols, esters, alkanes, nitro, and carbonyl groups. This is in line with the findings of *Vairavan et al.*, 2018, that reported the presence of alkyl halides, aliphatic amines, alcohols, esters, alkanes, nitro group, aromatic hydrocarbons, carbonyl group, imine group and phenols in *Catharanthus roseus* extract accounting for its usefulness as a powerful insecticidal agent. Also, in the findings of Baranitharan *et al.,* 2019, the presence of functional groups such as alcohol, amines, amides, alkenes, amines, aromatic amines, aliphatic amines, amines, and alkyl halides were present in methanol leaf extract of *Erythrina variegate*.

The gas chromatography analysis revealed the presence of 41 compounds with a total of 108.56% peak area. The 7-anti-hydroxy bicyclo[2,2,2] oct-2-en-2-one (46.46%), Methyl ester hexadecanoic acid (8.66%), Hexamethyl cyclotrisiloxane (8.56%), Arsenous acid (8.56%), Octamethyl cyclotetrasiloxane (8.23%), and 2-pentyne (5.09%) were all in abundance in the *Pleurotus pulmonarius* methanol extract. The presence of these compounds in abundance is suggested to be the cause of the high mortality rate of the *Anopheles* mosquito larvae after exposure to the extract. A similar study by Baranitharan *et al.,* (2019), on the inhibition of *Anopheles stephensi,* and *Culex quinquefasciatus* larvae development with methanol extract of *Erythrina variegate* with chemical constituents of twenty-five compounds identified in the methanol extract. The major components were 12-octadecenoic acid and methyl ester (37.31%). Shaaban *et al.,* (2021), reported the antibacterial activities of Methyl ester hexadecanoic acidfrom Clove alcoholic extract (CAE) on multi-drug resistant bacteria isolated from diabetic patients. Also, Abubacker and Deep alakshmi, (2013), also reported the effectiveness of Methyl ester hexadecanoic acid extracted from *Annona muricata* Linn. (Soursop) of Annonaceaeto inhibit *Alternaria solani* (NCBT-118), *Aspergillus erithrocephalus* (NCBT-124) and *Aspergillus albicans* (NCBT-120) less effective for *Aspergillus fumigatus* (NCBT126) and *Penicillium chrysogenum* (NCBT 162). This result is similar to the result of our study whereby the GCMS analysis revealed the presence of Methyl ester hexadecanoic acid (8.66%) in the mushroom (*Pleurotus pulmonarius*) extract. In addition, Hexamethyl cyclotrisiloxane (8.56%) and Octamethyl cyclotetrasiloxane (8.23%)were also identified in the extract and was suggested to be responsible for the inhibition of the development of the larvae which is in accordance to Keskın*et al.,* 2012 who reported the presence of cyclotrisiloxane hexamethyl (36.98%), cyclotetrasiloxane octamethyl (15.18%) and cyclopentasiloxanedecamethyl (14.59%) being the main components in the aqueous extract of West Anatolian olive (*Olea europaea* L.) leaves which was effective and inhibited the growth of all tested Gram-positive and Gram-negative bacteria except for *Bacillus cereus* CCM 99, *Enterobacter aerogenes* ATCC 13048 and *Enterobacter cloacae* ATCC 13047 in their report. In another study by Keskın *et al.,* (2012), GCMS analysis also revealed from aqueous extract of walnut green husks (*Juglans regia*) the bioactive compounds were ethylene oxide (83.67%), cyclotrisiloxane hexamethyl (5.04%), and from walnut leaves were ethylene oxide (14.74%), cyclotrisiloxane hexamethyl (17.89%). The aqueous extract of the walnut leaves was effective against four Gram-positive and one Gram-negative organism while both walnut green husks and leaves extracts exhibited antifungal activity. The combination of these compounds in abundance causes the termination of the developmental stages of the *Anopheles* mosquito larvae.

The initial concentration of 2500 ppm of *Pleurotus pulmonarius* methanol extract exhibited good larvicidal activities following exposure of the larvae beginning from the 12thhour. 100% *Anopheles* mosquito larvae mortality rate was achieved at 60 hours of exposure to the extract. This is similar to the study of Vairavan *et al,* 2018, who achieve 100% mortality rate beginning from 24thhour of exposure of *Culex quinque fasciatu s*larvae to 400 ppm of acetone extract of *Catharanthus roseus* leaf. In the exposure to 2000 ppm concentration of the extract, 100% mortality was attained at 72 hours of exposure whereas, 60%, 50%, and 30% mortality were achieved in 1500 ppm, 1000 ppm, and 500 ppm at 72 hours of exposure to the extract. The low mortality rate of the larval could be as a result of the reduction in the concentration of the *Pleurotus pulmonariu*s methanol extract. The lower the concentration, the lower the mortality rate obtained. Baranitharan *et al.,* 2019 exposed mosquito immature third instar larval, Anopheles *stephensi*, and *Culex quinque fasciatus* to different concentrations of 50-250 µg/mL *Erythrina variegate* extract and 98.2% total death rate of the larvae was achieved.In another report, 100% mortality effect of petroleum ether and N-butanol extract of *Cassia occidentalis* (Linn.) was observed at 200 and 300 ppm on la te third instar larvae of *Culex quinque fasciatus* (Kumar *et al.*, 2014).

CONCLUSION

This study revealed the phytochemical contents and the identity of the compounds present in mushroom (*Pleurotus pulmonarius*) methanol extract. It also helped to determine the larvicidal efficacy of the extracton *Anopheles* mosquito larvae. Overall, this study suggests that the methanol extract from the mushroom (*Pleurotus pulmonarius*) can be scaled up in the pharmaceutical industry to produce liquid antilarvicides and mosquitocides to reduce the spread and development of mosquitoes in developing countries.

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THE EFFECTS OF CEFIXIME AND ASPIRIN ON PHYTOPLANKTON COMMUNITY STRUCTURE AND DYNAMICS: A MESOCOSM APPROACH

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ABSTRACT

The increase in anthropogenic activities of industries, agricultural settlements, households amidst others can change the species composition of aquatic ecosystems. Pharmaceuticals have especially been reported as emerging contaminants that alter the balance of aquatic biota. This study used the mesocosm approach to investigate the effects of a cephalosporin antibiotic, cefixime and nonsteroidal anti-inflammatory drug, aspirin on the community structure (species diversity, richness and abundance) of phytoplankton. The mesocosm approach used three treatments: cefixime, aspirin and the combination of cefixime and aspirin, in addition to a control experiment over the course of 21 days. Samples were collected on days 0, 7, 14 and 21. A total of 31 phytoplankton species belonging to five groups were identified; with diatoms and green algae being the most diverse groups. *Scenedesmus spp., Pediastrum spp. and Zygnema spp.* were the most recurring species in all the samples taken throughout the experiment. *Navicula spp.* were the most recurring diatoms. The exposure of phytoplankton to cefixime, aspirin, cefixime and aspirin, significantly reduced the diversity, richness and abundance of all the species by the 21st day of the study. The combination of cefixime and aspirin reduced the abundance of all species, especially the top 10 most abundant species and the least abundant species. The control had the highest diversity, richness and abundance of phytoplankton, by the end of the experiment. The control had the highest species cell density (8,910 cells mL^{-1}) on the 21st day, while the cefixime treatment had the lowest cell density (48 cells mL^{-1}) on the 7th day of the study. This study demonstrates that pharmaceuticals can alter phytoplankton community structure and dynamics.

INTRODUCTION

Pharmaceuticals are defined as chemical compounds used for preventive and therapeutic purposes (Xin *et al.,* 2020). The use of pharmaceuticals has increased globally in recent decades and has been a concern for researchers (Ginebreda *et al.,* 2010). Pharmaceuticals are often found in aquatic ecosystems worldwide (Osorio *et al.,* 2016, Swiacka *et al.,* 2022). This can be attributed to continuous discharge of these compounds from residential areas, industrial settlements and wastewater treatment plants (Gomaa *et al.,* 2021; Ngqwala and Muchesa, 2020). Due to the biological activity of pharmaceuticals, they have been identified as substances of emerging concerns which could be detrimental to non-target aquatic biota (Pinckney *et al.,* 2017). Recently, they have been included on the European Union Framework Directive watch-list as chemical compounds that have detrimental effects on aquatic organisms (Miller *et al.,* 2018).

Pharmaceutical products such as analgesics, antibiotics, antihypertensives and antidepressants used in the treatment of human diseases have been identified as the most prevalent pharmaceuticals in aquatic ecosystems (Swiacka *et al.,* 2022). Advancement in science and technology have demonstrated the presence of pharmaceuticals in drinking water and aquatic ecosystems in the range of ng/L-ug/L concentrations (aus der Beek *et al.,* 2016; Ding *et al.,* 2020). The continuous use and discharge of pharmaceutical products coupled with their low degradation tendency are factors responsible for their pseudo-persistence and bioaccumulation in the environment (Ngqwala and Muchesa, 2020).

Aspirin, also known as acetylsalicylic acid (ASA) is a non-steroidal anti-inflammatory drug (NSAID) that is used to reduce fever, pain and/or inflammation and serves as an antithrombotic (Sachs, 2005). Cefixime is a cephalosporin antibiotic sold under the brand name, Suprax. It is used in the treatment of bacterial infections such as pneumonia, strep throat, gonorrhea, urinary tract infections, otitis media and Lyme disease (Grayson, 2017).

Phytoplankton are primary producers in freshwater ecosystems and are major contributors to the food chain. They play important roles in food and oxygen production (Falkowski and Raven, 2013). Research studies have implied that pharmaceutical substances can exert a negative influence on phytoplankton, and higher trophic organisms (Gomaa *et al.*, 2020). Scientific studies have demonstrated that phytoplankton species have varying responses to different pharmaceuticals (Grzesiuk *et al.*, 2016). It is therefore crucial to study the different pharmaceuticals and their influence on the community structure of phytoplankton.

There have been scientific reports on the impacts of certain NSAIDs (such as Ibuprofen and diclofenac) and antibiotics on the phytoplankton community. However, there is a knowledge gap as regards the roles of aspirin and cefixime in aquatic ecosystems. Thus, this study aims to examine the impact of aspirin and cefixime on the community structure of phytoplankton.

Materials and Methods

Study Area

The experiment was carried out in a screenhouse under standard conditions, at the department of plant biology, Osun State University, Osogbo. Twelve (12) 20 L plastic containers, sample bottles, nitrate, compound microscope, Aspirin, Cefixime, pond water containing phytoplankton, sediments and pebbles.

Mesocosm Set-up

The pond water containing phytoplankton was collected from Owode, Ilesha garage, off riverside hotel bus stop, Osogbo, Osun State with coordinates 7.74299, 4.57233. The pond water was collected with eight (8) 25 liters kegs and were taken to the Osun State University's screen house. Twelve mesocosms were constructed by filling twelve (12) plastic containers of twenty (20) litres capacity with fifteen (15) litres of pond water containing phytoplankton.

Experimental Design

The study was a 4 x 3 factorial trial laid out in randomized complete block design. Four treatments (control, aspirin, cefixime, aspirin and cefixime) and three replicates of each treatment were used in this study.

The treatments used in the study are control (no aspirin and cefixime), 10 ug/L of aspirin, 10 ug/L of cefixime and the combination of aspirin and cefixime. Each tablet of aspirin and cefixime; 300 mg and 400 mg respectively, were used for the preparation of the treatment. One tablet of aspirin and cefixime were respectively dissolved in 1 liter of distilled water. A stock solution of cefixime and aspirin were prepared at the concentration of 10 ug/L.

Sample Collection

Water samples were collected on day 0. The samples were collected from the twelve mesocosm set-up using twelve bowls (a bowl for each mesocosm). The bowl was dipped into each mesocosm, and the water collected was transferred into a 75 cl bottle. Storage containers were labeled with date, time, and treatment. After the collection of samples on day 0, treatment was added to each mesocosm and samples were collected on days 7, 14 and 21 to check for physicochemical parameters. The samples were kept in the refrigerator. On day 21, all the samples collected from day 0 until day 21 were taken to the department of botany at Ahmadu Bello University for analysis.

Identification and cell count of phytoplankton

Phytoplankton were identified using the standard keys of Prescott (1964) with the aid of a light microscope. Phytoplankton cell count was carried out using the drop count technique (Chia *et al.*, 2012).

Species richness and Species diversity

Species richness is a measure of the number of species in a community, while species diversity is the number of different species that are represented in each community. Species richness is simply a count of species, and it does not consider the abundances of the species or their relative abundance distributions. In this study species richness was calculated as number of individual species discovered in each mesocosm while Species diversity was determined using Shannon diversity index (1948).

The Shannon diversity index is a popular metric used in ecology. The index demonstrates the number of species living in a habitat (richness) and their relative abundance (evenness).

$H = -\Sigma p_i * ln(p_i)$

$H = -\Sigma p_i * ln(p_i)$

Where:

H- Shannon diversity index

Pi- the proportion of individuals of species ‘i’ in the community. Where ‘i’= 1

Where: n- Individual of a given species

N- Total number of individual species in a community

∑- sum symbol

RESULTS

A total of 31 species belonging to 5 groups; Bacillariophyta, Chlorophyta, Euglenophyta, Charophyta and Cyanophyta, were identified in the study. 14 species were identified in bacillariophyta including *Navicula sp.*, *Coscinodiscus sp.*, *Synedra sp.*, *Actinocylus sp.*, *Caloneis bacillum, Fragilaria sp.*, *Nitzschia sp.*, *Chaetoceros sp.*, *Melosira sp.*, *Achnanthes sp.*, *Stauroneis sp.*, *Cymbella sp.*, *Cyclotella sp.* and *Mastogloia sp.* Ten (10) chlorophytes were identified including *Scenedesmus sp.*, *Pediastrum sp. Ankistrodesmus sp.*, *Dictyosphaerum sp.*, *Sphaerocystis sp, Crucigeneiella sp.*, *Chlorella sp.*, *Selanustrum sp.*, *Oocystis sp.* and *Tetraedron trigonum. Zygnema sp.*, *Closterium sp.* and *Micrasterias sp.* are the 3 desmids identified. *Phacus sp.* and *Euglena sp.* are the only euglenophytes. *Microcystis sp.* and *Oscillatoria sp.* are the only blue-green algae identified in the study.

The results of the study suggest that the aspirin and cefixime treatments have a negative effect on the diversity indices and species richness of phytoplankton communities (figure 1). The control treatment has the highest diversity, followed by the cefixime treatment, then the aspirin treatment (figure 2). The cefixime and aspirin treatment has the lowest diversity.

The inverse Simpson, Simpson's Index, and Pielou's Evenness values decrease as the treatment becomes more toxic. This indicates that the aspirin and cefixime treatments have negative impact on the diversity of phytoplankton communities. The species richness values decrease as the treatment becomes more toxic, but they do not decrease as much as the other diversity measures. This indicates that the aspirin and cefixime treatments have negative influence on the abundance of the phytoplankton species, but with greater effect on the abundance of less abundant species.

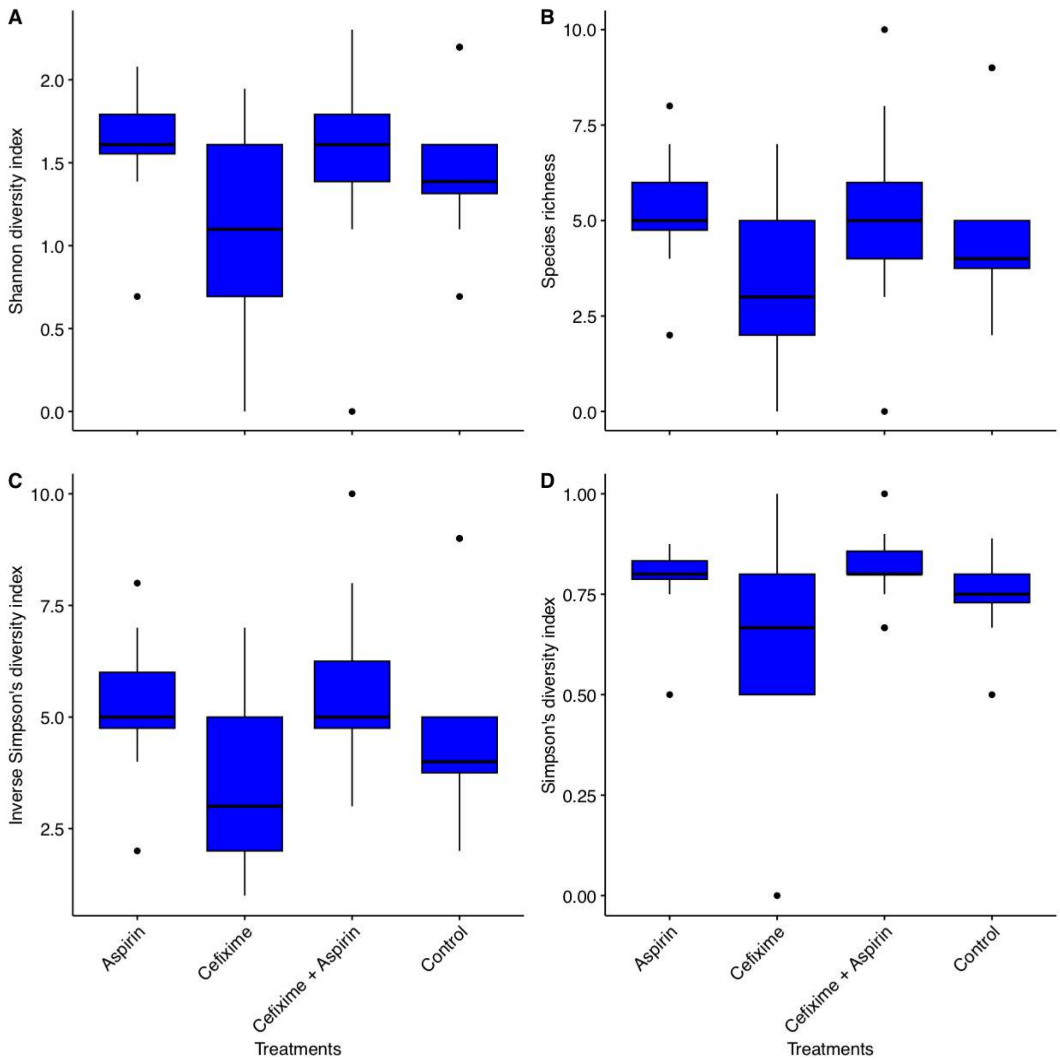

Figure 1: (A) Shannon diversity index (B) Species richness (C) Inverse Simpson's diversity index (D) Simpson's diversity index; of phytoplankton species exposed to aspirin and cefixime treatments for 21 days

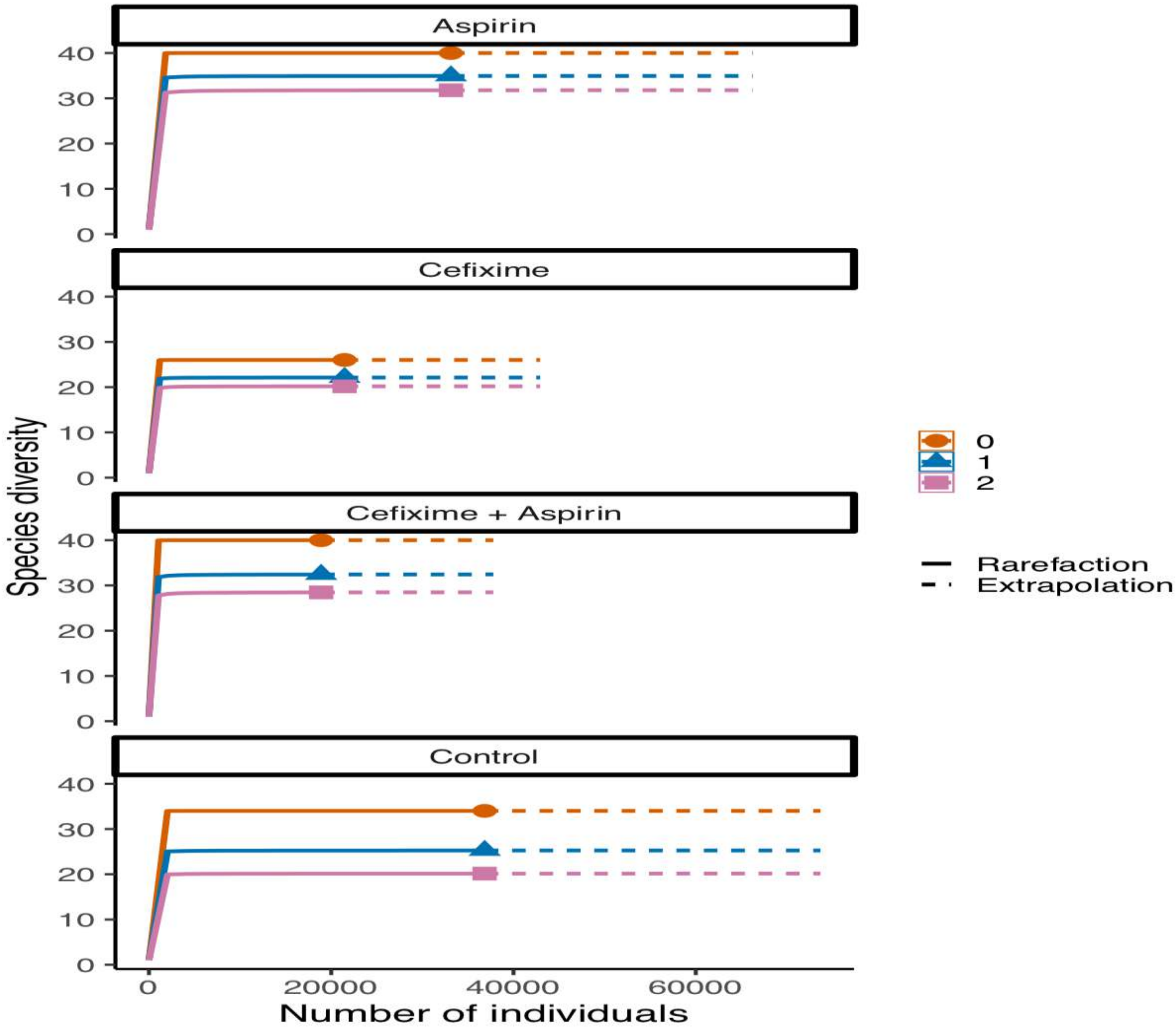

Figure 2: Species diversity of phytoplankton exposed to aspirin and cefixime treatments for 21 days

Rank Abundance

• The rank abundance curves for the three treatments are similar in shape, with few notable exceptions. The rank abundance curve for the control treatment is slightly higher than the curves for the cefixime and aspirin treatment at the beginning of the curve. This suggests that there are more abundant species in the control treatment than in the other two treatments.

• The rank abundance curves for the aspirin and cefixime treatments are similar. but they are lower than the rank abundance curve for the control treatment. This suggests that the aspirin and cefixime treatments have negative effect on the abundance of phytoplankton species.

• The rank abundance curves for the aspirin and cefixime treatments cross at rank 10. This suggests that the two treatments have a similar effect on the abundance of the top 10 most abundant phytoplankton species. However, the aspirin treatment has a greater effect on the abundance of less abundant phytoplankton species.

Overall, the results suggest that the aspirin and cefixime treatments have negative effect on the abundance of phytoplankton species.

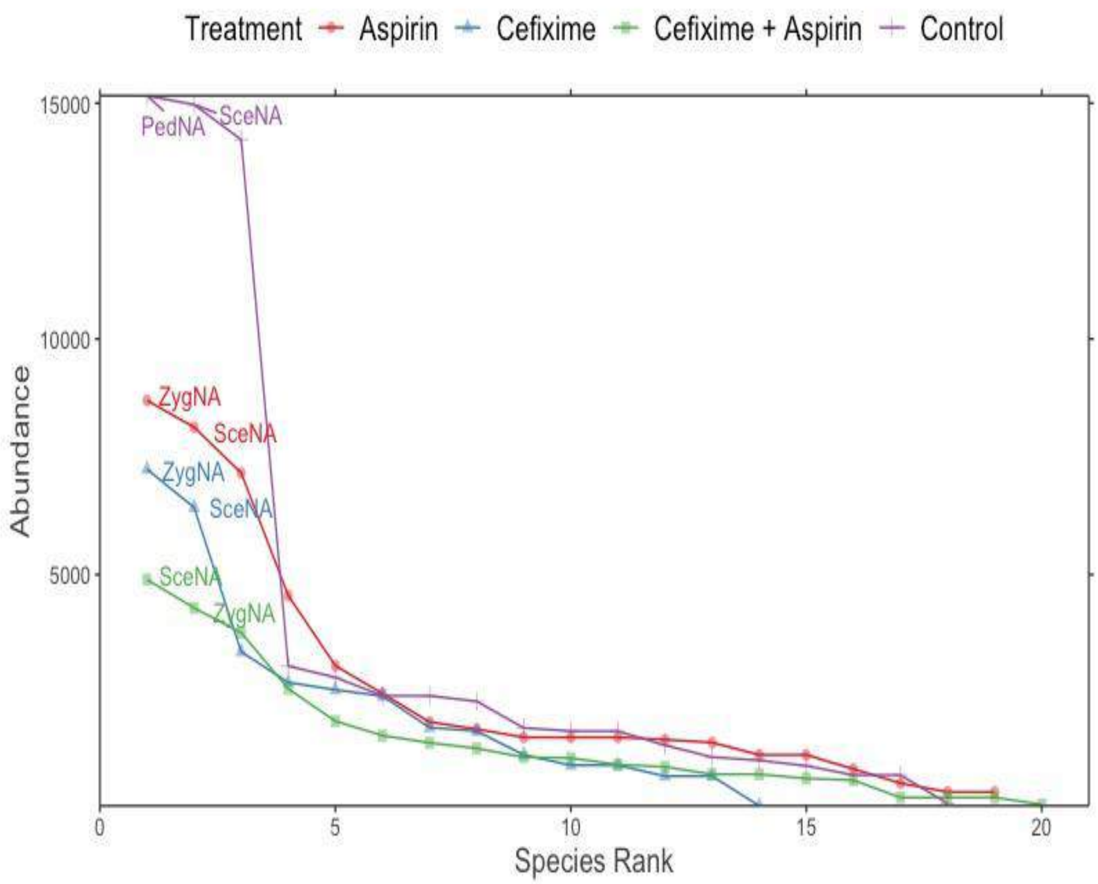

Figure 3: Rank abundance of phytoplankton species exposed to pharmaceutical treatments

Whitaker Beta Diversity

Table 1 represents the Whitaker beta diversity of the phytoplankton community exposed to different treatments. Whitaker beta diversity is a measure of the similarity between two communities. A high value indicates that the communities are similar, while a low value indicates that the communities are different. In this case, the table shows that the phytoplankton community exposed to aspirin is the most different from the control. The phytoplankton community exposed to cefixime is different from the control, but not as different as the phytoplankton community exposed to aspirin. The phytoplankton community exposed to cefixime, and aspirin is intermediate between the other two communities.

Table 1: Whitaker beta diversity of phytoplankton community exposed to different treatments.

	Aspirin	**Cefixime**	**Cefixime + Aspirin**	**Control**
Aspirin	0.00000000	0.39393939	0.28205128	0.35135135
Cefixime	0.39393939	0.00000000	0.47058824	0.37500000
Cefixime + Aspirin	0.28205128	0.47058824	0.00000000	0.36842105
Control	0.35135135	0.37500000	0.36842105	0.00000000

DISCUSSION

Phytoplankton play important roles in nutrient cycling and oxygen production (Falkowski and Raven, 2013; Schiermeier, 2010). A shift in their population can disrupt the balance of the entire ecosystem. Research studies have shown that APIs (Active Pharmaceutical Ingredients) have detrimental effects on phytoplankton, which exerts influence on higher trophic organisms (DeLorenzo and Fleming, 2008). Phytoplankton have receptors and metabolic pathways that are similar to bacteria which makes them susceptible to pharmaceuticals (Guo *et al.,* 2016). Several factors such as nutrient availability, physicochemical parameters and sensitivity to APIs are major contributors to phytoplankton community structure (Litchman and Klaumeier, 2008). According to Gomaa *et al* (2021), pharmaceuticals affect the structure and diversity of phytoplankton with different responses from different taxa of organisms. Pharmaceuticals are capable of exerting synergistic, additive, or antagonistic effects on phytoplankton community (DeLorenzo and Fleming, 2008). Chia *et al.* (2021) stated that pharmaceuticals could lead to decrease in abundance and diversity of organisms.

Eukaryotic algal groups such as Chlorophyta and Bacillariophyta generally dominate other phytoplankton groups of ecosystems exposed to pharmaceuticals (Porsbring *et al*, 2009). This is confirmed in this study, where diatoms and green algae contributed to more than 70% of the total species composition. The study by Duarte *et al*. (2023) also observed a high composition of diatoms and green algae in the treatments with sulfamethoxazole and diclofenac. Green algae are abundant in aquatic ecosystems with varying responses to nutrient concentrations, nutrient, light availability, and environmental factors (Kruk and Segura, 2012). In this study, *Scenedesmus* and *Pediastrum* contribute majorly to the abundance of the chlorophyta division. However, the richness, diversity and abundance of phytoplankton species were decreased with aspirin and cefixime treatments. Duarte *et al.* (2023) observed that the Genera *Closteripsis* and *Desmodesmus* had highest abundance at lower concentrations of sulfamethoxazole and diclofenac. Diatoms possess silica in their cell wall. Silica is the second most abundant element on earth and polymerization of monosilic acid into silica is a process that consumes less energy in diatoms. Therefore, diatoms can save energy in cell wall synthesis, while channeling it to other cellular activities such as growth (Martin-Jezequel *et al*., 2000). There was an increase in the diversity of diatoms over days of exposure to treatments, but an overall decrease in abundance by the end of the experiment. *Navicula sp* were the most recurring of the diatoms, which may be attributed to their higher survival ability compared to the other species.

Studies reveal that APIs, even at low concentrations, reduce the populations of cyanobacteria (Azevedo *et al.*, 2019). Taskan *et al.* (2016) demonstrated that populations of blue-green algae were reduced with increasing concentrations of tetracycline. This study noted only two species of cyanobacteria. Duarte *et al*. (2023) reported that cyanobacteria were most abundant at high and intermediate concentrations of diclofenac. *Zygnema spp.* were the most abundant of the desmids and were recurrent in almost all treatments of aspirin and cefixime on different days of exposure. This may suggest that they are tolerant species with the capacity to survive polluted environments. Duarte *et al.,* (2023) noted that desmids had the highest abundance with low and intermediate concentrations of both diclofenac and sulfamethoxazole. Euglenophyta was represented by only two genera in this study, with *Phacus sp* being the most abundant. This may be attributed to the ability of *Phacus sp* to form mucilaginous walls for protection under unfavorable environmental conditions. The exposure of phytoplankton community to pharmaceuticals modifies their adaptability to the environment, therefore exerting a negative impact on the richness, diversity and abundance of species in the community. The aforementioned is also subject to the interplay between the response of different phytoplankton species to stress and physicochemical parameters of the ecosystem.

CONCLUSION

This study demonstrates a decrease in diversity, richness and abundance of phytoplankton species when exposed to aspirin and cefixime treatments. Further studies should be conducted to determine the effects of multiple pharmaceuticals on phytoplankton communities.

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WATER QUALITY STATUS OF LOWER RIVER NIGER, AGENEBODE, NIGERIA

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ABSTRACT
Freshwater is often exposed to pollution, unhealthy environment due to rapid industrialization and population resulting in human afflictions and disease transmission. This paper reports findings from a study which evaluated the spatio-temporal variations in the physical and chemical parameters of the study area which is a vital resource for fishery and domestic uses for communities of over two-hundred thousand. Unfortunately, it's fast degrading due to various anthropogenic activities. Lower River Niger (LRN) was stratified downstream (DNS), midstream (MDS) and upstream (UPS) zones based on hydrological features and two sampling points each were randomly selected. Water samples were collected bi-monthly over two wet and dry seasons and analyzed for Dissolved-Oxygen (DO, mg/L), Chemical-Oxygen-Demand (COD mg/L), Total Suspended Solids (TSS mg/L), Alkalinity(mg/L), Phosphate(mg/L), conductivity(S/cm), Biochemical-Oxygen-Demand (BOD,mg/L), and temperature (^{0}C) following standard methods. Highest (84.46±24.95) and lowest (75.45±24.23 mg/L) alkalinity was recorded for MDS and DNS respectively. Temperature and DO ranged from 27.52±1.48°C (DNS) to 28.32±1.56°C (MDS) and 4.27±0.42 (UPS) to 6.06±10 mg/L (DNS) respectively, TSS varied between 51.68±8.81mg/1 to 84±19.8mg/L, with maximum value in UPS and MDS. The seasonal variation showed that mean DO values, COD, transparency, temperature, conductivity, ammonia, phosphate, chloride, TDS, TSS, calcium, magnesium, sulphate, and depth vary significantly. Conductivity were 60.28±6.1 and 58.67±6.52 mg/L, phosphate (3.89±1.63;0.52±0.09) mg/L, temperature (28.20±2.34; 25.52±1.74) °C and DO (5.25±0.56; 5.5±0.61) mg/L in dry and wet seasons respectively. The mean values for BOD (68.52±61.21 mg/L), temperature (27.52±1.48) °C, conductivity (59.55±25.19) mg/L, alkalinity (79.03±22.61) mg/L and ions were within desirable limits for aquatic life. However, TSS 101.49 ±105.27, Transparency 49.88±12.46, Sulphate 5.30±4.40 and COD 84.03±25.37 (mg/L) were above the recommended level for aquatic life. These findings are indicative of warning signs for pollution which impact not only aquatic organisms but also drinking water. Crucial restorative steps are needed therefore to reduce direct discharges of agricultural and anthropogenic effluents into LRN

Keywords: Water quality, River Niger, Aquatic Pollution, Ecosystem restoration, Hydrology.

INTRODUCTION

Water, the matrix of life is exposed to pollution, unhealthy environment resulting in human afflictions and disease transmission due to rapid industrialization and population. Nigeria is one of the tropical countries endowed with immerse natural resources including freshwater resources. One of these natural resources is Lower River Niger Water at Agenebode. Physical and chemical parameters are known to affect the biotic components of the aquatic environment (Chia *et al.*, 2011). The quality of water is closely associated with sustainable fish production in the aquatic system (Ajani, 2011).

The role water play in human life cannot be quantified. Despite the importance of water to man and his animals, little attention is often paid to the quality of these resources and sustenance of life. In regard, therefore a lot of the water consumed on daily basis is often polluted and in some extreme cases unfit for human consumption and unhealthy for the organisms living in the water body. Some of the diseases we battle with today are inherent in polluted water. The people of Agenebode, a major fish commercial town depends almost solely on the water of the Lower River Niger. A state-owned Water Board is unable to supply drinking water for household use. Private boreholes cannot meet the demand of the community. This river is a major destination for industrial waste, human excrement, wastes from abattoirs, heavy metals as well as sewage (Plates a – c). Due to the difficulties in getting easy access of portable water, the residents have no choice but to draw the water from the river for domestic use. This poses a lot of health dangers and could make the children predisposed to illness such as cholera and other water borne diseases.

Plates 1a – c: Anthropogenic Activities around Lower River Niger at Agenebode

Regrettably, Agenebode is fast growing and developing into a big city in Edo State, this brings along human influx and other anthropogenic activities and unrestricted dumping of pollutants into the river. At present a new bridge is being constructed across the river - at Agenebode/Idah villages. This construction has distorted the ecosystem of the water body. Thus, the need to have a comprehensive update information on the physico-chemical parameters of this important river so as to assess its pollution status. The significance of this study therefore, is to help narrow the dearth of information on the water quality of Lower River Niger at Agenebode as well as provide opportunity for monitoring changes in its physico-chemical parameters.

This work therefore is carried out to investigate some selected physical and chemical parameters of Lower River Niger at Agenebode and to make deductions on temporal and spatial variations in water quality in terms of pollution.

MATERIALS AND METHODS

Agenebode is a serene, water-side town located by the banks of the river Niger in Edo state, South-South geo-political zone of Nigeria. It is located on latitude $7^0$06’N and longitude of $6^0$42’E (Figure 1) with an estimated population of 264,509 (2013 census).

The area is characterized by a typical rainforest climatic condition of rainy season from April to November and dry season from December to March.

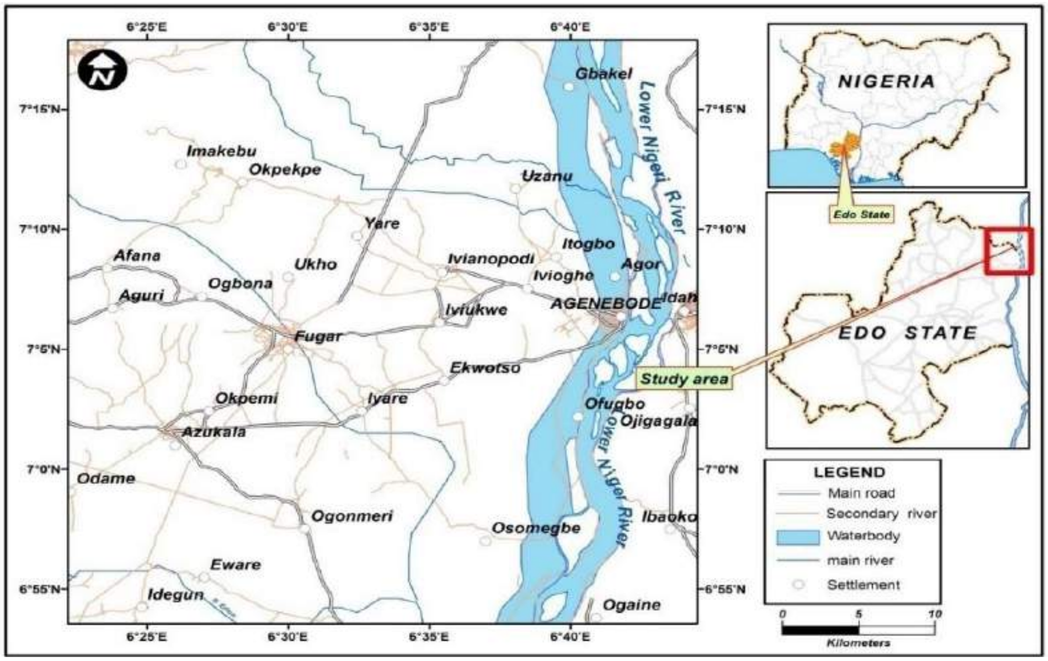

Fig. 1: map of Edo State, Nigeria showing the location of the study area

Spatial stratification was adopted according to Southwood and Henderson, 2000; ISO, 2006, in which the river was divided into three zones (Downstream (DNS), Middle stream (MDS) and Upper stream (UPS)) and two stations were randomly selected in each zone (Figure 2).

Sampling of the physico-chemical parameters was done bimonthly for in two dry and rainy seasons. Water sample was collected early hours of the morning (6.00am) at a depth of 20cm below the water surface in line with the procedure of USEPA, (2022) at each station with water sampler. The water sample for DO was collected using DO bottles and fixed with Winkler's solution in situ before taking it to the laboratory, Amber BOD bottles were used to collect water samples for BOD for analysis. Calibrated rope line attached to lead sinker was used to ascertain depth, Mercury in glass thermometer was used to measure temperature, Secchi disc attached with calibrated rope was used for the depth, Digital pH meter Suntex (Model TS-2) calibrated using 2 buffer solutions of pH 4.7 and 10 at 25°C was used for pH. DO was measured using Dissolved oxygen meter standardized by using saturated Potassium Chloride and zero solution. Intelligent meter (AD. 33915) for conductivity and total dissolved solid, HANNA meter (HI3811) for total alkalinity while chloride, total hardness, calcium, magnesium, sodium, potassium, total dissolved solids, biochemical oxygen demand, chemical oxygen demand, sulphate, phosphate, nitrate, and ammonia were analyzed according to APHA [2022]. Data generated were subjected to both descriptive (means and standard deviations) and inferential statistics (ANOVA) at $\alpha_{0.05}$ and presented as seasonal and spatial mean variances.

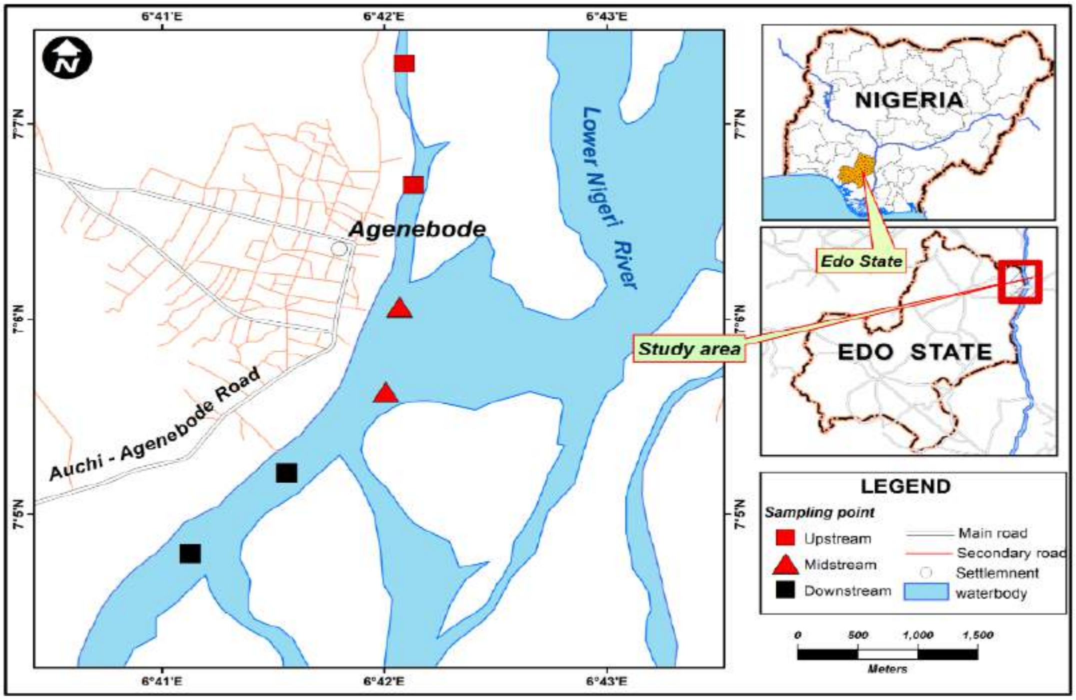

FIG. 2: Map of Edo State, Nigeria showing sampling points for the Study

RESULTS

Temporal and Spatial Variations in Physico-chemical Parameters of Lower River Niger

The mean depth of Lower River Niger recorded during the period of study was 264.00cm, the highest (401.36cm) mean depth was obtained for UPS while DNS recorded the lowest (174.45cm) mean depth. Spatially, water depth was highly significant (P< 0.01) among the sampling stations using Analysis of variance (ANOVA) as represented in Table 1. Result of follow up test shows that downstream and midstream are not significantly different. There are no significant differences among the three sampling stations in terms of the water temperature and Transparency (Table 2).

The mean water temperature was 27.51 °C and there was no significant difference (P>0.05) among the sites; There were no significant difference (P>0.05) for pH, Suspended Solids (SS), Turbidity, Phosphate, Phosphorus, Sulphate, Nitrate, Ammonia-N, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Chloride among the sampling stations while the Electrical Conductivity was highly significant (P<0.01) among the sampling stations during the study period as represented in Table 2.

Seasonally, there were no significant difference (P>0.05) for Conductivity, Phosphate, Phosphorus, Sulphate, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Chloride among the sampling stations while Suspended Solids (SS), Turbidity, pH and Nitrate showed significant difference (P<0.05) among the sampling stations and Ammonia-N was highly significant (P<0.01). All these are represented in Table 3.

Table 1 Water Depth, Temperature and Transparency of Lower River Niger

	DNS	MDS	UPS	Mean ± Std. Deviation	F-value	P-value
Water Depth	174.45±119.12[a]	216.18±99.38[a]	401.36±191.78[b]	264.00±170.42	7.9106	0.002
Water Temperature	27.36±1.29[a]	27.36 ±1.69[a]	27.81 ± 1.54[a]	27.52 ± 1.48	0.330	0.721
Water Transparency	45.55 ± 15.21[a]	53.73±12.12[a]	50.36 ± 9.03[a]	49.88 ±12.46	1.214	0.314

Table 2: The spatial variation of the physico-chemical parameters of the Lower River Niger at Agenebode

Parameters	DNS Mean ± SE	MDS Mean ± SE	UPS Mean ± SE	P-value	Significance
PH	6.64 ± 0.18	6.66 ± 0.21	6.88 ± 0.25	0.682	P>0.05
Conductivity (Mg/l)	76.36[a]± 9.82	58.64[b] ± 3.76	43.64[b] ± 4.53	0.006	**P<0.01
Total Suspended Solids (Mg/l)	69.86 ± 23.83	84 ± 19.8	51.68 ± 8.81	0.477	P>0.05
Turbidity (NTU)	98 ± 35.55	113.09 ± 32.86	93.36 ± 29.3	0.905	P>0.05
Phosphate (Mg/l)	4.06 ± 2.4	0.45 ± 0.11	2.57 ± 1.35	0.286	P>0.05
Phosphorus (Mg/l)	1.31 ± 0.77	0.2 ± 0.04	0.89 ± 0.43	0.314	P>0.05
Sulphate (Mg/l)	30.41 ± 7.73	35.05 ± 7.38	24.45 ± 3.11	0.513	P>0.05
Nitrate (Mg/l)	6.87 ± 1.68	4.93 ± 1.17	4.09 ± 1.0	0.323	P>0.05
Ammonia-N	0.68 ± 0.37	0.55 ± 0.27	0.36 ± 0.15	0.715	P>0.05
Chloride (Mg/l)	17.32 ± 2.06	16.49 ± 2.41	16.15 ± 2.76	0.94	P>0.05
Dissolved Oxygen (Mg/l)	6.06 ± 1	5.75 ± 0.49	4.27 ± 0.42	0.162	P>0.05
B.O.D. (Mg/l)	4.11 ± 1.05	2.7 ± 0.57	3.22 ± 0.43	0.399	P>0.05
TDS (Mg/l)	87.10 ± 20.37	89.55 ± 32.42	87.00 ± 38.65	0.612	P>0.05
Alkalinity (Mg/l)	75.45 ± 24.23	84.46 ± 24.95	77.18 ± 0.43	0.261	P>0.05
Calcium (Mg/l)	43.64 ± 13.28	38.00 ± 14.93	34.55 ± 14.29	0.422	P>0.05
Magnesium (Mg/l)	2.43 ± 1.70	3.89 ± 1.81	4.84 ± 1.33	0.120	P>0.05
COD (Mg/l)	86.55 ± 26.97	90.12 ± 22.18	75.44 ± 26.66	0.524	P>0.05
Water temp. (^{0}C)	27.36 ± 1.86	27.36 ± 1.68	27.82 ± 1.54	0.425	P>0.05

*Note: P>0.05- Not Significant, *P<0.05-Significant, **P<0.01- Highly Significant*

Table 3: The seasonal variation of the physico-chemical parameters of the Lower River Niger at Agenebode

Parameters	Wet season	Dry season	t-value	p-value	Significance
pH	6.5±0.12	7±0.21	-2.15	0.04	*P<0.05
Conductivity (Mg/l)	60.28±6.1	58.67±6.52	0.18	0.86	P>0.05
Suspended Solids (Mg/l)	89.67±17.56	43.13±6.1	2.32	0.03	*P<0.05
Turbidity (NTU)	136.19±30.54	59.83±10.13	2.2	0.04	*P<0.05
Phosphate (Mg/l)	3.89±1.63	0.52±0.09	1.88	0.07	P>0.05
Phosphorus (Mg/l)	1.29±0.52	0.21±0.04	1.89	0.07	P>0.05
Sulphate (Mg/l)	33.33±5.73	25.93±4.22	1	0.32	P>0.05
Nitrate (Mg/l)	6.81±0.92	3.48±1.12	2.32	0.03	*P<0.05
Ammonia-N	0.87±0.26	0.12±0.03	2.6	0.01	**P<0.01
Chloride (Mg/l)	14.98±1.65	18.67±2.19	-1.37	0.18	P>0.05
Dissolved Oxygen (Mg/l)	5.25±0.56	5.5±0.61	-0.3	0.77	P>0.05
B.O.D. (Mg/l)	3.08±0.53	3.66±0.7	-0.67	0.51	P>0.05

*Note: P>0.05- Not Significant, *P<0.05-Significant, **P<0.01- Highly Significant*

Correlation (r) between different Physico-chemical Parameters of Lower River Niger at Agenebode

The correlation coefficient (r) between every parameter pair was computed by taking the average values as shown in table 4.14. Correlation coefficient (r) between any two parameters, x & y was calculated for PH, water temperature, dissolved oxygen, electro-conductivity, nitrates, calcium of the Lower River Niger. The degree of line association between any of the water quality parameters measured by the simple correlation coefficient (r) is presented in table 4.14 as correlation matrix. The PH has been found to show positive correlation with water temperature (r=0.037), conductivity (r=0.087), nitrate (r= 0.121), BOD (r= 0.396), and transparency (r=0.142). dissolved oxygen(r=-0.305), has been found to show strong correlation with conductivity (r=0.104), turbidity (r=0.062), phosphate (r=0.090), phosphorus (r=0.086), and correlated significantly Biochemical oxygen demand (r=0.590). Water temperature showed had a negative correlation with BOD (r= -0.072) and positive correlation with pH (r= 0.037). However, conductivity showed positive significant with transparency (r= -0.117) and dissolved oxygen (r= -0.104) as represented in Table 4.

Table 4: Correlation of Physical and Chemical Parameters of Lower River Niger, Agenebode, Nigeria

	pH	EC	Turb.	PO_4	P	SO_4	NO_3	NH_3	Chloride	DO	BOD	TSS	TDS	Alk	Ca	Mg	COD	Depth	WT	Trans.
pH		1																		
EC	.087	1																		
turbidity	-.493**	-.321	1																	
phosphate	-.263	-.145	.713**	1																
phosphorus	-.247	-.163	.737**	.998**	1															
sulphate	-.352*	-.133	.770**	.556**	.576**	1														
nitrate	.121	.496**	.102	.284	.280	.310	1													
ammonia	-.327	-.119	.886**	.770**	.792**	.809**	.431*	1												
chloride	-.508**	-.076	-.140	-.206	-.224	-.136	-.525**	-.347*	1											
DO	-.005	.104	.062	.090	.086	-.095	.183	.105	.060	1										
BOD	.396*	.322	-.383*	-.211	-.213	-.340	.330	-.164	-.176	.590**	1									
SS	-.494**	-.236	.928**	.648**	.674**	.797**	.191	.923**	-.110	.135	-.318	1								
TDS	-.077	.088	-.053	-.188	-.176	-.044	.021	-.027	-.067	.144	.286	-.014	1							
Alk	-.022	-.173	.213	.093	.099	.086	.052	.198	-.162	.095	-.080	.194	-.092	1						
Ca	.050	.030	-.013	.073	.082	.120	.010	.043	.069	-.173	-.056	-.013	-.087	.016	1					
Mg	.379*	-.276	-.285	-.299	-.293	-.223	-.252	-.380*	-.107	-.315	-.130	-.381*	.184	-.084	-.077	1				
COD	.117	.046	-.184	-.180	-.183	-.002	-.079	-.162	-.088	-.168	-.032	-.234	-.142	.194	.142	.219	1			
depth	-.338	-.459**	.606**	.431*	.446**	.287	-.194	.395*	.046	-.026	-.283	.434*	.220	.108	-.250	.147	-.439*	1		
WT	.037	-.165	-.479**	-.317	-.326	-.295	-.475**	-.506**	.474**	-.234	-.072	-.418*	.048	-.150	.143	.158	.069	-.193	1	
trans	.142	.117	-.244	-.094	-.102	-.319	.144	-.190	-.016	.060	.113	-.174	-.347*	.067	.061	-.114	-.184	-.227	-.095	1

Keys: **. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

DISCUSSION

The Nigeria climate is tropical, characterized by high temperatures and humidity as well as marked wet and dry seasons. Previous studies on limnological investigations of some Nigerian reservoirs, lakes, springs and streams have also been reported (Chia *et. al*, 2011).

The temperature for all the sampling sites were normal for a tropical water body and this is in line with values between 26.5 and 32.8 ^{0}C recorded by APHA (2022) for tropical rivers. However, the temperature is within the recommended level (24-31 ^{0}C) for warm water fish (World Health Organization, 2019).

Higher water temperature during the dry season can be attributed to high atmospheric temperature, low relative humidity and high transparency. The present result also agreed with previous reports that temperatures in tropics vary between 21^{0}C and 32^{0}C (NASREA, 2011). Boyd (2017) recommended temperature range of 20 – 30^{0}C for optimum fish growth. Therefore, the temperature range of 25.3^{0}C – 31.0^{0}C observed in Lower River Niger at Agenebode during the course of this study falls within the optimal range for fish growth.

Seasonally, variations among the investigated parameters were not statistically significant ($p<0.05$) except for Total Suspended Solids (TSS). TSS are solid materials, including organic and inorganic, that are suspended in water. These would include silt, planktons and industrial waste. The marked higher TSS recorded during the rainy season months, could be attributed to periods of high rainfall and subsequent erosional over flooding; when particulate materials from within and outside the river's geographical boundaries are carried into the water body. Also the ongoing sand excavation activities by the local inhabitants and dredging could contribute suspended particulate materials along the river channel. Pooja (2018) classified water with TSS of 278mg/L and above as grossly polluted, while NESREA (2011) recommends value not greater than 0.25mg/L for aquatic life in surface waters. This therefore makes the Lower River Niger at Agenebode a polluted water body and unsuitable for both aquatic life and drinking water. Total suspended Solids is an important water quality parameter in assessing water pollution (EPA, 2022). Suspended solids can harbor pathogens which contribute to water borne diseases that can infect aquatic or human life.

Transparency is a parameter of water quality that varies with the combined effect of colour and turbidity. Turbidity is influenced by suspended solid materials such as clay, silt, colloidal organic matter, planktons and remains a major cause of low transparency. Increase in turbulence of waters usually increases all the suspended materials, especially in shallow waters. Transparency was lowest during the month of September, which coincides, with the peak of the raining season due to over flooding. The higher transparency observed during the dry season could also be due to reduction in allochthonous substances that find their ways into the river with flood. Water transparency was higher during the dry season than the rainy season. The lower transparency observed during the raining season could be attributed to high water run-off from the water shed into the reservoir.

The electrical conductivity value obtained in Lower Niger River was within the optimum value (Boyd, 2017). However, there was variation and significant difference in observed spatial conductivity, this could be attributed to utilization of the ions by flora and fauna. Similarly, the highest conductivity value obtained in DNS could be linked to its closeness to the most sand mining activity area of the river leading to high influx of flood water which contains suspended and dissolved materials. Enough storm water runoff from soil erosion and the washing of ions into the water channel in the rainy season were responsible for the higher values.

A pH range of 6 to 8.5 is normal according to the United States Public Health Association (APHA, 2022). The absence of marked spatial variation in pH at the locations in Lower River Niger at Agenebode indicates stable habitat, which could be linked to its stable photosynthetic rates measured as primary productivity. According to Adeniyi (2017), the pH of water is affected considerably as photosynthetic activities remove carbon (IV) oxide from water and shifts the carbonate-bicarbonate equilibrium.

The slightly acidic pH range of 6.00 – 6.88 recorded in this study conformed to values previously reported in Niger Delta freshwaters. The pH range also falls within (6.5-8.5) recommended limits for aquatic life. This pH makes it quite suitable for fish production in this river (USEPA, 2022)

The range obtained for nitrate fall within the optimum value (50mg/L) for drinking water by WHO (2019) and NESREA 9.10mg/L for aquatic life. This value is higher than 0.02-0.03mgl^{-1} reported by Medudhula et al. (2012) in Lower Manair Reservoir. The variation in nitrate concentration reflects the effects of human activities on various sections of the river. The positive correlation observed between nitrate and TDS indicates that nitrate ions also contributed to the total dissolved components of the river. The non-significant spatial variation in nitrate concentrations at several sampling locations indicates homogeneity in natural and anthropogenic inputs at those locations. However, there was significant difference

(P<0.05) in the mean values of nitrate obtained in Lower Niger River seasonally.

Like other nutrients, the sources of phosphate in aquatic environments have been identified as natural weathering of materials in the drainage basin, biological decomposition, and runoff from human activities in urban and agricultural areas (UNEP GEMS, 2022). The observed higher phosphate values recorded during the rainy season therefore could be attributed to increased leaching and surface runoff associated with rainfall and flooding from the catchment areas of the river.

The range of PO_4^{2-} ions in this study was within optimum limits for drinking water and aquatic life (Boyd, 2015). Values recorded in this study were also within the range of many Nigerian inland waters as reported by NASREA (2011). The absence of marked spatial variation in phosphate concentration in the study area implies homogenous natural and anthrogenic inputs at these stations. The positive correlations between phosphate, TDS and conductivity reveal the importance of nutrient ions in the overall dissolved and ionic compositions of an aquatic system.

SUMMARY AND CONCLUSION

All the physical and chemical parameters investigated fall within the limits required for sustainable fish production, however, total suspended solids, Transparency, Sulphate and COD were above the permissible level. Seasonally, there were no significant difference (P>0.05) for Conductivity, Phosphate, Phosphorus, Sulphate, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Chloride among the sampling stations while Suspended Solids (SS), Turbidity, pH and Nitrate showed significant difference (P<0.05) among the sampling stations and Ammonia-N was highly significant (P<0.01). These findings are indicative of warning signs for pollution which impact not only aquatic organisms but also drinking water. Suspended solids can harbor pathogens which contribute to water borne diseases that can infect aquatic or human life. Crucial steps are needed urgently to reduce agricultural activities and anthropogenic discharges in the Lower River Niger at Agenebode, otherwise, high levels of pollution will not only affect aquatic life but will also invite socio-economic disasters.

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MODELLING TREE DIAMETER DISTRIBUTION IN THE UNIVERSITY OF IBADAN BOTANICAL GARDENS, IBADAN, NIGERIA

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ABSTRACT

The distribution of diameters is the most potent simple factor for depicting the properties of a stand of trees and tree diameter is also a measured tree variable which exhibits physiological trait of a tree. Stratified random sampling technique was used for this study. The study area was stratified into 5: Arboretum, Open field, Nursery Garden, Ornamental Garden and Rock Garden. In each stratum, 20% sampling intensity was used to delineate Temporary Sample Plot (25m x 25m) using simple random sampling technique. A total of 15 TSPs were used and all trees with Diameter at Breast Height (DBH) ≥ 10 cm encountered in each sample plot was measured. The data obtained were DBH measurement of all trees for the 5 strata in the temporary plots sampled. Five distribution functions were fitted to the data. This study compared the accuracy and efficiency of the 2- parameter Weibull, 2- parameter Gamma, Log-normal, Log-logistic and Burr distributions. Comparison was based on the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) and estimates of the parameters were obtained. The assessment of the classification ability of the distribution functions revealed that the Log-normal distribution provided the best fit to the dataset for the 5 strata in the temporary plots sampled. The mean values for the AIC and BIC of the Log-normal distribution were 1030.419 and 1035.745, respectively. This was followed by Gamma, 2-parameter Weibull, Burr and Log-logistic with means AIC and BIC values of 1035.048 and 1040.374, 1042.752 and 1048.079, 1050.591 and 1056.652, 1062.423 and 1067.882, respectively. The stands showed diameter distribution with decreasing exponential curves. Greater percentage of the trees were in their lower diameter class, this may be attributed to high density of the species also as a result of the stand which not had been thinned.

Keywords: Diameter modelling, Distribution Function, Diameter at breast height, Strata, University of Ibadan Botanical Garden.

INTRODUCTION

The distribution of diameters is the most potent simple factor for depicting the properties of a stand of trees and tree diameter is also a measured tree variable which exhibits physiological trait of a tree. For the evaluation of the forest resources and the planning of upcoming silvicultural treatments, forest managers are very interested in the forecast of the diameter distribution of a stand. As opined by Ogana (2018), in some areas of forest science, such as forestry and silvics, diameter distribution and the associated statistical model can be crucial. For instance, in some growth modeling, it is critical to understand the type of diameter distribution function and its parameters in order to select the proper model. As a result, for more than 200 years, forest management planning and research have been fundamentally based on forest growth models. Most models work at the stand level and forecast stand-level factors such basal area or dominant height to offer data needed to calculate harvesting expenses, estimated yield, financial outcome, etc. Diameter distributions can be used to assess the potential sustainability of a forest and to determine whether the density of smaller trees in a stand is sufficient to replace the existing population of larger trees. A probability density function (pdf) is typically fitted to the actual diameter distributions at the beginning of a two-stage process to model the DBH distribution (parameter prediction method). The pdf parameters are then regressed against other, easily measurably or a priori known stand attributes. Basic resource planning necessitates both qualitative and quantitative data, which are often obtained by assessing the features of stands. Accurate knowledge of the inventory of standing forests and the many types of trees is essential for proper forest management. One of these fundamental pieces of knowledge is the distribution of trees according to diameter classes, which enables tree markers to intervene in stands with greater assurance and maintain stand structure.

In forestry, stand tables or diameter distributions have always been crucial. Software packages based on distributions are being utilized to integrate data collecting, growth forecasts, product usage planning, and management information considering the growing accessibility of computer power and sophisticated statistical methodologies. It is asserted that stand inventories or stand-level models, as well as individual-tree growth models, can be used to manipulate distributions of tree diameters to produce accurate predictions of product mixes (Hyink and Moser 1983, Depta 1984, and Borders 1990). It's remarkable that there is no need for definitions because the idea of diameter distribution is assumed to be self-evident. The expression "characterized by a probability density function" or "determined by a list of tree diameters" is frequently used to describe the distribution of stand diameters. However, forest stands or sample plots are not haphazard gatherings of trees. The diameters are determined by the spatial interactions between the trees and their surroundings and are related to where the trees are located on the ground. As a result, it is difficult to define diameter distribution in a way that is satisfactory and does not depend on the size of the area under consideration. Garc'a (1984, 1988) issued a cautionary note stating that, at least theoretically, the features of plot distributions, on which models are based, may differ from those for full stands or compartments, which are typically required in applications.

The University of Ibadan Botanical gardens was established for research purpose. Lots of researches have been carried out in the garden (Aderounmu *et al.*, 2017) but unfortunately, diameter distribution models are yet to be studied and developed. Hence, this study would help to model the diameter structure of tree species for prediction of method of maximum likelihood and parameters of theoretical models in the study.

MATERIALS AND METHODS

The Botanical Garden, which belongs to the University of Ibadan is located approximately at 3km to the north of the city of Ibadan, Oyo State, Nigeria at the latitudes 7°26’N and 7°45’N, Longitudes 3°54’E and 3°89’N and at a mean altitude of 227m above sea level (Fig 1). It has an annual rainfall of about 1220 mm, which has its peak at June and August that lasts for about 8 months (April to October). The dry season occurs between November and March.

The garden was established in 1984 by management of University of Ibadan to conserve and enhance plant diversity growth for tourism, teaching and research. University of Ibadan Botanical Garden has an area of about 19.26 hectares. It is situated on the side of the river Ona which is a sluggish perennial stream in the dry season but a turbulent river when in flood. The soil is freely drained, mildly acidic and of moderate fertility with colluvial deposits in the river valley and numerous outcrops of basement complex rocks on higher ground.

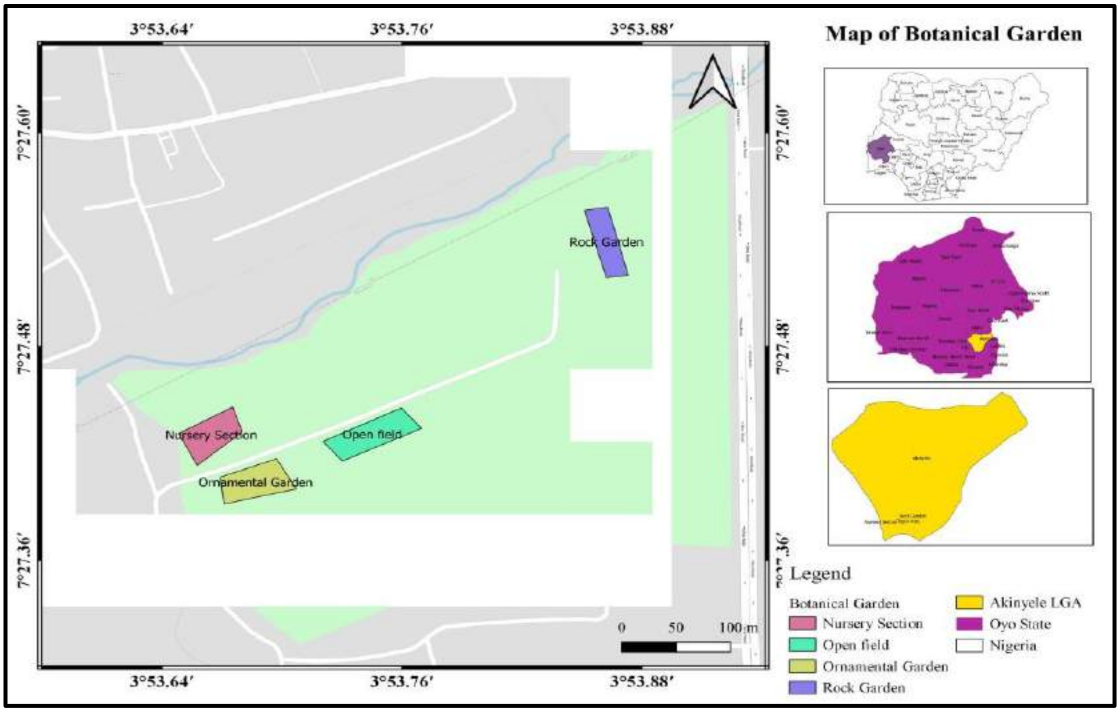

Fig 1: Map of the University of Ibadan Botanical Garden

Data Collection

Stratified random sampling technique was used for this study. The study area was stratified into 5: Arboretum, Open field, Nursery Garden, Ornamental Garden and Rock Garden. In each stratum, 20% sampling intensity was used to delineate Temporary Sample Plot (25m x 25m) using simple random sampling technique. A total of 15 TSPs were used and all trees with Diameter at Breast Height (DBH) ≥ 10 cm encountered in each sample plot was measured.

Data Analysis

Estimating Parameters for Diameter Distribution Models

Estimating Parameters for Diameter Distribution Models Parameters for diameter distribution model were estimated. The probability density function (pdf), cumulative distribution functions (cdf) were analysed. Descriptive statistics such as mean, median, standard deviation and range changes were calculated and histograms were drawn. The statistical distribution models considered are represented below.

Weibull distribution

The two parameter weibull distribution was fitted to the data with an assumption that the location parameter will be set at 0. The probability density function is given as:

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

The cumulative distribution function is given as:

$$f(x) = 1 - exp - \left(\frac{x-\alpha}{\beta}\right)^{\gamma} \quad ...... 2$$

Where: γ is the location parameter

β is the shape parameter

The function is less flexible than the three-parameter version, but is preferred when a more parsimonious model is required.

Gamma distribution

The gamma probability density function is given as:

$$\boldsymbol{f(x)} = \frac{\boldsymbol{x^{a-1}}}{\boldsymbol{\beta^{a}\gamma(a)}} \mathbf{exp} \left(-\boldsymbol{x}/\boldsymbol{\beta}\right) \quad \ldots\ldots 3$$

While the gamma cumulative density function is given as:

$$\boldsymbol{F(x)} = \frac{\boldsymbol{\gamma_{x/\beta}(\alpha)}}{\boldsymbol{\gamma(\alpha)}} \quad \ldots\ldots \ldots\ldots.. 4$$

Log-normal distribution

The log-normal model is a statistical distribution that is commonly used to model variables that are positively skewed and have a skewed distribution on the logarithmic scale. It is particularly useful for modeling variables that are strictly positive and have a wide range of values.

The log-normal distribution is defined by its probability density function (PDF), which is given by:

$$\boldsymbol{f(x;\mu,\sigma)} = (\mathbf{1}/(\boldsymbol{x\sigma}\sqrt{(\mathbf{2\pi})})) * \mathbf{exp}(-\mathbf{ln}(\mathbf{x}) - \boldsymbol{\mu})^{\mathbf{2}} / (\mathbf{2}\boldsymbol{\sigma}^{\mathbf{2}})) \quad \ldots 5$$

where:
- x is the variable for which the PDF is evaluated,
- μ is the mean of the natural logarithm of x,
- σ is the standard deviation of the natural logarithm of x.

Log-logistic distribution

The Log-Logistic (LL) distribution introduced to forestry with the probability density function (pdf) and cumulative distribution function (cdf) 0f LL are expressed as:

$$(x) = \frac{\lambda}{\sigma} \frac{1}{(\chi-\xi)(\xi+\lambda-\chi)} \frac{1}{e^{-(\mu/\sigma)\,(\frac{\chi-\xi}{\xi+\lambda-\chi})1/\sigma \;+\; e\mu/\sigma \left(\frac{\chi-\xi}{\xi+\lambda-\chi}\right) - \,(\frac{1}{\sigma})+2}} \quad \ldots\ldots 6$$

$$(x) = \frac{1}{1+e^{\mu/\sigma}\,(\frac{\chi-\xi}{\xi+\lambda-\chi})\,-(1/\sigma)} \quad \ldots\ldots\ldots\ldots 7$$

Where;

f(x)=probability density function, F(x)=cumulative distribution function, x=diameter/height. The parameters μ = mu and σ = sigma are the shape parameters. This distribution was used by Wang and Rennolls (2005), Ogana *et al.*, 2018).

Burr distribution

The Burr has pdf and cdf expressed as:

$$(x) = \frac{a\mathrm{k}(\frac{\mathrm{x-y}}{\beta})a-\hat{1}}{\beta\left(1+\left(\frac{\mathrm{x-y}}{\beta}\right)a\right)^{\mathrm{k+1}}} \quad \ldots.8$$

$$(x) = 1 - (1+ \left(\frac{\mathrm{x-y}}{\beta}\right) a) - k \quad \ldots 9$$

Where:

f(*x*) = probability density function (pdf); *F*(*x*) = cumulative distribution function (cdf); k and α = two shape parameters ($k > 0$; $\alpha > 0$); β = scale parameter ($\beta > 0$); γ = location parameter.

Model assessment criteria

This study compared the accuracy and efficiency of the 2- parameter Weibull, 2-parameter Gamma, Log-normal, Log-logistic and Burr distributions. Comparison was based on the Akaike information criterion (AIC) and Bayesian information criterion (BIC). The evaluation of the candidate models was based on graphical and numerical analysis of the residuals. The Model Selection Criteria are represented below:

1. **Bayesian Information Criterion (BIC):** for a model to be considered valid its BIC must be relatively low.

   $$\text{BIC} = \text{n ln}\,(\frac{\boldsymbol{rss}}{\boldsymbol{n}}) + \text{p ln n} \ldots\ldots\ldots.10$$

2. **Alkaike Information Criteria (AIC)**: for a model to be considered valid, its AIC must be relatively low

   $$\text{AIC} = \text{n ln}\,(\frac{\boldsymbol{rss}}{\boldsymbol{n}}) + 2\text{p} \quad \ldots\ldots\ldots.11$$

Where rss = residual sum square, n = sample size, p = number of parameters, = average tree height; Y_i = the observed value and Y^{i} = the theoretical value predicted by the model.

RESULTS AND DISCUSSION

Diameter Distribution Model

The summary of the descriptive statistics and Model Assessment Criteria of distribution functions for University of Ibadan Botanical gardens are presented on Tables 1 and 2. The value of the skewness is 1.23 while that of excess kurtosis is 1.00 (Table 1). High positive skewness and peakedness means that considerable numbers of trees are concentrated in the lower diameter classes (Gadow, 1983). The result of predicted value for each model are as shown in Table 2 and 3. Log-normal had mean AIC and BIC values of 1030.419 and 1035.745, respectively. This was followed by 2-parameter Weibull Gamma, 2-parameter Weibull, Burr and Log-logistic with means AIC and BIC values of 1035.048 and 1040.374, 1042.752 and 1048.079, 1050.591 and 1056.652, 1062.423 and 1067.882, respectively. The AIC and BIC revealed that the Log-normal distribution provided the best fit to the dataset. Log-normal is the best model fitted compared with the 2-parameter Gamma, 2-parameter Weibull, Burr and Log-logistic since model with least AIC and BIC is always selected as the best. The relative flexibility of the Log-normal distribution could have influenced its performance. The 2-parameter Gamma distribution used in this study did not provide good fits to the dataset. Its fits for the five plots were far from the usual reverse J-shaped that is typical of natural forest. This suggests the fact that the 2-parameter Gamma distribution may be inappropriate for describing the stand structure of the natural forest. The fit provided by the Gamma distribution for this study also suggested that the 2-parameter Gamma could be adequate for even-aged stands. This study agreed with Eslami *et al*. (2011) who investigated the structure and distribution of diameter classes in beech forest; reported that the Gamma distribution did not fit the dataset, as such recommended the beta distribution model for the natural stand.

Table 1. Summary of Descriptive Statistics for diameter at breast (dbh) Class

Statistics	Value
Minimum Value	15
Maximum Value	182
Range	167
Mean	61.4
Sample Variance	1405.88
Coefficient of Variation	0.61
Standard Error	3.64
Skewness	1.23
Kurtosis	1.00

Table 2: Model Assessment Criteria

S/N	Distribution	Selection Criterion		Rank
		AIC	BIC	
1.	2P Weibull	1042.752	1048.079	3rd
2.	Burr	1050.591	1056.652	4th
3.	Log logistics	1062.423	1067.882	5th
4.	Gamma	1035.048	1040.374	2nd
5.	Log-normal	1030.419	1035.745	1st

Table 3 shows the parameter values of the five distribution functions while Figure 2 shows that the distribution pattern of the dbh of trees in University of Ibadan Botanical Gardens is positively skewed. This pattern shows that there are more trees in lower dbh class that is sufficient enough to replace trees in the upper dbh class in the future. Boubli *et* *al.*, (2004); Bobo *et al.*, (2006) also reported positive skewness distribution pattern in their studies. The implication of this is that the forests are still undergoing regeneration and recruitment, which are vital indicators of forest health and vigour (Jimoh *et al.*, 2012).

Table 3: Distribution parameter estimates of the University of Ibadan Botanical Gardens

S/N	Distribution	Parameters			
1.	2P Weibull	$\alpha = 68.887$	$\beta = 1.746$		
2.	Burr	$\gamma = 2.172$	$\beta = 53.546$	$a = 2.975$	$k = 1.006$
3.	Log-logistics	$\alpha = 2.853$	$B = 50.908$		
4.	2P Gamma	$\alpha = 2.959$	$\beta = 0.049$		
5.	Log-normal	$\sigma = 3.9314$	$\mu = 0.6012$		

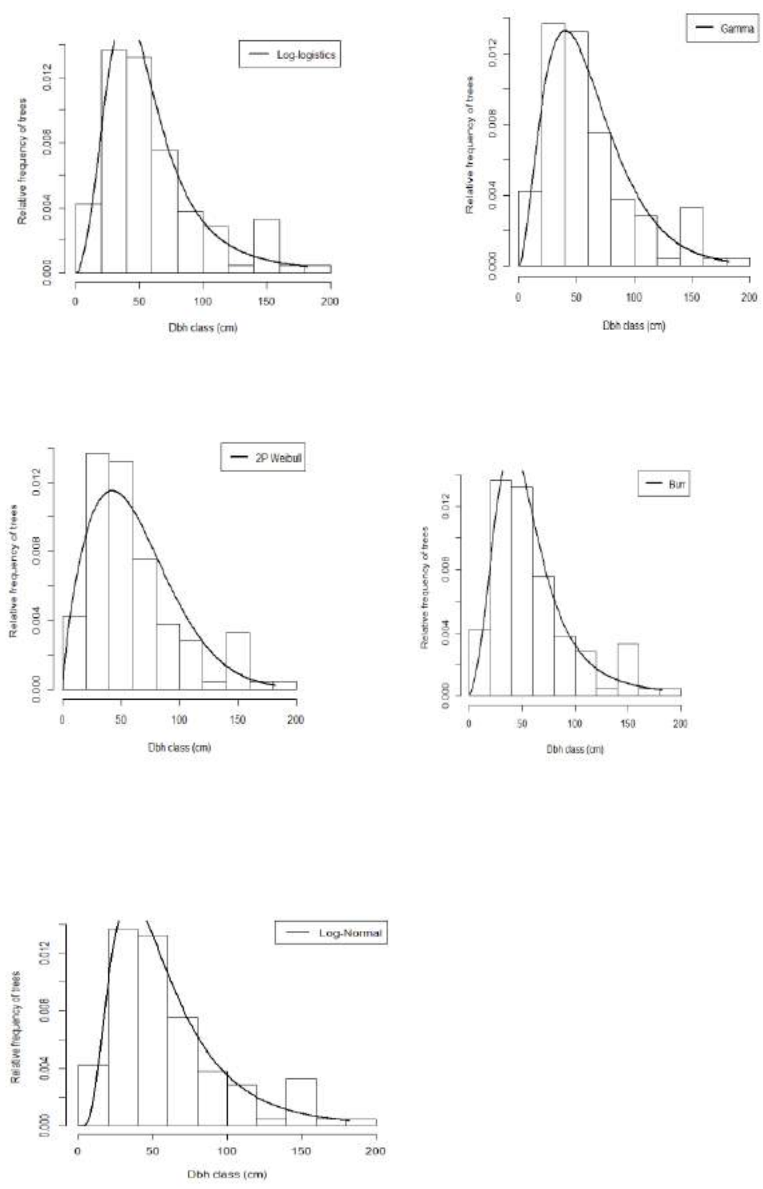

Figure 2: Graphs of observed and estimated probability function of dbh class for the Botanical Gardens

CONCLUSION AND RECOMMENDATION

Effective forest management planning requires timely and reliable information on forest development. Reliable information is very crucial and fundamental to sustainable management. Diameter distributions are important decision-making tools for stand management. This study has provided some baseline information on the diameter distribution of the natural stands of University of Ibadan botanical garden. The stands showed diameter distribution with decreasing exponential curves. Greater percentage of the trees were in their lower diameter class, this may be attributed to high density of the species also as a result of the stand not had been thinned. The comparison on the effectiveness of the Burr, Log-logistic, Log-normal, 2-parameter Gamma and 2-parameter Weibull distributions for characterizing the tree diameter of the study area shows that the Log-normal distribution were successful in fitting the data. Further and more comprehensive study in this area is recommended. More studies are needed to achieve more applied results

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CROWN-WIDTH MODELS FOR *Parkia biglobosa* Jacq B PLANTATION IN WASANGARE, OYO STATE, NIGERIA

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ABSTRACT

Information on tree growth variables is an important factor during an inventory exercise. This information is beneficial in sustaining proper forest stocking, thinning, pruning, economic evaluation of trees, making aesthetic choices, and in selecting appropriate growth measurements to monitor individual tree growth, wildlife habitat suitability and in assessing forest health. In this study, crown-width models were developed for *Parkia biglobosa* plantations (seeds of this species were from Cameroon, Egypt, Guinea, Nigeria and Tunisia planted separately) in Wasangare, Oyo State, Nigeria. Diameter at breast height and Crown ratio were used as independent variables for developing the models. Four models were developed and tested in predicting the crown-width of the tree stands of this species. The 'R' programming statistical package was used to fit the models. To consider the best model, Akaike Information Criterion (AIC), Root Mean Square Error (RMSE) and the Welch two sample test were used for evaluating the models. The result of the assessment criteria for CW-DBH indicates that the AIC values are 250.07, 206.56, 171.43, 187.82 and 370.03 for Cameroon (Power model), Egypt (Saturation growth rate model), Guinea Simple linear model), Nigeria (Exponential model) and Tunisia (Saturation growth rate model) accessions, respectively.

Keywords: *Parkia biglobosa*, Akaike information criterion, crown-width models, power model.

INTRODUCTION

Modern forest management requires precise, accurate, timely and complete forest information. Forest information can be acquired by forest inventory, which includes collection of individual tree parameters such as location, diameter at breast height (dbh), tree height, tree crown size and tree species within a sampled forest plot, and includes the derivation of forest stand measurements such as forest density, age, mean height, and crown closure, etc using statistical extrapolation of plot measurements (Maltamo, *et al.*, 2006). Studies have shown that some variables such as diameter at breast height are easy to measure with no stress and simple instruments which is widely used by forest inventories (Toma Buba, 2013; Ezenwenyi *et al.*, 2018). Tree crown is defined as that part of a tree bearing live branches and foliage (Helms, 1998; Ezenwenyi *et al.*, 2018). The most important element of tree structure is the crown, where fundamental living processes like photosynthesis take place (Dubravac *et al.*, 2009). It is very relevant in studies of the growth of stands due to the close correlation between crown size and stem diameter, and the packing or density of trees in a stand (Hemery *et al.*, 2005).

However, several studies have shown that other variables which are not so easily obtained are also good predictors of forest dynamics and they can improve the reliability of tools like growth and yield models. One of these parameters is crown size, which has received increasing attention to estimate tree growth (Bragg, 2001). Crown size is an important factor for tree growth which determines the amount of solar radiation intercepted by a tree (Tanka, 2006). Crown width is used in tree and crown level growth-modelling systems, where simple competition indices are not available to adequately predict recovery from competition when a competitor is removed (Vanclay, 1994; Elmugheira and Elmamoun, 2014). Crown width is also used in calculating competition indices based on crown overlap (Elmugheira and Elmamoun, 2014) and predicting above ground biomass.

Parkia biglobosa, also called the African Locust Bean tree is a multipurpose tree indigenous to the tropical regions of West Africa. *Parkia biglobosa* belongs to the family Mimosaceae (Leguminosae-Mimosoideae) (Ige *et al.,* 2019). The matured tree can grow up to 30m in height with a crown large of low branches. *Parkia biglobosa* occurs in a diversity of agro-ecological zones, ranging from tropical forests with high and well-distributed rainfall to arid zones where mean annual rainfall maybe less than 400 mm. *P. biglobosa* has a wide distribution across the Sudan and Guinea savanna ecological zones. The range extends from the western coast of Africa in Senegal across to Sudan. *P. biglobosa* is found in nineteen African countries: Senegal, Gambia, Guinea Bissau, Guinea, Sierra Leone, Mali, Côte d'Ivoire, Burkina Faso, Ghana, Togo, Benin, Niger, Nigeria, Cameroon, Chad, Central African Republic, Zaire, Sudan, and Uganda (Daniels *et al.*, 1986; Biging and Dobbertin 1992; Modupeola, 2014). In Nigeria, *P. biglobosa* is found mostly in savannah and derived savannah ecosystem.

Tree exhibits its growth at diameter at breast height (dbh), this variable is easy to measure and reduce inventory cost and time. In modelling of crown-width, diameter at breast height can be used as predictor to overcome the problem of higher inventory cost. The objective of this study is to develop crown-width models for *Parkia biglobosa* stands in Wasangare plantation. This will be useful for forest managers in future to predict and evaluate forest resources in the plantation for sustainable management.

MATERIALS AND METODS

The Study Area

This study was carried out at *Parkia biglobosa* plantation in Wasangare, Oyo State. It is located in the Savannah zone of Oyo State, Nigeria. The area lies between Latitude 8.8558°N to 8.8573°N and Longitude 3.42353°E to 3.42353°E (Fig 1). The plantation was established in 1955 through Commission of the European Communities Directorate General for Science, Research and Development Programme. The project was aimed at Germplasm conservation and improvement of Parkia for multipurpose use. The accessions of *Parkia biglobosa* were from eleven (11) African countries and span across 10 hectares. This study assessed five (5) accessions: Cameroon, Egypt, Guinea, Tunisia and Nigeria.

The climate is of tropical savanna or tropical wet and dry climate where it exerts enormous influence on the area. This climate exhibits a well-marked rainy season and a dry season with a single peak known as the summer maximum due to its distance from the equator. The average monthly temperature of the site is 26.18^{o}C with highest value recorded in March (28.1^{o}C) and minimum in June and July (24.5^{o}C each) and an annual rainfall of about 1,500 mm with a single rainfall maximum in September. Generally, the soil is sandy loam and slightly acidic with outcrop of rocks (Ige *et al.,* 2019).

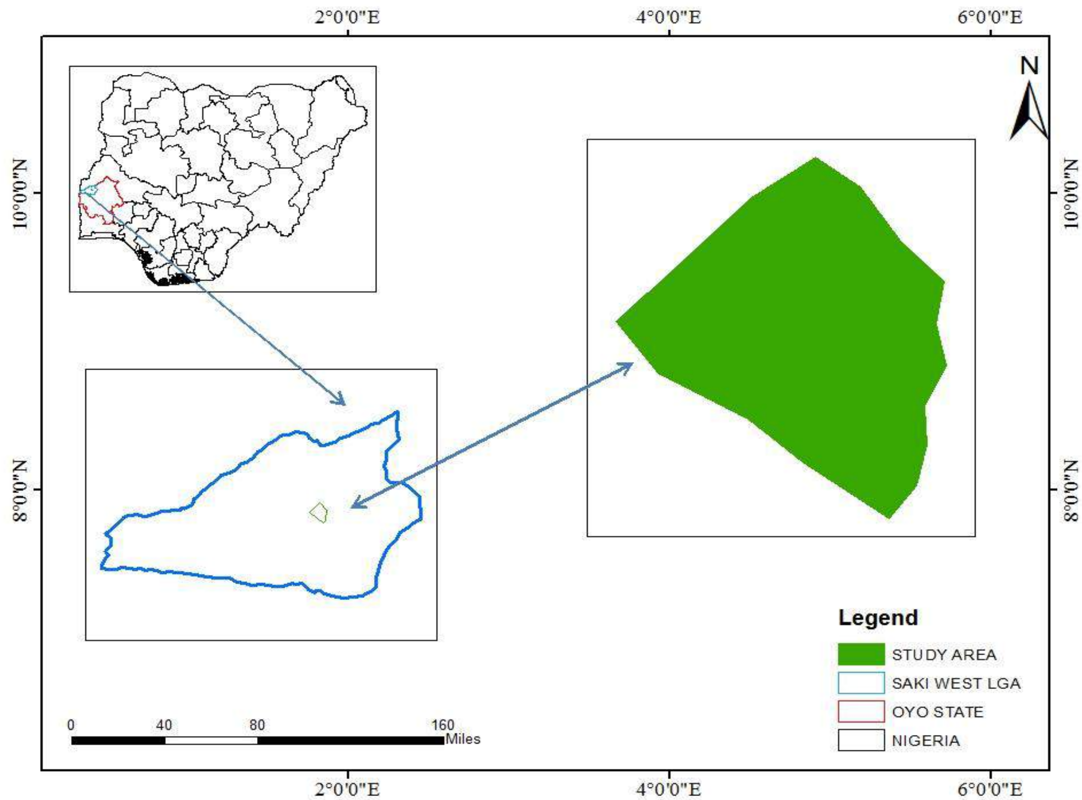

Figure 1: The Study Area at Wasangare, Oyo State, Nigeria

Sampling Technique and Data Collection

Total enumeration of the plantation stands for each accession of *Parkia biglobosa* of 20 x 20m size was made for this study. Data were collected for tree growth characteristics such as diameter at the base, diameter at breast height, diameter at the middle, diameter at the top, stem height and crown length. The diameter at breast height (dbh) was measured at 1.3m above the ground level with the aid of a girthing tape. Spiegel Relaskop was used in measuring the stem height which is in meters. Basal Area, Tree Slenderness Coefficient, Crown width, Crown ratio, Crown projection area were estimated using the following formula:

Basal area Estimation

The Basal Area (BA) of individual trees was estimated using the formula in equation 1 (Husch *et al.*, 2003).

$$BA = \frac{\pi D^2}{4} \qquad \ldots 1$$

Where, BA = basal area, π (pie) = 3.142, D= diameter at breast height (dbh).

Tree Slenderness Coefficient

The tree slenderness coefficient was estimated using the following formula:

$$TSC = \frac{THT}{DBH} \qquad \ldots 2$$

Where, TSC= Tree Slenderness Coefficient, THT= Tree Height, DBH= Diameter at Breast Height.

Crown Width Estimation

The crown width was calculated using the formula below:

$$CW = \frac{CRL}{2} \qquad \ldots 3$$

Where, CW= Crown Width, CRL= Crown Length

Crown Ratio Estimation

The crown ratio was derived using the following formula:

$$CR = \frac{CRL}{THT}\ x\ 100 \qquad \ldots 4$$

Where, CR= Crown Ratio, CRL= Crown Length, THT= total height/stem height.

Crown Projection Area Estimation

Crown projection area was calculated using the formula below:

$$CPA = \frac{\pi CD^2}{4} \qquad \ldots .5$$

Where, CPA= Crown Projection Area, π (pie) = 3.142, CD= Crown Diameter.

Data Analysis

The data collected were summarized using descriptive statistics and for further analyses, linear and non-linear models were developed using 'R' programming language and CurveExpert Professional version 2.7.3.

Fitting of Crown-Width Models

The data set was divided into two, 70% of the data set (calibrating set) were used to fit the crown-width models, while the remaining 30% was used for model validation as described by Akindele, (1990); Ige, *et al.*, (2019). Linear and Non-linear regression models were selected (Table 1) and used in fitting the crown-width models. Two independent variables were used all through for the fitting, these variables are diameter at breast height (dbh) and Crown Ratio (CR). The crown ratio was introduced as an independent variable for fitting because of the parameters used in deriving the formula which consist of crown length (CRL) and total height (THT).

Table 1: Adopted Models

Model Name	Function	Predictor	Eq. No
Simple Linear	$CW = a + bdbh$	Dbh	6
	$CW = a + bCR$	CR	
Power	$CW = adbh^b$	Dbh	7
	$CW = adbh^b$	CR	
Saturation Growth Rate	$CW = adbh/(b + dbh)$	Dbh	8
	$CW = aCR/(b + CR)$	CR	
Exponential	$CW = ae^{bdbh}$	Dbh	9
	$CW = ae^{bCR}$	CR	

CW=Crown-Width, dbh=diameter at breast height, CR=Crown Ratio, a and b= model parameters.

The model predictions function for each accession were compared using the root mean square errors, biases/residuals of stand diameter class. The absolute root mean square error (RMSE) was calculated as:

$$RMSE = \sqrt{\sum_{i=1}^{n}(Vi - \lambda i)^2}\,/n \qquad \ldots .10$$

Where: n = number of sample stands, Vi = diameter/height class of growing stock in stand i, λi = the diameter/height of stand i estimated from the predicted distribution. The bias of the predictions was calculated as:

$$Bias = \sum_{i=1}^{n}(Vi - \lambda i)^2\,/n \qquad \ldots 11$$

Also, Akaike Information Criterion (AIC) was used for criteria selection and the models were ranked based on the AIC value. The lower the AIC value the better the model. The AIC is of the form:

$$AIC = 2k - 2\log(L) \qquad \ldots 12$$

Where:

K = number of estimated parameters in the model

Log = logarithm

L = the maximized value of the likelihood function for the model.

RESULTS

The result from Table 2 shows the descriptive statistics summary of tree growth for each accession of *Parkia biglobosa*. Total enumeration of the tree stands was assessed with a total number of 375 stems. The mean and standard error of the dbh are 20.19±0.83, 18.057±0.990, 20.03±1.40, 21.63±1.15 and 18.72±0.75 for Cameroon, Egypt, Guinea, Nigeria and Tunisia respectively. Nigeria accession shows that *Parkia bilobosa* has the maximum dbh of 50.90 cm while Guinea accession has the minimum dbh of 5.60cm. In terms of height, the Cameroon accessions has maximum height of 20m while Tunisia accession has minimum height of 2.80m.

Table 2: Tree growth characteristics summary for each accession

DBH = Diameter at breast height, THT = Tree total height, TSC = Tree slenderness coefficient,

Accessions	Variables	DBH	THT	TSC	CPA	CRL	CR	CW
Cameroon	Mean±SE	20.19±0.83	9.05±0.46	46.77±2.13	34.47±2.70	4.06±0.21	50.85±2.64	6.20±0.25
	Minimum	6.00	3.60	15.38	2.84	0.80	10.84	1.90
	Maximum	40.00	20.00	109.29	103.88	8.50	94.44	11.50
	Stem No	87						
Egypt	Mean±SE	18.057±0.990	8.907±0.395	55.740±3.097	36.345±3.002	3.694±0.244	42.706±2.308	6.340±0.293
	Minimum	6.000	3.000	10.606	0.786	0.500	5.224	1.000
	Maximum	50.800	15.200	136.609	102.084	8.300	94.318	11.400
	Stem No	72						
Guinea	Mean±SE	20.03±1.40	8.25±0.49	44.57±2.17	43.00±8.47	3.13±0.22	39.42±2.20	6.39±0.52
	Minimum	5.60	2.60	20.49	3.14	0.60	12.00	2.00
	Maximum	49.50	16.00	93.36	268.84	7.50	100.00	18.50
	Stem No	53						
Nigeria	Mean±SE	21.63±1.15	8.96±0.30	46.04±1.86	31.19±2.55	3.93±0.29	42.56±2.39	5.97±0.25
	Minimum	7.60	3.80	20.00	2.01	1.00	12.50	1.60
	Maximum	50.90	14.20	80.00	109.37	9.50	85.71	11.80
	Stem No	67						
Tunisia	Mean±SE	18.72±0.75	8.20±0.35	48.97±2.57	48.90±7.31	3.64±0.21	8.33±91.07	6.98±0.38
	Minimum	6.00	2.80	18.54	4.91	0.4	8.33	2.50
	Maximum	42.50	18.00	130.00	615.83	10.2	91.07	28.00
	Stem No	96						

CPA = Crown projection area, CRL = Crown length, CR = Crown ratio and CW = Crown width

DBH = Diameter at breast height, THT = Tree total height, TSC = Tree slenderness coefficient, CPA = Crown projection area, CRL = Crown length, CR = Crown ratio and CW = Crown width

The models that performed better were presented in Tables 3 and 4 for each of the accessions. The table indicates the assessment criteria of CW-DBH models and CW-CR models. This also show that there is a strong positive relationship between crown-width, diameter at breast height and crown ratio. The best fit models were selected based on the Akaike Information Criterion. The table revealed that the same model performed best for CW-DBH models and CW-CR models for each of the accessions simultaneously except for Guinea and Tunisia accessions where simple linear model performed best in Table 3 while saturation growth rate function performed best in Table 4 respectively. Tables 5 and 6 also show that there is no significance difference between the observed crown-width and the predicted models at 5%

probability level, this is done using the Welch Two Sample t-test. The mean value of the observed and predicted models was also presented in Tables 5 and 6.

Table 3: Summary of the assessment criteria for CW-DBH models.

Accessions	Models	Model Parameters A	Model Parameters b	RMSE	AIC
Cameroon	Power	19.84	0.71	1.54	250.07
Egypt	Saturation Growth Rate	13.80	0.20	2.16	206.56
Guinea	Simple Linear	0.19	32.17	1.75	171.43
Nigeria	Exponential	3.99	1.78	1.51	187.82
Tunisia	Simple Linear	3.57	19.50	2.67	370.03

Table 4: Summary of the assessment criteria for CW-CR models.

Accessions	Models	Model Parameters A	Model Parameters b	RMSE	AIC
Cameroon	Power	10.5872	-0.1404	2.291657	282.68
Egypt	Saturation Growth Rate	6.5153	0.4655	2.802812	215.7325
Guinea	Saturation Growth Rate	8.6515	8.4755	2.80033	215.73
Nigeria	Exponential	4.4289	0.0068	1.780503	196.52
Tunisia	Saturation Growth Rate	7.8242	2.4842	2.858062	380.9955

Table 5: Validation result for CW-DBH with Welch Two Sample t-test

Accessions		**mean**	**t-value**	**p-value**	**remark**
Cameroon	Observed	6.168462	-0.24956	0.804	ns
	Predicted	6.314174			
Egypt	Observed	6.156818	0.047309	0.9626	ns
	Predicted	6.124581			
Guinea	Observed	5.168750	-1.1738	0.2502	ns
	Predicted	6.117931			
Nigeria	Observed	5.962500	0.1118	0.9118	ns
	Predicted	5.903506			
Tunisia	Observed	6.239655	-1.5575	0.128	ns
	Predicted	7.090545			

ns=not significant

Table 6: Validation result for CW-CR with Welch Two Sample t-test

Accessions		mean	t-value	p-value	remark
Cameroon	Observed	6.168462	-0.293	0.772	ns
	Predicted	6.300706			
Egypt	Observed	6.156818	-0.425	0.675	ns
	Predicted	6.415042			
Guinea	Observed	5.168750	-3.729	0.00178	ns
	Predicted	7.070447			
Nigeria	Observed	5.962500	0.0050394	0.996	ns
	Predicted	5.959906			
Tunisia	Observed	6.239655	-1.7064	0.09718	ns
	Predicted	7.148600			

ns=not significant

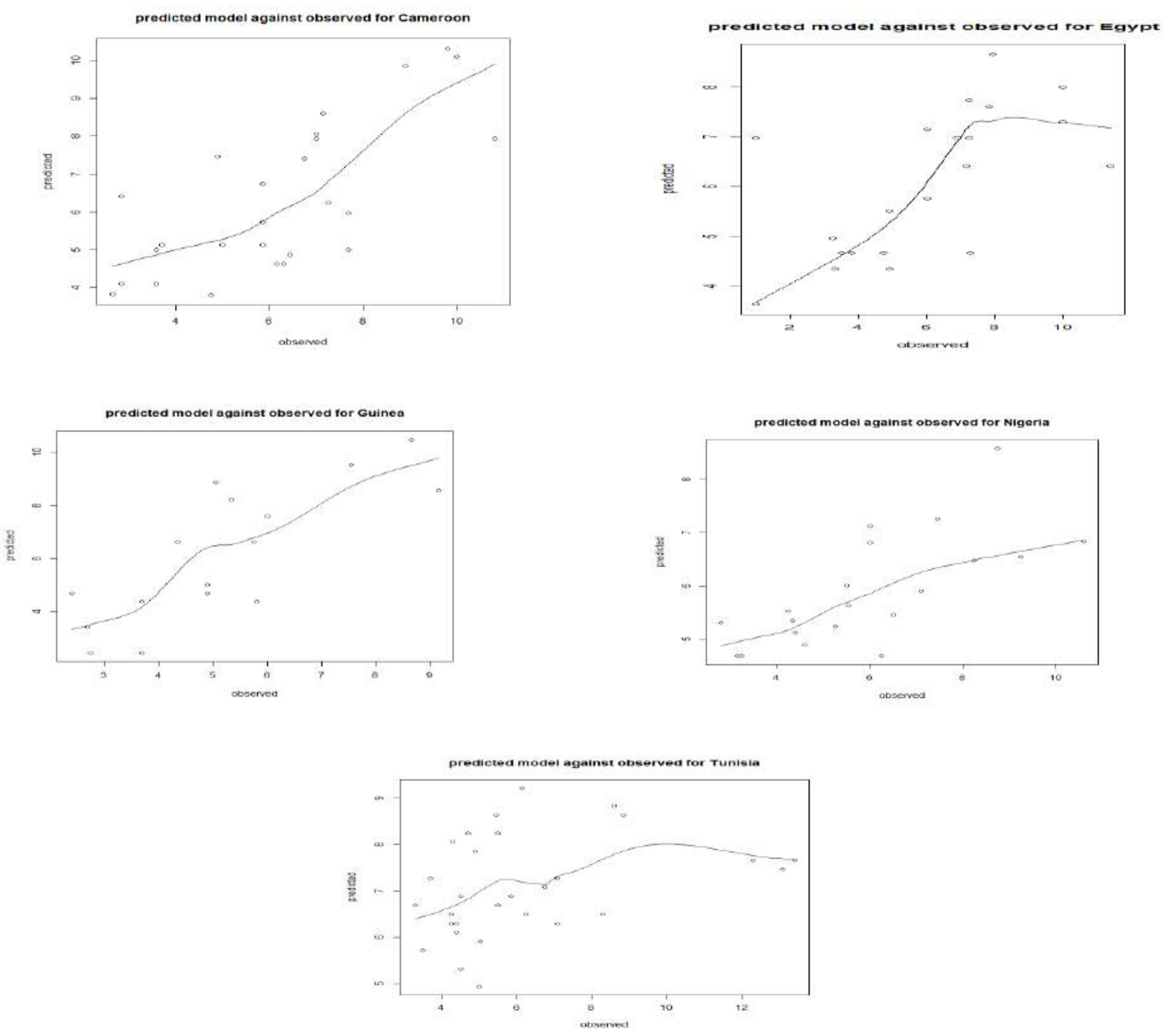

Figure 2: Scattered plots of predicted model against observed for each accessions

DISCUSSION

The result for this study reveals the regression models established between crown-width, diameter at breast and crown ratio (in relation to crown height and stem height) of *Parkia biglobosa* in Wasangare plantation. It is observed that there is a strong positive correlation between crown-width, diameter at breast height and the crown ratio which implies that trees with larger diameter has tendency to have wider crown-width. In the same vein, Ezenwenyi and Chukwu (2017) observed high correlation between crown diameter and crown projection area of *Tectona grandis* in Omo Forest Reserve, Nigeria.

Tree crown distribution is an effective method for describing a forest stand because tree productivity, gaseous exchange and health depends largely on the crown dimensions (Adesoye and Ezenwenyi, 2014; Chukwu *et al.*, 2018). Most of data collected during inventory are always based on tree growth characteristics neglecting the crown-diameter variables. Therefore, this study tends towards predicting crown-width models for each accession of the plantation. The Welch two sample t-test was used to deduced that, there are no signicant difference between the observed and predicted models ($p<0.05$) which indictaes that for further studies, diameter at breast height and crown ratio can be used as predictor for crown-width models.

According to Popoola and Adesoye (2012), model fitting and evaluation are important factors when developing models. In this study, simple linear model function, power model function, saturated growth model function and exponential model function was used for model development. Power model function performed best out of the four model tested in Cameroon accession for both the CW-DBH and CW-CR models. This was similar with the previous study on DBH-CD as described by Avsar and Ayyildiz (2005) which states that power function was most suitable for predicting crown diameter.

CONCLUSION

The study revealed that there is a strong positive relationship between diameter at breast height, stem height which is the total height, crown length, and crown ratio. The summary assessment criteria for CW-CR indicates that saturation growth rate model performed best for Egypt, Guinea and Tunisia while power model function and exponential model performed best for Cameroon and Nigeria respectively. Furthermore, CW-DBH and CW-CR models of *Parkia biglobosa* generated can be estimated using the adopted model functions.

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ASSESSMENT OF THE EFFECT OF PIT LATRINE AND SOAK PIT ON GROUND WATER QUALITY IN FUNTUA TOWN, KATSINA STATE, NIGERIA

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ABSTRACT

This study assessed the effect of pit latrines and soak pits on groundwater quality and the prevalence of waterborne diseases in the Primary health care in Funtua town, Katsina State, Nigeria. A total of 30 water samples were collected from different locations in the town during the dry season (February, 2022) and wet season (July, 2022) for physico-chemical and bacteriological analyses. Physico-chemical parameters, such as depth, temperature, pH, turbidity, HCO_3^-, PO_4^{3-}, SO_4^{2-}, NO_3^-, Cl^-, DO, BOD, COD, electrical conductivity, Ca^{2+}, and TDS, were analyzed. Bacteriological analyses were conducted to determine the faecal and total coliform counts. The physico-chemical results indicated that most of the parameters were within the limit set by World Health Organisation (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ), except for BOD, COD, DO, and NO_3^-. Analysis of variance (ANOVA) revealed that there was significance difference ($P< 0.05$) between the dry and wet seasons of chloride, pH and total coliform count and highly significantly difference ($P< 0.001$) between dry and wet season in the water temperature. *Escherichia coli* and *Shigella dysenteriae* were the bacterial isolates identified in the water samples and the highest reported waterborne diseases in the area were typhoid and dysentery. The study revealed that well water sources were located close to soak pits and pit latrines, averaging 11.4 meters, below the WHO recommended safe distance of 30 meters. The study concluded that the quality of well water in Funtua Town have been affected due to the proximity of some water sources to soak pit and latrines, therefore rendered the water unsuitable for use without prior treatment.

Key words: Groundwater, Water quality, Pit latrine, Soak pit and Bacteria

INTRODUCTION

Access to safe and clean drinking water is a fundamental necessity for sustaining human life and promoting health. It serves as a vital component for digestion, nutrient absorption, waste elimination, and overall well-being (WHO and UNICEF, 2019). Water covers approximately 70% of the Earth's surface while its distribution across the globe is unequal and varied in terms of quality and quantity (Falkenmark and Rockstrom, 2006). This disparity in water resources availability has prompted international attention to address water-related challenges in achieving equitable public health and economic development (United Nations General Assembly, 2010).

Various sources of water support human populations in tropical regions, including rainwater, surface water like streams, hand-dug wells, and boreholes (Ajibade *et al.*, 2013). In many developing countries, especially in Nigeria, wells and boreholes are the primary sources of water supply (National Ground Water Association, 2009). These groundwater facilities, essential for community water access, must be carefully situated to prevent pollution and contamination risks that can lead to health hazards (Texas Ground Water Production Committee, 2000).

Despite the significance of well water facilities, they often receive insufficient attention from authorities and policymakers, resulting in their contamination due to improper waste disposal practices and the proximity of pit latrines and soak pits (Bakobie *et al.*, 2020). The presence of pit latrines and soak pits in close proximity has been identified as a key contributor to the deterioration of water quality in boreholes and shallow aquifers (Ishaku, 2000). Soak pits, designed to gradually infiltrate wastewater into the ground, are potential sources of groundwater contamination when not appropriately located (Keshavarzi and Moore, 2017). Standards and guidelines for establishing safe distances between such facilities and water sources exist, with recommended setback isolation distances of 15 to 30 meters (USEPA 2001; NSDWQ 2015).

Maintaining the quality of drinking water is paramount for public health, encompassing factors like physical, chemical, and microbiological aspects (WHO, 2010). The quantity of water is important, ensuring it safe quality is crucial to mitigate waterborne diseases. Achieving potable water access is essential for preventing waterborne illnesses, particularly in economically disadvantaged communities. Recent outbreaks, such as the cholera cases reported in Adamawa State, underscore the urgency of addressing water quality challenges (Adamawa State Ministry of Health, 2021). In light of these considerations, this study focuses on assessing the impact of pit latrines and soak pits on groundwater quality, aiming to elucidate the potential risks posed by their proximity to water sources.

MATERIALS AND METHODS

Study Area and Sampling Stations

The study area is Funtua Local Government Area of Katsina State, Nigeria. The local government area (LGA) is located between Latitude 11° 32’N - 11.533°N of the equator and Longitude 7° 19’E - 7.317°E of the Greenwich Meridian as shown in Figure 1. It covers an area of 448 km^2. It is bounded to the South Giwa LGA of Kaduna State, to the East by Bakori LGA, to the West by Dandume LGA and to the north by Faskari LGA (Mai ruwa village) all in Katsina State. The inhabitants of the local government area are predominantly Hausa Fulani by tribe (Onamade, 2014). The climate is the tropical wet and dry type classified as Aw by Koppen. The total annual rainfall is about 1000 mm while the average minimum and maximum temperature is 19 ^oC and 32 ^oC respectively. Generally, the climate varies considerably according to months and seasons. A cool dry (harmattan) season from December to February, a hot dry season from March to May, a warm wet season from June to September, a less marked season after rains during the month of October to November, which is characterized by decreasing rainfall and a gradual lowering of temperature (Abaje, 2016). The study was conducted in fifteen different areas of Funtua town namely; Bagari, Nasarawa, Makera, Tudun and Tudun Malamai BCJ, Unguwan wanzamai, Filin kwallo, Tsohuwan kasuwa Dandaji areas Sokoto bye pass, Unguwan Dahiru, Jabiri, Maigamji and Unguwan mata. Recurrent visits were made to the study area during which samples of well water were collected for laboratory analyses and the data on well water sources and sanitation facilities were gathered through observations.

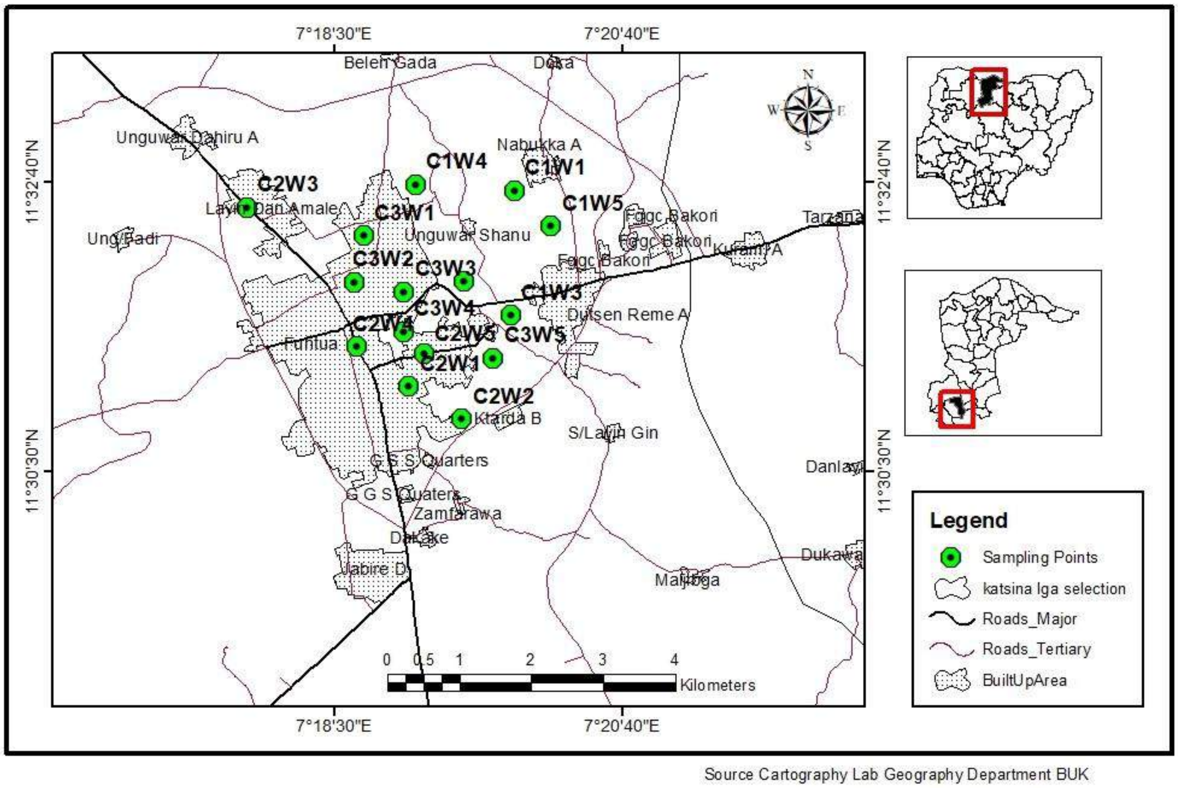

Figure 1: Funtua Town Showing the Sampling Locations

Collection of Water Samples

A total of 30 samples of well water were collected early morning, between the hours of 7.00 am to 10 am during dry season (February 2023) and wet season (July 2023) from the fifteen different sampling locations across the study area. The water samples were collected in a 2-liter sterilized plastic bottles for physicochemical parameters and sterilized 20 mL universal bottles for microbial analysis. Samples were covered in a cooler with ice packs and transported immediately to the laboratory for analysis to prevent changes or degradation of the water samples. Some parameters like temperature and pH were determined immediately during the sampling period due to their low stability. The distance between pit latrines and well water sources was measured using measuring tape, depth of the well was be measured using clean rope and a measuring tape

Physicochemical Analysis of the Water Samples

The physicochemical parameters analyzed include depth, water temperature, turbidity, pH, nitrate, phosphate, total dissolved solid (TDS), conductivity, chloride, chemical oxygen demand (COD), biological oxygen demand (BOD), Dissolved oxygen (DO), sulphate and calcium. All the samples were analyzed using standard method of American Public Health Association (APHA, 2015). Temperature, pH and depth were analyzed in situ using mercury in glass thermometer, digital pH meter and a clean rope and measuring tape respectively. Electric conductivity (EC) and total dissolved solid (TDS) were determined by electric method using conductivity meter (Henna H1255) model, turbidity was determined using digital turbidity meter (HACH 2100N), nitrate was determined using Devada's Alloy method, phosphate was determined by molybdate blue method, Chloride of water samples was determined by argentometric method, Bicarbonate was determined by titrimetric method. Determination of chemical oxygen demand was done using Reflux method, Biological Oxygen Demand (BOD) and Dissolved oxygen (DO) were determined by azide modification of Winkler's method, Sulphate was determined by turbidimetric method and calcium was determined by ethylenediamine tetra acetic acid (EDTA) titrimetric method.

Bacteriological Analysis of the Water Samples

Enumeration of Coliform and Faecal Coliform Counts

Serial dilutions of the water samples were carried out using tubes containing 9 mL of sterile peptone water. The dilutions were carried out from the 10^{-1} to the 10^{-3} dilutions. Nine tubes each containing 9 mL of sterile lactose broth and inverted Durham tubes were arranged. Exactly, 1mL of 10^{-1} dilution of water samples was transferred into three set of tubes containing 9 mL of sterile lactose broth and inverted Durham tubes and labeled as 10^{-1}. The transfer was repeated with 10^{-2} dilution of water samples into the second sets of three tubes containing 9 mL of sterile lactose broth and inverted Durham tubes and labeled as 10^{-2} and 10^{-3} dilutions of water samples into the third set of three tubes containing broth and inverted Durham tubes and labeled as $10^{-3.}$ The tubes were incubated for 24 hrs at 37 ^{o}C for total coliform and 40.5 ^{o}C for feacal coliform and were checked for gas formation in the Durham tubes. After 24 hrs, the tubes with gas production were scored positive and compared with the Most Probable Number (MPN) table.

Identification of faecal coliforms obtained from water samples

The faecal coliforms were identified based on cultural, morphological and biochemical laboratory tests. The organisms were maintained on the agar slant. MacConkey agar (MA), Eosin Methylene agar (EMB), Salmonella Shigella agar (SSA) and Xylose Lysine Deoxycholate agar (XLD) were used for identifying the organisms. The media were sterilized at 121^{o}C and 1.05 kg/cm^{3} for 15 minutes in an autoclave.

API 20E TEST

The organisms were confirmed by using Analytical Profile index 20E which is a standardized identification system for Enterobacteriaceae and Gram negative rods. The API 20E strip consists of 20 micro tubes containing dehydrated substrates to detect enzymatic activity or the fermentation of sugars by the inoculated organisms. The strips were inoculated with a 0.5 McFarland standard of the organisms and the sterile oil was added into the Arginine dihydrolase (ADH), Lysine decarboxylase (LDC), Ornithine decarboxylase (ODC), Hydrogen sulfide (H_2S) and Urea (URE) compartments. The trays containing the API test strips were incubated at 37 ^{o}C for 18-24 hours. After incubation, one drop of ferric chloride and Kovacs reagent was added to tryptophane deaminase (TDA) and indole (IND) compartments respectively while one drop of 40% KOH (VP reagent 1) and one drop of α-Naphthol (VP Reagent 2) was added to the Voges proskaeur (VP) compartment. The colour changes were compared with the API reading scale (colour chart). The API 20E results were read in sets of three to generate a 7-digit profile that was interpreted using the API 20E database to identify the organisms.

RESULTS AND DISCUSSION

Spatial and Seasonal Variations in Physical Parameters of the Ground Water Sampled

Depth

The mean depth of the water sources (wells) ranged from 5.00 m to 11.70 m. The lowest mean depth of the wells (5.0 m) was recorded in Unguwan Wanzamai and the highest mean depth of 11.70 m was reported in Filin kwallo sampling area (Table 1). The results of this study showed that most of the wells in the study area were shallow wells. Shallow wells are more likely to be impacted by activities such as agricultural runoff, septic systems, and industrial discharges. Pathogens from nearby pit latrine, soak pit and septic system can infiltrate shallow groundwater sources more easily, potentially compromising the water quality. The mean depth of well water recorded in this study is in line with 3.73 m to 8.45 m depth reported by Maju-Oyovwikowhe and Emofurieta (2021)

Temperature

The mean temperature ranged from 21.10 °C to 22.20 °C. The lowest mean of 21.10 °C was found in samples from Makera and Filin kwallo, while the highest of 22.20 °C was observed in Jabiri. In terms of seasons, the mean water temperature during the wet season was 26.45±0.03 °C, significantly higher ($P<0.001$) than the mean of 17.55±0.06 °C recorded during the dry season (Table 2). This difference could be attributed to cold weather during the early morning sampling period. Similar findings by Gongden and Lohdip (2015) in Plateau State reported a comparable temperature value of 25.67±3.03 °C. Although temperature generally influences the overall quality of water, there are no recommended limits set by WHO and NSDWQ.

Turbidity

Turbidity ranged from 2.53 NTU to 3.55 NTU across different sampling areas. The highest value of 3.55 NTU was recorded in the Bagari sampling area, while the lowest value of 2.53 NTU was observed in the Dandaji sampling area (Table 1). This finding contrasts with Adekola *et al*. (2014), who reported higher turbidity levels of 6.12-60 NTU in groundwater in Gassol Taraba State, Nigeria. The mean (3.29±0.08 NTU) of turbidity recorded during dry season was slightly higher than the mean value (2.81±0.07 NTU) recorded during wet season but there was no significant difference ($P>0.05$) between the two seasons (Table 2). These results indicated that all water samples, both in the dry and wet seasons, were relatively clear and free from suspended solids. None of the samples exceeded the 5 NTU standard set by NSDWQ and WHO. Additionally, the study revealed that the proximity of soak pits or pit latrines does not appear to significantly impact the turbidity of well water in the study area.

Spatial and Seasonal Variations in Chemical Parameters of the Ground Water Sampled

pH

The pH ranged from 6.6 to 7.20 in the water samples analyzed. The lowest pH value of 6.6 was observed in a sample from Sokoto bypass, while the highest pH value of 7.20 was recorded in Bagari and Nasarawa sampling areas (Table 1). All the pH values from the samples fell within the acceptable range of 6.5 to 8.5 set by WHO and NSDWQ. Similar results were reported by Fadili *et al*. (2019). The mean pH value of the water samples in dry season was 7.09 ± 0.09, slightly higher than the mean of 6.72 ± 0.05 recorded during the wet season (Table 2). This difference was found to be statistically significant ($P<0.05$). The increased pH during the dry season could be attributed to reduced water flow and evaporation, potentially leading to elevated mineral concentration and subsequently a higher pH level.

Total Dissolved Solid (TDS)

The study found that total dissolved solid (TDS) concentrations varied from 117.00 mg/L to 1302.00 mg/L across different sampling stations. The highest TDS concentration of 1302.00 mg/L was recorded in Unguwar Dahiru, while the lowest of 117.00 mg/L was obtained in the Sokoto bye pass sampling station (Table 1). Most of the water samples met the NSDWQ standard of 500 mg/L for TDS, except samples from Bagari (934.50 mg/L), Dandaji (920.50 mg/L), Tsohuwar kasuwa (631.50 mg/L), and Unguwan Dahiru (1302.00 mg/L), which exceeded the standard. Comparatively, this study's TDS results were notably higher than those of a similar study by Fadiji *et al*. (2019) in Ijero-Ekiti, Ekiti State, Nigeria, which reported TDS values of 2.77 ± 0.15 to 4.5 ± 0.07. During the dry season, the mean TDS was 498.59 ± 105.90 mg/L, slightly higher than the mean of 495.42 ± 67.70 mg/L recorded during the wet season (Table 2). However, there was no significant difference (P>0.05) between the two seasons. The elevated TDS concentration during the dry season might be attributed to a lower water table, prompting the use of deeper wells with potentially higher TDS content.

Electric Conductivity (EC)

Electrical conductivity values ranged from 338.00 to 1571.35 µs/cm, with the highest value found in the Bagari sampling area and the lowest in Jabiri. Generally, the water samples met the standard limit of 1000 µS/cm recommended by the NSDWQ, except for Bagari, Tsohuwar Kasuwa, and Dandaji, which exceeded this limit with EC values of 1571.35 µS/cm, 1057.50 µS/cm, and 1522.50 µS/cm, respectively. The mean (827.73±112.8) electric conductivity during wet season was higher than the mean value (639.79±142.45) recorded during dry season but there was no significant difference (P>0.05) between the two seasons (Table 2). This might be attributed to the increased water availability in wells during the wet season, which could dilute substances that might seep into groundwater from soakpits or pit latrines. The findings of this study indicate lower EC values compared to the range of 300-2230 µs/cm reported by Musa *et al*. (2023).

Dissolved Oxygen (DO)

The range of dissolved oxygen observed was 7.20 mg/L to 15.20 mg/L, with the highest value in Tudun Malamai (15.20 mg/L) and the lowest in Sokoto bypass (7.20 mg/L) as shown in Table 1. This aligns with a similar study by Ekute (2021) in Nigeria. The mean (14.76±1.12 mg/L) of dissolved oxygen recorded during dry season was higher than the mean (6.61±0.12 mg/L) recorded for wet season (Table 2). However, this difference wasn't statistically significant (P>0.05), possibly due to increased biological activities in the well water during the dry season. This situation may be due to the fact that biological organisms in the water might contribute to oxygen production through photosynthesis, boosting dissolved oxygen levels. The results of this study revealed that all water samples exceeded the WHO's recommended maximum value of 6 mg/L for dissolved oxygen.

Table 1: Spatial Mean Concentrations of Physicochemical Parameters Analyzed in all Sampling Stations for the two Seasons

Sample ID	Sampling Area	Depth (m)	Temp (°C)	Turbidity (Pt.Co)	pH	TDS (mg/L)	EC (µs)	DO (mg/L)	BOD_5 (mg/L)	COD (mg/L)	Ca^{2+} (mg/L)	PO_4^{3-} (mg/L)	SO_4^{2-} (mg/L)
C1W1	Bagari	7.50	21.90	3.55	7.2	934.50	1571.00	12.25	9.13	107.35	80.00	16.98	0.22
C1W2	Nasarawa	7.70	22.05	3.15	7.2	499.00	830.00	14.15	11.33	61.10	60.00	16.09	0.21
C1W3	Makera	8.70	21.10	2.72	6.8	293.50	498.00	12.30	8.90	47.00	60.00	15.78	0.15
C1W4	T. Wada	9.80	21.85	2.89	7.0	251.00	414.50	12.25	9.95	45.65	50.00	16.09	0.29
C1W5	T. Malami	10.00	22.05	3.03	7.0	423.00	536.50	15.20	11.53	106.05	65.00	16.09	0.36
C2W1	BCJ	8.00	22.05	3.01	6.8	234.50	391.00	9.70	6.08	44.70	55.00	15.74	0.20
C2W2	U.Wanzamai	5.00	21.85	3.12	7.1	379.50	634.50	9.45	5.53	35.15	55.00	16.39	0.20
C2W3	Filin Kwallo	11.70	22.10	3.01	6.7	496.50	824.50	10.75	7.98	65.60	40.00	15.78	0.17
C2W4	T. Kasuwa	7.60	22.15	3.43	7.2	631.50	1057.50	10.35	7.78	104.10	45.00	22.11	0.36
C2W5	Dandaji	11.20	21.80	2.53	7.0	920.50	1522.50	9.75	6.55	37.80	15.00	15.73	0.23
C3W1	S. Byepass	8.50	22.00	3.42	6.6	117.00	196.10	7.20	4.05	45.60	30.00	16.69	0.10
C3W2	U. Dahiru	7.90	22.00	3.07	6.9	1302.00	923. 33	8.95	3.45	44.50	35.00	15.48	0.25
C3W3	Jabiri	10.00	22.20	3.12	6.7	202.10	338.00	7.45	4.98	26.85	30.00	14.53	0.17
C3W4	Maigamji	9.90	22.00	2.70	6.8	470.00	775.50	10.85	7.15	62.80	50.00	15.79	0.21
C3W5	U. Mata	9.80	21.95	3.07	6.6	300.50	493.50	9.65	3.98	47.90	45.00	14.83	0.21

Sources: Laboratory, Analysis, 2022
Key: C1W1 - Cluster one well No 1, C1W2 - Cluster 1 well No 2, C1W3 - Cluster one well No 3, C1W4 - Cluster one well No 4, C1W1 - Cluster one well No 5, C2W1 - Cluster 2 well No 1, C2W2 - Cluster 2 well No 2, C2W3 - Cluster 2 well No 3, C2W1- Cluster 2 well No 4, C2W1 - Cluster 2 well No 5, C3W1 - Cluster 3 well No 1, C3W2 - Cluster 3 well No 2 C3W3 - Cluster 3 well. No 3, C3W4 - Cluster 3 well No 4, C3W5 - Cluster 3 well No 5

Table 2 ANOVA Seasonal Variation in Physical and chemical Parameters of Ground Water Sources Sampled in Dry and Wet Seasons in Funtua

PARAMETERS	Dry Season Mean ± S.E (n=15)	Wet Season Mean ± S.E (n=15)	ANOVA F	ANOVA P
Water Temperature (°C)	17.55 ± 0.06	26.45 ± 0.03	5.369	0.002**
pH	7.09 ± 0.09	6.72 ± 0.05	3.770	0.009*
HCO_3 (mg/L)	71.11 ± 11.30	520.53 ± 47.48	0.057	1.632
PO_4^{3-} (mg/L)	25.39 ± 0.62	7.15 ± 0.40	2.406	0.056
SO_4^{2-} (mg/L)	0.09 ± 0.02	0.35 ± 0.03	0.659	0.223
NO_3^- (mg/L)	4.39 ± 0.27	11.18 ± 1.92	0.039	1.713
Cl^- (mg/L)	288.08 ± 52.70	358.63 ± 99.18	0.282	0.012*
DO (mg/L)	14.76 ± 1.12	6.61 ± 0.12	92.118	2.671
TDS (mg/L)	498.59 ± 105.90	495.42 ± 67.70	2.447	0.053
BOD (mg/L)	12.73 ± 1.36	1.71 ± 0.21	41.492	6.056
COD (mg/L)	61.25 ± 6.95	56.37 ± 6.70	1.075	0.447
EC (**µs**)	639.79 ± 142.45	827.73 ± 112.87	1.593	0.197
Turbidity (NTU)	3.29 ± 0.08	2.81 ± 0.07	1.224	0.355
Calcium (mg/L)	39.33 ± 3.84	56.00 ± 5.76	0.444	0.071

Key: *= Significant difference (P<0.05) **= Highly significant difference (P<0.001)

Biological Oxygen Demand

Biochemical oxygen demand (BOD) concentrations ranged from 3.45 mg/L to 11.53 mg/L. The highest BOD value was found in Tudun Malamai (11.53 mg/L), while the lowest was in Unguwan Dahiru (3.45 mg/L) (Table 1). Most water samples had BOD levels exceeding the WHO's recommended limit of 6.0 mg/L, except for specific samples from Bypass, Unguwan Mata, Unguwar Dahuru, and Jabiri with values of 4.05 mg/L, 3.98 mg/L, 3.45 mg/L and 4.98 mg/L respectively. The BOD values obtained in this study surpassed the value of 3.66 mg/L reported by Nwidu *et al*. (2008). The mean BOD during the dry season was 12.73±1.36 mg/L, higher than the wet season's mean of 1.71±0.21 mg/L (Table 2). Nonetheless, this difference was not statistically significant (P>0.05), possibly due to decreased groundwater recharge from wells during the dry season.

Chemical Oxygen Demand

Chemical oxygen demand (COD) concentrations ranged from 26.85 mg/L to 107.35 mg/L, with the highest value observed in the Bagri sampling location and the lowest in the Jabiri sampling location (Table 1). All water samples analyzed showed COD concentrations higher than the WHO recommended limit of 10 mg/L. This study disagrees with Raji *et al*. (2019), who reported COD values of 1.0-1.1 mg/L in Okada Town, Edo State, Nigeria. The mean COD during the dry season was 61.25±6.95 mg/L, slightly higher than the mean of 56.37±6.70 mg/L during the wet season (Table 2). However, there was no significant statistical difference (P>0.05) between the two seasons. The elevated COD levels observed in this study suggested contamination of well water with organic matter. This contamination could arise from the close proximity of pit latrines or soak pits to the water sources. High COD levels can foster the growth of microorganisms that cause waterborne diseases like cholera, typhoid, and hepatitis (WHO, 2008).

Calcium (Ca^{2+})

Calcium concentrations ranged from 15 mg/L to 80 mg/L, with the highest value observed in the Dandaji (80 mg/L) area and the lowest in the Bagari (15 mg/L) sampling location (Table 1). The mean calcium value during the wet season (56.00±5.76 mg/L) was higher than that during the dry season (39.33±3.84 mg/L), but there was no significant difference (P>0.05) between the mean concentration values in the two seasons (Table 2). For most water samples in both seasons, the calcium levels were within the recommended limits of 75 mg/L set by both the WHO and NSDWQ. However, the Bagari water sample had a calcium value of 80 mg/L, which exceeded the two standards. The calcium values in both seasons are higher than the values of 6.4-40.0 mg/L reported by Maju-Oyovwikokwe and Emofurita (2021).

Phosphate (PO_4^{3-})

Phosphate levels ranged from 14.53 mg/L to 22.11 mg/L, with the highest concentration (22.11mg/L) found in the Maigamji sample and the lowest value (14.11mg/L) in the Tsohuwar Kasuwa sampling area (Table 1). This significantly differs from the range of 0.25-0.80 mg/L reported by Iliyasu *et al*. (2018) in Kano Metropolis, Nigeria. The mean phosphate value during the dry season (25.39±0.62mg/L) was notably higher than the mean during the wet season (7.15±0.40 mg/L), but no significant statistical difference (P>0.05) was observed between the two seasons (Table 2). This study observed that phosphate values in the study area were consistently high across both seasons, suggesting contamination of groundwater (well) with potentially human waste from sources like soak pits and pit latrines. Such contamination can introduce pathogens into the water, posing health risks

Sulphate (SO_4^{2-})

Sulphate levels ranged from 0.10 mg/L to 0.36 mg/L, with the highest concentration (0.36 mg/L) observed in the Sokoto bypass sample and the lowest (0.36 mg/L) in the Tsohuwar Kasuwa and Tudun Malamai sampling areas (Table 1). Sulphate does not have a direct health impact on drinking water according to the NSDWQ (2007), elevated levels can lead to a bitter taste and contribute to odors in the water. Abubakar and Saidu (2022) reported sulphate values ranging from 0.29 mg/L to 1.33 mg/L, similar to the values obtained in this study. The mean sulphate value during the wet season (0.35±0.03mg/L) was higher than the mean during the dry season (0.09±0.02 mg/L), but there was no significant statistical difference ($P>0.05$) between the two seasons (Table 2). The values of sulphate obtained in this study were remained below the maximum limit of 100 mg/L set by the NSDWQ.

Nitrate (NO_3^-)

Nitrate ranged from 4.90 mg/L to 18.21 mg/L, with the highest concentration (18.21 mg/L) observed in the Bagari sampling location, and the lowest concentrations (4.90mg/L) recorded in the Unguwa Dahiru and Jabiri sampling areas (Table 1). The mean nitrate value (11.18±1.92 mg/L) in the wet season was higher compared to the mean value during the dry season (4.39±0.27 mg/L), but there was no significant statistical difference ($P>0.05$) between the two seasons (Table 2). This might be attributed to poor well construction, as observed by cracks in the casing of some wells in the study area. Such well vulnerabilities could lead to contamination, particularly during the wet season when nitrate-rich water from nearby sources like pit latrines might infiltrate the well. All water sampling areas had nitrate levels below the WHO and NSDWQ limit of 50 mg/L, this could reflect the general nitrate levels in well water around the study area. However, it's important to regulate nitrate levels in drinking water due to the significant health risks it poses. Excessive nitrate in drinking water can have major health implications like hypertension and methemoglobinemia (Mkadmi *et al.*, 2018).

Chloride (Cl^-)

Chloride ranged from 97.89 mg/L to 637.23 mg/L. The highest concentration (637.23 mg/L) was recorded in the Dandaji sample, while the lowest concentration (87.86 mg/L) was found in the Jabiri sampling area (Table 1). The results indicated that the chloride concentration in most water samples exceeded the acceptable limit of 250 mg/L recommended by both the WHO and NSDWQ. However, this study's findings were slightly lower compared to a study by Fadiji *et al.* (2019) conducted in Ekiti. Elevated chloride concentrations (> 250 mg/L) signify a risk of pollution in water. The mean chloride value during the wet season (358.63±99.18 mg/L) was significantly higher ($P<0.05$) than the mean during the dry season (288.08±52.70 mg/L) (Table 2). The higher chloride concentration in well water during the wet season could be due to leaching of nitrate from the soak pit and pit latrines as observed in some well located close to pit latrines in the study area.

Bicarbonate (HCO^-_3)

Bicarbonate ranged from 122.00 mg/L to 497.15 mg/L in both dry and wet seasons. The highest bicarbonate concentration (497.15 mg/L) was found in the Unguwan Dahiru sample, while the lowest was recorded in the Sokoto Bypass sample (122.00 mg/L) (Table 1). Comparatively, the results of this study showed higher bicarbonate concentrations than the values of

27.7-90.0 mg/L reported by Maju-Oyovwikokwe and Emofurita (2021). The mean bicarbonate value during the wet season (520.53±47.48 mg/L) was higher than the mean during the dry season (71.11±11.30 mg/L), but there was no significant statistical difference ($P>0.05$) between the two seasons (Table 2). This could be attributed to the addition of organic matter in the groundwater, potentially originating from pit latrines, soak pits, and other organic sources. During the wet season, rainwater can infiltrate the ground and carry this organic matter into the groundwater, leading to an increase in bicarbonate concentration.

3.3 Total Coliform Bacteria in the Ground Water Sources of Funtua

Total coliform bacterial counts ranged from 2 cfu/100 mL to 47 cfu/100 mL. The lowest counts (2 cfu/100mL) were recorded in samples designated as C1W1, C1W5, C2W1, and C3W3. Conversely, the highest coliform count (47 cfu/100 mL) was obtained from the C1W4 sample. This finding aligns with Akinbile and Yusuf (2011), who reported total coliform counts exceeding the WHO-recommended limit of 0 cfu/100ml. The higher total coliform counts could be attributed to the close proximity of the wells to pit latrines, as indicated in Table 5. Study by Opera *et al*. (2011) highlighted microbial contamination in well water sources located within 27 meters of a soak pit. Pathogens and bacteria from pit latrines can infiltrate the soil and reach groundwater, leading to contamination of well water.

Table 3: Overall Mean Count of Total and Faecal Coliform Bacteria in all Sampling Stations for the two Seasons

	Samples Codes														
Analysis	C1W1	C1 W2	C1 W3	C1 W4	C1 W5	C2 W1	C2 W2	C2 W3	C2 W4	C2 W5	C3 W1	C3 W2	C3 W3	C3 W4	C3 W5
Total Coliform (cfu/100 mL)	2	4	2	47	2	2	6	6	22	4	0	4	2	0	6
Faecal coliform (cfu/100mL)	0	2	2	2	0	2	0	2	0	6	0	0	0	0	4

Identified Bacterial Isolates obtained from each of the Water Sampling Stations

The results of the bacterial isolates from the water samples showed the presence of *Escherichia coli* in all the water samples collected from the fifteen different sampling locations (Table 5). *Shigella dysenteriae* was identified in four water samples (C1W1, C1W4, C2W5 and C2W4) whereas *Escherichia coli* was identified in the sample designated as C1W2, C1W4, C1W5 and C2W4. The results showed the presence of both *Shigella* dysenteriae and *Escherichia coli* in some of the samples (C2W5, C3W4 and C3W5). The results further showed that most commonly distributed bacterial isolates in the water samples were *Shigella* dysenteriae and *Escherichia coli*. The findings of this study corroborated with the work of Abu *et al.* (2020) and Kabir *et al.* (2018) who reported *Escherichia coli*, *Shigella* spp and *Salmonella* spp as the most common isolated bacterial species in their work. Auta *et al*. (2021) studies bacteriological and parasitological analysis of hand-dugged well water in selected areas of Rigachikun community, Kaduna. It's finding revealed that *Salmonella* and *E. coli* had the highest occurrences in the water samples analyzed. Similarly, Odonkor and

Addo (2018) in cross-seasonal analysis of bacteriological profile of water sources as a disease risk measure reported high prevalence of *Shigella* and *Salmonella* in drinking water sources in the study area. Presence of *Shigella* and *E. coli* in most of the water samples suggests that the well water sources had probably come into contact with human or animal faeces. This could be attributed to the close proximity of the well water sources to pit latrine and soak pit in sampling locations

3.4 Faecal Coliform Bacteria in the Ground Water Sources Sampled in Funtua

This study observed faecal coliform bacterial counts ranged from 0 cfu/100mL to 6 cfu/100 mL. The lowest counts were recorded in samples designated as C1W2, C1W3, C1W4, and W2W3, each with a count of 2 cfu/100 mL. On the other hand, the highest faecal coliform count (6 cfu/100 mL) was found in the C3W5 sample (Table 3). It is highly likely that the elevated faecal coliform levels in the C3W5 well water sample are due to contamination from nearby pit latrines. Pit latrines are recognized sources of faecal matter and can introduce bacteria, including faecal coliforms, into the surrounding environment. This contamination can percolate into the groundwater, thereby affecting the well water source. The study revealed that most water samples (7 out of 15) in the study area were faecally contaminated. This level of faecal contamination indicated that a significant portion of the well water sampled are compromised and do not meet the standards for safe drinking water. The WHO and NSDWQ recommended a faecal coliform bacteria standard of 0 cfu/100 mL for drinking water. Faecal contamination in water can lead to waterborne diseases and illnesses, particularly gastrointestinal infections (Joseph and David, 2011). Such infections can manifest as diarrhea, abdominal pain, vomiting, nausea, and in severe cases, even life-threatening conditions (Ohwa and Omidiji, 2021).

Table 4: Coliform Bacteria in Ground Water Sources Sampled in Funtua

Sample Code	Identified Bacteria
C1W1	*Shigella dysenteriae*
C1W2	*Escherichia coli*
C1W3	*Shigella dysenteriae*
C1W4	*Escherichia coli*
C1W5	*Escherichia coli*
C2W1	-
C2W2	-
C2W3	*Shigella dysenteriae*
C2W4	*Escherichia coli*
C2W5	*Shigella dysenteriae, Escherichia coli*
C3W1	*Shigella dysenteriae*
C3W2	-
C3W3	-
C3W4	*Shigella dysenteriae, Escherichia coli*
C3W5	*Shigella dysenteriae, Escherichia coli*

Seasonal Variations in the Bacteriological Parameters of Groundwater Sampled in Funtua

Based on the bacteriological analysis, the result of this study revealed that the mean total coliform count during the wet season was 2.00 ± 0.36 cfu/100 mL, whereas it increased to 8 ± 0.56 cfu/100 mL during the dry season (Table 6). This finding was consistent with the results of Adedokun *et al*. (2018), who observed significant differences in total coliform counts between the dry and wet seasons. This increase was found to be statistically significant ($p<0.05$) and this could be attributed to the reduced dilution rate in the dry season due to lower water levels in the wells. With less water available, the dilution effect in well water sources is reduced. Consequently, any bacteria present in the water may not be effectively diluted, leading to higher bacterial counts. Moreover, there was no statistically significant difference ($P>0.05$) in the faecal coliform counts between the dry (2.00 ± 0.56 cfu/100 mL) and wet (2.00 ± 0.59 cfu/100 mL) seasons (Table 6).

Table 5: ANOVA Seasonal Variation in Bacteriological Parameters of Ground Water Sources in Funtua

PARAMETERS	Dry Season Mean ± S.E (n=15)	Wet Season Mean ± S.E (n=15)	ANOVA	
			F	P
Total Coliform (cfu/100 mL)	8.00 ± 7.50	2.00 ± 0.36	5.250	0.030*
Faecal Coliform (cfu/100 mL)	2.00 ± 0.56	2.00± 0.59	0.332	0.569

Key: *= Significant difference ($P<0.05$)

Ground Water Locations and their Proximity to Pit Latrines and Soak Pit in the Study Area

The distances between pit latrines and water sources, as shown in Table 6 varied from 5.9 to 19.2 meters. This variation raises concerns about the potential contamination of water sources, as coliform bacteria can leach from pit latrines into nearby wells. Similar studies have found that wells are at risk of contamination if located less than 12 meters away from pit latrines, as reported by Vinger *et al*. (2012). The table also indicated that 53.3% (8 out of 15) of the wells were located downstream. This raises concerns about potential groundwater contamination through leaching from nearby soak pits or pit latrines in the study area. Wells located downstream from sources of contamination are more susceptible to leaching, making it easier for excreta from pit latrines to enter nearby wells. This contamination threatens human health through well-water contamination (Mohammed, 2017).

Table 6: Location and Proximity of Ground Water to Pit Latrines/soak pit in the Study Area

		Neighborhood		
Sample Code	**Distance (m)**	**Right**	**Left**	**Location**
C1W1	19.2	27.0	-	Up stream
C1W2	10.5	14.4	13.7	Down Stream
C1W3	14.0	12.1	11.0	Down Stream
C1W4	6.0	7.8	10.0	Upstream
C1W5	15.0	30.5	30.0	Upstream
C2W1	8.0	12.1	-	Down Stream
C2W2	11.1	8.90	11.0	Down Stream
C2W3	10.0	20.0	-	Down Stream
C2W4	7.9	7.9	12.0	Down Stream
C2W5	9.0	19.9	14.0	Up stream
C3W1	18.0	10.0	21.5	Down Stream
C3W2	7.5	25.1	31.0	Up stream
C3W3	12.9	19	-	Upstream
C3W4	16.0	19.0	-	Upstream
C3W5	5.9	11.0	10.1	Down Stream
Average Distance	11.4			

Sources: Field Work, 2022

Prevalence of Water Related Diseases in Funtua Town

Based on the findings of this study, the highest reported cases of waterborne diseases in the hospital were diarrhea and typhoid, with 101 and 100 cases being the highest, respectively (Figure 1). Bagari recorded the highest number of diarrhea cases (101 cases), while S/bye pass had the lowest count, with 6 reported cases. Cholera had the lowest reported cases, with 1 case in Dandaji being the lowest value. These results align with the findings of Fadiji *et al*. (2019), who reported a high prevalence of water-related diseases in the Ijero-Ekiti community in Ekiti State, Nigeria. Similarly, Iren *et al*. (2019) found a high prevalence of diarrhea, dysentery, and typhoid in the Santa Sub-Division of the North West Region Cameroon. Water-associated infectious diseases are a significant cause of illness and death, primarily linked to unsafe water, inadequate sanitation, and poor hygiene practices (Hynds *et al.*, 2012). According to Water Aid (2009), approximately 4,000 people, mainly children, die daily due to diarrheal diseases, accounting for over 40% of deaths related to unsafe water, inadequate sanitation facilities, and poor hygiene behaviors. Assessing the extent of well water contamination is necessary to monitor potential risks to public health. The results for investigated water related diseases in Funtua Town are presented in Figure 2.

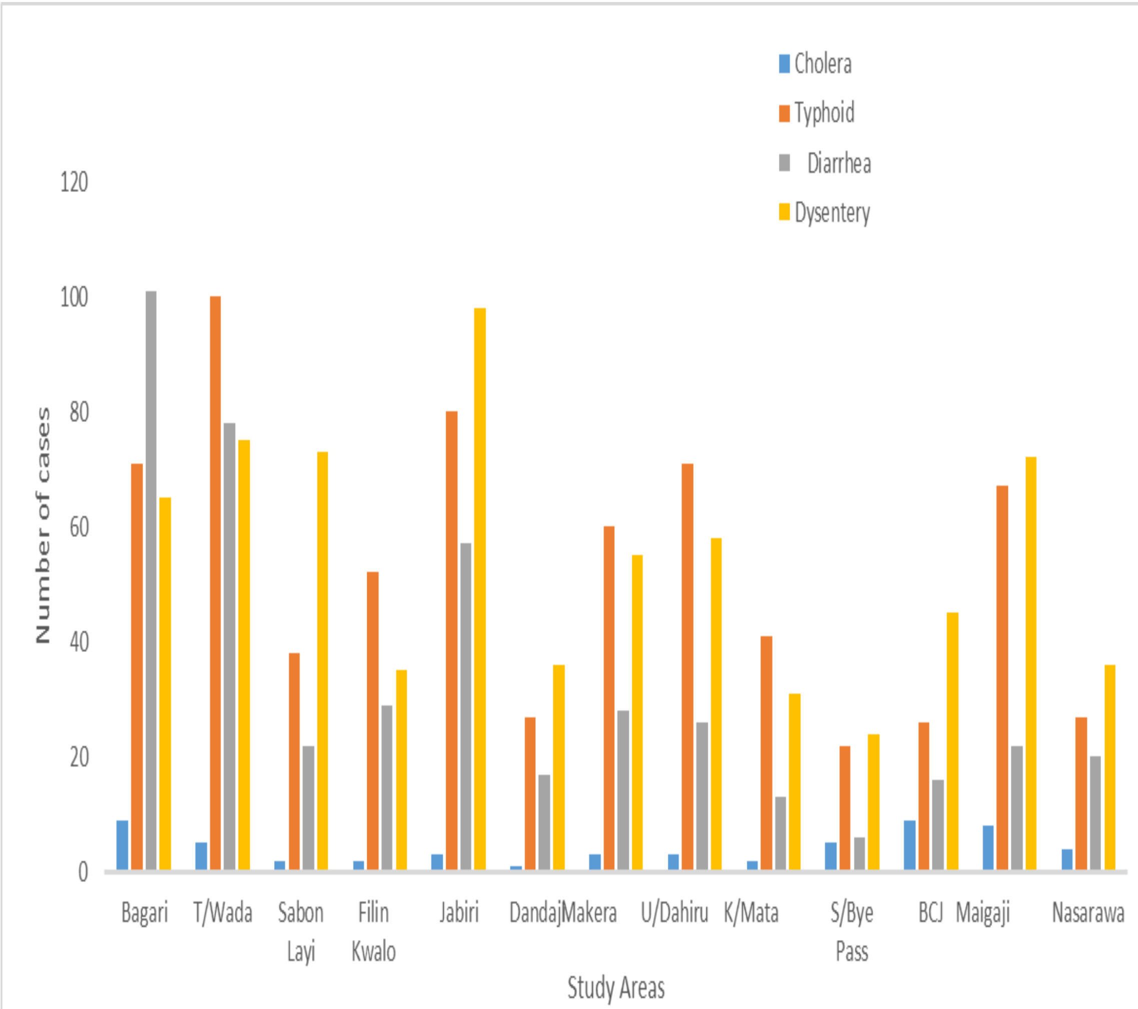

Figure 2: Distribution of Epidemiological Cases of Water Borne Diseases in the Study Area

CONCLUSION

Based on the findings of this study, the physicochemical parameters analyzed in the study were mostly within the permissible limits set by WHO and NSDWQ in some stations. However, elevated levels of BOD, COD, DO, and the presence of total and fecal coliform counts are above the WHO recommended limits indicated the contamination of groundwater sampled with fecal matter making the water unfit for human consumption without a prior treatment. This poses a significant health risk, as it suggests the presence of pathogenic bacteria and potential waterborne diseases.

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OCCURRENCE OF NEMATODES AND PROTISTS COMMUNITIES IN VERMICAST AND EARTHWORM AND THEIR IMPLICATION ON PUBLIC HEALTH

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ABSTRACT

Despite several control measures against Soil Transmitted Helminths (STH), it has been difficult to completely eradicate their infections. This research was directed at determining the protists and nematodes communities in vermicasts and earthworms and their implication on public health in two residential communities of Osogbo, Olorunda and Odo-Otin Local Government Areas of Osun State, Nigeria. Vermicasts and Earthworms samples were collected randomly from these communities using the quadrant technique. The vermicast was analysed with the Bearmann's extraction technique while the earthworms were macerated and processed using normal saline and floatation techniques. A total of Two hundred and sixty-seven (267) organisms comprising: protozoans 51 (19.1%) and nematodes 216(80.9%) were extracted from both vermicast and the earthworm. The vermicast has more parasites; 151 (56.6%) than the earthworm's gut; 116 (43.4%). The parasites comprise genera of nematodes; *Ascaris lumbricoides*, S*trongyloides* Spp., P*ratylenchus S*pp., *Paratylenchus S*pp., *Longidorus S*pp., *Hemicyclophora S*pp., *Rotylenchus S*pp., *Meloidogyne* Spp. and genera of protists; *Entamoeba S*pp. and *Coccidia* Spp. There was no statistical difference in the prevalence of nematodes and protists (P>0.05). The faunal structure shows more plant parasitic nematodes (PPN) 107 (53.5%) than obligate helminths 82 (41.0%) and obligate protists 51(25.5%). This research reveals that the vermicast and earthworm's gastrointestinal tracts and harbored both plant parasitic nematodes of agricultural significance and zooparasites of public health importance which shows that vermicast and earthworm can be an absolute agent of the spread of public health important STHs, including safe handling of vermicast and earthworm in its existing control measures could enhance eradication.

Keywords: Protists, Vermicast, Earthworm, Soil Transmitted Helminths, Nematodes, Public Health.

INTRODUCTION

Soil transmitted helminths (STH) cause significant morbidity and mortality throughout the world, particularly in underdeveloped countries, constitutes major health problems, especially in the tropical and sub-tropical regions where there is limited access to safe drinking water, sanitation and nutrition (Rufai *et al.*, 2018). An appraised population were affected by soil-transmitted helminths (STH). (772-892 million with *Ascaris lumbricoides*, 430 – 508 million with *Trichuris trichuria* and 406 – 480 million with hookworm). STH infections can result to crucial economic loss and deleterious health issues such as, anemia, stunting, loss of appetite low performance on a range of cognitive test, fatigue and truancy and malnourishment. (Malathi *et al*., (2021). It is estimated that 39 Million disability-adjusted life years (DALY) are lost worldwide each year because of STH (Aissatou *et al.*, (2013).

Protists constitute the invisible majority of eukaryotes. That are predominantly unicellular and present in all biomes on earth. Their number usually reach ten thousands of individuals per gram of bulk soil (Geisen *et al.,* 2015). Most of the soil-borne, medically relevant protists seems to be cosmopolitan, but since some of them are by fecal-oral transmission, they are mostly common in low-income countries with poor sanitation. (Stefan *et al*., 2018).

Nematode communities are the most populated animal community in any given environment (Ettema, 1998). Soil nematodes are functionally versatile active at various positions in the soil web and include bacterivores, fungivores, animals and plant parasites (Bongers and Bongers, 1998).

Many nematodes and protists species are harbored in the vermicast. However, nematodes parasite comprises the largest number of helminths organism in man. Soil transmitted nematodes are coined as geohelminth, *A. lumbricoides*, *T. trichuria*, the human hookworms; *Ancyclostoma duodenale* and *Necator americanus* are the important geohelmnith of human (Olubunmi *et al.*, 2013). Vermicast (earthworm house) formation is an important habit of ` most tropical earthworms which improves soil fertility and utility (Vidal *et al.*, 2019). To mold, earthworm heap up soil impregnated with parasites such as *Eimeria* spp, geohelminths and plant parasitic nematodes (PPNs) that are dispersed by run-offs and wind (William *et al.,* 2019).

The cast of earthworms which had parasites fauna is usually composed of phytoparasites, free living organisms and zooparasites groups. Nzeako *et al.*, (2013) Vermicasts are easily dispersed by various dispersal agents including; man, wind and runoffs with their incumbent parasites (Bohlem *et al.,* 2018).

Earthworms transport and cast out live and active nematodes, hence they add strategically in the dispersion of some parasites residing in the soil as mechanical vectors (Bailey *et al.,* 2013).

In this research paper an attempt will be made to determine the implication of earthworm and vermicast in the transmission of soil transmitted parasites (STPs) on public health in Osogbo, Olorunda and Odo-otin Local Government Osun state. This will provide empirical data that will enhance the existing control strategies against STHs.

MATERIALS AND METHODS

Study Areas

This study was conducted in selected communities in Osogbo Local Government (within coordinate 7^0 45N and 4^0 30E), Olorunda LGA (Within coordinate 7^0 77N and 4^0 56E) and Odo-otin LGA (within coordinate 7^0 57 and 4^0 41E) Osun state, Nigeria. Osogbo and Olorunda LGA is a capital city in Osun state predominantly occupied by skilled and unskilled labour with adequate facilities, while Odo-otin LGA is majorly occupied by farmers and unskilled labour with lesser infrastructural facilities, meanwhile they are mostly Yoruba ethnic group who practices Christianity, Islam and Traditional religion.

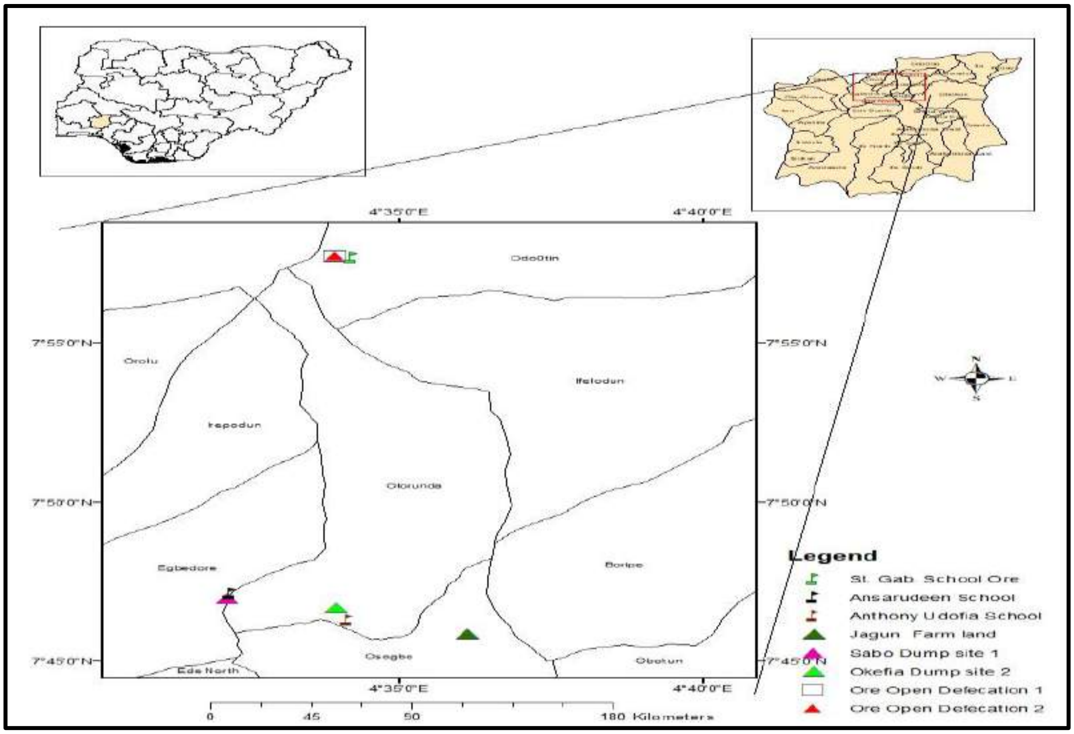

Figure 1: Map of Osun State Showing the Study Locations.

Methods of sample collection

Vermicasts were randomly collected with a stainless steel spoon and aggregated as described by Welss *et al*., (2008). Aggregated vermicasts sample was packed and stored in polythene bag to prevent the escape of water from the media for forward movement to laboratory for examination. Living earthworm were dug out and picked with forceps beneath the burrow. The vermicasts and earthworms samples were collected between six and seven o' clock in the morning (mekete *et al.*, 2012). The vermicasts and the Earthworms samples were exposed to the following techniques;

Extraction and Microscopy Identification of Nematodes and Protists.

Modified bearmann's techniques was adopted to detect mobile helminths and protists in the vermicasts. This is based on the active migration or movement of larvae. Vermicasts were placed on mesh suspended in water. The larvae move into the water. They sink to the bottom and were collected for identification (Imafidor and Nzeako, 2008).

Examination of Gut contents of Earthworms

Living earthworms were washed in a petri-dish with tap water to remove chaff intoxicated with saline solution and dissected to separate the gut (Bennett *et al.*, 2016). The earthworms gut were macerated in 5ml normal saline to form an aliquot.

The macerates were divided into two subsets (A) and (B). A was placed on a 25UM aperture mesh and rinse with water into a 10ml beaker. Out of (A) macerate, 0.1ml will be placed on a grease-free slide with a pipette, covered with a glass slide and view with x10 objectives. A minute portion of (B) macerate was placed between two glass slides for squash preparation and this was pressed slightly together to squash the tissue within the slide stained with lugos iodine and view with x10 objective to identify the gut fauna content. (Lavania *et al*, .1981).

Earthworm's Gut and Vermicast parasites Identification.

Identification of fauna specimen was done by the use of standard keys by (Makete *et al.*, 2012) Protozoa cysts and helminthes ova were identified by the use of key by Goodey (1963), Soulsby (1968) and Cheesbrough (2006).

Data Analysis

The data was analyzed using IBM SPSS (Statistical Package social science) version 25.0. The results were reported in frequency and percentage. Chi -square was used for analysis of categorical variables while mean and standard deviation for continuous variables with $p<0.05$ using as level of significance.

RESULTS

Prevalence of Nematodes and Protists recovered from Vermicast and Earthworm Communities by Microscopy Method.

Two hundred and sixty seven (267) parasites comprising protists 51 (19.1%) and Nematodes 216 (80.8%) were recovered from both earthworm' gut and vermicast. The earthworm's gut harboured 116(43.0%) and the vermicast 151(56.0%) parasites. According to Cheng (1986) and Cesarz *et al*, (2015) respectively. The functional group of parasite recovered from the vermicast and earthworm are obligate protozoans, obligate helminths and plant parasitic nematodes (PPNs).The obligate Protozoans recovered from the vermicast were *E. histolytical* 29(82.9%) and *Coccidia oocyst* 6(17.1%). *A. lumbricoides* 14(12.1%) and *strongyloides* Spp. 12(10.3%) were obligate helminths. *Pratylenchtus* Spp. 16(13.8), *Paratylenchus* Spp. 15(12.9%), *Longidorous* Spp. 9(7.8%), *Hemicyliophora* Spp. 24(20.7%), *Rotylenchus* Spp. 10(8.6%) and *Meloidogyne* Spp. 16(13.8%) were obligate plant parasitic nematodes (PPN). *Hemicyliophora spp*. PPN parasite is the most prevalent parasite in the vermicast. This shows that vermicast harboured PPNs than other parasites. While the parasites recovered from the earthworm's gut were *Coccidia oocyst* 16(100 %) the obligate only obligate protozoa, *Ascaris* Spp. 42(42.0%), *Strongyloides* Spp. 14(14.0%), *Ancyclostoma* Spp.27 (27.0%) were obligate helminths and *Hemicyliophora* Spp. 17(17.0%) was the only PPNs. This shows that *Ascaris Spp.* was the most prevalent parasite in the gut of the earthworms. (Table 1).

Table 1: Isolate data on nematodes in earthworms and vermicasts

Variable	Frequency		Percentage	
Site Name				
Sabo dump site (Olorunda LGA)	5	5	20.0	20.0
Oke-fia dump site (Osogbo LGA)	5	5	20.0	20.0
Isale-oja Ore open Defecation site (Odo-otin LGA).	5	5	20.0	20.0
Oke-odo Ore open Defecation site (Odo-otin LGA).	5	5	20.0	20.0
Jagun farmland site Oke-bale (Osogbo LGA).	5	5	20.0	20.0
Vermicast's nematodes Isolated (N=116)				
Ascaris Spp.	14			12.1
Strongyloides Spp.	12			10.3
Pratylenchus Spp.	16			13.8
Paratylenchus Spp.	15			12.9
Longidorous Spp.	9			7.8
Hemicycliophora Spp.	24			20.7
Rotylenchus Spp.	10			8.6
Meloidogne Spp.	16			13.8
Earthworm's nematodes Isolated (N=100)				
Ascaris Spp.	42			42.0
Strongyloides Spp.	14			14.0
Ancyclostoma Spp.	27			27.0
Hemicycliophora Spp.	17			17.0
Vermicast's Protists Isolated (N=35)				
Entameoba histolytica	29			82.9
Coccidia oocyst	6			17.1
Earthworm's Protists Isolated (N=16)				
Coccidia oocyst	16			100.0

Analysis of Nematode and protists recovered from Vermicast and Earthworm in Association to their Locations.

Table 2 showed the prevalence of isolate in each of the location. There is no statistical significance in relation to location of the parasite (P> O.05).

The nematode recovered from vermicast of Sabo area dumpsite, Osogbo, were 28 (21.4%), Oke-fia dumpsite, Osogbo 19 (16.1%), Isale-Oja Open defecation site, Ore 25 (21.6%), Oke-odo Open defecation Site, Ore 24 (20.7%), Jagun Farmland, Oke-Baale, Osogbo 20 (17.2%). P = 0.997. Why protists were 8 (22.9%) from Sabo area, Osogbo, 5 (14.3%) Oke-fia, Osogbo, 10(28.6%) Isale-Oja, Ore, 9 (25.7%) Oke-Odo Ore and 3 (8.6%) from Jagun, Oke-Baale, Osogbo. P = 0.823.

More so, nematode recovered from earthworm's gut were 20 (20.0%) Sabo area dumpsite, Osogbo, 18 (18.0%) Oke-fia dumpsite, Osogbo, 21 (21.0%) Isale-Oja open defecation, Ore, 22 (22.0%)

Oke-Odo Open defecation, Ore and 19 (19.0%) Jagun farmland, Oke- Baale, Osogbo. P= (0.554). While protists was 5 (100%) in Sabo Area, 2 (100%) Oke-fia, 5 (100%) Isale-Oja Ore, 4 (100%) Oke-odo Ore and 0.0% in Jagun farmland Oke-Baale Osogbo. P= (NA).

Table 2: **The Association of the Isolates and their Locations**

Variable	Sabo dump site	Oke-fia dump site	Isale-Oja Open Defecation	Oke-odo Open Defecation	Jagun Farm land	X^2 value	p-value
Vermicast's Nematodes	**N (%) 28(24.1)**	**N (%) 19(16.1)**	**N (%) 25(21.6)**	**N (%) 24(20.7)**	**N (%) 20(17.2)**		
Ascaris Spp.	4(14.3)	2(10.5)	2(8.0)	3(12.5)	3(15.0)		
Strongyloides Spp.	2(7.1)	3(15.8)	3(12.0)	3(12.5)	1(5.0)		
Pratylenchus Spp.	5(17.9)	2(10.5)	3(12.0)	3(12.5)	3(15.0)		
Paratylenchus Spp.	3(10.7)	2(10.5)	3(12.0)	5(20.8)	2(10.0)	11.519	0.997
Hemicyloiphora Spp.	6(21.4)	3(15.8)	7(28.0)	3(12.5)	5(25.0)		
Longidrous Spp.	2(7.1)	3(15.8)	2(8.0)	0	2(10.0)		
Rotylenchus Spp.	3(10.7)	2(10.5)	2(8.0)	2(8.3)	1(5.0)		
Meloidogyne Spp.	3(10.7)	2(10.5)	3(12.0)	5(20.8)	3(15.0)		
Earthworm's Nematodes							
	N (%) 20(20.0)	**N (%) 18(18.0)**	**N (%) 21(21.0)**	**N (%) 22(22.0)**	**N (%) 19(19.0)**		
Ascaris Spp.	8(40.0)	7(38.9)	8(38.1)	11(50.0)	8(42.1)		
Strongyloides Spp.	2(10.0)	2(11.1)	4(19.0)	5(22.7)	1(5.3)		
Ancylostoma Spp.	5(25.0)	5(27.8)	5(23.8)	3(13.6)	9(47.9)	14.595	0.554
Hemicyloiphora Spp.	5(25.0)	4(22.2)	4(19.0)	3(13.6)	1(5.3)		
Vermicast's Protists							
	N (%) 8(22.9)	**N (%) 5(14.3)**	**N (%) 10(28.6)**	**N (%) 9(25.7)**	**N (%) 3(8.6)**		
Entameoba histolytica	6(75.0)	4(80.0)	9(90.0)	8(88.9)	2(66.7)	1.520	0.823
Coccidia oocyst	2(25.0)	`1(20.0)	1(10.0)	1(11.1)	1(33.3)		
Earthworm's Protists							
Coccidia oocyst	5(100.0)	2(100.0)	5(100.0)	4(100.0)	0	NA	

DISCUSSION

This study showed the overall prevalence of STHs infection which remains a worldwide public health importance as long as poverty continues in the developing world. Zheng *et al.,* 2009). Most of the soil-borne, medically relevant protists seem to be cosmopolitan, but since some of them are by faecal-oral transmission, they are mostly common in low-income countries with poor sanitation.

As reported by Olubunmi, *et al.,* (2013) 50million people are affected approximately yearly with an estimated 40-100 thousand death recorded yearly by *Ameobiosis caused by E. histolytica.* In this study, the species of soil transmitted parasites (STPs) in the vermicast was high, occasioned by their habit bio-physiochemical, geographical and tropic characteristics Loranger *et al.,* (2012). More so, the study shows that the earthworm gut compromised of obligate protozoan C*occidia* oocyst) and geohelminths and obligate plant parasitic nematode Dominnguez *et al.,* (2003). The only protozoa present in the earthworm gut is the *Coccidia* Spp while *A. lumbricodes* was the most prevalent geohelminths. This highly implicates the earthworms as a mechanical vector of STPs of public health importance. *Hemicyclophora* Spp is the only survivor of PPN in earthworm's gut because of its resistance to the gut enzymes (Nzeako, *et al.,* 2013) The faunal structure shows more plant parasitic nematodes (PPN) 107 (53.5%) than obligate helminths 82 (41.0%) and obligate protists 51(25.5%).

CONCLUSION

The study submits that earthworm play phoretic and vectoral roles in the spread of STPs. Protists (*E. histolytica and Coccida* spp) and nematode geohelminths (*A.lumbriocoides*, *An. duodenale* and *S. stercoralis.* The high concentration release of vermicast on soil surface gives a veritable environment for the movement of incumbent parasitic constituents by run offs. Plant parasitic Nematodes (PPNs) is most prevalent in the cast as a result of physiochemical status of the vermicast which stimulate positive taxism of minute invertebrate thereby making it conducive for them in the soil surface. Though plant parasite nematodes barely survive in earthworm guts. However, this study shows that earthworm are significant in the epidemiology of geoprotozoans and geohelminths as well as PPNs. The study thereby alludes for addition of earthworm in the existence epidemiological accounts of geoprotozoans, geohelminths and PPNs.

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TRADITIONAL MANAGEMENT TECHNIQUES OF SACRED FORESTS CONSERVATION IN SOUTH-WESTERN NIGERIA

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ABSTRACT

Traditions, customs, beliefs, and cultural rights play significant roles in environmental conservation and biodiversity. This study assessed the traditional management techniques of sacred groves in southwestern Nigeria. The sacred groves are Igbo-Ile, Igbo-Oba, Igbo-Olua, Igbo-Olodumare and Igbo-Gbopo. 150 copies of the questionnaires were administered randomly to custodians (16), community heads (40) and residents (94) in the 5 communities for information on the various traditional methods adopted in the conservation of sacred groves. All the data obtained were analyzed using descriptive statistics. The results revealed that 72.82% of the respondents were male while 27.18% were female; the conservation of the sacred groves was largely carried out by 93.00% of the local people of which Christians were the majority. 74.66% of respondents believed that the sacred groves are conserved for spiritual purposes compared to environmental purposes which ranked 17.81%, burial purposes 4.11%, while the least for recreational purposes (3.43%). The communities of Igbo-Ile, Igbo-Gbopo, Igbo-Olodumare and Igbo-Oba sacred groves affirmed that the groves served as sources of food, income, energy, medicine, and shelterbelt. Poverty was recognized as a main factor hindering the conservation of sacred groves in Nigeria. Socio–cultural and religious functions of the groves could boost the tourism sector if the government properly harnesses it.

Keywords: Biodiversity, Forest conservation, Rural communities, Sacred groves, Religious functions

INTRODUCTION

Several case studies of the definition of a sacred grove have been highlighted (Okali and Amubode, 1995; Alabi, 1992; Kokou, 1997). Sacred groves are a rich heritage among the tribal communities which played significant roles in religion and socio-cultural life among the local tribal people (Malhotra, *et al*., 2001). Sacred groves are recognized as a system that informally forces traditional communities to harvest natural resources sustainably (Gadgil, 1985). According to Naiola (2002), and Waluyo (2003), the people of Dawan in West Timor culturally protect a special landscape for their sacred sites closely related to spring water. Aye community in Osun State, Nigeria culturally protect the source and watershed river *Yemo* which has been a major source of potable water in the community (Oyelowo, 2014). The Sacred forests are rich in perceptions that show how people see nature and its social significance, behaviour, religion, customary practices, regulation and bondage (Hanna and Jentoft, 1996).

Despite the small extent of Nigeria's tropical rainforest ecosystem, forests perform a key role in providing vital services, which usually have no clear market value, notably global climate regulation and watershed protection (Onyekwelu *et al*., 2008). There are actions against the survival of primarily anthropogenic rainforest ecosystems. However, Nigeria's rich rainforest ecosystems are unknowingly and indirectly protected by traditional spiritual beliefs and practices, which serve as the cornerstone of traditional ecological knowledge and environmental protection. Sacred groves emerged as a tool for biodiversity conservation, they house large numbers of plant and animal species. These areas are of spiritual significance to people and communities.

Socioeconomic, ecological and conservation importance of sacred groves have been recognized and it has been emphasized that immediate conservation of them is a must. Several approaches and options have been adopted to conserve these sacred spaces (Ola-Adams, 1998). In most of these sacred groves, festivals have contributed to the people's and communities' economic status. Socio-cultural meanings of sacred grove exist with the religious functions of the indigenous people or tribal people. According to Kokou (1997), sacred groves provide many useful goods such as hardwood and poles, fuelwood, medicine, vegetables and edible fruits. The fuel wood could be old dead wood collected by women. Edible fruits are collected by everyone who goes into the forest, women often collect leaves for wrapping meals (leaves of *Thalia welwitschii*, *Cola gigantea*). There are more abundant forest-based resources in sacred forests than in conservation areas due to the richness and diversity of tree species and biomass in the sacred forests (Anthwal *et al*., 2006; Soury, 2007; Khan *et al*., 2008; Rao *et al*., 2011). Roots, barks, fruits and leaves of many plants are used as sources of medicine by many local people (Agbo *et al*., 1993).

Perceptions of sacred grove conservation among communities vary globally. Some believe that sacred groves are meant for burial purposes, and some, for initiation, festivals etc. *Aranyami,* the Goddess of the forest, was worshipped as the primary source of life and fertility, and the forest as a community was viewed as a model for societal evolution and civilization evolution. Turnbull (1960), in his classic description of life among the pygmies of Congo, relates their belief in the forest as a world which, in return for their affection and trust, supplies them with all their needs. Traditional religious and cultural practices thus contributed greatly to restricting and controlling the utilization of the resources of these very representative land areas (Godson, 1998). The main objective of this article is to study perceptions associated with the conservation of sacred forests in Southwestern Nigeria to enhance existing knowledge on sacred forest conservation and management.

MATERIALS AND METHODS

Study Area

The study area is in the tropical rainforest ecosystem of southwest Nigeria. The ecological zone is a continuous belt around the world between Lat. 24^{o} S and 24^{o}N and Longitude 10oE and 20^{o}W. In southwest Nigeria, the tropical rainforest begins a few kilometres inland along the coastal vegetation, it is 300km wide in its widest area (Okojie, 1994). It comprises Lagos, Ogun, Oyo, Osun, Ekiti and Ondo (Fig 1). There are distinct dry and rainy seasons, having an average annual rainfall and temperature of 1489mm and 26.5ºC respectively. The zone has a high-density of the human population with agriculture as the primary occupation of the people. The zone is known for the cultivation of maize, cassava, vegetables, yam, oil palm etc. (Sowunmi and Akintola, 2010) National Population Commission, (2007) reported that 27, 511 892 people lived (14, 049 594 males and 13 462 298 females) in Southwest, Nigeria.

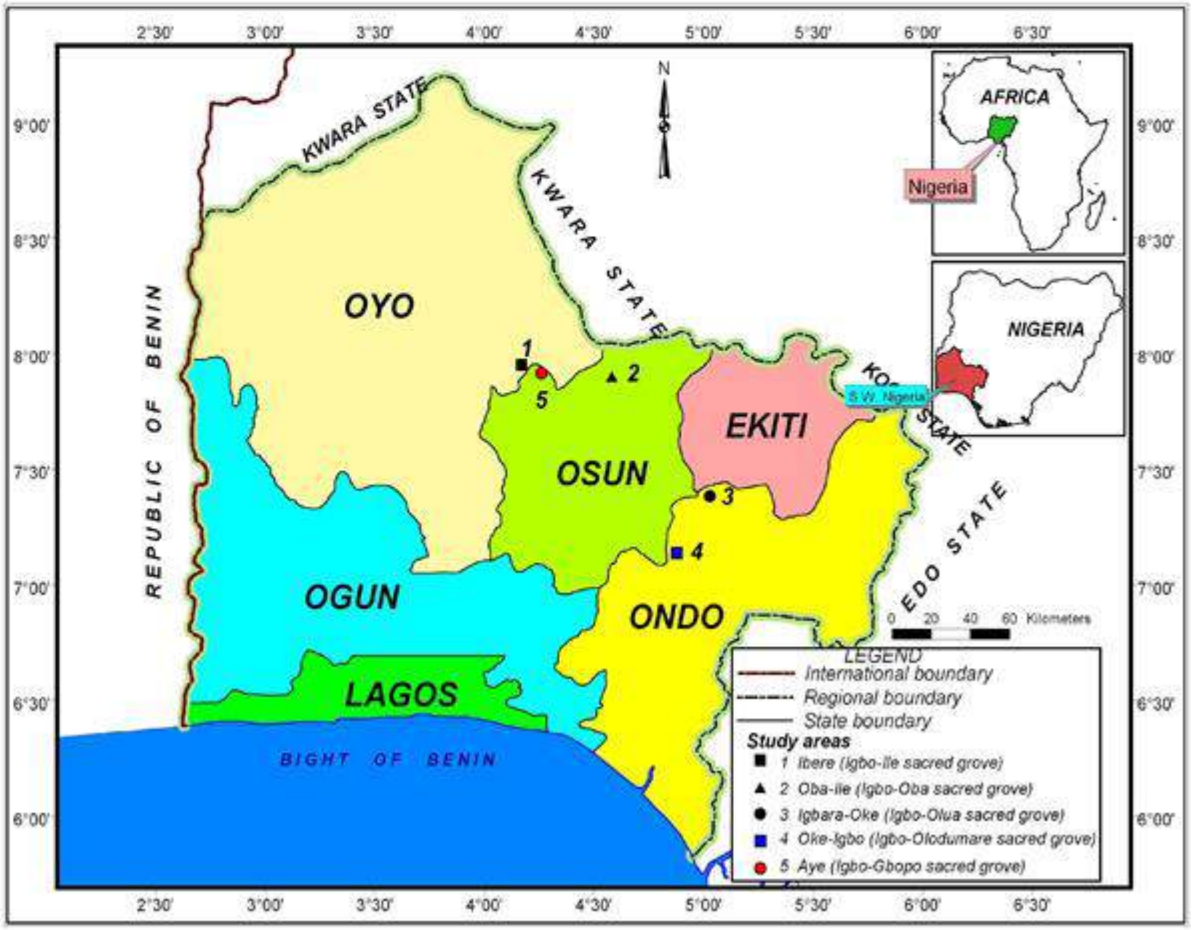

Fig 1: Map of Southwestern states, Nigeria, showing the location of the sacred groves with maps of Africa and Nigeria in the inset. Source: Oyelowo, 2014

Selection of Study Areas

Five sacred groves were purposely selected from South-Western states (Table 1).

Table 1: Sacred Groves and Their Location Coordinates

Sacred Groves	Town	Local Government Area	State	Latitude	Longitude
Igbo-Ile	Ibere	Ogo Oluwa	Oyo	7.9333333°,	4.2°.
Igbo-Oba	Oba Ile	Olorunda	Osun	7^0 54'	4^0 35'
Igbo-Olua	Igbare Oke	Ifedore	Ondo	$7^0 24^1 0^{11}$	$5^0 3^1 0^{11}$
Igbo-Olodumare	Oke Igbo	Oke Igbo	Ondo	7^0 12^1 0^{11}	3^0 18^1 0^{11}
Igbo-Gbopo	Aye	Ejigbo	Osun	7.9166667°	4.25°

Data Collection and Analysis

Five different communities were purposively selected for this study. Questionnaires were administered to communities selected for enumeration using simple random sampling. 300 questionnaires were distributed and administered randomly through the meetings held with village heads, custodians, and the people. During field visits, information on the use of sacred forests, taboos, deities, festivals and cultural aspects etc. through personal contacts and by interviewing villagers. All the data obtained from the structured questionnaire were subjected to descriptive statistical analysis. Firstly, a qualitative survey was conducted in the sacred grove communities based on interviews with the religious leaders (priests of the grove, Christian, Muslim) and villages. Secondly, a quantitative survey was carried out subsequently to better appreciate the social-cultural importance of the groves. This is in the form of frequency and percentage distribution. All studies were carried out with the prior consent of the local communities concerned- in particular, the consent of village chiefs, community elders and priests, who have a wealth of indigenous ecological knowledge.

RESULTS

Demographic Survey of the sacred groves

Igbo-Ile Sacred Grove

The people in the village are predominantly farmers. Igbo-Ile forest is where the community was first settled before they moved to the present location. During the Fulani war, the community left the area for more protection under Ogbomosho. When they returned after the war, they decided to relocate along the major road. Where the community first settled was protected against human activities and they started appeasing the spirit of the buried kings. Igbo-Ile is also a sacred place for king initiation during coronation. The relics of the first palace and buildings are still in Igbo-Ile sacred grove (Plate 1 & 2). Though the annual festival in Igbo-Ile stopped over the years, the forest is still intact against human activities. The king and chiefs were interviewed in the palace before entering the Igbo-Ile grove (Plate 3).

Plate 1: Point of worship and Plate 2: Evidence of rituals at Igbo-Ile Sacred Grove

Igbo-Oba Sacred Grove

The forest is located in Oba-Ile, Olorunda Local Government. Oba-Ile is one of the most ancient towns in Yoruba Land according to history. History has it that it was founded in the 12th Century by one Oduyale who was the son of Oduduwa and also a sibling of Alaafin and Olufon Ade. The town, Oba-Ile is a rural quiet community with a chequered history of bravery, conquests, and internecine wars, tackled in the savannah and forest belt of Olorunda Local Government Council of Osun state, Nigeria. It stands about twenty kilometres North West of Osogbo, the state capital of Osun. It commands attention from neighbouring towns and villages because it is a market town, standing in between four administrative headquarters of Olorunda, Ifelodun, Orolu and Irepodun. The town is joined by a cross-network of roads. It is predominantly a cocoa farming community in the mixed forest type.

Plate 3: Worship Point in Igbo-Oba Sacred Grove, Oba-Ile, Osun State.

Igbo-Olua Sacred Grove

The forest is an ancestral heritage for the community and a symbol of unity and peace to the community. The forest stands as a major cultural site for the annual festivals. The festivals are the Yam festival (Odun Ijesu), Alabasaba festival, Ijobi festival and Ikedi festival where the cow is killed once in three years for the rituals. The importance of this forest to the community has been established in praising each other *"Olua Ugbara a gbe kete ra o"*. The igbara-Oke community has a big mud house, housing the Olua shrine which is located outside the sacred grove. The custodian was interviewed in his house (Plate 5) before proceeding to the Olua shrine to appeal to *Olua*. This was done to permit us to enter the grove (Plates 6 and 7).

Plate 4 and 5: Chief appeals to *Olua* in the shrine with the researchers

Igbo Olodumare Sacred Grove

Igbo Olodumare is a small community near Oke-Igbo. The main occupations of the people are farming, teaching, hunting and petty trading. Some are also artisans, traditionalists and herbalists. This is a thick evergreen forest preserved for its beautiful and fascinating nature. The forest is significant for its spiritual value and it was believed that demons and spirits existed in the forest. This is a unique historical place in Ondo State, blessed with numerous wonders of nature. It is suitable for camping, film shooting, picnics, and bird watching. This forest was made popular by the famous novel titled *"Ogboju Ode ninu Igbo Irunmole*" by Chief D.O. Fagunwa in 1948. The Late Governor of Ondo state, Chief Adebayo Adefarati constructed an entrance making the place a tourist centre (Plate 8). At the base of the rock is the sculpture of *Baba Onirungbon Yeuke*, a fictional character from Fagunwá's Igbo Olodumare with his legendary long beard and pot, smoking his pipe (Plate 9).

Plate 8: Entrance to Igbo Olodumare Sacred Grove, Igbo Olodumare, Oke-Igbo, Ondo
Plate 9: Researcher with *Baba Onirungbon Yeuke* (a fictional character from Fagunwá's Igbo Olodumare) Statue in Igbo Olodumare

Igbo-Gbopo Sacred Grove

Aye is considered as one of the oldest villages in Ejigbo Local Government Area. The majority of Aye people migrated from Ogbomoso; they are known for farming activities. The object of worship in Gbopo forest is River Yemo, which takes its source and meanders through the forest (Plate 10 & 11). Gbopo forest is protected against human activities.

Plate 10: Source of River *Yemo* (object of worship) in Igbo-Gbopo Sacred Grove, Aye.
Plate 11: Point of worship in Igbo-Gbopo Sacred Grove, Aye, Osun State

Socio-economic Characteristics of Respondents in all the Sacred Grove

Table 2 shows the summary of the demographic characteristics of the sampled population in the 5 Sacred Groves (SG). In all the SGs, 147 questionnaires were recovered out of 150 questionnaires administered. Among the respondents, 72.82% of respondents were male while 27.18% were female. Marital status shows that 49.4% of respondents were married, 36.44% were singles, and others recorded 11.48%. Christianity had the highest percentage of 47.98 compared with Muslim (31.04%) and traditionalist (11.18%), others (9.76%). The majority of the respondents had primary school education (38.06%), followed by secondary education (25.62%), tertiary education (19.78%), Adult education (7.56%), and 2.06% of respondents had "No formal education". Farming (50.06%) was the major occupation of the respondents, followed by Trading (24%), Artisan (11.48%), Civil servant (10.44%) and the least student (4%). About 95.92% of the respondents subscribed that they were familiar with the sacred groves while the remaining 4.08% were not familiar with the sacred groves in their communities. 74.66% of respondents believed that the main function of the sacred grove is for spiritual purposes compared to Environmental purposes (17.81%), Burial purposes (4.11%), and the least is recreational purposes (3.43%). All the respondents (100%) affirmed the ownership of the sacred groves to be owned by the community. However, in all 5 sacred groves, 87.76% of the respondents visited the grove anytime, 4.08% visited once a week and 2.04% visited once fortnightly, 1.36% visited 2-3 times/week and 1.36% visited once a month.

Table 2: Socio-economic Characteristics of Respondents in all the Sacred Grove

x	Variables	Igbo Ile		Igbo Oba		Igbo Olua		Igbo Olodumare		Igbo Gbopo	
		Freq (n=3)	%	Freq (n=30)	%	Freq (n=30)	%	Freq (n=27)	%	Freq (n=30)	%
Sex	Male	23	76.7	21	70.0	24	80.0	20	74.1	19	63.3
	Female	7	23.3	9	30.0	6	20.0	7	25.9	11	36.7
Marital status	Married	18	60.0	11	36.7	15	50.0	10	37.0	19	63.3
	Single	10	33.3	11	36.7	10	33.3	15	55.6	7	23.3
	Others	2	6.7	4	13.3	5	16.7	2	7.4	4	13.3
Religion	Christianity	14	46.7	10	33.3	13	43.3	9	33.3	25	83.3
	Muslim	12	40.0	12	40.0	12	40.0	5	18.5	5	16.7
	Traditional	0	0	4	13.3	5	16.7	7	25.9	0	0
	Others	4	13.3	4	13.3	0	0	6	22.2	0	0
Edu. Status	Primary	15	50.0	10	33.3	15	50.0	10	37.0	6	20.0
	Second	9	30.0	6	20.0	7	23.3	4	14.8	12	40.0
	Tertiary	2	6.7	9	30.0	5	16.7	6	22.2	7	23.3
	Adult Edu.	3	10.0	2	6.7	1	3.3	3	11.1	2	6.7
	Quranic	1	3.3	3	10.0	1	3.3	3	11.1	2	6.7
	No formal	0	0	0	0	1	3.3	1	3.7	1	3.3
Occupation	Farming	24	80.0	7	23.3	13	43.3	10	37.0	20	66.7
	Trading	5	16.7	10	33.3	9	30.0	9	33.3	2	6.7
	Civil servant	0	0	8	26.7	1	3.3	6	22.2	0	0
	Artisan	0	0	4	13.3	5	16.7	2	7.4	6	20.0
	Student	1	3.3	1	3.3	2	6.7	0	0	2	6.7

x	Variables	Igbo Ile		Igbo Oba		Igbo Olua		Igbo Olodumare		Igbo Gbopo	
		Freq (n=3)	**%**	**Freq (n=30)**	**%**	**Freq (n=30)**	**%**	**Freq (n=27)**	**%**	**Freq (n=30)**	**%**
Sex	Male	23	76.7	21	70.0	24	80.0	20	74.1	19	63.3
	Female	7	23.3	9	30.0	6	20.0	7	25.9	11	36.7
Marital status	Married	18	60.0	11	36.7	15	50.0	10	37.0	19	63.3
	Single	10	33.3	11	36.7	10	33.3	15	55.6	7	23.3
	Others	2	6.7	4	13.3	5	16.7	2	7.4	4	13.3
Religion	Christianity	14	46.7	10	33.3	13	43.3	9	33.3	25	83.3
	Muslim	12	40.0	12	40.0	12	40.0	5	18.5	5	16.7
	Traditional	0	0	4	13.3	5	16.7	7	25.9	0	0
	Others	4	13.3	4	13.3	0	0	6	22.2	0	0
Edu. Status	Primary	15	50.0	10	33.3	15	50.0	10	37.0	6	20.0
	Second	9	30.0	6	20.0	7	23.3	4	14.8	12	40.0
	Tertiary	2	6.7	9	30.0	5	16.7	6	22.2	7	23.3
	Adult Edu.	3	10.0	2	6.7	1	3.3	3	11.1	2	6.7
	Quranic	1	3.3	3	10.0	1	3.3	3	11.1	2	6.7
	No formal	0	0	0	0	1	3.3	1	3.7	1	3.3
Occupation	Farming	24	80.0	7	23.3	13	43.3	10	37.0	20	66.7
	Trading	5	16.7	10	33.3	9	30.0	9	33.3	2	6.7
	Civil servant	0	0	8	26.7	1	3.3	6	22.2	0	0
	Artisan	0	0	4	13.3	5	16.7	2	7.4	6	20.0
	Student	1	3.3	1	3.3	2	6.7	0	0	2	6.7

Stakeholders' responsibilities

Local people, community leaders, and custodians shared the responsibility of protecting the sacred groves. In Igbo-Ile, 93.3% of respondents attached the protection of the grove to local people, followed by costodians (6.7%). About 60% of the respondents agreed that Igbo-Oba is being protected by local people, followed by Community leaders (23.3%) and custodians (16.7%). However, Igbo-Olua and Igbo-Gbopo showed higher percentages recorded against community leaders as the protectors of the grove. The government was responsible for the protection of Igbo-Olodumare. (Fig. 3).

Functions of the Sacred Groves to the Communities

Functions of the groves varied, 72.4% of respondents responded that Igbo-Ile is protected for spiritual purposes, followed by burial (17.2%), while the remaining respondents ascribed the function of the grove to environmental purposes (10.4%). About 80% of the respondents believed Igbo-Oba functions as a spiritual forest, and 16.7% attached the function of the grove to environmental and burial purposes (3.3%). In Igbo-Olua, all respondents (100%) agreed that the grove is mainly for spiritual purposes. Igbo-Olodumare functions for spiritual purposes (74.1%), followed by recreation (18.5%) and environmental (7.4%). Igbo-Gbopo is regarded for its environmental purposes (53.3%), followed by its spiritual functions (46.7%) (Fig 4)

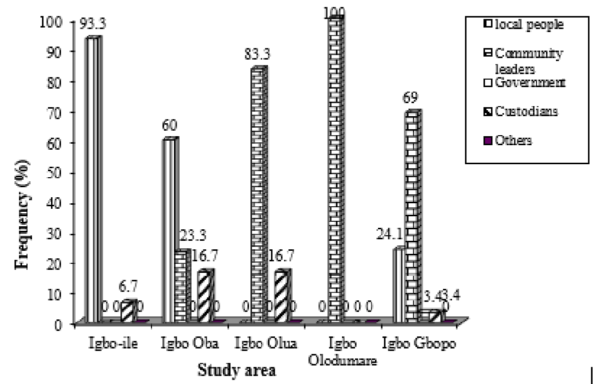

Fig. 3: Responsibilities of Stakeholders in Sacred Grove Conservation

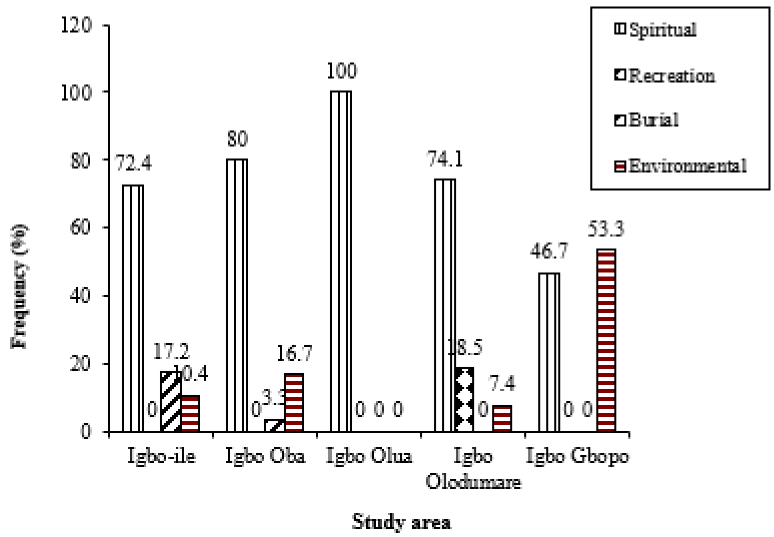

Fig 4: Functions of the Sacred Groves to the Communities

Purpose of Visiting the Groves

Respondents entered the grove for various purposes; hunting, firewood collection (dead wood), worship/festivals, and to appease the gods. A higher percentage (83.3%) entered Igbo-Ile for hunting. 6.7% entered to collect firewood (dead wood) and the remaining 10% did not enter the grove. In Igbo-Oba, 46.7% entered the grove to worship and for festivals, 40% did not visit while the remaining 13.3% entered to appease gods. The majority of respondents (43.3%) in Igbo-Olua responded they did not enter the grove, followed by appease (30%) and 26.7% entered for the purpose of worship and for festivals. Igbo-Olodumare was regarded as a worship place for inspiration by 54.5% of respondents, while the remaining 45.5% responded that they do not visit. About 60% entered Igbo-Gbopo for hunting which was highest compared to other purposes. 33.3% of respondents subscribed to firewood collection, while 6.7% did not visit (Fig. 5).

Perception of people towards restrictions to the Sacred Groves

Different perceptions of the respondents with respect to the reasons behind the conservation of the grove were recorded. In all the groves, higher percentage was recorded against protection (Fig. 6). In Igbo-

Ile, about 71.4% of respondents considered the conservation of the grove as "very good", Good (10.7%), bad (10.7%), very bad (7.1%). In all the remaining sacred groves, conservation of the grove was rated higher.

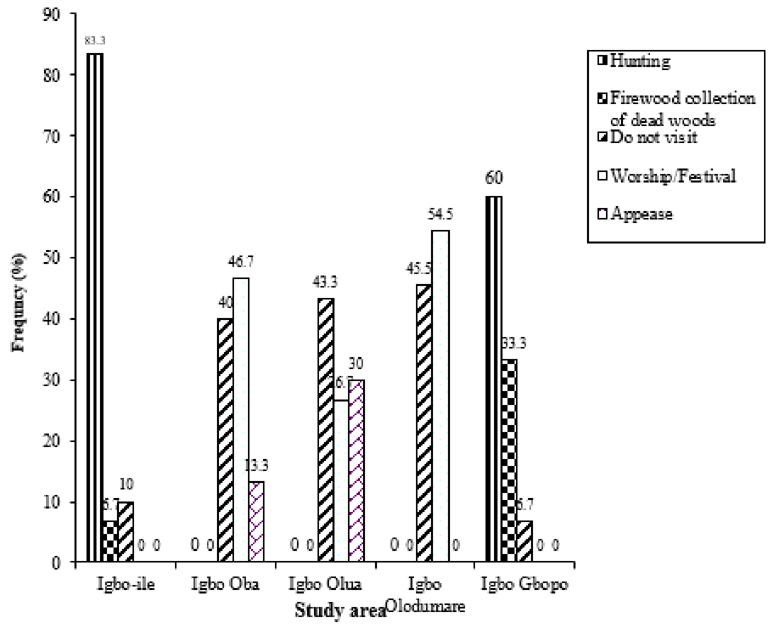

Fig. 5: Purpose of Visiting the Groves

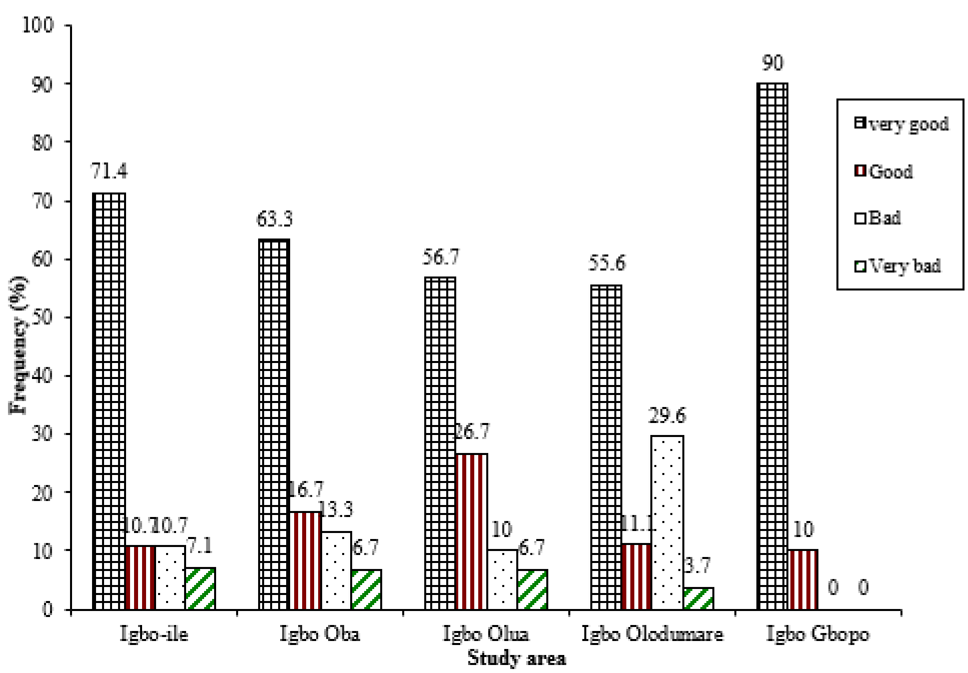

Fig 6: Perception of people towards restrictions to the Sacred Groves

DISCUSSION

The study investigated the perception of the sacred groves' conservation, their significance, impact, and intimate spiritual relationship. Table 2 shows the demographic structure of the 5 sacred groves (Igbo-Ile, Igbo-Oba, Igbo Olua, Igbo-Olodumare and Igbo Gbopo Sacred Groves). The respondents were 72.82% males and 27.18% females. Men were more available to be interviewed than women. Dafni (2007) reported in his study that women were more reluctant to be interviewed than men. The higher percentage of Christians (47.98%) and Muslims (31.04%) compared to Traditionalists within the communities could be attributed to the increase in the change to Western religion. This supported the report of Adomako and Adomako (1997) that in the Guako sacred forest, Ghana, the religion of respondents showed that Christianity (64%) had the highest percentage compared to Islam (20%) and Animism (16%). This suggested that members of the community who had a religious interest in the conservation of the sacred groves to worship gods are in the minority since Christianity (especially) regards the worship of ancestral gods as idolatry. In similar research carried out in Oboto village, Nigeria, Okali and Amubode (1995) reported that about 82% were Christians, 13.5% were Muslims and 4.5% were traditionalists. The traditional beliefs and practices are seriously threatened by Christian and Muslim activities. This might weaken the resource conservation of these sacred groves.

There is a low level of education among the respondents across the 5 communities. The majority of the respondents had Primary School Education (38.06%) compared to Secondary education (25.62%), Tertiary (19.78%), and adult education (7.56%). This could be attributed to the low level of education in rural areas. Only 45% of the women in Oboto village had formal primary education, while 9% had Secondary education (Okali and Amubode, 1995). Farming (50.06%) was the major occupation of the respondents compared with other occupations. This could be attributed to the land availability among rural dwellers or as a source of income. Traditionally, in communities in Nigeria, the land is owned as common, communal, clan or extended family property freely used by those owning it. Rural people have access to good land to farm. Okali and Amubode (1995) reported that farming is the predominant occupation of both men and women in Oboto village, Nigeria and this accounted for about 70% of it devoted to cocoa, kola nut and oil palm as cash crops dominated by men, the rest goes for food crops, dominated by women.

About 95.92% of the respondents subscribed that they were familiar with the sacred groves while the remaining 4.08% were not familiar with the grove. This could be attributed to the transfer of knowledge to the next generation within the communities. Also, it could be attributed to the economic importance, festivals or celebrations attached to the groves. The transfer of knowledge to the next generation was mainly by the grandparents in the family, and in school, the children were made aware of the importance of the sacred groves (Ishani and William, 2009). Malhotra *et al.* (1998) attributed the awareness of sacred groves among the communities based on the economic benefits derived from the groves.

Local people, community leaders, and custodians shared the responsibility of protecting the sacred groves. In Igbo-Ile, 93.3% of respondents attached the protection of the grove to local people, followed by custodians (6.7%). About 60% of the respondents agreed that Igbo-Oba is being protected by local people, followed by Community leaders (23.3%) and custodians (16.7%). In Igbo-Ile and Igbo-Oba SGs, the protection of the sacred groves fell largely on local people. This could be attributed to the fact that; local people see the groves as their physical and spiritual heritage and protect it by not going against taboos. Most of Malshegu's inhabitants worship the ancestral kpalevorgu, in addition to their household gods (Dorm–Adzobu *et al*., 1995). Various communities in India follow nature worship based on the premise that all creations of nature must be protected (Ganesan *et al*. 2007). In Afghanistan, after the advent of Islam, the creation and conservation of sacred groves became a part of the historical and geographical tradition of the rural people (Mohamed, 1998). The positive role of sacred groves in the socio-economic and cultural lives of many rural folks in Ghana has been possible because of the collective efforts of people to protect them (Michaloud and Durry 1998). However, Igbo-Olua and Igbo-Gbopo showed higher percentages recorded against community leaders as the protectors of the grove.

The government is responsible for the protection of Igbo-Olodumare. Only Igbo-Olodumare has Ondo State legal protection among the 5 sacred groves. Gadgil and Vartak (1981) have documented 223 such groves. Legally all sacred groves in Meghalaya are under the control of District councils. (Tiwari *et al.*, 1998)

In all the sacred groves, the maximum percentage of respondents attached the function of sacred groves to spiritual purposes, except Igbo –Gbopo where 53.3% of respondents regarded the grove for its environmental purposes. The inhabitants of the villages could believe in the sanctity of the groves and deities and this could make them aware of the spiritual purpose of groves (Dorm-Adzbu and Ampadu-Agyer, 1995). Local inhabitants recognize that trees have an economic value (especially the Dawa Dawa and shea–nut trees) and a medicinal value as well as providing shade and wood for building houses and making farm implements; and that they contribute to protecting the headwaters or rivers and streams; to the collection of wild honey; the control of soil erosion; and the protection of buildings against storms. The environmental importance attached to the grove by the Aye community where Igbo-Gbopo is located could be attributed to the roles of the grove in providing a more dependable source of water for the community. *Yemo* River takes its source from the grove. Aye, community harvested the trees along the river owing to the neglect of the worshipping of River *Yemo*, despite the immediate past king's enforcement of the taboos against the removal of trees along River *Yemo*. At the demise of the king, people started cutting trees, causing the flow of River *Yemo* to reduce drastically during the dry season. It took a long time before the community woke up to these destructive realities. The present king mandated a total shift from farming along the river. Puspangadan *et al*., 1998 reported that one of the important ecological roles of this grove is the provision of water for the organisms living in and around the sacred grove. In addition, transpiration from the sacred grove vegetation would increase atmospheric humidity reduce the temperature in the immediate vicinity and produce a more favourable microclimate for many organisms (Khiewtam and Ramakrishnan, 1989). Hunting was valued in Igbo-Ile and Igbo-Gbopo sacred groves. A higher percentage of 83.3% entered the grove for hunting.

Rituals and worshipping of gods faded away when the community started embracing Western religion. The trees and other forms of the plant are protected to date. Hunting (83.3%), and firewood collection (6.7%) i.e. the dead woods were allowed in the grove. The head of the community pointed out that the grove abhorred the relics of the village. The community was first located where the Igbo-Ile sacred grove was established, it was the Fulani war that displaced them to the present location, hence there was a need to protect the area as the community heritage. The relics of the buildings are still present in the Igbo-Ile sacred grove. Okali and Amubode (1995) reported that hunting is men's work, done during the dry season (October-March) which is declared the open season. It takes place mainly, but not exclusively, in the Orisagogoro forest in Oboto village. This statement also agreed with the Aye community where Igbo-Gbopo is located. Rituals and deity worship receive no more attention, and the people are allowed to hunt in the sacred grove. Festivals and sacrifices are regular practices in Igbo-Oba and Igbo-Olua sacred groves. In these groves, rituals and festivals were performed for specific deities. During the Igbo-Olua festival in Igbara-Oke, a big cow is made for the sacrifices. The festival involved dancing, appeasing and praying. Igbo-Oba sacred grove in Oba-Ile also witnessed annual sacrifices and rituals. This could be attributed to the fact that deities are believed to look after the well-being of the people. According to Malhotra and Das, (1997), people take vows for wish fulfilment when there is a crisis, particularly bearing on health, and offering most of the terracotta of animals, birds, humans, etc, are made. In Igbo-Ile and Igbo-Oba sacred groves, broken pots were found which showed evidence of worship and sacrifice. Just to mention a few illustrations: Vidyarthi and Rai (1977) reported that different tribes of Bihar celebrate their major festivals at the sacred groves. Fuelwood i.e. dead woods were part of the reasons people entered the Igbo-Ile sacred grove. This is certainly true in many sacred groves found across the world. Gadgil and Vartak (1976), Roy Burman (1995) and Godbole *et al.* (1998) reported such groves in the Western Ghats of Maharashtra. Malhotra *et al*. (1998) reported the existence of numerous groves in Kerala from which plants and animals are not harvested, the same goes for Igbo-Olua, Igbo-Olodumare and Igbo–Oba. The groves from where fuelwood is extracted, local communities derive certain direct economic benefits from the sacred groves.

Sacred groves are good source of a variety of medicinal plants, fruits, fodder, and fuelwood among others. The respondents mentioned some of their benefits from the groves. The communities of Igbo-Ile, Igbo-Gbopo and Igbo-Oba sacred groves agreed that the groves served as a source of food, income, and medicine. The roles and benefits of the sacred groves in the conservation of the regional medicinal plant have been emphasized in several studies from different parts of the world. A total of 120 medicinal plants widely used for the treatment of various ailments were reported from four sacred groves of Manipur (Khumbongmayum *et al.* 2005). Conservation, utilization, and assessment of the implications of exploitation of these species have become an important task (Dhar 2002, Sumit and Dhar 2002). Igbara – Oke community, where Igbo –Olua sacred grove is located attached the benefits to the annual festival which brings people together but transforms the economy of the community. It was observed from the study that some communities were not in full support of the spiritual benefits but the environmental benefits of the sacred groves. The community of Ibere, where Igbo–Ile is located reported that the sacred grove prevents wind havoc, and the presence of the grove also brings rain, this is not spiritual to them, they believe in the role of trees in evapotranspiration. Okali and Amubode (1995) reported that Igbo-Orisa bordering the stream is protected as a watershed, and fishing is prohibited, to ensure the stream does not dry –up from siltation and that water is clean for domestic use.

Objects of worship vary from one sacred grove to another. Trees are the objects of worship in Igbo-Ile, Igbo-Oba and Igbo-Olua sacred groves. Trees and statues are objects of worship and inspiration in Igbo-Olodumare, although there were no sacrifices, to be inspired in the sacred grove. The river is an object of worship in Igbo-Gbopo.

CONCLUSION

Poverty is one of the unfortunate factors that hinder the conservation of sacred grove, the village people living nearby the sacred groves are poor and so they depend on the grove to meet their vital domestic necessities, such as fuel wood, vegetables, medicinal plants e. t. etc. Sacred groves have important socio–cultural functions, in addition to religious functions. This could boost the tourism sector if it is properly harnessed by the government.

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HAEMATOLOGICAL PARAMETERS OF *C. gariepinus* and *O. niloticus* FROM RIVER JAMA'ARE, NIGERIA

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ABSTRACT

The study was conducted to determine the influence of season on haematological parameters of *C. gariepinus* and *O. niloticus* caught from River Jama'are. A total of 20: five each of matured fish species were obtained in dry and wet seasons. Blood samples were collected from the cardiac vein of the fishes using separate heparinized dispensable syringes and hypodermic needles. Some physicochemical parameters of the water were determined. The data collected were analysed by two-sample t-test. Temperature was statistically significant with the mean values of 25.90^0C in dry season and 25.70^0C in the raining season in River Jama'are. The same trend was observed in Dissolved Oxygen (DO) with mean value of 5.90 mg/L in dry season while in the raining season was 5.30 mg/L in. The mean pH of 8.30 was higher during raining season than 7.80 in the dry season. The WBC, Hb and MCHC were statistically significant between raining and dry seasons while RBC, PVC, MCV and MCH were statistically not significant in both wet and dry seasons. All the haematological parameters were statistically not significant between *C. gariepinus* and *O. niloticus* in River Jama'are. Similar research should be carried out on other species of fishes in the river.

Key words: Haematological Parameters, *Clarias gariepinus*, *Oreochromis niloticus*, River Jama'are

INTRODUCTION

Fish is one of the most important food resources and is considered as cheapest source of protein worldwide. *Clarias gariepinus* and *Oreochromis niloticus* were amongst the most common freshwater fish species in Nigeria. Fish health and physiological status can be evaluated through haematological examination. However, haematological parameters varied with species, age and sex of fish as well as environmental factors. The temperature of river water is an important physical parameter that influences various ecological processes and the distribution of aquatic organisms. Temperature can affect the dissolved oxygen levels, nutrient availability, and metabolic rates of aquatic organisms (Duan *et al*., 2018).

Changes in pH can impact the availability of nutrients, the function of aquatic organisms' physiological process, and the overall river ecosystem (Sidhu *et al*., 2012). The pH level of river water is a crucial parameter as it affects the availability and toxicity of certain chemicals and metals, as well as the distribution of aquatic organisms. Acidic or alkaline conditions can have detrimental effects on fish and other aquatic life (Ebeniro *et al*., 2020). Low pH levels affected the behavior and reproduction of fish species in rivers (Julian *et al*., 2015).

Dissolved oxygen (DO) is a vital parameter in assessing water quality and the health of aquatic ecosystems. The concentration of dissolved oxygen in river water can vary depending on temperature, photosynthesis, and organic matter decomposition. Low dissolved oxygen levels can lead to hypoxia, causing stress or death in fish species (Zenner *et al*., 2015). Low DO levels were associated with decreased fish abundance and diversity in rivers; DO is a crucial chemical parameter that indicates the water's ability to support aquatic life (Ji *et al*., 2019). It is influenced by factors such as temperature, photosynthetic activity, and organic matter decomposition. Low dissolved oxygen levels can lead to hypoxia, impacting the health and survival of aquatic organisms (Zhao *et al*., 2017).

Morphological and quantitative variations in blood parameters can be induced by environmental factors. Blood parameters of fish species have been studied in order to determine the haematological values of different species in their natural environment, so that value of each species can be standardised and in order to provide information on fish health status of fish species in captivity were also determined, so that abnormalities such as temperature and dissolved oxygen variations, disease and other factors can be detected (Ranzami paiva *et al*., 2000).

Blood physiology is currently considered as an essential index to the general health status in a number of fish species. Haematological analysis provides a quick screening method for the assessment of the health status of the fish thus its variables are now in use when clinical diagnosis of fish physiology is applied to determine the effects of external stressors (Adamu and Audu 2008). The aim of this study was to determine some blood parameters of *C. gariepinus* and *O. niloticus* in wet and dry seasons in River Jama'are, Bauchi State.

MATERIALS AND METHODS

Description of Site

The Jama'are River, also known as the Bunga River its upper reaches, starts in the highlands near Jos, Plateau State, Nigeria and flows northeast through Bauchi State and Yobe State before joining the Hadejia River to form the Yobe River. There was controversy over a plan to build the Kafin Zaki Dam on this river. 0ver 15 million people were utilizing the river for agriculture, fishing, livestock keeping and some domestic water supply for households. The Hadejia Jama’are Komadugu-Yobe Basin (HJKYB) drains a catchment of approximately 84,000km2 in north east Nigeria before discharging into Lake Chad (Anon., 2009).

Sample Collection and Preparation

A total of 20: five each of matured *Clarias gariepinus* and *Oreochromis niloticus* were obtained from River Jama'are Bauchi State in dry and wet seasons. Blood samples were collected through the vertebral blood vessels towards the caudal peduncle. 2 ml of blood from each fish was collected from the cardiac puncture using different 5ml disposable heparinized syringes, with ethylene diamine tetra acetic acid (10 ml EDTA) as anticoagulant.

Determination of Haematological Parameters

Standard haematological procedures described by Svobodova *et al.* (1991) were employed in the determination of white blood cell (WBC), red blood cell (RBC), packed cell volume (PVC), haemoglobin (Hb). The values of mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) were calculated according to the method of Stockham and Scott (2008).

Data Analysis

The data collected were analysed by two-sample t-test.

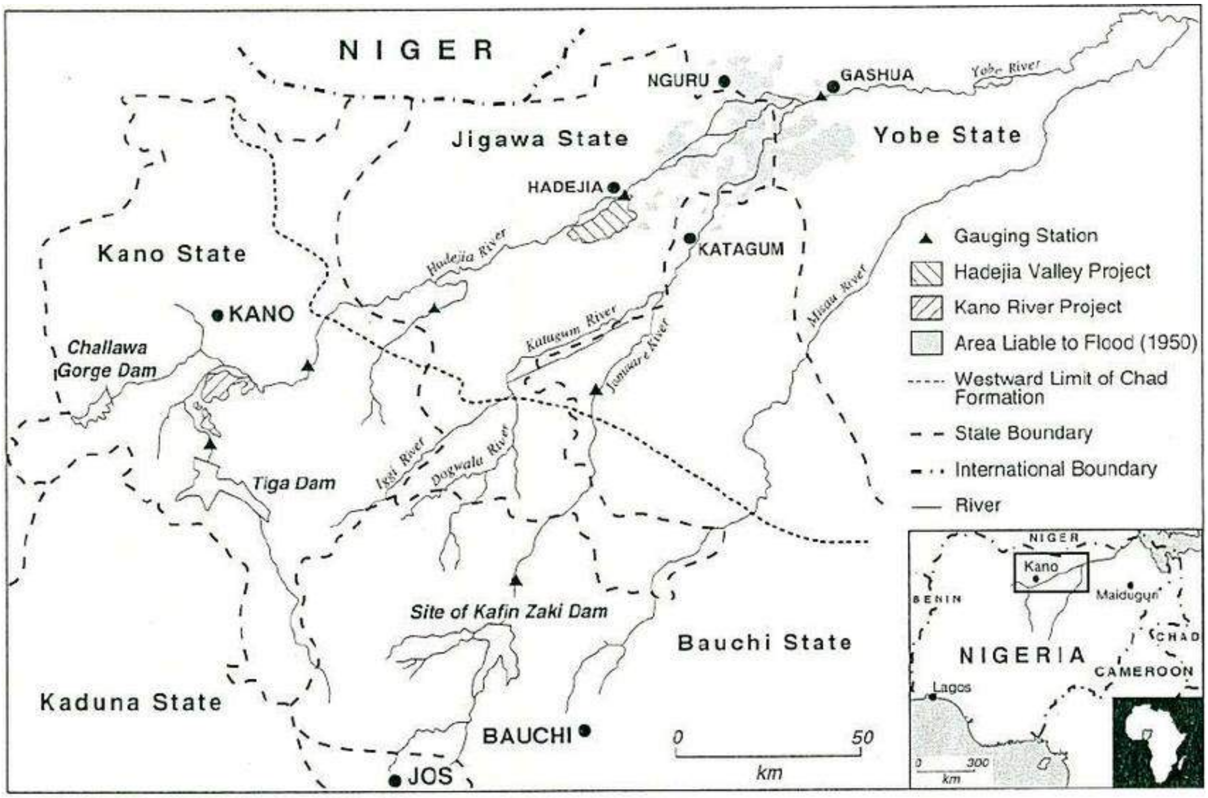

Figure 1: Hadeja-Jama'are Basin comprising River Jama'are

RESULTS AND DISCUSSION

Three Physicochemical parameters of River Jama'are were elucidated in Table 1. Temperature was not statistically significant. The mean temperature recorded was 25.9^{0}C and 25.7^{0}C in dry and wet seasons respectively.

These results are consistent with the findings of Obire *et al*., (2003) who observed similar trend in Elachi Creek in Port Harcourt. The results were also slightly similar with the findings of Ogbe *et al.*, (2020) who recorded a temperature means of 26.41^{0}C and 25.76^{0}C during dry and wet seasons respectively at lower river Niger, Kogi state. The same trend was observed in Dissolved oxygen (DO) in which dry season has slightly higher DO (5.90mg/L) compared to rainy season (5.30mg/L). However, these findings contradict the work of Izonfou and Bariweni (2001), in Niger Delta while working in Epie Creek. Their observed average DO levels of 4.45mg/L in the rainy season was higher than 3.35mg/L obtained in the dry season. The pH was statistically significant, with rainy season having the highest value (8.30) compared to dry season (7.80). The results of the pH were within the permissible level (6.5 to 8.5) set by World Health Organisation (WHO) and Standard Organisation of Nigeria (SON). The lower pH recorded during dry season is probably due to concentration of dissolved substances. The results corroborated the report of Akpan-Ebe (2014) for Qua Iboe River.

Table 1: Physicochemical Parameters of the Jama'are River in Rainy and Dry season

Season	Temperature (°C)	pH	Dissolved oxygen (mg/l)
Dry	25.9 ± 1.12	7.80 ± 0.58	5.90 ± 0.66
Rainy	25.7 ± 1.54	8.30 ± 0.34	5.30 ± 0.42

The haematological parameters were presented in Table 2. The results elucidated that almost all the parameters were higher in rainy season as compared to dry season. However, only WBC, Hb and MCHC were statistically significant. The least value of WBC observed in dry season could probably there are lower incidence of diseases in the dry season compared to wet season. The WBCs are the defensive cells of the body; there levels have implication for immune responses and the ability of the animal to fight infections (Divaware *et al*., 2012). Species with higher level of WBC would be able to fight infection more effectively than other species. The result of the Hb is not consistent with the findings of Argungu *et al*. (2021) who reported lower values of 6.678g/dl and 6.711g/dl than those of the present study for rainy and dry seasons respectively. Moreover, Hb values found in this study were higher than those recorded by Diyaware *et al*. (2012), 9.00 to 10.33g/dl.

The mean corpuscular haemoglobin concentration (MCHC) in this study corroborated the findings of Argungu *et al*. (2021) who reported higher MCHC during rainy season as against dry season. Similarly, the MCHC values in the current study (34.55 and 24.32 for rainy and dry seasons respectively) were higher than those reported by Omitoyin (2006) but lower than the results obtained by Onyia *et al.* (2013) which had 196.51 and 196.29 for rainy and dry seasons respectively. The differences could be due to differences in environment and data sample.

There was significant difference ($p < 0.05$) between rainy and dry season in mean WBC, Hb and MCHC which indicated that fish during rainy season has high WBC, Hb and MCHC compared to dry season at River Jama'are. However, RBC, PVC, MCV and MCH were statistically similar during rainy and dry seasons.

Table 2: Seasonal Variations in Haematological parameters of *C. gariepinus* and *O. niloticus* at River Jama'are, Bauchi

Parameters	Dry season	Rainy season	P-value
White blood cell ($x10^3/\mu l$)	8.48±36.41	9.74±10.98	*0.045
Red blood cell ($x10^6/mm^3$)	1.82±0.18	2.337±0.72	0.253
Haemoglobin (g1D/dL)	6.893±1.49	11.775±1.23	*0.002
Packed cell volume (%)	28.82±4.31	34.88±7.46	0.21
Mean corpuscular volume (f1)	151.1±19.9	157.8±11.02	0.579
Mean corpuscular haemoglobin (pg)	38.05±7.64	52.85±14.7	0.124
Mean corpuscular haemoglobin concentration (g/dL)	24.32±5.82	34.55±5.21	*0.041

The haematological parameters of *C. gariepinus* and *O. niloticus* caught in River Jama'are elucidated considerable variations between the two species (Table 3). Both species exhibit differences in white blood cell (WBC) counts, where the catfish had a WBC count of 8.26, while the tilapia fish had a WBC count of 9.39. However, both counts fall approximately within the normal range for fish species, which is typically between 10,000 – 50,000 cells per microliter of blood.

In terms of red blood cell (RBC) counts, the tilapia fish has a higher count (2.37 RBC) than the catfish (1.78 RBC). This suggests that tilapia fish have a higher oxygen-carrying capacity than catfish, which may be due to differences in their lifestyles and microhabitats.

The Hb and PVC also reveal differences between the two species, with the tilapia fish having higher values than the catfish. Hb is responsible for carrying oxygen in the blood, while PVC represents the proportion of RBCs in the blood. In general, higher Hb and PVC values indicate better oxygen-carrying capacity.

The mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC) parameters provide information about the size, weight, and amount of haemoglobin in individual RBCs. In this case, the *C. gariepinus* had a higher MCV and MCH, indicating that its RBCs are larger and contain more haemoglobin than those of the tilapia fish. Also, the MCHC value is higher in *C. gariepinus*, indicating a greater concentration of haemoglobin in individual RBCs. These results suggested that the two fish species have significant haematological differences that may be related to their lifestyles and microhabitats. All the blood parameters were within the average ranges of values.

Table 3: Haematological Parameters of Tilapia and Clarias in River Jama'are

Parameters	*C. gariepinus*	*O. niloticus*	P-value
White blood cell (x103/µl)	8.26±41.83	9.39±24.09	0.308
Red blood cell (x106/mm3)	1.78±0.25	2.377±0.66	0.144
Haemoglobin (g 1D/dL)	8.5±2.89	10.17±3.08	0.459
Packed cell volume (%)	28.62±4.45	35.08±7.17	0.177
Mean corpuscular volume (f1)	161.1±13.25	147.8±15.93	0.247
Mean corpuscular haemoglobin (pg)	48.95±19.64	41.95±1.44	0.528
Mean corpuscular haemoglobin concentration (g/dL)	30.27±10.94	28.6±3.21	0.779

CONCLUSION AND RECOMMENDATIONS

The rainy season and dry season samples of *C. gariepinus* and *O. niloticus* elucidated that WBC, Hb and MCHC were statistically significant at 5% level; this means that during rainy season, fish has high WBC, Hb and MCHC when compared to dry season in River Jama'are. RBC, PVC, MCV and MCH were statistically similar during rainy and dry season. Based on haematological parameters assessed *C. gariepinus* and *O. niloticus* were within the normal ranges

However, the pH was statistically significant seasonally at 5% level of significance with high value in wet season compared to dry season. The temperature and dissolved oxygen were statistically not significant in both seasons. River Jama'are in both dry and wet seasons had moderate temperature, dissolved oxygen and pH. Further research should be conducted to determine the condition and health status of other fish species of River Jama'are.

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COMPARATIVE STUDY OF PLANT CONSERVATION IN HOME GARDENS OF DRY AND WET LAND AREAS IN BONNY, RIVERS STATE, NIGERIA

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ABSTRACT

This study assessed the conservation of plant species in home gardens of the dry land areas (Finima Light House, Akiama and Oguwede) and wetland areas (Park, Orosikiri and Amariria) in Bonny Local Government Area of Rivers State, Nigeria. Home gardens in dry land contained 20 (Finima), 20 (Akiama) and 14 (Oguwede) plant species respectively, whereas home gardens in wetland areas were three (Park), six (Orosikiri) and one (Amariaria). *Syzgium aqueum* was highest (30%) in fequency, and the lowest was *gratissimum* in dry land, whereas in the wetland area the highest was in *Cyrtosperma senegalense* (51) and the lowest was *Dissotis rotundifolia* (3%). Akiama had the highest percentage species composition in dryland while in wetland area, percentage frequency was highest in Orosikiri. Plant population density shows that dry land (Akiama) had the highest population density of (0.09) while Finima Light House had(0.05) and the lowest was Oguwede (0.07). In the wetland, Species in the Park had the highest frequency of occurrence. The similarity indices for plant species at Finima and Akiama was 0.40 and 0.29 for Finima and Oguwede, while plants in Akiama and Oguwede had 0.24 similarity. Similarity index for plants species in the three wetlands were 0.44 (Park and Orosikiri), 0.50 (Park and Amariaria) and 0.29 for (Orosikiri and Amariaria). This study revealed that habitat differences affect plant species composition, and frequency of occurrence.

Keywords: Species conservation, Wetland flora, Dryland flora, Home gardens, Bonny Island.

INTRODUCTION

Home garden is a confined piece of land cultivated with a variety of annual and perennial trees or crops within where houses are built (Karyono, 1990) and is a type of agroforestry. In combination with annual and perennial farming crops, home gardens are distinguished by numerous plant Species such as trees, shrubs, and herbs (Fernandez et al, 1986). It helps in restoration of genetic diversity of natural habitats in an area (Eyzaguirre, 2004).

This study of home gardens can constitute an alternative that can serve as a basis for the promotion of family farming and planting of trees within homes. They are able to take into account as a priority, the basic needs of the rural populations. The contribution of the home gardens to Socio-economic livelihoods has been emphasized by many authors (Lal, 2020). Home gardens which are one of the oldest practices to manage land use and improve ecological zones, are rich in bio- diversity conservation (Montagnini, 2004). However, species richness of home gardens within a region is influenced by homestead size, structure, climatic conditions, market and socio-cultural factors.

All over the world, home gardens have enormous Socio-economic, nutritional impact on livelihoods. 'Food production on small plots adjacent to human settlements is the oldest and most enduring form of cultivation (Rowe, 2009). For centuries, home gardens have been an integral component of family farming and local food systems. Home gardening is an ancient and widespread practice all over the world, home gardens are classified as mixed, kitchen, backyard, farmyard, compound or homestead garden (Terra, 1958).

The need to document the Plant Species found in the Dryland and Wetland Area of Bonny Local Government Area of Rivers State because there is scarcity of research on documentation on the area. Therefore, this research aimed in providing documentations of the various plant species found within the Dryland and the Wet Area as a baseline for further research around Bonny communities, dryland (Finima Light House, Akiama and Oguwede) Wetland (Park, Orosikiri and Amariaria)) both areas for ecological and Socio-economic and environmental benefits.

Objectives

The objectives of the strudy were to:

i. identify the composition of the various plants species in the home gardens of Dryland and Wetland areas of Bonny Local Government Areas; and

ii. determine the frequency of occurrence and population density of plant species in the two habitat types.

MATERIALS AND METHODS

Study Area

The study was conducted in wetland and dry land plant communities in Bonny LGA of Rivers State, Nigeria. The study area lies within the Niger Delta which features both natural dryland and wetland areas. The climate of this study area is characterized by high temperature and precipitation. The areas of studies are found within the three agro-ecological zones of the forest ecosystem (i.e., Coastal Mangrove Forest/brackish swamp forest, fresh water raffia palm/swamp forest/barrier island forest and the lowland rainforest ecozones) (Teme, 2001).

Bonny is located about 40 kilometers to the south-eastern part of Port Harcourt, which is the state capital. It is comprises an Island located on the outer southern section of the Niger Delta complex. It's a trapezoid shaped landmass with co-ordinates: Northwestward Latitude 4˚33'N and Longitude 7˚08'E: North eastward Latitude 4˚30'N and Longitude 7˚20'E: Southwestward Latitude 4˚22'N and Longitude 7˚20'E; Southwestward Latitude 4˚22'N and Longitude 7˚08'E. Bonny L.G.A comprises of Bonny Island and the outlying mainland areas around it. Bonny Island is mostly surrounded by the Atlantic Ocean and has a population of about 170,000 people. Figure 1 shows the map of Bonny Island, (including the outlying lands, adding together to form the local government area) and the communities.

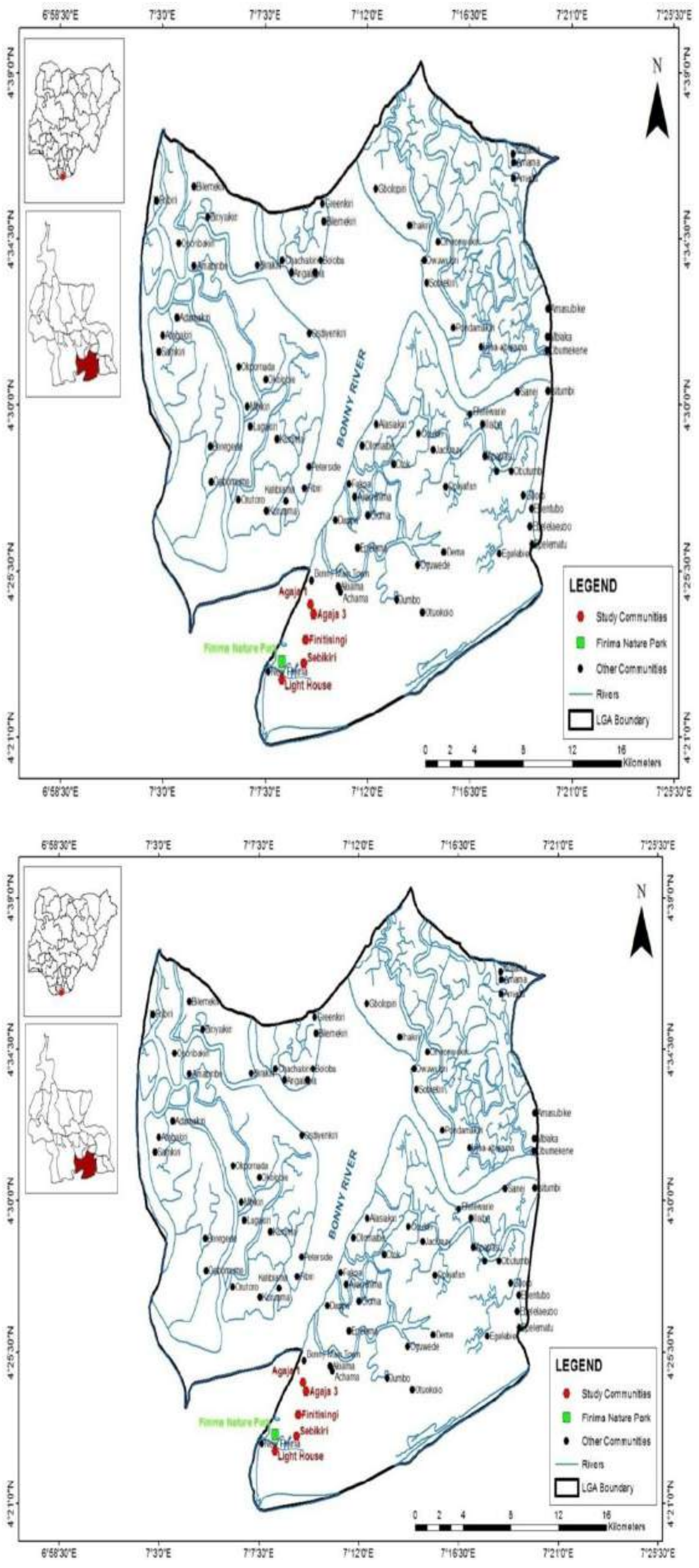

Figure 1: Map of Bonny Local Government Areas Showing the Communities

The study areas were divided into three groups (stations) for the upland area, we have 3 communities

For Upland in Bonny

i. Finima Light House Community
ii. Akiama Community
iii. Oguwede Community

For Wet Land Communities in Bonny

i. Park Community
ii. Orosikiri Community
iii. Amariaria

The various plants species are identified and recorded. Data gotten from the field was analyzed.

Parameters

Plant Species Composition per Location

Plant Species composition of the various home gardens were determined by recording at about an area of 100 m by 50 m in the various communities of both the Dry and Wet land communities.

Percentage Frequency of Occurrence Per Location

The frequency of occurrence, of each species was determined for both the Dry land and Wet Land communities using the formula below.

$$F = \frac{n}{N} x \frac{100}{1}$$

Where;
n is number of sample plots in which species occurs
N is total number of sample plots used .

Population Density of Plant Species Per Location

Number of Individual Plant Species/ Total number of Sample

Similarity Index

Similarity Index

$$SI = \frac{2C}{A+B}$$

Where;

SI is Similarity Index
C = no of species common to each location
A = no of species present in site A
B = no of species present in site B

Diversity Indices (dry land)

The diversity indices were determined using the Shannon index.

$$\text{Shannon Index } H = -\sum_{i=1}^{S} p_i \; 1n\, pi$$

In the Shannon and Weaner (1949) Index where;

pi = the proportion of individuals of each species of the total number of individuals species

(n) = divided by the total number of individuals found (N)

1n = the natural log, Σ is the sum of the calculations

S = the number of plant species

RESULTS

Species Composition of Dry Land and Wet Land Communities

The species composition found in Finima Light House, Akiama, and Oguwede is 20, 20 and 14 species respectively, with a total of 252, 450 and 331 plants species present respectively in the communities.

Whereas the species composition of the Wet land area found in Park Community, Orosikiri and Amariaria are 3, 6 and 1 respectively. The study revealed that home garden plant species are more within the Dry land communities as compared to wetland areas as shown in the table below. (Tab 4.1)

Table 1: Plant Species Composition of Dry Land in the Three Communities

S/N	Plant Species	Common Name	No of Plants enumerated
	Finima Light House Community		
1.	*Phyllantus amarus* Schumacher	Gale of wind	5
2.	*Xylopia aethiopica* (Dun.) A. Rich	African pepper,	10
3.	*Cleistopholis staudtii* Engl. & Diels	Local name: Canoe wood Salt and oil tree	6
4.	*Terminalia catappa L.*	Sea Almond umbrella tree	15
5.	*Funtumia africana* (Benth.) Stapf	Lagos rubber, Bush rubber, Silk rubber	10
6.	*Albizia Adianthifolia* (Schum.) W. F. Wight	Flat crown albiza, rough-bark-flat crown, platkroon	7
7.	*Erythrophleum ivorense* A. Chev	Tali Family Facaceae Size/height 40m	5
8	*Lasimorpha senegalensis* (Schott).	Swamp arum	20
9.	*Nauclea diderichii* (De Wild. & T.Durand) Merril	Local name: Brimstone tree, African peach tree Badi	15
10.	*Pentaclethra macrophylla* Benth.	African Oil Bean	10
11.	*Dacryodes edulis* H. J. Lam	Bush Butter tree	5
12.	*Cola pachycarpa* K. Schum.	Local name: Monkey Cola, Ogugu, Wild cola	4
13.	*Anacardium occidentale* L	Cashew	50
14.	*Artocarpus communis* (Parkinson) Fosberg	Bread Fruit	1
15.	*Acanthus montanus* Nees	Local name: Opipi False thistle, bears breech,	3
16.	Lonchocarpuscyanescens Perkin	Local name: Anunu (Igbo), talaki West African indigo	5
17.	*Elaeis guineensis* Jacq	African oil palm	35
18.	*Monodora myristica* (Gaertn.) Dunal.	Local name: ehuru Custard apple family, calabar nutmeg	1
19.	*Citrus* Tangerine Sp.	Tangerine	15
20.	*Mangifera indica*	Mango	30

S/N	Plant Species	Common name	No of plants enumerated
		Akiama Community	
1.	*Terminalia catappa L.*	Sea Almond umbrella tree	18
2.	*Elaeis guineensis* Jacq	African oil palm	15
3.	*Anacardium occidentale*	Cashew	10
4.	*Cleistopholis staudtii* Engl. & Diels	Local name: Canoe wood Salt and oil tree	8
5.	*Cola pachycarpa* K. Schum.	Local name: Monkey Cola, Ogugu, Okokoro Wild cola	10
6.	*Acanthus montanus* Nees	Local name: Opipi False thistle, bears breech	10
7.	*Chromolaena odorata* (L.) R.M. King & H. Rob	Local name: Paraffin weed, Awolowo Siam weed, Devil weed	25
8.	*Bambusa vulgaris* Schrad. Ex. J. C. Wendl.	Local name: Igbon Ikira Common bamboo	50
9.	*Mangifera indica*	Local name: Mangoro Mango	6
10.	*Cocos nucifera*	Coconut Tree	13
11.	*Carica papaya*	Paw-Paw	15
12.	*Irvingia gabonensis*	Irvingiaceae	30
13.	*Citrus* tangerine	Tangerine	10
14.	*Syzgium aqueum*	Rose Apple	15
15.	*Spinacia Oleracea L.*	Spinach	5
16.	*Psidium Guajava*	Guava	15
17.	*Saccharum officinarum*	Sugar cane	30
18.	*O. gratissimum*	African Basil.	25
19.	*Vernonia amygdalina*	Bitter leaf	50
20.		Cashew	60

S/N	Plant Species	Common Name	No of enumerated
		Oguwede Community	
1.	*Chromolaena odorata*	Local name: Paraffin weed, Awolowo Siam weed,	10
2.	*Saccharum officinarum*	Sugar cane	20
3.	*O. gratissimum*	African Basil.	15
4.	*Cocos nucifera*	Coconut Tree	10
5.	*Carica papaya*	Paw-Paw	17
6.	*Cola pachycarpa* .	Local name: Monkey Cola, Ogugu Wild cola	12

7.	*Acanthus montanus* Nees	Local name: Opipi False thistle, bears breech, mountain thistle	10
8.	*Mangifera indica*	Mango	8
9.	*Nauclea diderichii*	African peach tree, Badi	17
10.	*Spinacia Oleracea L.*	Spinach	50
11.	*Psidium Guajava*	Guava	65
12.	*Abelmoschus esculentus*	Okra	45
13.	*Colocasia esculenta*	Coco yam	90
14.	*Musa acuminata*	Banana	100

For Wet Land Area

S/N	Plant Species	Common Name	No of plants found
		Park Community	
1.	*Dissotis rotundifolia* (Sm.) Triana	Pink lady, Spanish shawl	15
2.	*Aframomum melegueta* K. Schum	Local name: Spice Alligator pepper	95
3.	*Cyrtosperma senegalense* Schott Engl.	Local name Bush maize English swamp arum	155

S/N	Plant Species	Common Name	No of Plants
		Orosikiri Community	
1.	*Palisota hirsuta* (Thunb.) K.Schum	Local name: Sheep's knee (Igbo), Knee cap (Yoruba)	5
2.	*Dissotis rotundifolia* (Sm.) Triana	Pink lady, Spanish shawl	10
3.	*Symphonia globulifera* L.F.	Local name: Okilolo Boarwood	3
4.	*Cyrtosperma senegalense* Schott Engl.	Local name: Bush maize English swamp arum	95
5.	Calamus deeratus G. Mann & H. Wendl	Local name: Rattan Slender Palm, rattan cane	25
6.	*Aframomum melegueta* K. Schum	Local name: Spice Alligator pepper	45

S/N	Plant Species	Common Name	No of plants
		Amariaria Community	
1.	*Aframomum melegueta* K. Schum	Alligator pepper family	1

Percentage Frequency of Plant Species Encountered in the Dryland and Wetlands Communities of Bonny Local Government Areas of Rivers State, Nigeria

The Result in Percentage frequency shows that Akiama had the highest percentage frequency of occurrence of Plant Species followed by Oguwede and lastly Finima Light House as shown on Table 2.

Population Density (Dry Land Communities)

The result on population density for dry land Communities; Akiama had the highest 0.09/m^2 followed by Oguwede 0.07 and FInima had 0.05 as show on Table 3. Whereas the wetland population Density shows that Park Community had 0.045/m^2,while Orosikiri Community had 0.03/m^2 and Amariaria had 0.0002/m^2

While in the Wet land study area, the Park Community has the highest frequency of occurrence of Plant Species followed by Orosikiri, and the least was in Amariaria .

Table 2: Percentage Frequency for Plant Species in the Dry Land Communities

Plant Species	Finima Light House	Akiama	Oguwede
Terminalia catappa	1.984	4.000	3.021
Elaeis guineensis	3.968	3.333	6.042
African pepper	2.381	1.778	4.531
Anarcadium occidentale	5.952	2.222	3.021
Cleistopholis staudtii	3.968	2.222	5.136
Cola pachycarpa	1.984	5.556	3.625
Acanthus montanus	7.937	11.111	3.021
Chromolaena odorata	5.952	1.333	2.417
Bambusa vulgaris	3.968	2.889	5.136
Mangifera indica	1.984	3.333	15.106
Cocos nucifera	1.984	6.667	19.638
Carica papaya	7.937	2.222	13.595
Irvingia gabonensis	5.952	3.333	27.190
Citrus tangerine	0.397	1.111	30.212
Syzgium aqueum	1.191	3.333	
Spinacia oleracea	1.984	6.667	
Psidium guajava	13.889	5.556	
Saccharum officinarum	0.3952	11.111	
O. gratissimum	5.952	13.333	
Vernonia amygdalina	11.905	8.889	
Mangifera indica			
Total Species	**252**	**450**	**331**

Table 3: Percentage Frequency for Plant Species in the Wet Region

Plant Species	Park Community % Freq	Orosikiri % Freq	Amariara % Freq
Dissotis rotundifolia	6.67	2.73	1
Aframomum melegueta	42.22	5.464	
Cyrtosperma senegalense	51.11	1.639	
Palisotahirsuta sp.	-	51.913	
Calamus deeratus	-	13.661	
Symphonia globulifera	-	24.590	
Total Species	**225**	**183**	**1**

Table 4: Population plant Density for Dry Land Communities

Finima	Total Individual Plant	252
	Area of land	5000
	Plant density	$0.05/m^2$
Akiama	Total Individual Plants	450
	Area of land	5000
	Plant Density	$0.09/m^2$
Oguwede	Total individual plant	450
	Area of land	5000
	Plant density	0.07

Population Density for Wet Land

Park community	Total Individual Species	225
	Area	5000
	DP	$0.045/m^2$
Abalamabie	Total Individual Species	183
	Area	$5000m^2$
	DP	$0.037/m^2$
Amariari	Total Individual Species	1
	Area	$5000m^2$
	DP	$0.0002/m^2$

Similarity Index of the Communities

The result on Similarity Index shows the common similarities between the species found in the three communities of the Dryland study area (Finima and Akiama is 0.40, (Finima Light House and Oguwede is 0.29, and (Akiama and Oguwede is 0.20 (Figure 3). Whereas the Similarity index between the three wet land communities 0.44 for Park and Orosikiri) and (Park and Amariaria had 0.50 while Orosikiri and Amariaria had 0.29 respectively (Figure 4).

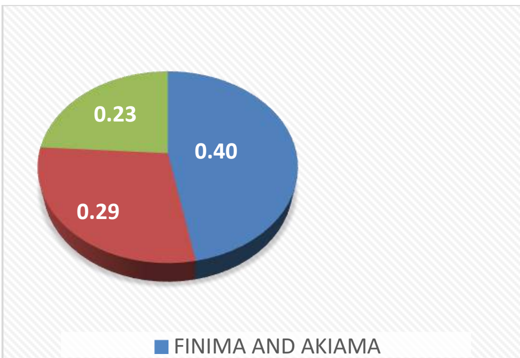

Figure 3: Similarity Index for Dry Communities

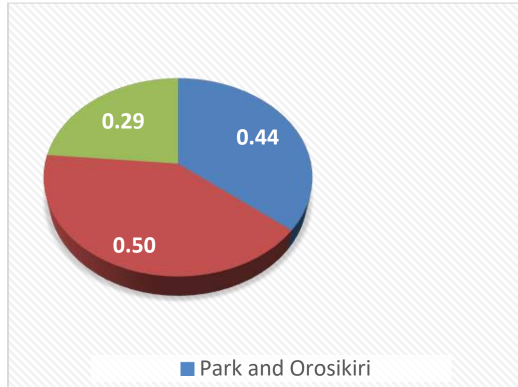

Figure 4: Similarity Index for Wetland Communities

Diversity Indices

Finima Light House had 2.600 while Akiama had 2.772 and Oguwede Community had 2.210 as shown on Table 5.

Table 5: Diversity Indices (Dry Land)

	Finima	Akima	Oguwede
Shannon (H)	2.600	2.772	2.210

DISCUSSION

Plant species composition in the dry land communities: Finima Light house, Akiama and Oguwede, compared to wetland Communities: Park community, Orosikiri and Amariaria had few plant species compositions. This is similar to what Abere (2018) reported that the increase in species number and diversity is dependent on structure of an ecological habitat.

The continuous practice of home garden can enhance plant species populations and biodiversity conservation. The contribution of the home gardens to Socio-economic livelihoods has been emphasized by Fernandes *et al* (1986) and Udofia (2021) that species richness is influenced by numerous ecological conditions.

The plant species and their diversities could have been be affected by levels of light intensity, water, minerals according to Cornwell and Grubb (2003) and Cardinale (2009), and which can increase plant productivity. Due to urbanization, the need to improve human health, food quality, ecosystem resilience, and biodiversity conservation motivate emergence of new approaches for operating home gardens, and which can affect plant diversity (Santos *et al.*, 2022).

CONCLUSION

This study has documented the plants species that were found in the wet and dry areas of Bonny Local Government Area of Rivers State, and it has revealed the need to promote sustainable agro-ecological management in home gardens.

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ASSESSMENT OF AIR POLLUTION EFFECTS ON PUBLIC HEALTH IN INDUSTRIAL AND NON-INDUSTRIAL AREAS IN KANO STATE, NIGERIA

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ABSTRACT

Air quality is a top environmental risk to public health. Air quality of two locations in Sharada industrial area and Aviation quarters (a non-industrial area) were assessed. Gaseous and particle concentrations of pollutants (CO, SO_2, NO_2, P.$M_{1.0}$, $PM_{2.5}$ and PM_{10}) were measured. Hospital records of patients (n=1512) of Sharada industrial health clinic were obtained purposively for prevalence of air pollution related ailments. This study revealed higher concentrations of CO, $PM_{1.0}$, $PM_{2.5}$ and PM_{10} in Sharada industrial area at $p<0.05$ compared to concentrations observed in Aviation quarters. The mean concentration of CO (0.12±0.05 µg/m^3 was within the National Environmental Standards and Regulations Enforcement Agency (NESREA) recommended standards of 35 µg/m^3 while the mean concentrations of $PM_{2.5}$ (67.70±3.56 µg/m^3) and PM_{10} (80.72±5.10 µg/m^3) were higher than the recommended WHO standard of 25 µg/m^3 and 50 µg/m^3 respectively. The SO_2 and NO_2 were not detected in the two study sites. The prevalence of malaria (60.1%) was significantly ($P > 0.05$) higher compared to that of catarrh (1.7%), general body pain (0.8%), asthma (2.6%), diarrhea (10.2%), bleeding (0.5%), rashes (0.7%), respiratory tract infection (2.4%) and hypertension/high blood pressure (4.9%) across the entire population. The Pearson correlation coefficients between the air quality indices and health status had relatively low values of r, and the corresponding p-values were higher than 0.05 which indicates that exposure to environmental air pollutant may have a significant effect on the health status of the respondents. The study concludes that minimal exposure to air pollution has a significant effect on human health and may predispose individuals to higher risks of diseases.

Keywords: Air pollution, Air quality, Pollutants, Industrial area and Public health, Hospital records

INTRODUCTION

Air pollution is a serious problem that impacts billions of people across the globe. In Nigeria, pollutants emanate from different sources. The common air pollutants in the chemical industries are sulphur dioxide, which are emitted from process and from fuel combustion, while the major pollutant from automobiles is carbon monoxide. According to the Environmental Protection Agency (EPA), in 2017 about 111 million Americans (about 35% of the U.S. population) were living in counties with unhealthy air (EPA, 2018). In tropical West African countries, emissions from vehicular traffic, emissions from industries, biomass bush burning, biomass burning for cooking purpose, uncontrolled waste burning and particles from the Sahara Desert generally contribute to air pollution (WHO, 2016).

Air pollutants are substances in the air that can be adverse to humans and the environment. Pollutants can be in the form of solid particles, liquid droplets and they may be natural or man-made. According to Mahendra and Vaibhav (2015), pollutants can also be classified as primary or secondary. Primary pollutants are directly produced from a process, such as ash from a volcanic eruption, the carbon monoxide gas from a motor vehicle exhaust or sulphur dioxide released from factories. Secondary pollutants are not emitted directly but are rather formed in the air when primary pollutants react or interact. Public health as the science of protecting the safety and improving the health of communities through education, policy making and research for disease and injury prevention (CDC, 2000), focuses mainly on public concern and government policy in terms of air pollution impacts on human health continues to be outdoor air. The quality of air breath in by human principally remains an environmental concern affecting the health and quality of human life especially in concentrated settlement (Adeyinka, 2005). The World Health Organization (2023) released its most detailed study on global pollution to date and the results were breath taking. The report revealed that over 90% of the population lives in places where air pollution exceeds safe limits. Three million people are reportedly dying every year as a result of tiny particulates in the air. Solid and liquid matters that are suspended in the air are breathed in and this result from a wide range of human-made sources, such as car fumes and power plants. The rate of this contaminants in the surrounding air may result to increase in asthma cases, rise in chances of having cancer and congenital defects in babies.

Residents of Sharada industrial area in recent years have been complaining of outbreak of different types of ailments which according to them is as a result of harmful substances that are being released to the environment by the industries that surrounds their neighborhood (Ekpa, 2022). Hence, the necessity for an assessment of the concentration of air pollutants and particulate matter in the environment and how it comparatively affects the health of residents the Sharada industrial area and Aviation quarters in Kano State, Nigeria.

MATERIALS AND METHODS

Study Area

Kano is the capital city of Kano state in northern Nigeria and also the capital of the great Kano emirate, in the Sahelian geographic region. It has coordinates of Latitude 11^{o} 25`N to 12$^{o}$47`N and Longitude 8^{o} 22` E to 8$^{o}$ 39`E. The Kano urban core area covers 137 km^2 and comprises eight local government areas (LGA) which are: Kano Municipal, Fagge, Dala, Gwale, Tarauni, Ungogo Kumbotso and Nassarawa. The Kano metropolitan area covers 499 km^2 with elevation of 481 meters above sea level. Generally, the climate of the study area is that of tropical continental type. This type of climate has clear wet and dry seasons with more dry months than wet months (Olofin, 1987), which is categorized under Aw in Koppen's climatic classification. Consequently, a low mean annual rainfall of 880 mm is a typical occurrence. The area is characterized by four months of wet season and eight months of dry season. The temperature is characterized by warm to hot throughout the year, although cool periods occur around October to February. Olofin (1987) observed the mean annual temperature of about 26^{o}C, but the monthly values of coldest months range between 21^{o}C and that of hottest months have the mean value of 31^{o}C. Evapo-transpiration (ET) is generally higher than the precipitation with estimate of 2,538 mm per annum. The climate is very much influenced by two air masses namely tropical maritime and tropical continental air masses. Figure 1 indicated the map of Kano State showing the two study locations.

Sampling Technique and Instrument for Data Collection

Purposive sampling method was adopted for this study in both the Sharada industrial area and the aviation quarters. Air Pollutants such as SO_2, NO_2, CO, $PM_{1.0}$, $PM_{2.5}$ and PM_{10} were measured both in the morning (6 am – 9 am), and evening between the hours of 3 pm to 6 pm, and sampling was taken 3 days in a week (Monday, Wednesday and Saturday) for a period of one month. Concentration level of each pollutant was recorded using Crowncos Gasman detector from four designated points and then the average value of all readings was taken for each of the study areas. Particle concentrations of $PM_{2.5}$, PM_{10} and $PM_{1.0}$ were also measured using TSI DustTrak DRX Aerosol Monitor (Model 8533). The DustTrak DRX simultaneously measures mass and size fraction corresponding to $PM_{2.5}$, PM_{10} and $PM_{1.0}$. The instrument uses a 90º light scattering laser photometer which provides the mass concentration of a photometer and size resolution of an optical particle counter. The pump flow rate was 3.0 L/min with a flow accuracy of ±5% of the factory set point, internal flow controlled. The aerosol concentration range is 0.001 to 150 mg/m^3 and the particle size range was 0.1 to 15 µm. The resolution of the instrument was ±0.1% of reading or 0.001 mg/m^3 and a zero-calibration check was performed prior to each use of the instrument using a zero filter.

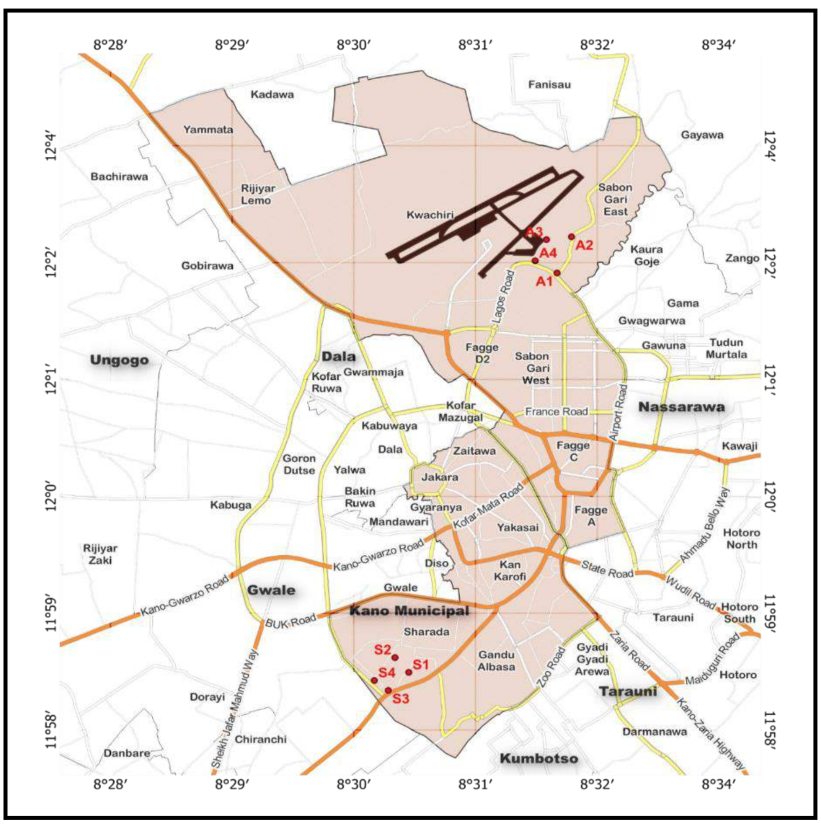

Figure 1: Kano State showing the study locations

RESULTS

Concentrations of Gaseous pollutants and Particulate Matter in Aviation Quarters and Sharada Industrial Area

As shown in Table 1, the result of the study revealed that nitrogen (IV) oxide (NO_2) was not detected in Aviation Quarters and Sharada industrial area, while SO_2 was not detected in Aviation Quarters. Concentrations of CO (1.98×10^{-1} µg/m^3) and SO_2 (2.10×10^{-3} µg/m^3) were below the NESREA standard of 20 µg/m^3 and 0.1 µg/m^3 respectively in Sharada industrial area. The overall mean concentration of $PM_{1.0}$ in Sharada industrial area (40.99 µg/m^3) was higher than the 35.24 µg/m^3 observed in Aviation Quarters. Also, the concentrations of $PM_{2.5}$ in Aviation Quarters (64.54 µg/m^3) and Sharada industrial area (70.85 µg/m^3) exceeded the NESREA standard of 25 µg/m^3. Similarly, the concentrations of PM_{10} in Aviation Quarters (74.89 µg/m^3) and Sharada industrial area (86.56 µg/m^3) exceeded the NESREA standard of 50 µg/m^3.

Table 1: Overall Mean Concentration of Pollutants in Aviation Quarters and Sharada Industrial Area

Study Sites	**Mean Concentration of Pollutants (µg/m^3)**					
	CO (µg/m^3)	**SO_2 (µg/m^3)**	**NO_2 (µg/m^3)**	**$PM_{1.0}$ (µg/m^3)**	**$PM_{2.5}$ (µg/m^3)**	**PM_{10} (µg/m^3)**
Aviation Quarters	4.17×10^{-2}	0	0	35.24	64.54	74.89
Sharada Industrial	1.98×10^{-1}	2.10×10^{-3}	0	40.99	70.85	86.56
NESREA Standard	20	0.1	200	None	25	50

CO – carbon monoxide; SO_2 – Sulphur (IV) oxide; NO_2 – Nitrogen (IV) oxide; PM – particulate matter; *NESREA - Environmental Standards and Regulations Enforcement Agency*

Temporal Concentrations of Gaseous and Particulate Matter across the Sampling Sites

Carbon monoxide (CO) Concentration (µg/m^3) across the Sampling Sites

The result of this study showed that the temporal mean concentration of CO across the four sampling sites of the two study sites of Aviation Quarters and Sharada Industrial Area within the morning hours of 6 am to 9 am and evening hours of 3pm to 6pm (Table 2). CO was detected during the morning hours in site C (0.08 µg/m^3) and during the evening hours in site A (0.25 µg/m^3) in Aviation quarters. However, in Sharada industrial area, CO was detected during the morning hours in sites A (0.67 µg/m^3) and B (0.08 µg/m^3), as well as sites A (0.75 µg/m^3) and B (0.08 µg/m^3) of the evening hours. The mean concentration of CO detected in Sharada industrial area was found to be higher when compared to the mean concentration of CO detected in Aviation quarters. This variation could be due to the negligible contributions of CO from other combustion sources, such as biomass burning and traffic emissions. Meanwhile, due to the industrial activities in Sharada industrial area, higher mean concentration of CO was observed which might be traceable to emissions from productions, diesel powered engines and high rate of vehicular emissions in the area. However, the CO concentration in all the sampling sites and locations was below the 20 µg/m^3 permissible limits as described by *National Environmental Standards and Regulations Enforcement Agency*.

Table 2: Mean Concentrations of CO (µg/m^3) across the Sampling Sites

Sampling Sites	Aviation Quarters		Sharada Industrial Area	
	Morning (µg/m^3)	Evening (µg/m^3)	Morning (µg/m^3)	Evening (µg/m^3)
A	0.00	0.25	0.67	0.75
B	0.00	0.00	0.08	0.08
C	0.08	0.00	0.00	0.00
D	0.00	0.00	0.00	0.00

Source: Field work, 2021

Sulphur dioxide (SO_2) and Nitrogen dioxide (NO_2) Mean Concentrations (µg/m^3) across the Sampling Sites

Mean concentration of 0.02 µg/m^3 was only detected for SO_2 in site D of Aviation quarters during the morning hours but it was not detected in all other sampling sites of the two study locations, both in the morning and evening (Table 3). The SO_2 mean concentration of 0.02 µg/m^3 observed in only site D of the sampling sites and locations is below the 0.1 µg/m^3 permissible limit as described by *National Environmental Standards and Regulations Enforcement Agency*. This could be due to the negligible contributions of SO_2 from cars and other combustion sources, such as biomass burning and traffic emissions. Though, site D of the aviation quarters had observable SO_2 mean concentration of 0.02 µg/m^3 which may have resulted from several speed breakers on the roads at that site resulting to slow speed of moving vehicles.

No concentration of NO_2 was detected in the entire sampling sites both in the morning and evening hours at the two study locations throughout the sampling period. NO_2 concentration in the environment are from vehicular engine, coal fumes and other combustion sources, such as biomass burning and traffic emissions (Ipeaiyeda *et al.*, 2018). It has been reported that NO_2 is easily oxidized to nitric acid (HNO_3) vapour during the day, which is absorbed directly by the soil, is converted into nitrate-containing particles, or dissolves in cloud droplets (Baumbach, 2012). This could have resulted to the no detection concentration of NO_2 that was observed in the present study.

Concentration of $PM_{1.0}$ (µg/m^3) across the Sampling Sites

The result of the mean concentration of $PM_{1.0}$ across the sampling sites was presented in Table 4. The result showed that in all the sampling sites at Aviation quarters, $PM_{1.0}$ concentrations in the evening was lower (22.33 - 25.50 µg/m^3) compared to the morning (44.58 - 48.17 µg/m^3). Similarly, in Sharada industrial area, $PM_{1.0}$ concentrations in the evening was lower (22.42 – 37.25 µg/m^3) compared to the morning hours (42.42 – 65.25 µg/m^3). The higher concentration of $PM_{1.0}$ in the morning hours of all the sampling sites compared to the evening hours could be due to higher commercial and vehicular movement in the morning hours as against the evening hours. The result further showed that $PM_{1.0}$

concentrations in Sharada industrial area was higher in the morning and for almost all the sites in the evening compared to aviation quarters. This might be due to the fact that Sharada industrial area was characterized by significant industrial and commercial activities noted by industrial engine emission, vehicular road congestion from commercial and private transport facilities resulting to higher pollution concentrations encountered in the area compared to aviation quarters which was more of an ambient environment for residential area.

Table 4: Mean Concentration of $PM_{1.0}$ (µg/m^3) across the Sampling Sites

Sampling	Aviation Quarters		Sharada Industrial Area	
Sites	**Morning**	**Evening**	**Morning**	**Evening**
A	46.75	22.33	65.25	35.25
B	45.08	24.75	50.00	37.25
C	48.17	25.50	42.42	22.42
D	44.58	24.75	48.67	26.67

Source: Field work, 2021

Concentration of $PM_{2.5}$ (µg/m^3) across the Sampling Sites

The $PM_{2.5}$ mean concentrations in the sampling sites during the morning and evening hours at the two study locations are presented in Table 5. The result shows $PM_{2.5}$ mean concentration in the morning hours (82.25 - 85.58 µg/m^3) was higher compared to the evening hours (42.50 - 47.08 µg/m^3) across the four sampling sites. Similarly, in Sharada industrial area, $PM_{2.5}$ concentration in the morning hours (75.58 – 100.75 µg/m^3) was higher compared to the evening hours (43.17 – 65.58 µg/m^3) across the four sampling sites. Site A had higher $PM_{2.5}$ concentration (100.75 µg/m^3) in the morning hours compared to other sites probably due to the higher number of industries within that site that contributed to higher emission of gaseous particulate matter ($PM_{2.5}$). The higher concentrations of $PM_{2.5}$ in the morning hours at the two study locations could be aligned to higher industrial, commercial, and traffic congestion in the morning hours compared to the evening hours. These activities result to higher emission of environmental pollutants such as particulate matter. The mean range of $PM_{2.5}$ (42.50 - 100.75 µg/m^3) detected in all the sampling sites and locations are above the 25 µg/m^3 permissible limits by World Health Organization (WHO, 2016) and *According to* Pilz *et al.* (2015), the observed elevated values of $PM_{2.5}$ could result from bush National Environmental Standards and Regulations Enforcement Agency (NESREA, 2011) respectively. burning and other agricultural practices. Particulate matter in the study area could also be influenced by road condition, age and maintenance of vehicles, traffic volume, and driving behaviour (Pirjola *et al*., 2006; Pant and Harrison, 2013).

Table 5: Mean Concentration of $PM_{2.5}$ (µg/m^3) across the Sampling Sites

Sampling	Aviation Quarters		Sharada Industrial Area	
Sites	**Morning**	**Evening**	**Morning**	**Evening**
A	84.08	42.50	100.75	59.67
B	82.58	46.08	86.42	65.58
C	85.58	46.17	75.58	43.17
D	82.25	47.08	86.08	49.58

Source: Field work, 2021

Concentration of PM_{10} (µg/m^3) across the Sampling Sites

The PM_{10} mean concentrations in the sampling sites during the morning and evening hours at the two study locations are presented in Table 6. The result showed that in Aviation Quarters, PM_{10} concentrations in the morning hours (97.00 – 99.50 µg/m^3) were higher compared to the evening hours (45.75 – 53.67 µg/m^3) across the four sampling sites. Similarly, in Sharada industrial area, PM_{10} concentrations in the morning hours (86.83 – 131.50 µg/m^3) were higher compared to the evening hours (48.83 – 80.75 µg/m^3) across the four sampling sites. The PM_{10} concentrations in the four sampling sites at aviation quarters were high and within the same range which signified similar activity in the sampling sites. Site A at Sharada industrial area had the highest PM_{10} concentration (131.50 µg/m^3) among all the sampling sites in the study area probably due to the higher human activity in the industries within that site that contributed to higher emission of gaseous pollutants and particulate matter. In the present study, the evening hours was observed to have lesser commercial, vehicular, and industrial activities that may have contributed significantly to less environmental pollution as against the effect observed in the morning hours. The PM_{10} mean range of (45.75 - 131.50µg/m^3) detected in all the sampling sites and locations are above the 50µg/m^3 permissible limits by National Environmental Standards and Regulations Enforcement Agency (NESREA, 2011) except in the evening hours of site A at Aviation quarters and site C at Sharada industrial area.

Table 6: Mean Concentration of PM_{10} (µg/m^3) across the Two Sampling Sites

Sampling Sites	Aviation Quarters		Sharada Industrial Area	
	Morning	Evening	Morning	Evening
A	99.50	45.75	131.50	80.75
B	99.50	50.92	110.75	76.00
C	99.33	53.67	86.83	48.83
D	97.00	53.42	102.33	55.50

Source: Field work, 2021

ANOVA Variation in the Mean Concentration of Gaseous and Particulate Matter in the Morning and Evening in the Study Locations

The study findings showed that there were statistically significant differences ($P < 0.05$) in $PM_{1.0}$, $PM_{2.5}$ and PM_{10} concentrations between the samples taken in all the sampling sites in the morning and in the evening at the two study locations (Table 7). However, there was no statistical differences ($P > 0.05$) in the concentrations of CO and SO_2 samples taken in all the sampling sites both in the morning and the evening periods of sampling in the two study locations.

Table 7: Analysis of Variance (ANOVA) in the Mean Concentration of Gaseous and Particulate Matter in the Morning and Evening in the Study Locations

Parameters	Morning	Evening	F	Sig.
CO (µg/m^3)	0.041	0.001	0.082	0.774
SO_2 (µg/m^3)	0.001	ND	1.000	0.319
NO_2 (µg/m^3)	ND	ND	ND	ND
$PM_{1.0}$ (µg/m^3)	0.051	0.019	21.368	0.000*
$PM_{2.5}$ (µg/m^3)	0.045	0.038	28.324	0.000*
PM_{10} (µg/m^3)	0.089	0.071	21.800	0.001*

** = significant difference at P < 0.05; ND = Not Detected*

Concentrations of Gaseous and Particulate Matter between the Study Locations

The result of this study also revealed that there was no significant difference ($P > 0.05$) between the mean concentrations of gaseous and particulate matter across the two sampling sites (Table 8). This means that location did not have any significant influence on the concentration of CO, NO_2, SO_2, $PM_{1.0}$, $PM_{2.5}$ and PM_{10} across the two locations. The CO concentration observed in Aviation quarters and Sharada industrial area were 0.04±0.03 and 0.20±0.10 $\mu g/m^3$ respectively while SO_2 and NO_2 were not detected in the two sample locations. The concentration of $PM_{1.0}$, $PM_{2.5}$ and PM_{10} observed in Sharada industrial area were higher compared to the concentration observed in Aviation quarters (Table 8).

Correlation between Gaseous and Particulate Matter in the two Study Locations

The result of Pearson Correlation Coefficients values between Gaseous and Particulate Matters in the two study sites was presented in Table 9. Positive strong correlation was observed between $PM_{1.0}$ and $PM_{2.5}$ ($r = 0.971$), CO and PM_{10} ($r = 0.846$), $PM_{1.0}$ and PM_{10} (0.978) and $PM_{2.5}$ and PM_{10} ($r = 0.981$) and all were significant at ($P < 0.05$).

Table 8: Mean Concentrations of Gaseous and Particulate Matter between the Study Locations

Parameters	Aviation Quarters	Sharada Industrial Area	*P-value*
CO ($\mu g/m^3$)	0.04±0.03	0.20±0.10	0.151
SO_2 ($\mu g/m^3$)	0.00±0.00	0.00±0.00	0.319
NO_2 ($\mu g/m^3$)	0.00±0.00	0.00±0.00	ND
$PM_{1.0}$ ($\mu g/m^3$)	35.24±3.26	40.99±3.65	0.241
$PM_{2.5}$ ($\mu g/m^3$)	64.54±4.91	70.85±5.16	0.377
PM_{10} ($\mu g/m^3$)	74.89±6.69	86.56±7.69	0.253

NO_2 – Nitrogen (IV) oxide; SO_2 – Sulphur (IV) oxide; CO – carbon (II) oxide; PM – particulate matter; *ND = Not Detected*

Table 9: Pearson Correlation Coefficients Values between Gaseous and Particulate Matter

Parameter	CO ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	$PM_{1.0}$ ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)
CO	1				
SO_2	-0.012	1			
$PM_{1.0}$	0.121	-0.049	1		
$PM_{2.5}$	0.116	-0.051	**0.971****	1	
PM_{10}	**0.846****	-0.055	**0.978****	**0.981****	1

Correlation was significant at the 0.05 level (2-tailed).

Health Status of the Sharada PHC Patients Recorded during the Study Period

The health status according to the patients' record as indicated in this study was presented in Figure 2**.** The prevalence of diseases that are associated with air pollution recorded across the entire population during the period of the study are catarrh (1.7%) and asthma (2.6%). Since exposure to air pollutants weakens the immune system of human, therefore the recorded diseases might have emanated due to frequent exposure to air pollutants and particulate matter in the Sharada industrial area.

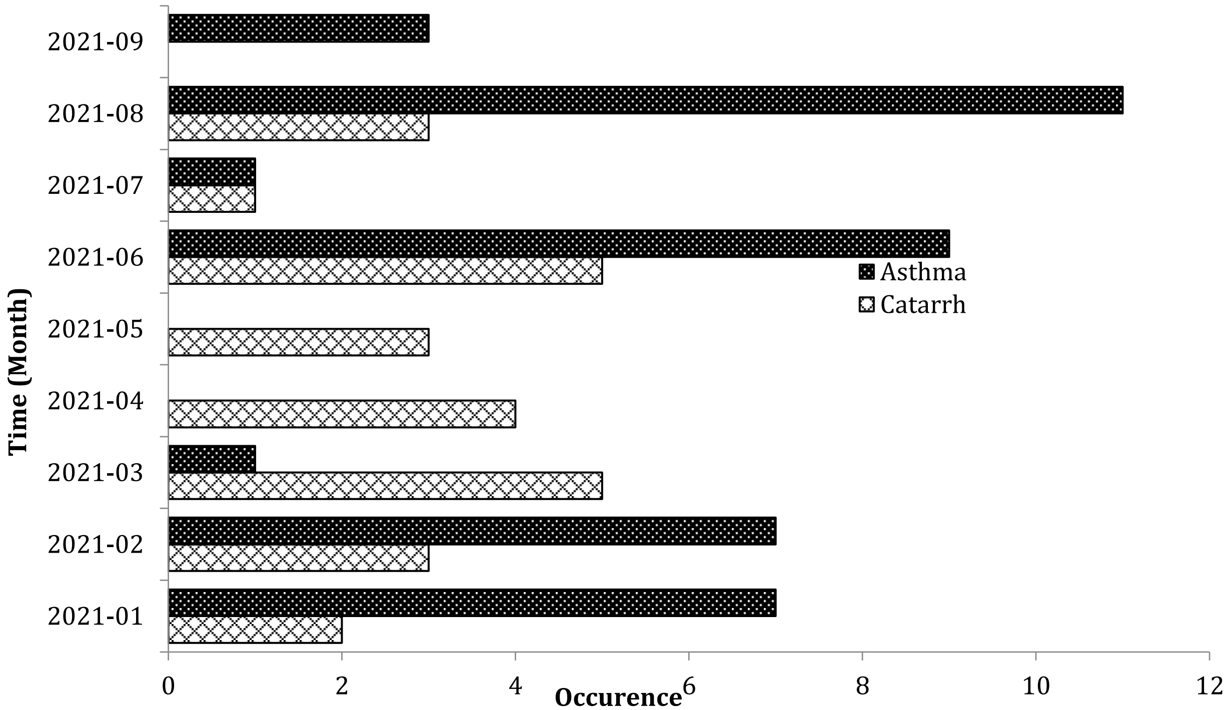

Figure 2: Prevalence of Disease in the Months of Sampling with respect to number of patients.

DISCUSSION

Carbon Monoxide Concentration at the Study Sites

The mean concentration of CO pollutants in the sampling points was found to be 0.12±0.05 µg/m^3 and below the NESREA (20 µg/m^3 for 8-hour limit) and WHO (35 µg/m^3 for 8-hour limit) recommended standards. The CO concentration observed in the present study was significantly lower than the mean concentrations of 15.6±5.3 µg/m^3 observed by Ipeaiyeda *et al*. (2018) at Ota Industrial Estate, Ogun State, Nigeria. From the present study, lower concentration of CO (0.04±0.03 µg/m^3) was detected in Aviation quarters compared to 0.20±0.10 µg/m^3 detected in Sharada industrial estate, and so the low concentrations of CO pollutants in Aviation quarters can be explained as being negligible contributions from other combustion sources, such as biomass burning and traffic emissions. The relationship exhibited between the CO and particulate matter (PM_{10}) at almost all the sampling points was in accordance with the results obtained by Oguntoke and Yusuf (2008) where the variation in pollutants concentrations was attributed to the variation in traffic volume as well as the presence of industries in some location as against other locations. This study finding revealed that there was significant higher ($P < 0.05$) concentration of pollution in the evening compared to the morning hours in CO concentration. This is attributed to the high vehicular movement in the evenings as a result of the higher number of residents returning to their respective homes. This reason makes the road to be congested with vehicles, buses, cars and bikes. Human exposures in transportation environments, such as on-roads, roadsides, inside vehicles and public transport facilities are a growing concern due to higher pollution concentrations encountered in these environments (Jayaratne *et al*., 2008, Wang *et al*., 2011).

Nitrogen (IV) oxide (NO_2)

Finding of the present study revealed that Nitrogen (IV) oxide (NO_2) was not detected in both study area. The present result contradicts the findings from previous studies by Ipeaiyeda *et al*. (2018) who recorded NO_2 concentration of 33.3±4.7 µg/m^3 from Ota, Nigeria; 71.4 µg/m^3 in Incheon, Korea by Yoo *et al*. (2011); 176.9 µg/m^3 in Kualar Lumpur, Malaysia by Norela *et al*. (2010) and 141.1 µg/m^3 in Port Harcourt, Nigeria by Ideriah and Stanley (2008). NO_2 is easily oxidized to nitric acid (HNO_3 vapour) during the day which is absorbed directly by the soil, is converted into nitrate-containing particles, or dissolves in cloud droplets (Alhassan and Jimoh, 2006; Baumbach, 2012). This could have resulted to the very low concentration of NO_2 (below the limit of detection) observed in the present study. Though NO_2 was not detected in the present study, several research conducted from the last two decades have attributed both short and long time increase in concentration of NO_2 to increase in hospitalization for cardiac diseases (Almeida, 2014; Wang, 2014; Zhao, 2014).

Sulphur (IV) oxide (SO_2) Concentrations at the Study Sites

This study showed that SO_2 was not detected in Aviation quarters but a concentration of 2.10×10$^-$3 µg/m^3 was detected in Sharada industrial estate. The SO_2 concentration observed in the present study was significantly lower compared to 246±32 µg/m^3 observed by Ipeaiyeda *et al*. (2018) in Ota, Nigeria. Similarly, the present result was lower compared to 15.7 µg/m^3 observed in Incheon, Korea by Yoo *et al*. (2011); 202 µg/m^3 in Kualar Lumpur, Malaysia by Norela *et al*. (2010) and 25 µg/m^3 in Port Harcourt, Nigeria by Ideriah and Stanley (2008). The reason for the presence of SO_2 in Sharada industrial estate could be the burning of fossil fuels by power plants and other industrial facilities.

In addition, high pollution concentration in Sharada industrial area may be traced to the slow speed with which vehicles were moving because the point is characterized by bus stops and busy roads linking different part of the metropolis which is usually crowded with people engaging in different commercial activities such as hawking, loading of vehicles with goods and passengers etc. Near to this point is also a round about where vehicles need to slow down. In addition, it is noted that industries within the area, especially in Sharada industrial area function during the 24 hours of the day compared to Aviation quarters where domestic activities terminate by 5pm daily.

Particulate Matter Concentration at the Study Sites

This study revealed higher concentration of $PM_{1.0}$ (40.99±3.65 µg/m^3), $PM_{2.5}$ (70.85±5.16 µg/m^3) and PM_{10} (86.56±7.69 µg/m^3) pollution in Sharada industrial area compared to the concentrations of the pollutants in aviation quarters. Sharada industrial estate is characterized by significant commercial activities noted by vehicular road congestion by commercial and private transport facilities resulting to higher pollution concentrations encountered in the area compared to aviation quarters which is more of an ambient environment for residential area. In agreement with the finding of the current study, Kaur *et al*. (2007), Jayaratne *et al*. (2008), Wang *et al*. (2011) and Mirowsky *et al*. (2017) in their separate studies identified industrial areas as environment with high potential for pollution by gaseous and particulate matter. The mean values of $PM_{2.5}$ (67.70±3.56 µg/m^3) and PM_{10} (80.72±5.10 µg/m^3) observed in the two locations were above the NESREA air quality standard of 25 µg/m^3 and 50 µg/m^3 (Bono *et al*., 2016). The high concentration of $PM_{2.5}$ and PM_{10}

reported in this study may be attributed to several factors, including that the Northeast part of Nigeria is known for winds heavily loaded with dust and other particles. This may have contributed significantly to the elevated concentration of $PM_{2.5}$ and PM_{10}.

Respiratory Diseases Associated with Air Pollution

In contrast with the present finding, Faustini (2013); Ding (2014) and Loftus (2014) in their separate studies concluded that air pollution causes respiratory and could predispose individuals to cardiovascular diseases. However, Ding (2014) stated that at early stage of life, air pollution could predispose children to development of childhood asthma. Asides from the respiratory symptoms and allergic reactions that may be associated with the air pollution, some unexpected diseases also manifest which may difficult to trace to air pollution as a causative agent. Respiratory diseases are common manifestation of air pollution. The lesser symptoms include runny nose, sore throat, cough and allergy (Health Canada, 2014). Serious condition includes asthma, pulmonary emphysema, pneumonia, chronic bronchitis (Faustini, 2013).

CONCLUSION

The study concludes that higher and significant ($p<0.05$) concentrations of CO, $PM_{1.0}$, $PM_{2.5}$ and PM_{10} were recorded in Sharada industrial area compared to concentrations observed in Aviation quarters which were within the WHO and NESREA standards. Also, the prevalence of ailment recorded in Sharada Primary Health clinic are malaria, diarrhea, high blood pressure, asthma, respiratory tract infection, catarrh, general body pain, rashes and bleeding. Hence, exposure to air pollutants especially in industrial area may not have a direct significant effect on human health but could predispose individuals to higher risks of developing diseases.

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THE FOOD AND FEEDING HABITS OF *Heterotis niloticus* (Cuvier, 1829) OF SEBORE RESERVOIR, MAYO-BELWA, ADAMAWA STATE, NIGERIA

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ABSTRACT

The food and feeding habits of *Heterotis niloticus* in the Sebore reservoir of Mayo-Belwa, Adamawa State was studied for a period of a year. Stomach contents of 79 specimens of *H. niloticus* with ranges of total length of 23cm -- 58cm and body weight of 180g – 1.3kg were examined. The food and feeding habits were evaluated and determined using frequency of occurrence method. Findings from this study revealed that the *H. niloticus* consumed only planktons. *Oscillatoria spp*, among the phytoplankton species, was having the highest frequency of occurrence (69) which represents 93.24% and the *Phacus spp.* was having the least frequency of occurrence (49) representing 66.21%. Among the zooplanktons, the *Rotaria spp.* was having the highest frequency of occurrence (69) representing 93.24% and the *Chydrous spp.* was having the least frequency of occurrence (52) representing 70.27%. These results indicated that *H. niloticus* feeds only on phytoplankton and zooplanktons, therefore the *H. niloticus* of Sebore reservoir can be considered to be planktivores.

Keywords: *Heterotis niloticus*, Sebore reservoir, feeding habits, stomach contents, Planktivores

INTRODUCTION

Fish like other animals required adequate nutrition to grow and survive in the wild and also in captivity (Udeze, 2022). The knowledge of the food and feeding habits of fish is necessary to all ichthyologists who are concerned with all the aspects of fisheries (Mshelia *et al.,* 2014). Nature provides variety of organisms that are used as food by fish which differ in size and taxonomy (Ikongbeh *et al*., 2012).

Various researches have been conducted on the food and feeding habits of fish in order to assess the dietary composition and food habits of fish aimed at a sound fisheries management programme and on fish rearing in captivity (Ikongbeh *et al*., 2012). *Heterotis niloticus* (Cuvier, 1829) of the family Arapaimidae is widely distributed in the rivers, freshwater lakes, swamps and creeks of Nigeria (Olaosebikan and Raji, 2013). There is only one genus in this family, that is, *Heterotis* and also one species which is *niloticus* in Nigeria (Mustapha, 2010). It contributes significantly to the animal protein sources within many freshwater bodies and also made up of a portion of the inland fisheries in Nigeria as a result of its delicacy (Bake and Sadiku, 2005).

Sebore reservoir is blessed with many commercial aquaculture species but there are no published accounts on their food and feeding habits especially on *H. niloticus*. The objectives of this study therefore to provide information on the food and feeding habits of *H. niloticus* from Sebore reservoir.

MATERIALS AND METHODS

Study Area

Sebore reservoir is located in Mayo – Belwa Local Government Area (LGA), Adamawa State Nigeria. Mayo – Belwa LGA lies within Latitude 9°3'0'' North; and Longitude 12°3'0'' East. It covers an area of 1768km² and is 75 km away from Yola which is the capital city of Adama state.

Sample Collection

From December 2021 to November 2022, a total of 79 samples of *H. niloticus* were collected. The sampling was carried out monthly for one year. Fishing was done using gill nets as the fishing gear and canoe was used as fishing craft. The fish specimens were washed with clean water and preserved in ice crest to minimize any post-mortem changes and taken to the laboratory at the Department of Fisheries Modibbo Adama University, Yola for analysis of the stomach contents.

Laboratory Analysis of Samples

The total length of the *H. niloticus* samples were measured in centimetres (cm) using a meter rule of measuring board and weighed using an accurate digital scale in grams (g). The *H. niloticus* body cavity was opened using a pair of scissors, beginning ventrally from the anus to the mouth. The visceral organs such as the liver, fat and other organs attached to the intestine and stomach were gently removed and emptied into a plastic dish.

The length and weight of the stomachs were measured and recorded. Thereafter, the visceral organs were preserved in four per cent (4%) formalin solution to avoid any form of deterioration and contamination of the stomach contents. The stomach contents were opened using a pair of scissors and the complete stomach contents were emptied into petri dish for examination and identification (Ikongbeh *et al*., 2012).

The random samples of the stomach contents were taken and dropped on a slide (counting chamber) with the aid of a dropping pipette which served as the dropper and viewed under a light microscope. The general viewed were made with a binocular dissecting microscope stereo zoom total magnification of 100×. The stomach contents were studied and recorded.

The stomach contents of each of the *H. niloticus* samples were identified and analysed using the frequency of occurrence method as described by Balogun (2006). In the frequency of occurrence methods, all stomach containing food were recorded and expressed as the percentage of the total number of stomachs examined using the following formula

$p = (b/a) \times 100$ Where:

a = Total Number of fish examined with food items in the stomach
b = Number of fish containing a particular food item
p = Percentage (%) occurrence of each food item

Statistical Analysis

All data obtained were analysed using descriptive statistics in Microsoft Excel Windows 2010.

RESULTS

Length and Weight of the *H. niloticus* Samples

The total samples of 79 *H. niloticus* were collected and examined. The total length ranges from 23cm -- 58cm while the weight ranged from 180g – 1.3kg respectively.

Degree of Fullness of Stomach of the *H. niloticus*

From the results recorded from the 79 samples of *H. niloticus* collected from the Sebore reservoir, 49 *H. niloticus* representing 62.02% have their stomachs full with food items, while 25 *H. niloticus* representing 31.65% were having half-filled stomachs and five (5) *H. niloticus* representing 6.33% were having empty stomachs (Table 1). The higher frequency of *H. niloticus* samples recorded with full stomach than the *H. niloticus* samples with half-filled and empty stomach in the study area could be as a result of the higher primary productivity of phytoplankton and the corresponding increase in the secondary production of zooplankton's, thereby making them constantly available as food for the fish.

The *H. niloticus* of Sebore reservoir feed on different phytoplanktons and zooplanktons: 23 food items were identified in the stomach contents within the study period. These include 11 phytoplanktons (Table 2) and 12 zooplanktons (Table 3).

Assessment of Food Items

Table 1: Fullness of Stomach of *H. niloticus* from Sebore Reservoir

Parameters	Frequency	Percentage (%)
Full Stomach	49	62.02
Half-filled Stomach	25	31.65
Empty Stomach	5	6.33

Table 2: Phytoplanktons in the Stomach Contents of *H. niloticus* from Sebore Reservoir

Family and Species	Frequency	Percentage (%) of occurrence
Bacillariophyta:		
Diatomella spp	68	91.89
Fragilaria spp	64	86.48
Tabellaria spp.	61	82.43
Synedra spp.	53	71.62
Chlorophyta:		
Chlorella spp.	66	89.18
Closterium spp.	56	75.67
Spirogyra spp.	59	79.72
Cryptophyta:		
Anabaena spp.	61	82.43
Aphanocapsa spp.	51	68.91
Oscillatoria spp.	69	93.24
Euglenephyta:		
Phacus spp.	49	66.21

Table 3: Zooplanktons in the Stomach Contents of *H. niloticus* from Sebore Reservoir

Family and Species	Frequency	Percentage (%) of occurrence
Cladocera:		
Chydrous spp.	52	70.27
Daphnia spp.	63	85.13
Moina spp.	58	78.37
Copepoda:		
Diaptomus spp.	62	83.78
Nauplius spp.	60	81.08
Megacyclops spp.	57	77.02
Rotifers:		
Branchionus spp.	67	90.54
Trichocerca spp.	65	87.83
Rotaria spp.	69	93.24
Protozoa:		
Arcella spp.	61	82.43
Centropyxis spp.	55	74.32
Loxodes spp.	59	79.72

DISCUSSION

The total length of *H. niloticus* ranged from 23cm to 58cm, and the total body weight ranged from 180g to1.3kg as obtained from this study were lower to those obtained from the findings of Idodo-Umeh (2003) who reported a maximum length of 77.5cm and maximum weight of 4.6kg for *H. niloticus* at River Ase, Edo State. Also, Udeze (2022) reported that *H. niloticus* can reach a maximum length of 1m and maximum weight of 10kg.

With respect to the frequencies and percentages of the stomach fullness of *H. niloticus* from Sebore reservoir, higher frequencies of 49 and 25, representing 62.02% and 31.65% were observed with filled and half-filled stomachs respectively; this could be that the planktons consumed by the *H. niloticus* are readily available year-round in the reservoir. The half-filled stomach could also be attributed to the digestion of the food consumed by the *H. niloticus* while they were trapped in the gillnets set during the night, as a result of digestion and absorption of the various food items consumed might have taken place during the period before morning; thereby leading to reducing the stomach food contents. Very low number (5) representing 6.33% of the *H. niloticus* with empty stomach recorded from this study could be attributed to the high availability of the food organisms of the *H. niloticus* in the study area as a result of high primary production of the Sebore reservoir and very low oligotrophic nature of the reservoir. This value is lower compared with the findings of Mshelia *et al.* (2014) who reported 15.83% of empty stomach for *Schilbe intermedius* at Lake Alau, Borno State. In this study the very low frequency and percentage of *H. niloticus* recorded with empty stomach could be due to the natural feeding habits of *H. niloticus* which are mostly active during the day and with the higher primary production of the planktons making them readily available during the day period.

The result of the stomach contents analysis of the *H. niloticus* collected from Sebore reservoir elucidates that the fish are exclusively plankton feeders which was corroborates the findings of Bake and Sadiku, (2005) who reported that the *H. niloticus* of River Kaduna floodplains were predominantly planktivorous and Udeze (2022) who reported a similar result for *H. niloticus* in Oguta Lake, Imo State, Nigeria. Also, Olaosebikan and Raji (2013) reported that *H. niloticus* feed exclusively on planktons. Frequency of occurrence methods of analysis indicated that *Oscillatoria spp.* (93.24%) were the most preferred and most predominant food organisms while *Phacus spp.* (66.21%) were the least preferred and the least predominant food organisms from the phytoplankton recorded from the stomach contents (Table 2). The *Rotaria* spp. (93.24%) were the most preferred and predominant food organisms while *Chandrous spp.* (70.27%) were the least preferred and least predominant food organisms from the zooplanktons recorded from the stomach contents (Table 3).

CONCLUSION

Findings from this study indicated that the *H. niloticus* of Sebore reservoir are exclusively planktivores with *Oscillatoria spp.* being the most preferred among phytoplanktons while *Rotaria spp.* was the most preferred among zooplanktons consumed by the fish.

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SPATIO-TEMPORAL VARIATION IN TWO FOREST RESERVES OF LOWLNAD RAINFOREST NIGERIA

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ABSTRACT

Land Use Land Cover (LULC) changes are one of the significant factors that determine 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 need for information on the dynamics of many forests cover in Southwestern Nigeria. Therefore, this study examined the spatiotemporal pattern of forest cover changes in Omo and International Institute of Tropical Agriculture (IITA) forest reserves. Landsat (TM, ETM+ and OLI) imagery for the years 1993, 2003, 2013 and 2023 were subjected to supervised maximum likelihood classification. Omo was classified into four LULC classes (Vegetation, Bare land, built up and Water bodies); while IITA was classified into five LULC (Dense forest, less dense forest, Built up, Bare land and Water bodies). Normalized difference Vegetation Index (NDVI) was used to determine the greenness of the reserves. In Omo, vegetation reduced from 95.96% in 1993 to 90.51% in 2023, built up increased from 1.92% in 1993 to 3.58% in 2023. However, in IITA, dense forest reduced from 94.62% in 1993 to 91.00% in 2023, while significant increment was observed in experimental land which increased from 0.023% in 1993 to 4.115% in 2023, a reflection of the mandate of IITA. Omo had the highest NDVI (0.5) in 2012 the least in 2002 (0.1), however IITA had the highest in 2002 (0.4) and (0.2) in 2012. In conclusion, the study areas have been altered over time as a result of natural occurrences and anthropogenic activities, therefore the need to be sustainably preserved.

Keywords: Land use land cover, Vegetation indices, Spatio temporal variation, Lowland Rainforest

INTRODUCTION

Vegetation is a sensitive indicator of climate change because it makes up the majority of terrestrial ecosystems. Scientists from all across the world are paying close attention to the worldwide environmental shift known as "global warming" since it could have major effects on ecosystems (Hughes *et al.,* 2019). The strongest indication of the regional ecological environment is vegetation cover, which is a significant element of the environment (Wang *et al.,* 2007). Environmental change is the primary cause of the fluctuation in vegetation cover (Zhong *et al.*, 2008). To control ecological processes and provide ecological security in the face of global climate change, it is crucial to understand the spatiotemporal properties of vegetation cover. The Normalized Difference Vegetation Index (NDVI) can be used to measure the improvement and degradation of vegetation cove, NDVI is a good satellite-based indicator of vegetation at the landscape scale (Qin *et al.*, 2008; Xu *et al.*, 2011).

The NDVI time series intuitively reflects the vegetation growth and coverage status. It is widely used in global and regional vegetation change research. Spatial and temporal variability in forest has become a topic attracting great attention regarding the role of the forest ecosystems in biogeochemical cycles, climate change and biological diversity and in human society.

Advances in the natural sciences have brought insights into and a better understanding about the patterns and processes at different spatial and temporal scales. At the same time, this supports a better management of the forest ecosystems and landscapes (João *et al.*, 2020). The objectives of this study are to: (i) analyze the land use land cover of the study area (ii) to estimate the area occupied by the land cover (iii) to assess the vegetation health over time using NDVI.

MATERIALS AND METHODOLOGY

The study was carried out in two forest reserves in the South West of Nigeria; Omo Forest Reserve Area J4 Ijebu Ode, Ogun State and International Institute of Tropical Agriculture (IITA) Forest Reserve in Ibadan Oyo State. Omo Forest Reserve, a protected area of tropical rainforest in the Nigerian State of Ogun, in the country's south-west, is about 135 kilometers (km) northeast of Lagos and 80 kilometers (km) east of Ijebu Ode. It has a total area of 130,500 hectares (322,000 acres), receives an annual average rainfall of about 2,000 millimeters, and is a part of the Omo River watershed, The geographical boundaries are located within latitude 6.6˚ to 7.04˚ N and longitude 4.18˚ to 4.62˚ E

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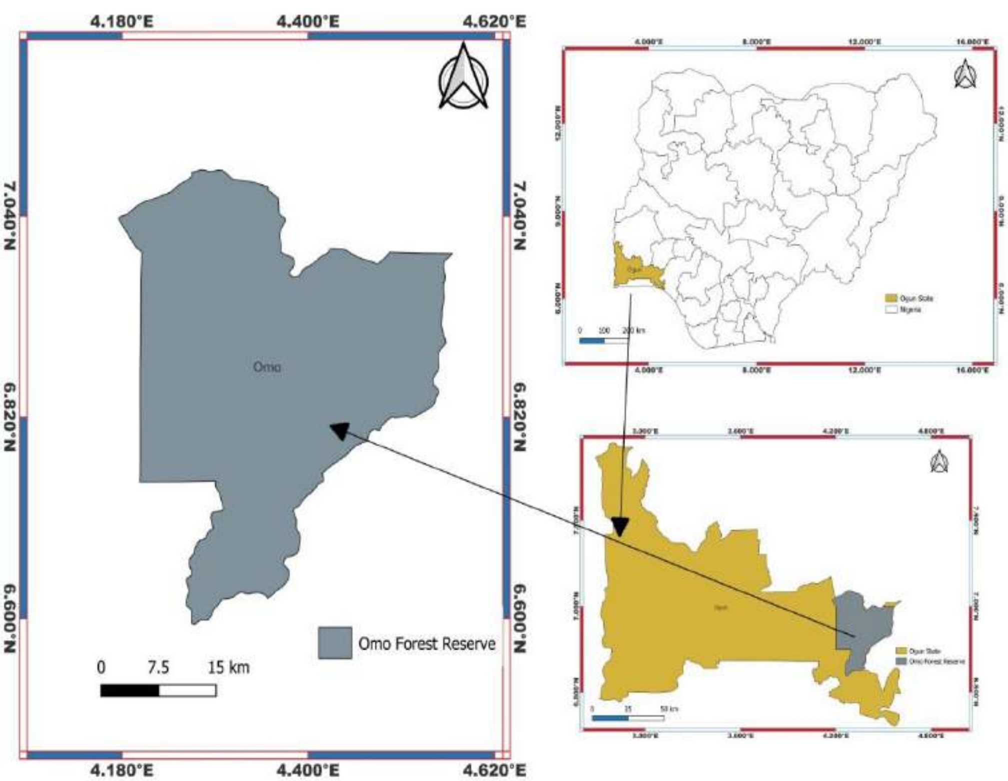

Figure 2: Map of the Omo Forest Reserve Ogun State, Nigeria

IITA FOREST RESERVE

The study area is situated on a 1,000-hectare parcel of land on the campus of the International Institute of Tropical Agriculture (IITA), north of Ibadan in Idi-Ose. It is situated 243 meters above sea level at 7.290° N to 7.305° N and latitude 3.524° E to 3.545°

E. Slopes of 3–10% predominate in the rolling topography (Moormann et al., 1975). The region is covered by metamorphic rocks from the Store-Cambrian Basement Complex, which are primarily banded gneiss with quartzite and quartz schist in between, Ferric luvisols make up the majority of the soils (Moormann *et al.*, 1975; Oladoye, 2012).

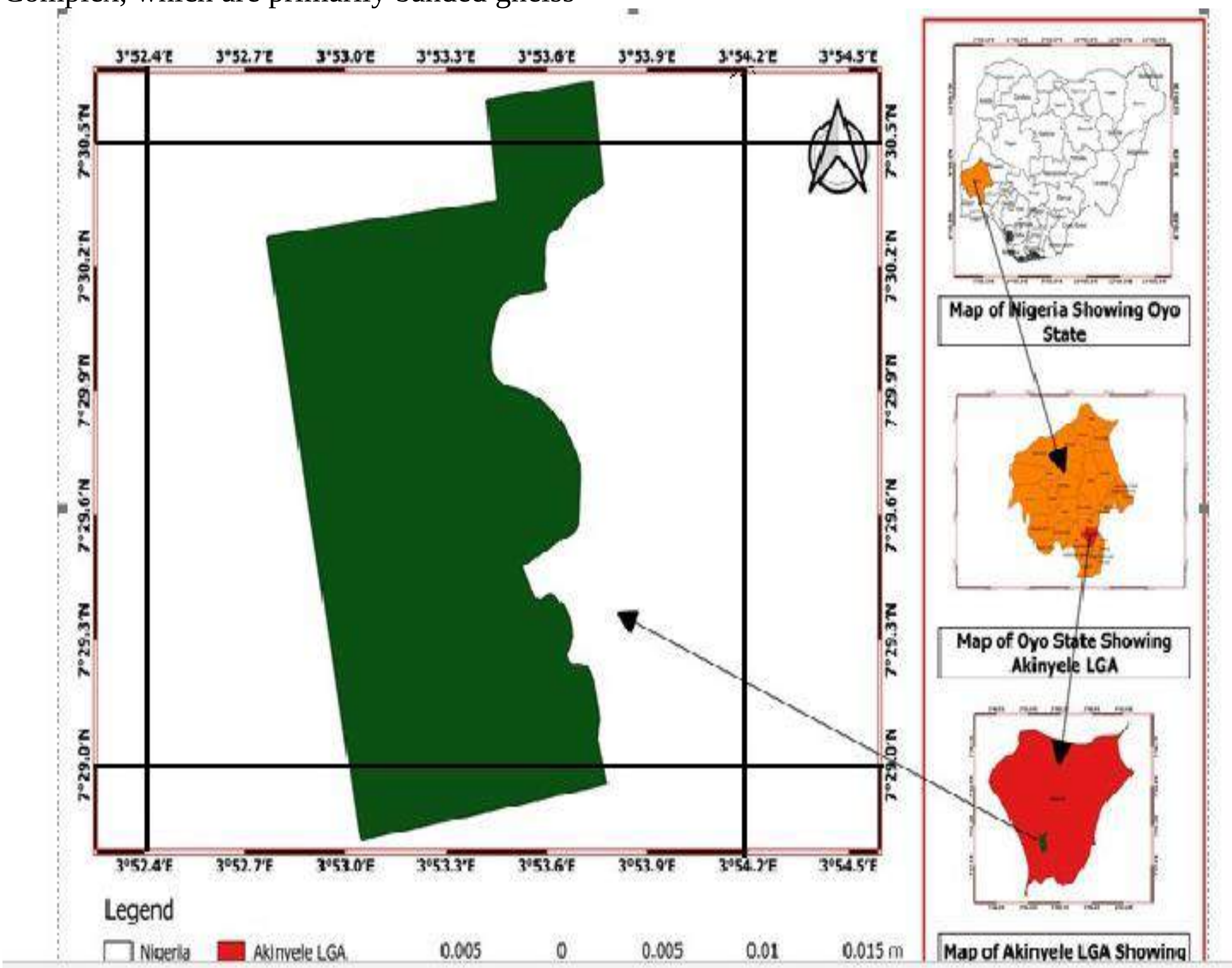

Figure 3: Map of International Institute of Tropical Agriculture Forest Reserve.

Table 1: Land use/ land cover classification to be done using supervised classification for satellite images acquired for four decades(1993, 2003, 2013 and 2023) using 5% maximum likelihood

Image type	Acquisition Data	OMO Path Row	IITA Path Row	Bands composites	No of Bands	Spatial Resolution
Landsat 5	19/01/1993	P 190,R 55	P 191, R 55	432	7	30 Meter
Landsat 7	20/01/2003	P 190,R 55	P 191, R 55	543	8	30 Meter
Landsat 7	20/01/2013	P 190,R 55	P 191, R 55	543	8	30 Meter
Landsat 8	20/01/20233	P 190,R 55	P 191, R 55	543	8	30 Meter

The area occupied was estimated from the land cover classification and were classified into four (4) categories; vegetation, bare land, built-up and water bodies.

Vegetation health was assessed over time using NDVI dataset from the time series of 1993 to 2023.

$$NDVI=\frac{NIR-R}{NIR+R}$$

where; NDVI is a normalized difference vegetation index

NIR: Near Infrared (NIR represents the spectral reflectance measurements in the near infrared region of band 5)

R is the invisible red (Red represents the spectral reflectance measurements in the invisible red of band 4).

N.B: Theoretically, NDVI values ranges from -1 to +1. An NDVI value that ranges from negative to +0.4 means the vegetation is bad, whereas NDVI values that ranges from +0.5 to +1 indicates the highest concentration of green vegetation i.e. the vegetation is good.

Results

The distribution of land use and land cover changes between 1993 and 2023 is shown in Table 2 and Figures 1 and 2 respectively for Omo forest reserve. The features identified land use and land cover were bare land, built up, vegetation and water bodies. In 1993, vegetation was the most dominant land cover with 1265.51 ha (95.96 %), followed by built up which accounted for 25.35 ha (1.922 %), bare land 24.42 ha (1.852 %), while water bodies covered the least 3.49 ha (0.26 %). In 2003, vegetation dominated the land 1252.30 ha (94.88 %) followed by bare land 36.06 ha (2.734 %), built up 26.96 ha (2.044 %), while water bodies had the least 3.45 ha (0.261 %). In 2013, vegetation dominated the land cover with 1193.89 ha (90.53 %) followed by bare land which accounted for 76.79 ha (5.82 %), built up 44.43 ha (3.37 %), while water bodies had the least 3.65 ha (0.28 %). In 2023, vegetation dominated the land cover with 1193.69 ha (90.51 %) followed by bare land 74.29 ha (5.63 %), built up 47.16 ha (3.58 %), while water bodies had the least 3.62 ha (0.27 %).

Table 1: Change analysis of LULC between 1993 and 2023

LULC Type	Area 1993	Area 2003	Area 2013	Area 2023
Built up	25.3503	26.9622	44.4348	47.1627
%	1.922	2.044	3.37	3.58
Vegetation	1265.5062	1252.3005	1193.8874	1193.6934
%	95.96	94.88	90.53	90.51
Bare land	24.4215	36.0553	76.7988	74.2941
%	1.852	2.734	5.82	5.63
Water bodies	3.4920	3.4520	3.6495	3.6198
%	0.26	0.261	0.28	0.27
TOTAL	1318.77	1318.77	1318.77	1318.77
%	100	100	100	100

Figure 1: Land Cover for the year 1993 and 2003

Figure 2: Land Cover for the year 2013 and 2023

Land Use/Land Cover (LULC) Distribution for IITA Forest Reserve.

The distribution of land use and land cover changes between 1993 and 2023 is shown in Table 3 and Figures 3 and 4 respectively for IITA forest reserve. The features identified land use and land covers were bare land, dense forest, built up, less dense forest and experimental land. In 1993, dense forest was the most dominant land cover with 3.767 ha (94.6 %), followed by bare land which accounted for 0.1116 ha (2.8 %), less dense forest 0.098 ha (2.46 %), built up 0.0036 ha (0.09 %) while experimental land covered the least 0.0009 ha (0.02 %). In 2003, dense forest dominated the land 3.69 ha (92.9 %) followed by less dense forest which accounted for 0.1233 ha (3.09 %), bare land 0.122 ha (3.07 %), experimental land 0.0315 ha (0.79 %) while built up had the least 0.0036 ha (0.09 %). In 2013, dense forest dominated the land cover with 3.6729 ha (92.26 %) followed by less dense forest which accounted for 0.1233 ha (3.09 %), bare land 0.1134 ha (2.84 %), experimental land 0.0675 ha (1.695 %) while built up had the least 0.0036 ha (0.09 %). In 2023, vegetation dominated the land cover with 3.6225 ha (91.001 %) followed by experimental land 0.1638 ha (4.114 %), less dense forest0.13332 ha (3.346 %), bare land 0.053 ha (1.333 %) while built up had the least 0.0081 ha (0.203 %).

Table 3: Change analysis of LULC between 1993 and 2023

LULC	Area 1993	Area 2003	Area 2013	Area 2023
Bare Land	0.1116	0.1224	0.1134	0.0531
%	2.804	3.075	2.849	1.334
Dense Forest	3.7665	3.6999	3.6729	3.6225
%	94.62	92.95	92.27	91.002
Built up	0.0004	0.0036	0.0036	0.0081
%	0.09	0.09	0.09	0.023
Less Dense Forest	0.098	0.1233	0.1233	0.1332
%	2.464	3.0974	3.097	3.346
Experimental Land	0.0009	0.0315	0.0675	0.1638
%	0.023	0.791	1.696	4.115
Total	3.9807	3.9807	3.9807	3.9807
	100	100	100	100

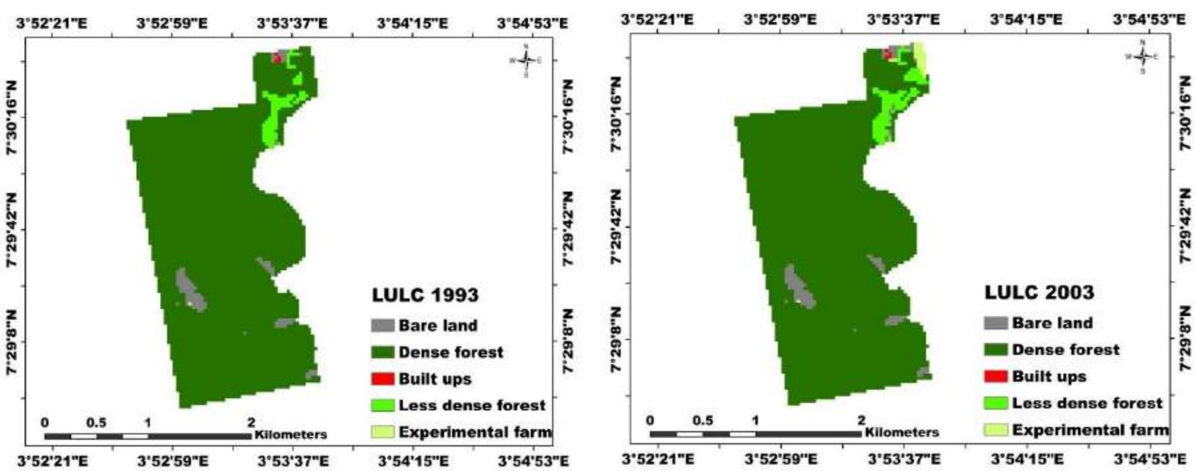

Figure 3: Land Cover for the year 1993 and 2003

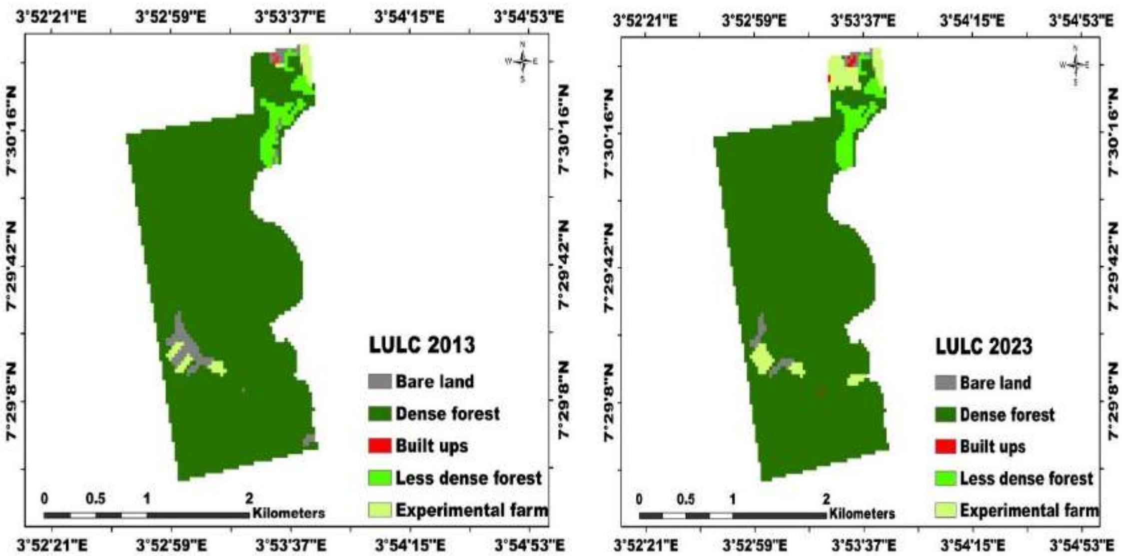

Figure 4: Land Cover for the year 2013 and 2023

Normalized Difference Vegetation Index for Omo Forest Reserve

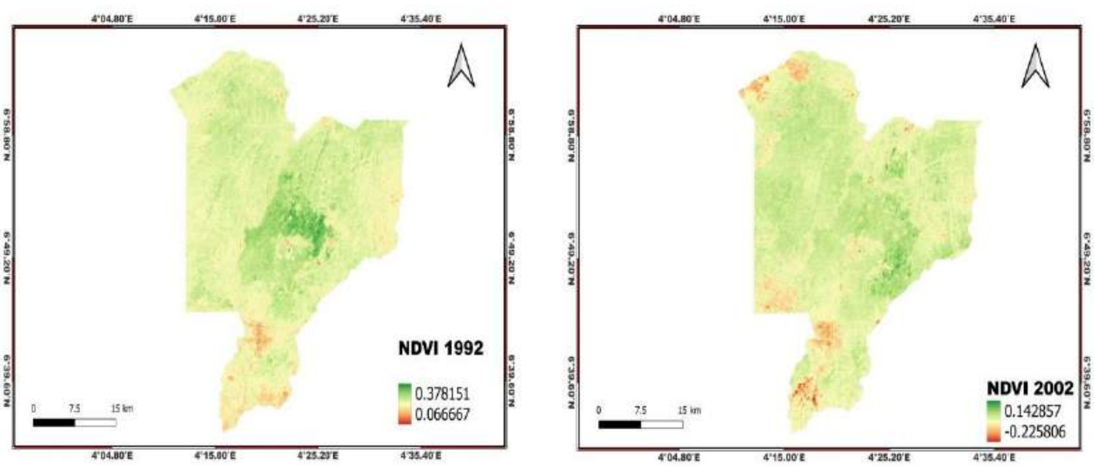

Figure 5: NDVI for the year 1992 and 2002

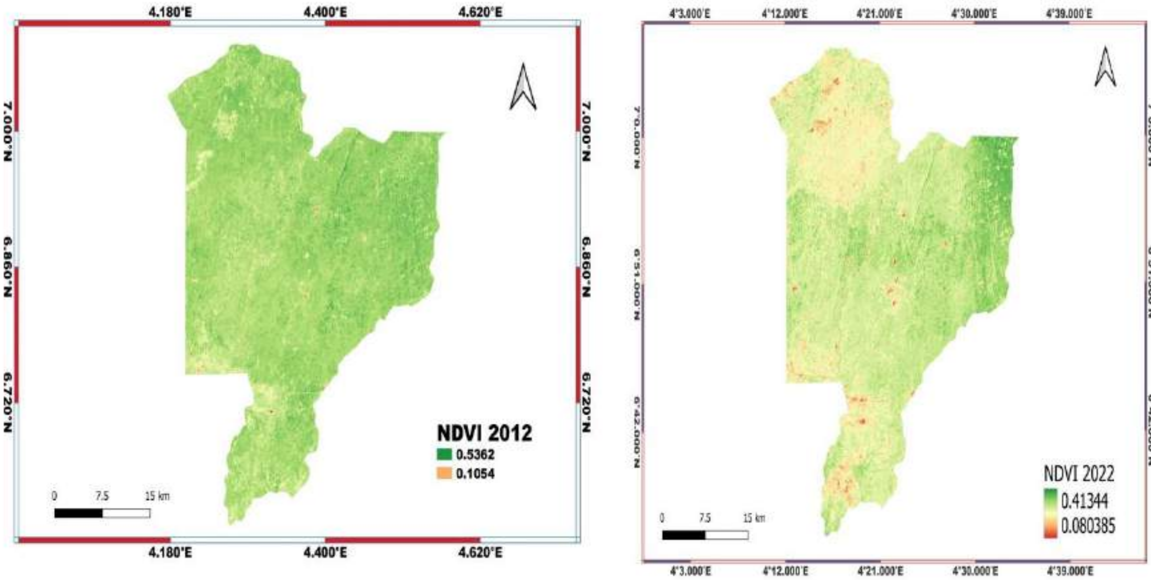

Figure 6: NDVI for the year 2012 and 2022

Normalized Difference Vegetation Index for IITA Forest Reserve

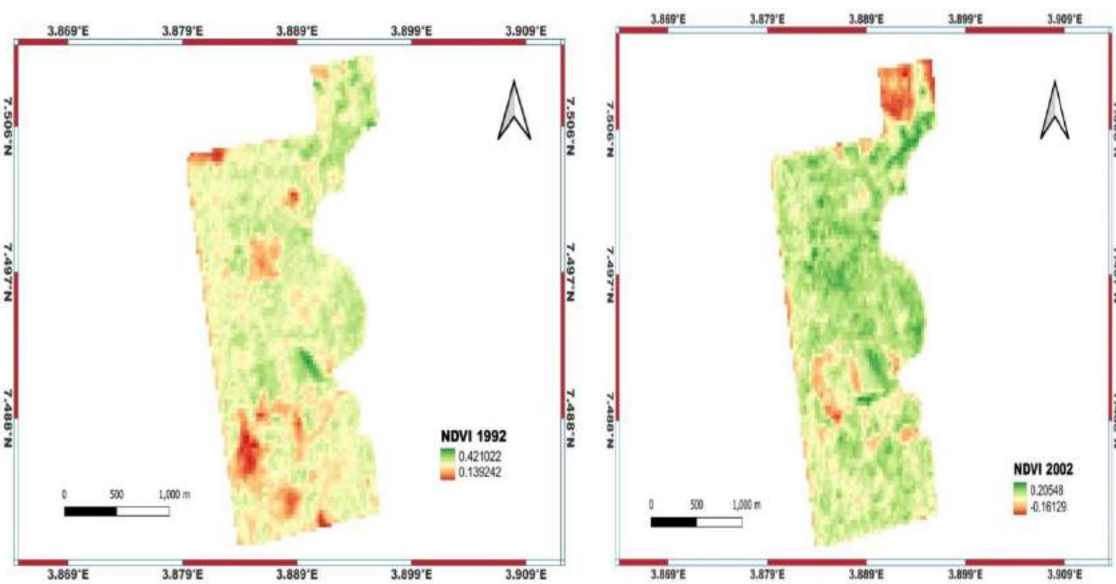

Figure 7: NDVI for the year 1992 and 2002

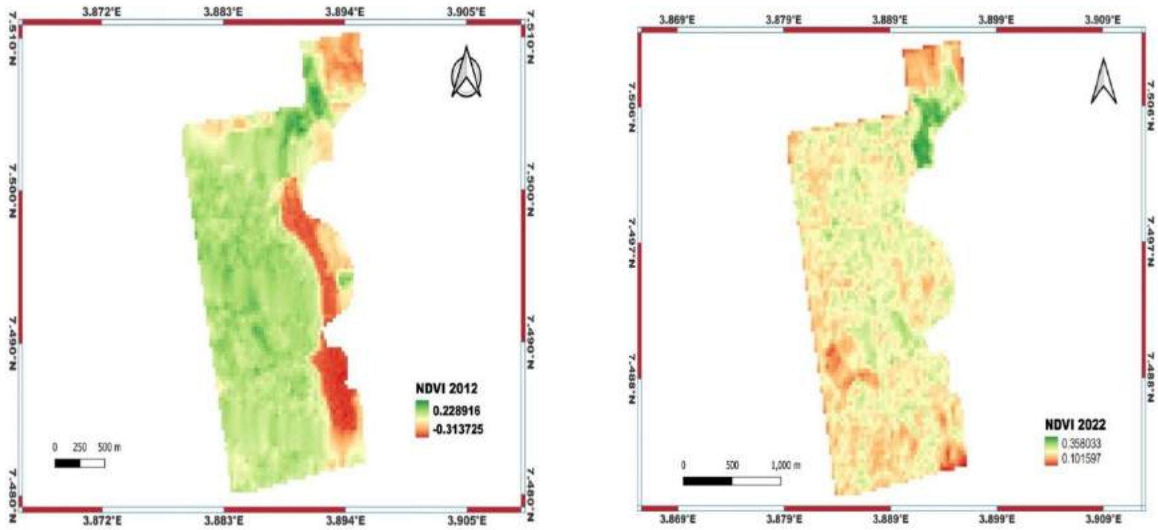

Figure 8: NDVI for the year 2012 and 2022

DISCUSSION

Having the understanding of 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). A supervised method of image classification was adopted and used for analyzing changes in the LULC of this study.

The results and statistics derived from the classified satellite images of the study areas shows various changes in the land use/land cover of Omo and IITA forest reserves. However, the attention of this study is based on the extent and trend of land use/land cover categories within the study area, which is directly expressed in terms of changes in land use/ land cover over the period of thirty (30) years. The reduction and disappearance of the forest cover in the floristic components of the forest reserves are as a result of the alteration of the forest to other land use, which 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. The large decrease in dense forest to less dense forest as well as conversion less dense forest into built up was due to several anthropogenic activities and uncontrolled of human entry into the forest reserve. Many of the villagers found in Omo Forest Reserve derived their livelihood through illegal felling of trees for charcoal and other use, removal of some part of plant such as root, leaves, twig and barks for herbs could be injurious to the living plants thereby leading to the dead of such plant.

The result of the land use/land cover analysis in Omo Forest Reserve varies from one decade to another. Vegetation kept decreasing each decade, in 1993 vegetation covers about 95.96 % of the total land and then decreased to 94.88 % in 2003, 90.53 % in 2013 and 90.51 % in 2023. Built up in Omo Forest Reserve kept increasing, it accounted for 1.922 % of the total area in 1993 and then to 2.044 % in 2003, 3.37 % in 2013 and increased to 3.58 % in 2023. In 1993, bare land occupied 1.852 % of the total land area and then increase to 2.734 % in 2003, and later increased drastically in 2013 to 5.85 %, then decrease to 5.63 % in 2023. There is no much difference in the water bodies over the year; it accounted for 0.26 % in 1993, 0.261 % in 2003, 0.28 % in 2013 and 0.27 % in 2023.

The result of the land use/land cover analysis in IITA forest reserve varies from one decade to another. Dense forest kept decreasing each decade, in 1993 dense forest covers about 94.6 % of the total land and then decreased to 92.9 % in 2003, 92.26 % in 2013 and 91.001 % in 2023. Less dense forest fluctuated within the decades, it accounted for 2.46 % in1993, 3.09 % in 2003, 3.09 % in 2013 and later increased to 3.346 % in 2023. Built up in IITA forest reserve did not increase for three decades but later increased in 2023 from 0.09 % to 0.203 %, the increase in built up leads to increase in loss of forest trees. The experimental land in IITA forest reserve increase yearly which means the reserve is been used for research purpose, in 1993, experimental land accounted for 0.02 % of the total land, 0.79 % in 2003, 1.695 % in 2013 and then increased to 4.114 % in 2023. The bare land fluctuated over the decade, it accounted for 2.8 % of the total land and increased to 3.07 % in 2003 then decreased to 2.84 % in 2013 and to 1.333 % in 2023.The research from this study shows the significant reduction in the area occupied by forests due to human activities in various LULC types at the expense of forest land. Vegetation indices derived from satellite remote sensing data are one of the primary sources of information for monitoring the Earth's vegetation cover (Ghorbani *et al.,* 2010). Normalized difference vegetation index (NDVI) is a vegetation index that is correlated with several important biophysical properties and generates different crop indices (Bushra *et al.,* 2016). In this study, the NDVI data were used to calculate the Proportion of Vegetation (PV) of the study areas for 1993, 2003, 2013, and 2023 (Figure 5, 6, 7 and 8). Furthermore, Lamchin *et al*. (2016) pinpointed that NDVI techniques serve as one of the most efficient spectral indices used for monitoring changes in vegetation, especially in an area with high and low vegetation cover. Da Silva *et al*. (2020) also highlighted that mapping and monitoring vegetation cover changes using NDVI as regarded as some of the most efficient spectral vegetation indices with higher validation accuracy. The present study in shows that the NDVI of 2003 (0.142857, -0.225806) was low, indicating reduced vegetal cover when compared to 1993 (0.378151, 0.66667), 2013 (0.5362, 0.10540) and 2023 (0.41344, 0.080385) in Omo forest reserve, while the study in IITA forest reserve showed that NDVI in 2003 (0.20548, -0.16129) was low, indicating reduced vegetal cover when compared to 1993 (0.421022, 0.139242), 2013 (0.228916, -0.313725) and 2023 (0.358033, 0.101597), NDVI was high in the areas with dense vegetal cover. The low vegetation cover observed in the study area can be traced to increase in anthropogenic activities such as illegal tree felling. According to Tobore *et al.* (2021), the abrupt or gradual change of the past, present and possible future changes of vegetation cover are better assessed using NDVI, and this is similar to the present result obtained. Besides, Warner *et al.* (2016) also highlighted that mapping and monitoring vegetation cover changes using NDVI as regarded as some of the most efficient spectral vegetation indices with higher validation accuracy. Additionally, encroachment or indiscriminate grazing of cattle might be responsible for the low vegetation observed in the LULC, especially during the dry season when the chlorophyll content is low, and this is also coincide with the study of Tobore *et al.*, (2021).

Conclusions and Recommendations

Landsat imageries were used to successfully assess forest vegetation features and spatial pattern changes in Omo and IITA forest reserves between year 1993 to 2023.According to the result, the forest had lost almost all its vegetative cover within 30 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 looking into the law and policy for proper monitoring of the forest reserves.

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WATER QUALITY INFLUENCE ON THE GROWTH OF SELECTED INDIGENOUS TREE SEEDLINGS IN RAINFOREST ECOLOGICAL ZONE, NIGERIA.

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ABSTRACT

Moisture plays important roles in plant growth. But the quality of water is not acceptable for a specific use; it is as good as the water is not available for that particular purpose. Influence of well and stream water on the early growth performance of six indigenous trees species was investigated. Seeds of *Entandrophragma angolensis*, *Cordial millenii, Triplochiton scleroxylon, Terminalia ivorensis*, and *Mansonia altissima* were collected, processed and sown. Uniformed germinated seedlings were transplanted into polythene pots that contained 4kg of top soil. Each potted seedling is applied with 400 ml of water daily. The experimental design was 2 *x 5* factor factorial in Completely Randomized Design. Four weeks after transplanting, growth variables that included shoot height, stem girth and leaf production were assessed fortnightly for 12 weeks. Data collected were subjected to Analysis of Variance (ANOVA) and correlation between influence of the two water sources and growth variables were tested. There were significant differences ($P<0.05$) in growth variables among seedlings of the same species as influenced by water sources but there were no significant differences ($P>0.05$) among seedlings of different trees species. There were high degrees of correlation between water sources and growth variables in all tree species as R ranges between ($R = 0.84$ – $R= 0.99$). It can therefore be inferred that the two water sources influence positively the growth variables of all the five indigenous tree species at nursery age.

Key words: water sources, indigenous tree species, growth variables, moisture, water quality.

INTRODUCTION

Water is an important natural resource that supports life and growth of plants, but there is a growing concern on permanent water availability in tree nursery establishment and management especially in the drier regions of the tropics and sub-tropics (Goyne and McIntyre, 2003). Numerous human activities impact water quality: agriculture, industry, mining, human waste disposal, population growth, urbanization, and climate change. Its quality has serious impact on all living creature and can negatively affect its use for drinking, household needs, recreation, fishing, transportation and commerce (Akintan *et al*., 2011). Meanwhile, growing populations will potentially magnify these impacts while climate change will create new water quality challenges. Water will become increasingly scarce in most geographical zones of the world with the effects of climate change (Morrison *et al*., 2009). Sufficient quantity of quality water is extremely important for the production of nursery crops; this requires careful planning and management. Poor quality water can be responsible for slow growth, poor aesthetic quality of the crop and, in some cases, can result in the gradual death of the plants. High soluble salts can directly injure roots, interfering with water and nutrient uptake. Salts can accumulate in plant leaf margins, causing burning of the edges. Water with high alkalinity can adversely affect the pH of the growing medium, interfering with nutrient uptake and causing nutrient deficiencies which compromise plant health (CAFÉ, 2023).

Tropical tree nurseries can use water from several different sources: rivers, ponds or reservoirs, rainwater, groundwater and municipal sources. The types and concentrations of dissolved salts (total salinity and individual toxic ions) and the presence of pests (pathogenic fungi, weed seeds, algae, and possible pesticide contamination) are important water quality parameters (Zheng *et al*., 2009). Seedlings management is intensively required at the nursery stage to enhance resource use efficiency and minimize potentially harmful effects of inappropriate water and/or nutrient element uptake (Akinrinde and Ayegboyin 2006).

Initial growth of seedlings largely depends on stored food reserves contained in the cotyledons and also availability of soil moisture. After depletion of food reserves, seedlings rely on photosynthesis and nutrient uptake from the growing media for their continued growth and survival (Shao *et al*., 2008). For tree nurseries, regular watering is necessary to produce good quality seedlings at economic rate. This is because any stagnation in seedling growth or subsequent mortality translates into economic loss to a nursery operator. The losses can be huge because seedlings take long to reach an appropriate size for grafting and transplanting (Mhango *et al*., 2008). Water use requirements depend on tree species, growth stage, and time of the year and hence, it is necessary to establish this for each tree species as there are differences in growth rates (Bargali and Tewari 2004).

Knowledge of water quality effect to sustain growth and survival at the nursery of most indigenous tree seedlings that thrive in rainforest is limited. Therefore, this research intends to study water quality effect on the early growth of selected indigenous tree species in the nursery.

MATERIALS AND METHODS

Study Area

The experiment was carried out at the nursery site of Forestry Research Institute of Nigeria: Rainforest Research Station, Ore in Ondo State, Nigeria (06°35.754N – 06°36.599N; 004°50.388E – 004°51.932E), between October 2021 and April 2022 (dry season). Mean annual temperature of about 25VC (minimum 19°C and maximum 34°C); relative humidity 84% and mean rainfall of 76mm is obtainable in the study area (Oyun *et al.*, 2006). The elevation is about 350 m above sea level with gently undulating land form. The soils of the study area are classified as basement complex rocks composed mainly of granite-gneiss, mica-schist, and feldspathic rocks. The soils belong to the Omotosho soil series (Esu *et al.*, 2014). The experimental soil was collected randomly within the forest reserve at a depth of 0-15 cm using a soil auger. Stones, roots and other debris were removed after the soil was air-dried and sieved through 2 mm mesh size.

Experimental design

The experiment was laid out in 2 x 5 factor factorial in Completely Randomized Design. Well and stream waters are factors and five tree species. Each plant species was replicated thrice.

Seed Collection, Viability Test and Seed Pretreatment

Seeds of *Entandophragma angolensis*, *Cordial millennii*, *Triplochiton scleroxylon*, *Terminalia ivorensis*, and *Mansonia altissima* were collected from the Rainforest Research Station, Ore arboretum and forest reserve. The seeds were put into different bowls each of 12 litres capacity, 10 litres of water was then poured into each, these were allowed to stay for 2 minutes after which the floated seeds were decanted and taken to be not viable. The viable seeds were then immediately dried for further tests. The viable seeds were thereafter soaked in cold water for 24 hours before sowing as a pretreatment, when removed they were placed immediately in an open place so that they can be dried and thereafter sown into germination boxes.

The collected seeds were pre-germinated in germination trays of 20 cm x 30 cm x 1cm for four weeks after which they were transplanted into 4kg size polythene pots of 38 cm x 26cm with perforations at the base. The germination trays were separated such that the water quality variable was applied from the onset of experiment. Each potted seedling was watered once daily by applying 400 ml measure of water using measuring can.

Data Collection

Seedlings assessment for morphological parameters (number of leaves, stem circumference and height) were measured after four weeks of transplanting into polythene pots with topsoil when the seedlings were observed to have been established and this was repeated forth nightly.

Seedling heights were measured by taking the vertical distance from the ground level to the tip of each tree seedling using a long meter ruler; Stem circumference was obtained by measuring the diameter at the collar point with the use of a vernier caliper while the number of leaves was obtained by visual counting.

RESULTS

Soil analysis for the experiment

The soil analysis result for the experiment is presented in Table 1. Data obtained showed that the soil belongs to the sandy loamy texture class. The soil pH was found to be 6.7 indicating that the soil was near neutral and had high levels of residual nutrients with total nitrogen at 3.2 g/kg. The available Phosphorus in the soil was 18.61 mg/kg, organic carbon was at 33.65 g/kg, organic matter at 42.66 g/kg and soil exchangeable acidity 0.15 cmol/kg. The exchangeable bases were Ca (6.21 cmol/kg), Mg (1.60 cmol/kg), K (0.90 cmol/kg) and Na (0.60 cmol/kg). These values were considered adequate for crop growth and can support optimum plant growth at the nursery (Kogbe and Adediran, 2003). There is therefore sufficient nutrients supply for an efficient plant growth rate.

Table 1: Pre-planting soil properties of Forestry Research Institute of Nigeria: Rainforest Research Station, Ore in Ondo State, Nigeria

Soil properties	Value
Particle size distribution (g/kg)	
Sand	740
Silt	168
Clay	92
Textural class	Sandy loam
pH (1: 1 H_20)	6.7
pH (1: 2 $CaCl_2$)	5.2
Exchangeable acidity(E.A., cmol/kg)	0.15
Organic carbon g/kg	33.65
Organic matter g/kg	42.66
Total nitrogen g/kg	3.2
Available phosphorus mg/kg	18.61
Exchangeable bases and ECEC (cmol/kg)	
Ca	6.21
Mg	4.65
K	0.90
Na	0.60
ECEC	6.68

ECEC = Effective Cation Exchange Capacity, Ca = Calcium, Mg = Magnesium, K = Potassium, Na = Sodium

Water quality analysis for the experiment

The water quality analysis result for the experiment is presented in Table 2. Data obtained showed that: pH was found to be 6.6 indicating that the waters were near neutral. Alkalinity (2 meq/L), Total Carbonates as $CaCO_3$ (100 ppm), Bicarbonate (HCO_3^-) (122 ppm), Hardness (Ca + Mg) (150 ppm). Electrical conductivity (EC) 90.6 dS/m), Total dissolved salts (1280 ppm), Sodium absorption ratio (SAR) (10), Sodium (Na) (69 ppm) and Chloride (Cl^-) (71 ppm). Macro elements: Total Nitrogen (9 ppm), Phosphorus (0.9 ppm), Nitrate (NO_3^-) (44 ppm), Ammonium (10 ppm), Phosphate (3 ppm), Calcium (Ca) (70 ppm), Magnesium (Mg) (20ppm), Sulphur (S) (23 ppm), Sulfate (SO_4^-) (75 ppm), Aluminum (Al) (4 ppm), Boron (B) (0.4 ppm), Copper (Cu) (0.1 ppm), Flouride (F) (1ppm), Iron (Fe) (3ppm), Manganese (Mn) (1ppm) and Zinc (Zn) (0.3 ppm). These values were considered adequate for crop growth and can support optimum plant growth at the nursery (Bilderback, *et al.*, 2011). There is therefore sufficient nutrients supply for an efficient plant growth rate.

Table 2: Water quality analysis

Water quality parameters	Value
pH	
pH	6.6
Alkalinity	2 meq/L
Total Carbonates (as $CaCo_3$)	100 ppm
Bicarbonate (HCO_3^-)	122 ppm
Hardness (Ca + Mg)	150 ppm $CaCO_3$
Salinity	
Electrical conductivity (EC)	0.6 dS/m
Total dissolved salts	1280 ppm
Sodium absorption ratio (SAR)	10
Sodium (Na)	69 ppm
Chloride (Cl^-)	71 ppm
Macro elements	
Total Nitrogen	9 ppm
Nitrate (NO_3^-)	44 ppm
Ammonium	10 ppm
Phosphorus	0.9 ppm
Phosphate	3 ppm
Calcium (Ca)	70 ppm
Magnesium (Mg)	20 ppm
Sulphur (S)	23 ppm
Sulfate (SO_4^-)	75 ppm
Micro elements	
Aluminum (Al)	4 ppm
Boron (B)	0.4 ppm
Copper (Cu)	0.1 ppm
Fluoride (F^-)	1 ppm
Iron (Fe)	3 ppm
Manganese (Mn)	1 ppm
Zinc (Zn)	0.3 ppm

Data collected on seedlings morphology during the Experiment

Analysis of variance (ANOVA) result for growth parameters of well and stream watered seedlings of *Entandophragma angolensis* (EA), *Cordial millennii* (CM), *Triplochiton scleroxylon* (TS), *Terminalia ivorensis* (TI), and *Mansonia altissima* (MA) are presented in tables 3, 4, 5, 6, 7 and 8. Tables 3 and 4 showed heights of stream watered (SW) and well-watered (WW) seedlings. There was no significant difference (P <0.05) among the height of seedlings predisposed to different water qualities throughout the weeks of measurements. Tables 5 and 6 showed collar diameter of stream watered (SW) and well-watered (WW) seedlings. There was no significant difference (P <0.05) among the collar diameter of seedlings predisposed to different water qualities throughout the weeks of measurements. Tables 7 and 8 showed leaf number of stream watered (SW) and well-watered (WW) seedlings. There was no significant difference (P <0.05) among the leaf number of seedlings predisposed to different water qualities throughout the weeks of measurements.

Table 3: Effect of well water watering on seedlings height

	Height (cm)				
Plant species	**4WAT**	**6WAT**	**8WAT**	**10WAT**	**12WAT**
Cordial millennii	13.90[a]	15.60[a]	17.50[a]	19.80[a]	21.90[a]
Entandophragma angolensis	13.86[a]	15.20[a]	18.20[a]	21.22[a]	23.42[a]
Mansonia altissima	12.27[a]	14.90[a]	16.35[a]	18. 83[a]	21. 53[a]
Terminalia ivorensis	14.03[a]	16.60[a]	19.20[a]	21.08[a]	23.10[a]
Triplochiton scleroxylon	12.54[a]	15.20[a]	16.78[a]	19.13	20.83[a]

WAT = Weeks After Transplanting; Means are not significantly different $(P \leq 0.05)$

Table 4: Effect of stream water watering on seedlings height

	Height (cm)				
Plant species	**4WAT**	**6WAT**	**8WAT**	**10WAT**	**12WAT**
Cordial millennii	12.00[a]	15.60[a]	17.10[a]	19.80[a]	20.91[a]
Entandophragma angolensis	11.86[a]	13.80[a]	16.20[a]	19.83[a]	21.75[a]
Mansonia altissima	10.27[a]	12.64[a]	15.90[a]	16. 60[a]	19. 10[a]
Terminalia ivorensis	11.03[a]	13.20[a]	17.60[a]	20.85[a]	21.95[a]
Triplochiton scleroxylon	14.78[a]	17.70[a]	18.08[a]	18.60[a]	21.15[a]

WAT = Weeks After Transplanting; Means are not significantly different $(P \leq 0.05)$

Table 5: Effect of well water watering on seedlings collar diameter

	Collar Diameter (cm)				
Plant species	**4WAT**	**6WAT**	**8WAT**	**10WAT**	**12WAT**
Cordial millennii	0.26[a]	0.28[a]	0.32[a]	0.34[a]	0.61[a]
Entandophragma angolensis	0.20[a]	0.22[a]	0.28[a]	0.32[a]	0.49[a]
Mansonia altissima	0.24[a]	0.26[a]	0.32[a]	0.35[a]	0.52[a]
Terminalia ivorensis	0.26[a]	0.29[a]	0.32[a]	0.34[a]	0.49[a]
Triplochiton scleroxylon	0.27[a]	0.29[a]	0.34[a]	0.38[a]	0.53[a]

WAT = Weeks After Transplanting; Means are not significantly different $(P \leq 0.05)$

Table 6: Effect of stream water watering on seedlings collar diameter

	Collar Diameter (cm)				
Plant species	**4WAT**	**6WAT**	**8WAT**	**10WAT**	**12WAT**
Cordial millennii	0.26[a]	0.28[a]	0.30[a]	0.32[a]	0.51[a]
Entandophragma angolensis	0.27[a]	0.29[a]	0.31[a]	0.34[a]	0.49[a]
Mansonia altissima	0.20[a]	0.30[a]	0.32[a]	0.34[a]	0.60[a]
Terminalia ivorensis	0..27[a]	0.29[a]	0..31[a]	0.32[a]	0.52[a]
Triplochiton scleroxylon	0.33[a]	0.27[a]	0.30[a]	0.36 [a]	0.53[a]

WAT = Weeks After Transplanting; Means are not significantly different $(P \leq 0.05)$

Table 7: Effect of well water watering on seedlings leaf number

	Leaf number				
Plant species	**4WAT**	**6WAT**	**8WAT**	**10WAT**	**12WAT**
Cordial millennii	8.00[a]	10.00[a]	13.00[a]	15.00[a]	16.00[a]
Entandophragma angolensis	8.00[a]	10.00[a]	12.00[a]	14.00[a]	15.00[a]
Mansonia altissima	9.00[a]	11.00[a]	13.00[a]	15.00[a]	16.00[a]
Terminalia ivorensis	7.00[a]	9.00[a]	11.00[a]	13.00[a]	14.00[a]
Triplochiton scleroxylon	8.00[a]	10.00[a]	12.00[a]	14.00[a]	15.00[a]

WAT = Weeks After Transplanting; Means are not significantly different $(P \leq 0.05)$

Table 8: Effect of stream water watering on seedlings leaf number

	Leaf number				
Plant species	4WAT	6WAT	8WAT	10WAT	12WAT
Cordial millennii	10.00[a]	12.00[a]	14.00[a]	16.00[a]	17.00[a]
Entandophragma angolensis	9.00[a]	11.00[a]	13.00[a]	15.00[a]	16.00[a]
Mansonia altissima	8.00[a]	10.00[a]	12.00[a]	14.00[a]	14.00[a]
Terminalia ivorensis	10.00[a]	12.00[a]	14.00[a]	16.00[a]	17.00[a]
Triplochiton scleroxylon	10.00[a]	12.00[a]	14.00[a]	16.00[a]	17.00[a]

WAT = Weeks After Transplanting; Means are not significantly different $(P \leq 0.05)$

Correlation matrix between water quality and growth parameters of trees seedlings

The correlation matrix between water quality and growth parameters of *Cordial millennii*, *Entandophragma angolensis*, *Mansonia altissima*, *Terminalia ivorensis and Triplochiton scleroxylon* seedlings are presented in Tables 9, 10, 11 and 12. The tables show positive relationship among the growth parameters irrespective of the water quality.

Table 9: Showing correlation matrix between water quality and growth parameters of *Cordial millennii* seedlings

	H(W)	**CD(W)**	**LN(W)**	**H(S)**	**CD(S)**	**LN(S)**
H(W)	1					
CD(W)	0.986148	1				
LN(W)	0.993322	0.998274	1			
H(S)	0.981687	0.959713	0.973876	1		
CD(S)	0.997614	0.989949	0.996546	0.988165	1	

H(W)=Height well watered, CD(W)=Collar Diameter well watered, LN(W)=Leaf Number well watered, H(S)=Height stream watered, CD(S)=Collar Diameter stream watered, LN(S)=Leaf Number stream watered

Table 10: Showing correlation matrix between water quality and growth parameters of *Entandophragma angolensis* seedlings

	H(W)	CD(W)	LN(W)	H(S)	CD(S)	LN(S)
H(W)	1					
CD(W)	0.996177	1				
LN(W)	0.986906	0.984495	1			
H(S)	0.99561	0.984911	0.989427	1		
CD(S)	0.992857	0.983013	0.994377	0.998853	1	
LN(S)	0.986906	0.984495	1	0.989427	0.994377	1

Table 11: Showing correlation matrix between water quality and growth parameters of *Mansonia altisima* seedlings

	H(W)	CD(W)	LN(W)	H(S)	CD(S)	LN(S)
H(W)	1					
CD(W)	0.958019	1				
LN(W)	0.994451	0.982708	1			
H(S)	0.956326	0.975461	0.974875	1		
CD(S)	0.931569	0.847483	0.9135	0.926207	1	
LN(S)	0.994451	0.982708	1	0.974875	0.9135	1

Table 12: Showing correlation matrix between water quality and growth parameters of *Terminalia ivorensis* seedlings

	H(W)	CD(W)	LN(W)	H(S)	CD(S)	LN(S)
H(W)	1					
CD(W)	0.999828	1				
LN(W)	0.997401	0.99591	1			
H(S)	0.988513	0.986315	0.992558	1		
CD(S)	0.997476	0.998615	0.989778	0.978965	1	
LN(S)	0.997401	0.99591	1	0.992558	0.989778	1

DISCUSSION

The observable growth with time in *Cordial millennii, Entandophragma angolensis, Mansonia altissima, Terminalia ivorensis and Triplochiton scleroxylon* seedlings under the two different water sources (Well and Stream) have a positive effect on plant height, collar diameter and leaf counts of the seedlings. This observation could be attributed to good aeration as well as nutrient availability in the soil and water supporting the growth of the seedlings. A previous study by Gordon (1988) and Kuiper and Olenburger (2005) suggested that water collected from streams, rivers or dams to water seedlings is not likely to cause problem. This is supported by a similar experiment conducted by Akinrinde and Ayegboyin (2006) on performance differences among seedlings irrigated with water from borehole, river, well, stream and rain there was insignificant differences in the test species of *Theobroma cacao* (L.).

In the research work of CAFÉ 2023, poor quality water can be responsible for slow growth, poor aesthetic quality of the crop and, in some cases, can result in the gradual death of the plants. High soluble salts can directly injure roots, interfering with water and nutrient uptake. Salts can accumulate in plant leaf margins, causing burning of the edges. Water with high alkalinity can adversely affect the pH of the growing medium, interfering with nutrient uptake and causing nutrient deficiencies which compromise plant health. Therefore, the observed positive effect on test plants in this experiment is attributable to good water quality also.

CONCLUSION

In this research work, applied water from stream and well resulted in observed positive differences in the mean growth and early performance of the seedlings. This indicated a significant impact of the water sources employed in watering them.

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ECOLOGICAL ASSESSMENT OF TRACE METALS IN TOP SOIL OF AN AUTO-MOBILE WORKSHOP IN OSOGBO METROPOLIS, SOUTHWESTERN, NIGERIA

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ABSTRACT

Unchecked auto-mechanic and panel fitting activity especially in developing countries may contribute essentially to elevated levels of heavy metals in soils, negatively impact vegetation composition, and pose serious health issues to the populace. Aim at evaluating the extent of ecological disturbance due to toxic metal in the topsoil around the auto-mobile workshop in Osogbo Metropolis, three locations including workshops that major in the repair of trucks engines (TEW), those that major in spraying of vehicle body (SVB) and control site were selected. At each sampling site, 12 points were randomly selected for the determination of soil metal contents using ICP-OES. Pollution index and enrichment factor analysis were used to evaluate the extent of ecological disturbance due to toxic metals. The soil pH, electric conductivity and organic matter content (OM) differed across the study sites. The soil pH at TEW was significantly higher than that of the SVB and the control. Compared to the control site, the concentration of Chromium (Cr), Copper (Cu), Nickel (Ni), Zinc (Zn), and Lead (Pb) was significantly higher at TE and SVB than at the control site. The value of the enrichment factor showed that SVB was significantly enriched with Cr, Cu, Ni, Pb, Cd, and Zn, while TEW and the control site were minimally enriched with those metals. Except for Pb, the comparison of the concentration of observed metal at TEW and control with the reference value of WHO and EPA indicated no current risk of health hazards for humans at those sites. However, the values obtained at SVB suggest a need for effective pollution control as it is higher than the permissible levels.

Keyword: Auto-mechanic, Panel fitting, Plant species, Heavy metals, Pollution index.

INTRODUCTION

Soil contaminants by metal and metalloid has become an important issue of global concern owing to their non-biodegradable and persistence in the environment (Reimann *et al*., 2016). In recent decades, heavy metals contamination through artisanal activities has contributed immensely to environmental pollution because most of such artisanal activities are not well regulated, especially in developing countries (Buha *et al*., 2017). The auto-mechanic and panel fitting activities such as the discharge of oil grasses, petrol, battery electrolytes and spraying of the car body have become an important source of soil contamination, with subsequent adverse effects on the ecosystem due to the presence of heavy metals (Xie *et al*., 2016).

Previous research had shown that auto-mechanic operations might release various harmful metals into the environment, including arsenic, cadmium, chromium, lead, and mercury, through the deterioration of engine components, grease and oil leaks, metal wastes from vehicle catalysts, and panel beating (Obafemi *et al*., 2018; Ajeh *et al*., 2022). Although some of these metals have beneficial effects on biological systems, their release into the environment is of concern as it increases the likelihood of exposure of the flora and fauna to their detrimental effects when in excess. For instance, exposure to lead and Cd can have negative effects on plant metabolism, growth, and development as well as cause bone fractures and malformations, hypertension, and immunosuppression in animals (Ajeh *et al.*, 2022). Also, excess zinc and copper in the body can harm the liver, cause gastrointestinal issues, and interfere with the immune system.

In Nigeria, soil contamination due to the incident of oil spills around auto-mechanic and panel fitting workshop has been the subject of several discussions. Recently, Adedeji et al. (2019) reported significant health risks due to exposure to Cd, Cr, Cu, Mn, Ni, Pb, and Zn in the soil samples collected from Ijebu-Ode, Ogun State, Nigeria. Similarly, Isibor et al. (2020) highlighted notable health risk impacts of selected trace metals detected in soil samples of a tropical rainforest in Benin City, Nigeria. On the contrary, Ajeh *et al.* (2022) in their study of soil samples around automobile mechanic workshops in Benin City reported low ecological risks of the trace metals as the concentrations of metals in the soil were within safe limits. Thus, suggesting the need for a more all-inclusive investigation into the heavy metal status on soils around the auto-mechanic workshop within major metropolis.

In the Osogbo metropolis, there is a high-pitched in number of automobile mechanic workshops. The workshops are distributed all over the city and render car services that involve a change of the used engine oil, panel beating and vehicle parts which are indiscriminately discarded in the environment. Because these auto repair businesses' operations are unregulated, they occasionally engage in inappropriate waste disposal, releasing chemicals, vehicle body scraps, gasoline, and different motor lubricants into the environment. These may contaminate soil, have a negative effect on the diversity of plant species, and harm human health. Therefore, this study employs inductively coupled plasma-optical emission spectrometry (ICP-OES) to evaluate the extent severity of heavy metal pollution in the topsoil around the auto-mobile workshop in Osogbo Metropolis.

Materials and Method

Study Area, Plot Selection, and Sample Preparation

The study was carried out at three different locations within Osogbo metropolis (Fig. 1). The locations are the trucks engines workshop (TEW), (latitude of 7º 16'16'' N and longitude 4°35'8'' E), auto-mechanic workshop, major in spraying of the vehicle body (SVB) (latitude of 7°45'37''N and longitude of 4°33'52''E) and a control site at Osun groove where there are no artisanal activities.

Within each study location, 12 points were randomly selected. The points were laid at 1m away from each other. At each point, surface soil was collected at a depth of 0-15cm using an auger. The soil samples were homogenized and a total of 4 composite samples were selected for chemical analysis.

The soil samples were air-dried at room temperature for 14 days, crushed, and passed through a 2 mm sieve to remove coarse debris. The samples were packed into zip lock and transported to the laboratory for further analysis.

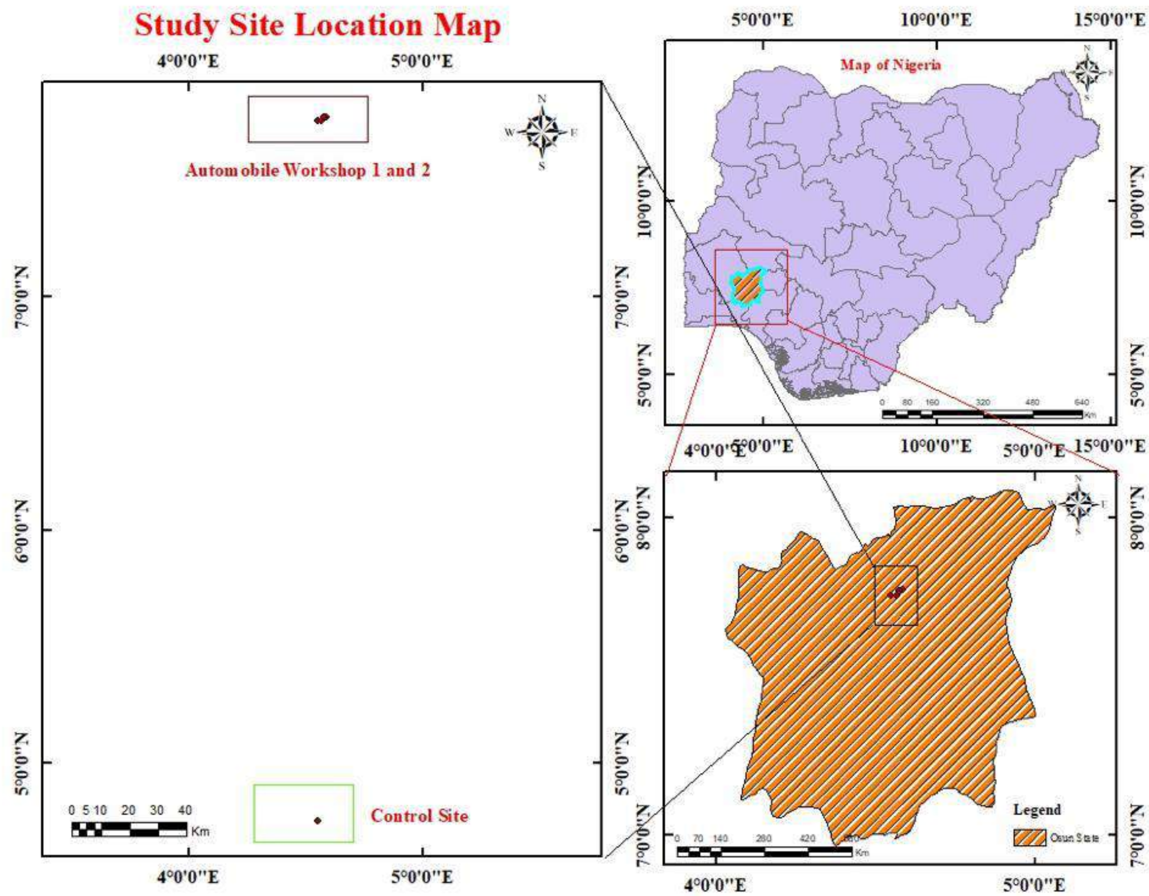


Figure 1: Map of the study area and sampling point locations

Soil sample Analysis

Determination of pH, Electrical Conductivity and Organic matter contents

Soil pH was measured in a deionized water suspension at a ratio of 25 mL water to 10 g soil using a pH meter. The electrical conductivity was determined at a ratio of 1 g of soil to 10 mL of distilled water using a conductivity meter. Soil organic matter contents were estimated through the determination of carbon content in the samples. The organic matter contents were then calculated from the carbon content on the assumption that soil organic matter contains 58% carbon.

Determination of soil metal content across the study sites

To determine the metal content in the soil samples, 0.5g of each homogenized sample was weighed and transferred into beakers in addition to 20 ml of Aqua Regia. The samples were digested by heating block in a fume hood at a temperature not exceeding 900 °C for about an hour. The beakers were allowed to cool and 2ml of Hydrogen peroxide was added to each beaker and heating for 10 minutes. At the completion of the digestion, the digestate volume of each sample was measured. The digestate was then filtered and diluted to 50ml using ultra-pure deionized water and loaded into ICP-OES for analysis (EPA, 2007**)**. The accuracy of the ICP-OES was validated by repeating the experimental procedure three times. Quality Control (QC) solution was prepared using Certified reference materials.

Determination of Metal Pollution level using

The concentration of the metals detected in soil samples was used to determine the contamination index (Pi) and enrichment factor (Ef) for the study sites.

The Pi was calculated using the equation described by Agyemang et al. (2021):

Pi = Ci/Si *Eq (1)*

where Pi is the identified heavy metals' pollution index. Ci (mg/kg) represents the amount of heavy metals present in the soil. Si(mg/kg) is the concentration of the benchmark heavy metal value for soil quality

The enrichment factor (EF) was used to evaluate the intensity of heavy metal contaminants due to the artisanal activity compared to their abundance in soil. The enrichment factors were calculated using the formula described by Mokhtarzadeh et al. (2020)

$$EF = \frac{\left(\frac{Ci}{Cref}\right)sample}{\left(\frac{Ci}{Cref}\right)background} \qquad Eq\ (2)$$

where *Ci* represents the target element's concentration, and *Cref* denotes the reference element's concentration. The EF < 1 indicates no enrichment, EF < 3 is minor enrichment, EF = 3–5 is moderate enrichment, EF = 5–10 is moderately severe enrichment, EF = 10–25 is severe enrichment, EF = 25–50 is very severe enrichment, and EF > 50 is extremely severe enrichment.

Data Analysis

Data obtained were analyzed using one-way variance (ANOVA) and mean separated using the Duncan multiple range test (DMRT) at $p < 0.05$. Results in this study were presented as mean ± standard error. All statistical analyses were carried out using SPSS. Figures were prepared using Microsoft Excel and presented as mean ± standard error (SE).

RESULTS

pH, Electric conductivity and Organic matter content across the study sites

The pH values of TEW were significantly higher ($p < 0.05$) as compared to SVB and the control site (Fig. 2A). Similarly, the TEW workshop has the highest EC, followed by the control site and SVB (Fig. 2B). There was a significant different ($p < 0.05$) in the OM content across the study sites, SVB workshop has the highest OM value compared to TEW and the control site (Fig. 2c).

Heavy metal contents across the study sites

There was a significant difference ($p < 0.05$) in the concentration of chromium (Cr), Copper Cu), Lead (Pb), Manganese (Mg), Nickel (Ni), Platinum (Pt), Thallium (TI), Titanium (Ti), Uranium (U), Vanadium (V) and Zinc (Zn) across the study site (Table 1). Among the three sites, the concentration of Cr, Cu, Pb, Ni, Ti, U, and V was significantly higher ($p < 0.05$) in the soil sample collected from SVB than in the TEW and the control.

The concentration of Cr at TEW and Control sites was lower than the value of 50 mg/kg recommended by WHO, while the concentration of Pb at all three sites was higher than the standard value of 15 mg/kg recommended by EPA. The concentration of As, Ni and U at the three sites is lower than the values of 10 mg/kg, 100 mg/kg and 30 mg/kg recommended by WHO. The control site has the highest concentration of Mg, followed by SVB and TEW respectively.

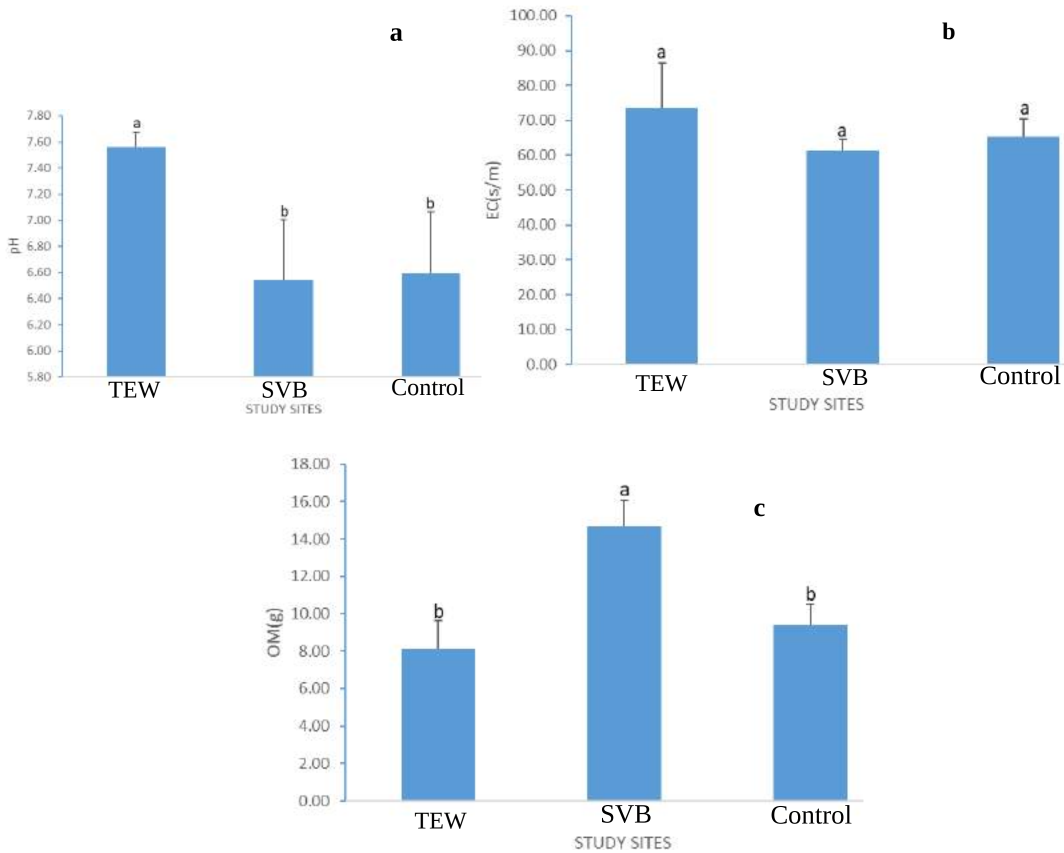


Figure 2: The Soil (A) pH, (B) Electrical conductivity, and (C) Organic Matter content across the study sites. Bar with different lower-case letters represent significant differences among the study sites @ $p < 0.05$. TEW: Trucks engines workshop, SVB: Spraying of vehicle body

Table 1: Metals concentration across the study sites

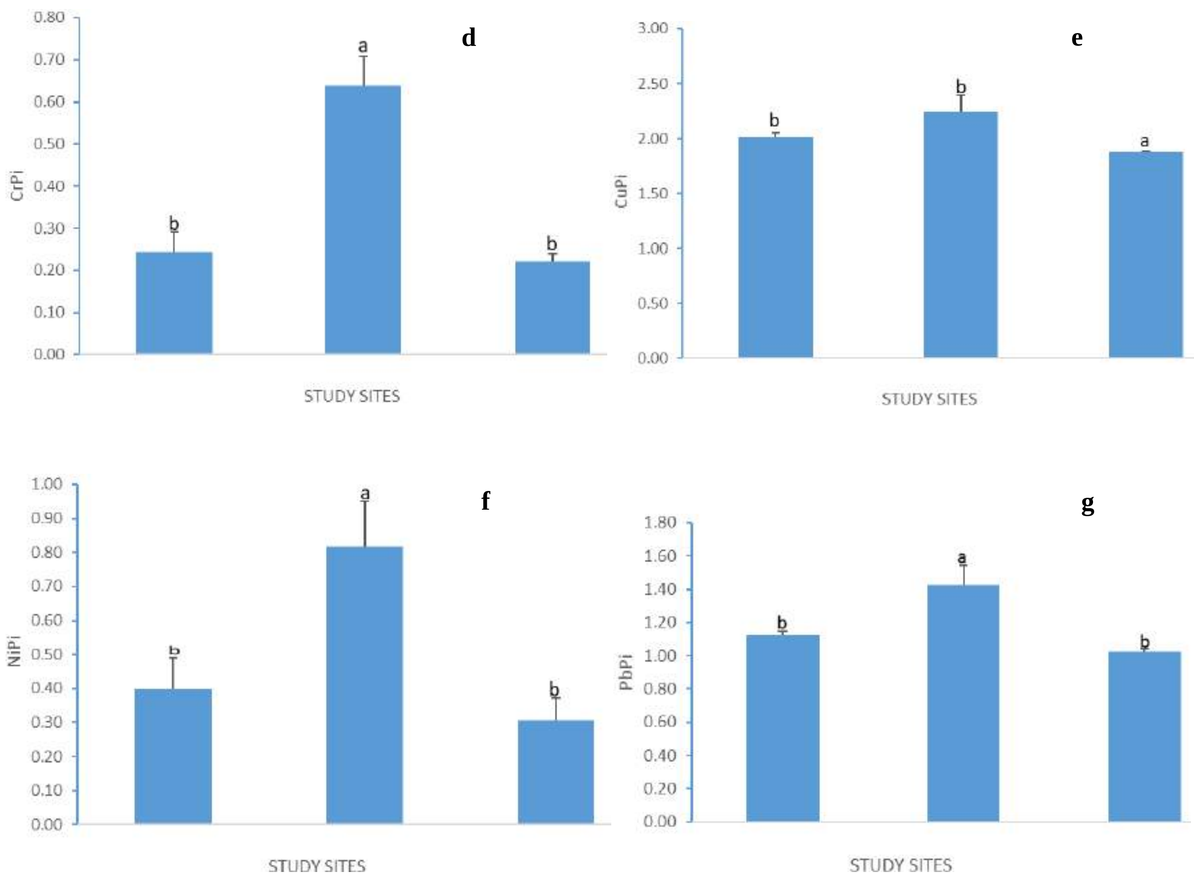
	SITES		
Elements (mg/kg)	**TEW**	**SVB**	**Control**
Arsenic (As)	8.3±2.7^a	5.8±1.5^a	5.8±1.0^a
Barium (Ba)	70±7.683.1^b	120.3±6.8^a	71.8± 2.8^b
Cadmium (Cd)	2.08±0.7^a	3.5±0.47^a	2.0±0.5^a
Chromium (Cr)	21.90±4.3^b	152.5±10.9^a	19.8±1.5^b
Copper Cu)	19.8±1.5^b	137.5±49.2^a	8.06±1.32^c
Lead (Pb)	61.2±4.7^b	126.4±25.7^a	40.3±3.1^b
Manganese (Mn)	439.3±89.3^b	725.6±141.8^b	929.6±71.9^a
Nickel (Ni)	16.0±3.5^b	32.6±5.30^a	12.23±2.6^b
Platinum (Pt)	12.9±7.90^a	1.15±0.1^b	2.9±1.1^b
Thallium (TI)	6.1±3.5^b	7.6±2.9^a	8.9±2.6^a
Titanium (Ti)	426.4±66.5^b	615.1±20.2^a	599.2±23.6^b
Uranium (U)	1.9±1.9^b	28.0±14.8^a	0.2±0.2^b
Vanadium (V)	37.8±3.7^b	152.7±10.9^a	46.5±2.97^b
Zinc (Zn)	736.6±433.3^a	610.7±102.9^b	92.4±9.1^c

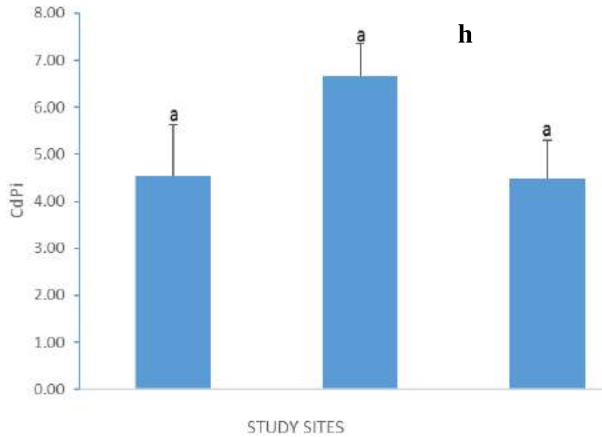
*Mean with different lower-case letters across the row represents significant differences in metal concentration among the study sites @ $p < 0.05$. Trucks engines workshop, SVB: Spraying of vehicle body.

The concentration of Zn followed the order of TEW > SVB > control. The concentration of Barium (Ba) in the workshop major in spraying of vehicle body was higher compared to the truck engine workshop and the control, but lower than the standard of 2000 mg/kg recommended by the Environmental Protection Agency (EPA) (Table 1). Workshop major in spraying of the vehicle body and the control has the highest concentration of TI concentration which was higher than the recommended value of 0.5 mg/kg by WHO. The concentration of Pt was significantly higher ($p < 0.05$) at TEW compared to SVB and the control site.

The pollution index of selected metals across the study sites

The workshop major in spraying of the vehicle body (SVB) had significantly higher Cr (CrPi), Cu (CuPi), Ni (NiPi), Pb (PbPi) and Zn (ZnPi) pollution index, compared to the workshop major in the truck engine and the control (Fig 3A, B, C, D and F). Although the workshop major in spraying of vehicle bodies has the highest cadmium pollution index (CdPi), there was no significant difference in the CdPi across the study sites (Fig 3e).





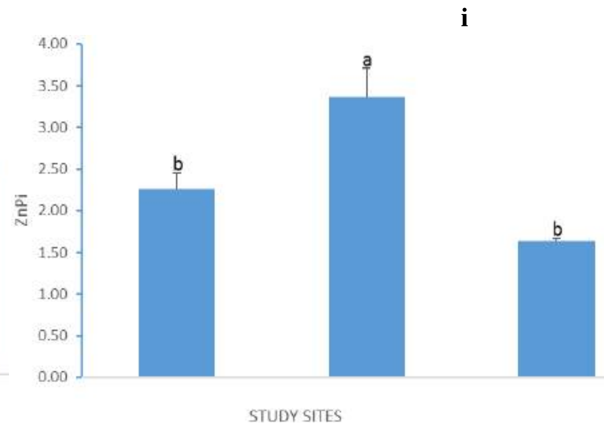
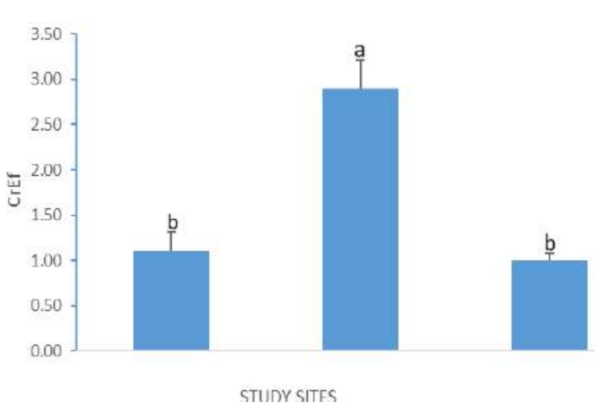
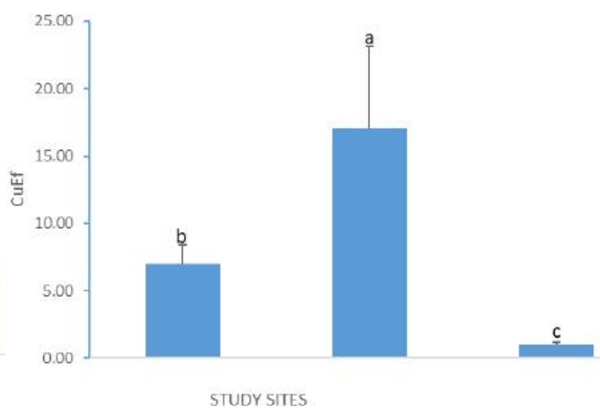


Fig 3. Pollution index of selected metals across the study sites**: (**a**)** Chromium pollution index, (b) Copper pollution index, (c) Nickel pollution index, (d) Lead pollution index, (e) Cadmium pollution index, and (f) Zinc pollution index. Bar with different lower-case letters represent significant differences among the study sites @ $p < 0.05$. TEW: Trucks engines workshop, SVB: Spraying of vehicle body.

Enrichment factor of selected metals across the study sites

The workshop major in spraying of body vehicle has the highest Cr (CrEf), Cu (CuFf), Ni (NiEf), Pb (PbEf) and Zn (ZnEf) enrichment factor as compared to the workshop major in the truck engine and the control (Fig 4a, b, c, d and f). Control site had the least Cu enrichment factor compared to the workshop major in the truck engine and spraying of the vehicle body (Fig 4b). There was no significant difference in the cadmium enrichment factor across the study sites, (Fig. 4e).





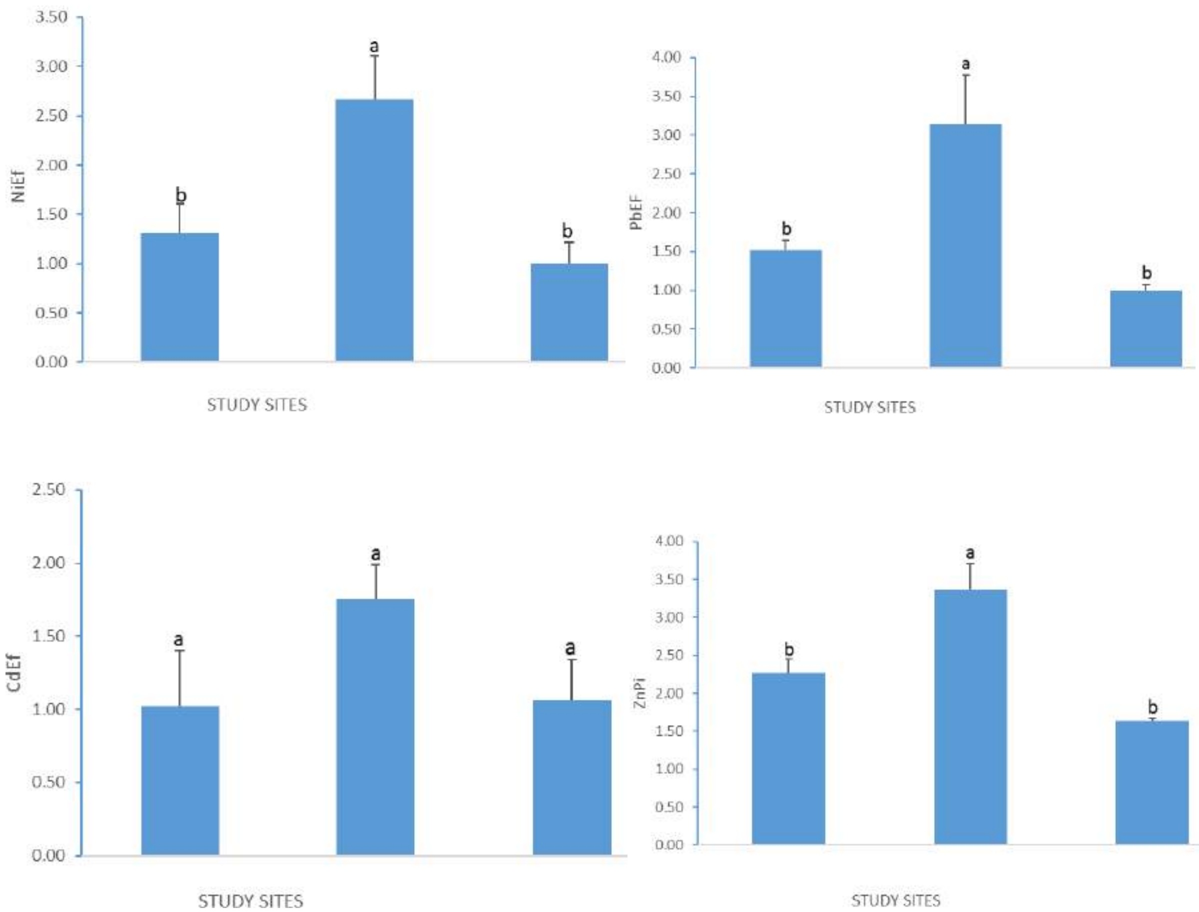


Fig 4. Enrichment factor of selected metals across the study sites. **(A)** Chromium enrichment factor, **(B)** Copper enrichment factor, **(C)** Nickel enrichment factor, **(D)** Lead enrichment factor, **(E)** Cadmium enrichment factor, and **(F)** Zinc enrichment factor. Bar with different lower-case letters represent significant differences among the study sites @ $p < 0.05$. TEW: Trucks engines workshop, SVB: Spraying of vehicle body.

DISCUSSION

In this study heavy metal concentration differed across the study site. While metals such as Ba, V, Cd, and Zn are within the permissible limit of EPA, Ti, Mn, and Pb are above the permissible limit. Metals such as Ba, Cd, Cr, Cu, Pb, Ni, Ti, U, and V were observed to be more concentrated in the soils of the workshop major in spraying of vehicle body parts than the on major in truck engine and control, suggesting intense auto-mechanic activities at this site than in the other two areas. The higher concentration of these metals corresponds with high organic matter content and low pH at this workshop. This indicates a greater bond of these metals to the topsoil due to their low mobility at the workshop major in spraying of vehicle body parts than the in-truck engine workshop and the control. Soil pH and OM could impact the mobility of metals in the soil (Caporale and Violante, 2016; Agyemang *et al.*, 2021). While low soil pH could boost the desorption of metals, high OM content could increase the buildup of metal pollutants in soils (Agyemang *et al.*, 2021). Furthermore, the present observation may also be attributed to the additives used in those workshops which consist of metals in various proportions (Agboola *et al.,* 2016)

The observed higher concentration of Ba, Cd, Cr, Cu, and Pb than the critical limit prescribed by WHO (1993; 1996) at the workshop major in the spraying of vehicle bodies is similar results of Orobator et al. (2019). Barium, with high negative consequences on the environment, is often used in auto-mechanic workshops, particularly in the form of barium sulfate (Adedokun *et al.*, 2019). It can degrade the soil structure and contamination of water resources (Agboola *et al.,* 2016). Cd and Pb are quite immobile and mostly persist in the soil for longer periods in an exchangeable form (Agyemang *et al.,* 2021). Moreover, activities such as the charging or improper disposal of batteries are known to be sources of Pb and Cd (Nna Orji *et al*., 2018). However, consistent with the findings of Ajeh et al. (2022), the observed Cd content across the study sites was below the permissible limit of EPA. Chromium and Cu are heavy metals commonly found in industrial settings, including panel fitting workshops (Agency of Toxic Substances, 2012). They are used in a variety of industrial processes, including metal plating, leather tanning, and paint production hence the reason for their higher concentration at the workshop major in the spraying of vehicle bodies. These results suggest a possible decrease in the soil nutrients and future deterioration of soil at a high rate at the workshop major in the spraying of vehicle bodies (Utang *et al.,* 2013).

Although the concentration of Zn and Pt across the study area was within the permissible limit of EPA, the workshop major in truck engine repair had the highest concentration of Zn and Pt while the control and workshop major in spraying of vehicle body had the least, respectively. This is expected as the engine exhausts, tire wear, degree brake pads, mechanical abrasion of vehicles and oil spills are the major activities at this site. The high rate of engine ignition of trucks at this workshop likely contributes more Zn than the other sites (Wei *et al.,* 2010). Although Pt is a precious metal commonly used in industrial settings, exposure to high concentrations of Pt can cause a variety of health issues in humans including respiratory disorders and lung cancer (WHO, 2005). The highest Mn content found at the control site and the least at the workshop major in truck engine repair suggest that the sources of Mn might be mainly natural and less anthropogenic. Moreover, Mn is a ubiquitous element in the environment which is distributed in the soils (Sharma *et al*., 2017). Uranium is a radioactive metal that is commonly found in industrial settings, including panel fitting workshops. Although the U content across the study sites is lower than the permissible limit of 30 mg/kg of WHO, there is a build-up of U at the workshop major in spraying vehicle bodies suggesting a potential health risk at this site. Exposure to high levels of uranium can lead to adverse health conditions including kidney damage, and cancer (WHO, 2006). Therefore, constant evaluation of the heavy metal content of this site is needed in order to precisely monitor the uranium load in its soil.

Using the pollution index as a quick tool to compare the heavy pollution level of the studied area, it was noted that the workshop major in spraying of vehicle bodies has the highest contamination load greater than the control and truck engine workshop. Contrary to the findings of Ajeh et al. (2022), these findings indicate that workshop majors in spraying vehicle body parts are more contaminated with Cr, Cu, Ni, Pb, and Zn at the moment. The enrichment factor of the metals across the studied site indicated that while the workshop major in spraying of the vehicle body is severely enriched with Cu, and moderately enriched with Zn, the control site and truck engine workshop exhibit moderate and minor enrichment of Cu and Zn, respectively. Consistent with the study of Rahman et al. (2022), it was observed that at the moment, the three studied sites a less enriched with metals such as Cr, Ni, and Cd. However, the workshop majors in spraying vehicle body parts is moderately enriched with Pb suggesting a potential environmental risk.

CONCLUSION

The severity of heavy contamination varies across the study sites as indicated by higher concentrations of elements such as Ba, Cd, Cr, Cu, Pb, Ni, Ti, U, and V. The findings of this study revealed that the concentration of metals including Cr, Cu, Pb, Ni, Ti, U, and V was higher in the soil sample collected from the workshop major in spraying of vehicle body parts than in the truck engine workshop and the control. On the other hand, the workshop major in truck engine repair has the highest Zn contents followed by the workshop major in major in spraying of the vehicle body and the control respectively. The pollution index and the enrichment factor indicate that the soil samples of the workshop major in spraying the vehicle body is at present moderately contaminated of which Cu, Ni, and Pb significantly contributed. Except for Pb, the comparison of the concentration of observed metal at TEW and control with the reference value of WHO and EPA indicated no current risk of health hazards for humans at those sites. However, when compared with the control site, this study indicates that artisanal activities including servicing of vehicle engines, spraying of vehicle bodies, and scraping of old vehicle bodies could contaminate soil if proper measures are not in place.

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Conflict of Interest

Authors declared that they have no known competing financial interests or relationships

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BIODIVERSITY CONSERVATION: CHECKLIST OF BOTANICALS USED DURING CHILD DELIVERY BY TRADITIONAL BIRTH ATTENDANT IN BAYELSA STATE, NIGERIA

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ABSTRACT

Plants play important role in human health especially in developing countries. Globally, about 70 – 80% humans sought for medical treatment from traditional herbal medicine practitioner. Plants abundant in the wild and they have been widely used for the treatment of several human and animal diseases. This study assessed the botanicals used during child bearing by traditional birth attendants in Bayelsa State, Nigeria. Semi-structured questionnaire and open-ended informal interviews were used to obtained data. Results indicated that females within the age of 50 and above with ≤ senior school qualification and inherited the practice from their family are the predominant people that use herbs for child delivery in Bayelsa State. Eleven botanicals which are distributed into 10 families were frequently used in preparing decoctions used by traditional birth attendants in Bayelsa State, Nigeria. The commonly used botanicals are *Elaeis guineensis, Vernonia amygdalina, Helianthus annuus, Carica papaya, Impatiens spp*., *Dioscorea* spp, *Arachis hypogaea, Eremophila thunderbolt, Digitaria sanguinalis, Capsicum* spp and *Aframomum melegueta.* The choice of herbs differs base on the locality and exact situation of the subject (pregnant women). Based on the identification of these plants, studies should be carried out to identify, isolate and purify the exact constituents of the plant that play essential role during child bearing.

Keywords: Bayelsa State, Child delivery, Medicinal Plants, Traditional birth attendants

INTRODUCTION

Plants have been a major source of medicine and food to human (Nwachukwu *et al*., 2010). As such plants are used as active ingredients in the treatment of several types of human and animal diseases in many regions of the world especially in developing nations (Alebiosu *et al*., 2012; Izah *et al.*, 2018a; Nwachukwu *et al*., 2010). In many rural communities, traditional medicine practitioners are mostly patronized due to cost of modern medicine and or/ their unavailability. Typically, medicinal plants have been widely reported to provide health coverage to 70 – 80% of world population though traditional approach especially in developing countries (Epidi *et al*., 2016a,b; Epidi, 2016; Kigigha *et al*., 2015, 2016; Tchouya and Nantia, 2015; Minochecherhomi and Vyas, 2014). Several authors have variously reported that medicinal plants are plant whose one or more parts (viz: root, leave, fruit, flower, stem-bark, latex etc) possess therapeutic properties (Epidi et al., 2016a,b; Izah *et al.*, 2018a-d; Izah and Aseibai, 2018; Kigigha *et al.*, 2018, 2016, 2015).

Several species plants belonging to different order, family and genus exists. The utilization of the plant parts depends on the knowledge of the indigenous of people of the area. Authors have variously reported medicinal plants in different regions and specific aliment they are for in Nigeria (Dike *et al*., 2012; Mohammed *et al*., 2014; Uzodimma, 2013; Eludoyin *et al*., 2015; Ekaiko *et al*., 2015). Typically, plants are found in nearly all regions of the world (Kigigha *et al*., 2016). The distribution of plants depends on the prevailing climatic and environmental conditions will determine the type of plants found in such areas (Kigigha *et al*., 2016).

The in-depth indigenous knowledge of traditional medicine practice have been preserved by the assistance of herbalists, herb sellers, herb collectors, hunters and other groups of people who have constant contact with nature, especially in rural areas (Borokini *et al*., 2013). The knowledge is often passed on from one generation to another orally especially to younger generation that are interested. Olatunji *et al*. (2014) reported that the knowledge and practices is mainly passed down orally and demonstration by elderly practitioners especially by a family member.

The medicinal potentials of plants have been attributed to their phytochemical, bioactive and essential oil constituents (Epidi et al., 2016a,b; Izah et al., 2018a-d; Izah and Aseibai, 2018). Plants are active ingredients used in the preparation of decoctions used by the birth attendants. Kayode *et al*. (2008) reported that several plants (viz: *Abelmoschus esculentus, Ageratum conyzoides, Anthocleista djalonesis, Aframomum melegueta Borrelia coriaceae, Baphia nitida, Bryophyllum pinnatum, Cissampelos owariensis, Costus alfer, Corchorus oliforius, Ficus exasperata, Myristica fragrans, Musa sapeintum, Ocimum gratissimum, Pisidium guajava, Piper guineense, Rauvolfia vomitoria, Sansevieria liberica, Tetrapleura tetraptera, Irvingia gabonensis, Jatropha* curcas) used for ante and post-natal and child delivery contains several diversity of bioactive constituents. Other plants that have been reported to be used child delivery process include *Aframomum melegueta, Capsicum frutescens, Carica papaya, Centrosema pubescens, Cochlospermum planchonii, Corchorus olitorius, Entandrophragma angolense, Euphorbia kamerunica, Jatropha curcas, Piper guineense, Piper nigrum, Spondias mombin, Talinum triangulare, Tetrapleura tetraptera, Ocimum gratissimum, Vernonia amygdalina, Xylopia aethiopica* (Olatunji *et al*., 2014; Uzodinmma, 2013; Chima *et al*., 2013; Kayode *et al*., 2008; Borokini *et al*., 2013).

Child delivery is carried out in hospital setting and traditional birth attendants. Unlike hospital that use drugs and other medical equipment during child birth, tradition medicine practitioners used herb to prepare decoction which are either rubbed on the stomach, drinked or inserted in the vulva. Economic factor including inadequate medical facilities, poor educational level, low-income size could be the reason for patronizing traditional birth attendants.

Plants used for post-natal care are usually prepared according to locally. For instance, Borokini *et al*. (2013) described the preparation of herbs used for post and ante natal and child birth delivery by Oyo, Ibadan, Oke-Ogun and Ibarapa peoples in notable cities include Ibadan (the State capital), Oyo, Ogbomosho, Saki, Okeho, Iseyin, Kishi, Eruwa and many others in Oyo state, Nigeria. Furthermore, Chima *et al*. (2013) also reported that plants used in the treatment of ante-natal and post-natal disorders in Nneochi Local Government Area of Abia State, Nigeria. But information about plants used by traditional birth attendant is Bayelsa state appears scanty in literature hence the need for this study.

MATERIALS AND METHODS

Study area

Bayelsa is one of the States in southern Nigeria. Bayelsa state shares boundary with Atlantic Ocean, Delta State and Rivers State. Yenagoa is the state capital. The state was created in 1996 from of Rivers State with 8 local government area at present. The state lies in the sedimentary basin characterized by riverine and estuarine setting. Many communities are almost (and in some cases) completely surrounded by water, making them inaccessible by road. The climatic characteristics is peculiar to other region of the Niger Delta that have been widely reported by authors (Ben-Eledo *et al*., 2017a,b; Seiyaboh *et al*., 2017a - c; Seiyaboh and Izah, 2017a,b; Ogamba *et al*., 2015a,b,c; Izah *et al*., 2017a-c, 2018e).

Data acquisition

The main data source consists of semi – structured and open-ended questionnaires as well as informal interviews administered on traditional birth attendant in Bayelsa state, Nigeria. The questionnaire administration and interviews were done in their native (Ijaw) as well as English language depending on the educational qualification of the birth attendant. The pictures, Ijaw and common names were given by the birth attendant, scientific names were sorted by using plant of the Niger Delta by Nyananyo (2006). The respondents provide information on the preparation and role of each of the plants. Socioeconomic characteristics (gender, education status, age, etc.) of the respondents were also obtained.

RESULTS AND DISCUSSION

Table 1 indicated that a total of 10 people were interviewed for traditional birth attendants practice in Bayelsa State, Nigeria. Of the 10 respondents, 2 (20%) were males while the remaining 8 (80%) were females. 90% of the respondents were within 51 - >70 years of age. Based on educational status, 60% has senior school certificate (SSCE), while 30% had first leaving school certificate as the highest qualification 10% do not have any formal education while none of them had degree/ national certificate in education (NCE)/ ordinary national diploma (OND). Furthermore, 100% of the respondents indicate that they learn the trade from their parents and grandparents (family history). Also, all the respondent are Ijaw by tribe or ethnicity.

The socioeconomics characteristics of the respondents (Table 1) showed that female practice the use of herbs in child delivery in Bayelsa State based on gender. The has similar trend with the work of Olatunji *et al*. (2014) that reported that 70% and 30% of female and males respectively in Yalgba local government area of Kogi State. Borokini *et al*. (2013) reported 58.1% and 41.9% for females and males involved in traditional medicine practice of women health in Oyo State. Based on age grade, elderly people (>50 years) are involved in child delivery in Bayelsa State. This is contrary to the value of 92.8% of individuals whose age were less than 50 years that are involved in herbal medicine practice in Yalgba Local government area of Kogi State by Olatunji *et al*. (2014). Borokini *et al*. (2013) reported also reported all the traditional medicine practitioners in Oyo State is above 40years, with 67.7% being within the age of 41 – 50 years. Based on education qualification, Olatunji *et al*. (2014) reported that 52.9%, 40.0% and 7.1% have less than FSLC (no formal education at all), only FSLC and higher degree, respectively among traditional medicine practitioners in Yalgba LGA of Kogi State. Borokini *et al*. (2013) reported that 58.1% and 32.3% of herbal medicine involved in women health have no formal education and only FSLC respectively. Based on these findings it can be deduced that most herbal medicine practitioners have low educational standard, and may not have idea about the scientific role of the herbs with regard of desired dose and body requirement. The variation suggests that basic demographic characteristics of an area influence the life pattern of the people.

Table 1: Socioeconomics structure of traditional birth attendants in Bayelsa State

Structures	Items	Frequency (10)	Percentage (%)
Gender	Male	2	20
	Female	8	80
Age	<50	1	10
	51-55	2	20
	56-60	2	20
	61-65	1	10
	66-70	2	20
	>70	2	20
Educational qualification	No formal education	1	10
	FSLC	3	30
	SSCE	6	60
	OND/NCE/Degree	0	0
Skill acquisition source	Learning from older people	0	0
	Family history	10	100
	No formal training	0	0

A total of 11 plants were identified belong to 10 families (Table 2 and 3). Several parts of the plants including leaves, stem, seed and root are used. The decoctions of the plants are prepared with 1 or more plants. The plants are distributed into 10 families including Arecaceae, Asteraceae, Balsaminaceae, Caricaceae, Dioscoreaceae, Fabaceae, Liliaceae, Poaceae, Solanaceae, and Zingiberaceae. The Asteraceae has two plant species including *Vernonia amygdalina* Del. and *Helianthus annuus* L. The use of plant for medicinal properties appears to vary from place to place. Furthermore, the medicinal potential of a plant known by traditional medicine practitioners are passed on from one generation to another.

The survey showed that individuals still patronize traditional birth attendants in Bayelsa State. Most of the herbs mentioned in this study have been documented and are also used in managing women reproductive health in Oyo State, Nigeria. Borokini *et al*. (2013) reported that alligator peppers is used in preparing decoction used in boosting breast milk production, reproductive problems in women, post-natal care. The authors also reported that pawpaw is used during antenatal, and as contraceptive decoction preparation. They further stated that paw-paw, bitter leaf is used for delayed birth (prolonged child labour) and easy delivery.

The mode of application includes infusion, decoctions, maceration, squeezing, soaking, pounding, drying and pulverization of the various parts. This typically depends on the type of preparation being carried out. These types of application have been reported by Borokini *et al*. (2013).

In different part of Nigeria, some of these plants identified in Bayelsa state have been reported to have medicinal properties against several times of diseases. For instance, alligator pepper is used to treat stroke, cough (fruit), (Olatunji *et al*., 2014). Like fruit of pepper, leaves and seed of pawpaw, leaves and fruits of oil palm, seed of alligator pepper is used in preparing decoctions used in the treatment of several kinds of disease (Kayode *et al*., 2008)

Leaves of pawpaw is used to treat jaundice, head ache (Olatunji *et al*., 2014). Uzodinmma (2013) reported ripe fruit, root, leaves of pawpaw is used as active ingredients for the treatment of malaria and typhoid fever, venereal diseases, eye infection, and smoothing of face. Alebiosu *et al*. (2012) reported that leaves and fruit of pawpaw have anti-ulcer, anti-inflammatory, laxative and wound healing potentials.

Root of oil palm is used to treat convulsion (Olatunji *et al*., 2014). Uzodinmma (2013) reported that palm oil from fruit of oil palm tree is used as anti-poison, while kernel oil from seed of oil palm can be used as cough suppressant. The anti-poisive potentials of palm oil could be associated to the present of anti-oxidants in it. Chima *et al*. (2013) reported that part of oil palm tree is used in preparing decoctions used for the treatment of infertility, breast lump, placenta delivery, womb cleansing, difficulty with breast – milk production, anaemia, miscarriage, umbilical wound etc.

Uzodinmma (2013) also reported that leaves and bark bitter leaf tree can used to treat cough, malaria, stop bleeding, and manage diabetes. Several other studies have suggested that bitter leaf have anti-cancer, anti-parasite, anti-oxidants, antipyretic and antimicrobial properties. The claims of have been scientifically validated. The fruit of chilli pepper are used in the treatment of ulcer (Alebiosu *et al*., 2012). In addition, chilli pepper has anti-cancer and anti-rheumatisms properties (Alebiosu *et al*., 2012). Furthermore, it has been scientifically validated that pepper have antimicrobial, respiratory problems, bowel complaints, ear-aches, and sores potentials.

Table 2: Plant preparations used for child birth in Bayelsa State

S/N	Plants name	Preparation	Implication
A	Crab grass	2 to 3 stem of the grab grass is washed and then washed. Then after the plant is pounded in mortal and pestle. The mashed grab grass is filtered and the extracts is injected into the vaginal of the women in labour	The extracts strengthen the woman and ease safe delivery
		Alternative preparation: the stem of the grab grass and its root is chewed with seven seed of alligator pepper (*Aframomum melegueta*) by a woman under labour	The extract which is swallowed aid in safe and quick delivery
B	Bitter leaf	The leave is chewed with alligator pepper and the mixture is swallowed. Furthermore, for children too big and/ or hooked up in the socket bone, the woman is massaged by centralizing the womb and or the child.	This aid to strengthen the woman under labour and for quick delivery
C	Alligator pepper	The seed of alligator pepper is chewed by the woman under labour to ease off pain	This help in speedy delivery
D	Yam	The fresh yam is mashed and used to rub the stomach of the woman under labour.	This gives much itching to the child in the womb and its facilitate safe delivery
E	Ground nut	A cup of fresh ground nut is socked for some minutes and the peels are removed. Thereafter, the groundnut seed is mashed and placed in a bottle	This aid to boost breast milk

		containing approximately 75cl of water. The mixture is filtered and the woman under labour drinks the extracts/filtrate during labour	
F	Pawpaw	The root of paw-paw is chewed with seven seed of alligator pepper	This aid to stop bleeding immediately after child delivery
G	Pepper	The root of pepper is chewed with seven seed of alligator pepper	This aid to stop bleeding immediately after child delivery
H	Palm wine tree	Seven pieces of dried palm wine tree leaf is chewed with alligator pepper. The mixture is rubbed in the belly of the woman experiencing miscarriage starting from the down of the belly to the navel. After which the birth attendant spit the rest chewed mixture on air saying “the child should stick or hold to heaven” Before using this method blood will not come cut first, rather pain of the stomach or womb will be the sign. On getting to month, the birth attendant has to reverse the statement after she must have chewed the same number of alligator pepper and palm wine tree leaves as previously chewed. This time spiting from the mouth staring from little below the breast down to the navel where it will stop. After that, the birth attendant will reverse the statement by saying “the child should come down and enter or hold to the womb of his mother” if the statement is not reversed, the woman will not give birth according to the believe	This aid in preventing miscarriage and showing that once believe is vital in child birth
I	Sun flower	The leaves of sunflower is squeezed and inserted into the virginal.	This aid to open the vulva for easy child delivery
J	Abol-Otuo (Ijaw name)	The leaves of Abol-Otuo is washed with mashed with a cup of water and then filtered. The extract is boiled with a bottle of ground nut oil. Its boiled till all the water have evaporated. The remaining oil is allowed to cool and poured into a bottle. The oil is taken by woman under labour.	This facilitate delivery processes
K	Thunderbolt (Ijaw name)	Soak the leaves of thunderbolt in an alcohol for 24 hour. Give some quantity to a woman under labour until she deliver safely	This aid to relax the vulva for easy child delivery

Table 3: Part of the plants used and their brief taxonomy

Family	Scientific name	Common name	Local/Ijaw name	Part used
Balsaminaceae	*Impatiens* spp.	Jewelweed	Abol-Otuo	Leaves
Arecaceae	*Elaeis guineensis* Jacq	Palm wine tree	Okain (Okine)	Dried leave
Asteraceae	*Vernonia amygdalina* Del.	Bitter leaf	Orugbo-Ikinmu	Leave

Asteraceae	*Helianthus annuus* L.	Sun flower	Inuntuko	leaves
Caricaceae	*Carica papaya* Linn.	Paw-paw	IDamda Ikinmu	Root
Dioscoreaceae	*Dioscorea* spp	Yam	Baru	Tuber
Fabaceae	*Arachis hypogaea* L.	Groundnut	Apapa	Seed
Liliaceae	*Eremophila Thunderbolt*	Thunderbolt	Thunderbolt	Leaves
Poaceae	*Digitaria sanguinalis* L. Scop.	Crab grass	Angolo	Stem, root
Solanaceae	*Capsicum* spp	Pepper	Igina Ikinmu	Root
Zingiberaceae	*Aframomum melegueta* (Rosc.) K. Schum.	Alligator pepper	Sanni	Seed

Conclusion and Recommendations

Medicinal plants are plant whose parts including root, stem, bark, flower, fruit, leaves etc have pharmacological purposes. In developing country about 80% of people patronize traditional herbal home. This study assessed the botanical used by traditional birth attendants in Bayelsa state Nigeria. The study found that *Elaeis guineensis*, *Vernonia amygdalina*, *Helianthus annuus, Carica papaya, Dioscorea* spp, *Arachis hypogaea*, I*mpatiens* spp, *Eremophila thunderbolt, Digitaria sanguinalis, Capsicum* spp, *Aframomum melegueta* are common plants used to prepare decoction used during child bearing by traditional birth attendants in Bayelsa State, Nigeria (Figure 1). The choice of herbs depends on the locality and knowledge about the medicinal properties. Patronizing of traditional birth attendants is usually higher among low educational pollution class, and unavailable or under equipped hospital facilities. The study also found that the practice is mostly based on from one generation to another through family. Based on the findings of this study quantification of dosage seems to the absent. Hence, attempt should be made to quantify the amount/dosage of the extract used during the delivery processes. As much as utilization of these plant species is important, effort should be made for their sustainable use and biodiversity conservation, particularly in their natural habitats.

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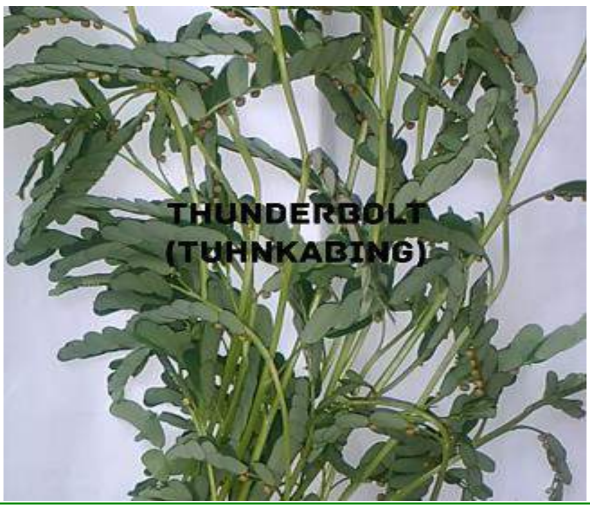

Thunderbolt

Bitter leaf

Crab grass

Sunflower

Ground nut seed

Alligator pepper

Pawpaw

Pepper

Dried oil palm leaves

Abolo-Otou (Ijaw name)

Figure 1: Plant species used for child delivery in Bayelsa State

Peer-Reviewed Abstracts

CLIMATE CHANGE ADAPTATION PRACTICES AND FOOD CROP FARMERS' PRODUCTION EFFICIENCY IN NIGERIA

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ABSTRACT

The research sought to determine the impact of climate change adaptation strategies (CCAS) on the production efficiency of Nigerian food crop producers. A multi-stage sample strategy was utilized to choose 480 rural farming families from three different states in Southwest Nigeria. The descriptive and Tobit regression methods were used to examine the data. The majority (76.0%) of respondents were married, with mean age, household size, and farm size of 47.1 years, 5.31 individuals, and 3.77 hectares, respectively, and 72.0% earning less than ₦100,000 per year from farming. Crop diversification is the most common CSA applied in the research region. The Tobit regression result revealed that gender, farm size, interaction with extension agents, and climate change adaption techniques such as crop diversification, mulching, and crop rotation all had a substantial impact on farmers' production efficiency. The research revealed that farmers in Nigeria production efficiency were impacted by climate change adaptation techniques used in their agricultural operations. Climate change adaptation measures that maintain agricultural sustainability in rural communities by reducing the effects of climate change should be promoted and encouraged by the government and all stakeholders

Keywords: Adaptation strategies**,** Climate change, Crop diversification, Tobit Regression.

HEALTH RISK ASSESSMENT OF HEAVY METAL UPTAKE BY VEGETABLES IRRIGATED WITH BATHROOM WASTE WATER IN MAGONGO, KOGI STATE, NIGERIA

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ABSTRACT

Irrigation of vegetables with bathroom effluent is a common practice in Magongo community in Kogi State owing to water scarcity. Some bathroom effluents are reported to contain heavy metals. The study assessed potential health risks associated with consumption of vegetables grown behind local bathrooms where the bath water irrigates the vegetables. Twenty-four samples of three different types of vegetables were analyzed using Atomic Absorption Spectrophotometer (AAS). The range of heavy metals in the vegetables were Cr (1.84mg/kg-2.5mg/kg) , Ni(53.76mg/kg - 64.65mg/kg), Pb(0.26mg/kg-0.31mg/kg) in T*elferia occidentalis;* Cr (2.15mg/kg-2.73mg/kg), Ni(63.46mg/kg-67.75mg/kg), Pb(0.29 mg/kg-0.36 mg/kg) in *Tallinum triangulare* ;and Cr (1.07mg/kg-2.21mg/kg), Ni (35.36 mg/kg-44.56 mg/kg), Pb(0.23mg/kg-0.28mg/kg) in *Vernonia amydalina*. The mean concentration of heavy metals was generally within the FAO/WHO permissible limits except for Cr in *Tallinum triangulare*. The health risk indices for consumption of T*elferia occidentalis* and *Tallinum triangulare* were higher than 1 for Cr in adults and children and Pb for children respectively. A strong correlation exists between the soil heavy metal content and the metal levels in the vegetables. It is recommended that consumption of vegetables irrigated with bathroom effluent be discouraged as its cumulative effect over time could have some serious health implications.

Keywords: Health risk, Vegetables, Heavy metals, Bathroom effluent, Heavy Metals uptake.

PHYTOEXTRACTION ABILITY OF TWO ORNAMENTAL PLANT SPECIES

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ABSTRACT

This study investigated heavy metal uptake ability of *Azadiracta indica* and *Polyalthia longifolia* in soil enhanced with different levels of cow dung. A Complete Randomized Design was adopted for the study. Two (2kg) of homogenous composite soil was weighed using a calibrated (Setra 80S, USA) weighing balance into 50 planting bags of 8cm height, 14cm diameter and surface area of 0.095 m^2. The planting bags were arranged into 4 groups of 5 replications, while another 5groups with 5 replications was filled with the reference. Cow dung concentrations of 100g, 200g and 300g was weighed into group 1, 2 and 3 respectively while group 4 and 5 with 0g of cow dung (polluted soil) stands as control and double control (referenced soil) respectively. After two weeks of post remediation, the entire experiment was divided into set A and B as seedlings of *Azadiracta indica* and *Polyalthia longifolia* were transplanted from the nursery unit into set A and B respectively. Findings showed that the addition of different levels of cow dung amendments enhanced plant morphological characters, metal availability and mobility in the biomass of the studied plant species. It also caused a decrease in soil pH and conductivity and triggered increase in the concentration of some soil essential nutrients such as potassium, phosphorus and nitrogen. Translocation factor and bioaccumulation factor greater than 1 was observed inthe test plants grown in treated soils at various levels. This showed that metals were more concentrated in studied plants than soil. *Azadiracta indica* and *Polyalthia longifolia* had the potentials to accumulate cadmium, lead and zinc in their biomass when grown in cow dung amended soil. Highest increment in plant height were in the order300g (2weeks), 0g unpolluted (4 weeks) and 200g cow dung (6 and 8 weeks) for *Polyalthia longifolia*, while *Azadiracta indica* indicated 200g (2 and 6 weeks), 300g (4 and 8 weeks). The study therefore recommends that 200g cow dung amendment has the potential to enhance the bioavailability and mobility of Zn, Cd and Pb in shoots and roots of *Azadiracta indica* and *Polyalthia longifolia.*

Keywords: Phytoextraction; *Azadiracta indica,Polyalthia longifolia*, cow dung, heavy metals. Phytoextraction, soil chemical properties.

EVALUATION OF RODENTICIDAL POTENTIAL OF YELLOW OLEANDER (*Thevetia neriifolia* Tuss.) SEED POWDER IN WILD AFRICAN GIANT RAT (*Cricetomysgambianus*Waterhouse)

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ABSTRACT

Rodents cause huge economic damage to crops. *Cricetomys gambianus*is a most destructive rodent pest species in the tropics. Chemical control of rodent poses health and environmental problems. *Thevetia neriifolia* Tuss. (yellow oleander)seed has shown good rodenticidal potential in the laboratory against rodents. However, the rodenticidal activity of itsseed has not been evaluated in wild rodent species. Therefore, the study aimed at evaluating the rodenticidal potential of *Thevetia neriifolia* seed powder in wild female *C. gambianus*. The study was conducted in Ecology Research Laboratory, Department of Crop Protection and Environmental Biology, University of Ibadan. Twenty wildly caught female African giant rats were acclimatized for 4 weeks and randomly allocated into 4 groups (5 individuals/group) including control. The *T. neriifolia* seeds were sundried, blended into powder, and mixed with a commercial feed with four to form concentrations (20%, 40%, 60%, and 0%) and then turned to pellet. The acclimatized animal groups were fed with appropriate concentrations of the formulated feed for 8 weeks. Body Weight (BW) andDaily Feed Intake (DFI) of the animals were taken. At termination, the blood sample of the animals was collected for hematology and serum biochemistry analysis. Tissue samples (Kidney, Liver, and Heart) were also collected for histopathology analysis. Data were analyzed in SPSS using ANOVA and means separated using DMRT at $\alpha_{0.05}$. The results showed no significant effect on the mean BW and DFI. No mortality and behavioral changes were observed in the animals at all the concentrations. The difference in the Hematology and serum biochemistry parameters showed no statistical significance among the groups.
In conclusion, *T. neriifolia* seed powder does not have rodenticidal effect on the wild female *C. gambianus*. Therefore, it could not be used as a rodenticide in wild rodent species.

Keywords: African Giant Rat, Economic Damage, Yellow Oleander, Rodenticide

PHYSIOLOGICAL RESPONSES OF *Vigna radiata* GROWN UNDER ARSENIC STRESS TO FOLIAR APPLICATION OF NANOCERIA

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ABSTRACT

The study was carried out to determine the physiological responses of enzyme and antioxidants in three cultivars of mungbeen grown under different concentrations of arsenic to foliar application of nanoceria. Seeds of three cultivars of mungbeen utilized for the study were obtained from International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The seeds were sown in pretreated soil in a nursery and watered. Seventy two experimental pots were obtained and were filled with the pretreated topsoil. The seventy two pots were divided into four groups of eighteen pots each. The soil in each group of pots was then contaminated with 0. 20, 50 and 100 mg/L of As respectively. Of the mungbean cultivars were transplanted into the pots at density of two plants per pot and allowed to stabilize fourteen days after when foliar application of nanoceria was carried out. The application was repeated at two weeks interval for six weeks. At maturity, root and leaves of the three cultivars under different treatments of As were taken for analyses for Catalase (CAT), Ascobic Peroxidase (APX), Super Oxide Dismutase (SOD), Glutathione Peroxidase (GPX). Anti oxidant compounds (Phenolics , Flavonoids, Prolline, Ascorbic acid and Sugar) were determined using standard methods. The data obtained were subjected to two way analysis of variance and means were separated using. Foliar application of nanoceria significantly enhanced enzyme activities in the leaves and roots of the three cultivars of mungbeen grown under different concentration of arsenic. There was a significant effect of nanoceria on antioxidant activities in the leaves and roots of plants grown under different arsenic concentrations.

Keywords: *Vigna radiata*, physiological responses, Nanoceria, Arsenic compound, Soil contamination

ENZYME AND ANTIOXIDANT ACTIVITIES OF *Vigna subterraenea* (L.) Verdc GROWN UNDER CADMIUM STRESS AS AFFECTED BY FOLIAR APPLICATION OF CERIUM OXIDE NANOPARTICLES.

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ABSTRACT

This study was carried out to investigate the enzyme and non-enzyme antioxidant activities of *Vigna subterraenea* grown under different concentrations of cadmium with foliar application of cerium oxide (CeO_2) nanoparticles. Seedsof Bambara nut used for the study were collected from Genetic resource center, IITA, Moniya, Ibadan, Nigeria. The seeds were sown in the nursery and transplanted to soil already spiked with different concentrations of Cadmium (0, 20, 50 and 100mg/L) after establishment. Fourteen days after transplanting, plants in each pot in the different treatment regimes were sprayed with 25mL of 200mg/L of cerium oxide (CeO_2) nanoparticles. This was done for six weeks at fourteen days interval. At harvest, plants from the different treatment regimes were harvested and separated into leaves and roots. Enzyme analysis of Catalase (CAT), Superoxide dismutase (SOD), Polyphenol dismutase (POD), Ascorbate peroxidase (APX) and Glutathione peroxidase (GPX) were carried out in the leaves and roots of the harvested plants. Antioxidant like Flavonoids, Sugar, Proline, Ascorbic acid and Phenols were also carried out in the leaves and roots of the plants. Data obtained from the study were subjected to two-way analysis of variance and means were separated using t-test. Results obtained from the study showed that application of cerium oxide (CeO_2) nanoparticles enhanced the enzyme as well as antioxidant activities in the root of the three cultivars of Bambara nut under Cd stress. Meanwhile, there were variations in the concentration of the antioxidants in the leaves as influenced by cerium oxide (CeO_2) nanoparticles under different concentrations of cadmium. It is concluded that in the three cultivars of Bambara nut used, enzyme as well as antioxidant activities of the stressed plants were enhanced by foliar application of cerium oxide (CeO_2) nanoparticles.

Keywords: *Vigna subterraenea, Cadmium stress, Foliar application,* Cerium oxide, Nanoparticles

AN EXAMINATION OF LOCAL AND REGIONAL AGROECOLOGICAL FOOD SYSTEMS

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ABSTRACT

This paper focused on the processes involved in adopting agroecological food systems in the light of the pressing need for food security, which is further complicated by a changing climate that affects agriculture and how food is distributed, as well as how it is influenced by these aspects. Using online database, the traits of an agroecological food system were determined to be: reducing the number of external inputs used, recycling internal resources as much as is practical, being robust and multifunctional, raising system. Complexity, and improving system integration, to mention a few. Contextuality, equity, and nourishment round out the list. The review concentrates on the context of city-region food systems and offers some helpful recommendations for expanding the usage of more agroecological food systems in city-region settings. Using multi-actors design, agroecological food systems are developed in rural, peri-urban, and urban regions. These systems are extremely complex and context-dependent. Finally, it is concluded that, agroecologically contextualised food systems require strong social organisation, community growth shared learning, and knowledge creation in addition to the backing of suitable institutional and legal frameworks.

Keywords: Food system, External inputs, agroecology, Legal frameworks, Natural resources

GROWTH AND PIGMENT ACCUMULATION IN MAIZE (*Zea mays* Linn.) GROWN UNDER AFRICAN ARMYWORM INFESTATION IN RESPONSE TO FOLIAR APPLICATION OF CALCIUM SILICATE

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ABSTRACT

The study was carried out to determine the effects of different levels of silicon applications on the growth and pigment accumulation of maize (*Zea mays L.*) subjected to African armyworm (*Spodoptera exempta*). Seeds of two varieties of maize utilized for the study were obtained from International Institute of Tropical Agriculture, Ibadan, Oyo State, Nigeria. The seeds were sown in pretreated soil in a nursery and watered until the seedlings were fully established. The seedlings were later transplanted into sixty-four plastic pots with holes bored at the bottom at the rate of two seedlings per pot. Seven days after transplanting, foliar application of calcium silicate was done at different level of concentrations (0mM, 100mM, 150mM and 200mM). Plants in the sixty-four pots were then divided into two groups of thirty- two pots each. Armyworms were introduced to plants in the first thirty-two pots while the plants in the second thirty-two pots served as control (without armyworm). Measurement of morphological parameters such as plant height, numbers of leaves, leaf area were taken at seven days intervals. At harvest, photosynthetic pigments were extracted using 80% acetone and chlorophyll a, chlorophyll b, total chlorophyll and carotenoid was determined using Beer- Lambert expression. Fresh weight and dry weight of plants were also taken at harvest. A statistical analysis was performed using Statistical Analysis System (SAS)and the test of significance of means was carried out by Duncan's Multiple Range Test (DMRT).The results obtained showed that foliar applications of calcium silicate significantly enhanced the morphological parameters studied when compared with plants under armyworm infestation without foliar application of calcium silicate.

Keywords: *Zea mays*, Chlorophyl, Calcium silicate, Foliar application, Armyworm

EMERGENCE AND EARLY GROWTH RESPONSE OF TWO VARIETIES OF*Hibiscus sabdariffa* L. TO GROWTH MEDIA AND MANURES

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ABSTRACT

Despite the substantial values of both red and green Roselle (*Hibiscus sabdariffa*), many constraints still limit the production and yield of quality calyces and seeds in the fields. The study evaluated the emergence and early growth response of two varieties of *Hibiscus sabdariffa* to growth media and manures. Three different growth media filled singly and in combination into 5kg polythene pots were used for the growth media experiment while two organic manures (poultry droppings and cow dung) and N.P.K 15:15:15 were used as inorganic fertilizer for the manures experiment. The experiments were completely randomized with four replicates each for the two varieties. Data collection for study 1 commenced a week after emergence and done continued weekly for eight weeks while study 2 data collection commenced a week after application of N.P.K fertilizer. All data obtained were subjected to percentages and Analysis of Variance (ANOVA) at 0.05 level of probability. The result indicated that top soil supported the red variety (100%) while the green variety responded better to top soil + river sand (100%) for their emergence. For the green variety,top soil + river sand gave the highest mean height of 31.25cm while for the red variety. River sand gave the highest height of 28.75cm. For the manure experiment, Poultry manure produced the highest mean values of 31.75cm and 31.50cm while Control recorded the least mean values of 24.25cm and 24.13 for green and red varieties respectively. The use of Poultry manure should be encouraged among farmers because of its superior performance compared to other nutrient sources. Also, the two varieties of *H. sabdariffa* responded well on top soil and require no special media for emergence and growth.

Keywords: Inorganic fertilizer, Growth media, *Hibiscus sabdariffa*, Organic manure, Varieties.

PERFORMANCE OF TOMATO (*Solanum lycopersium* L.) ON A MARGINAL SOIL AUGMENTED WITH *Bacillus subtilis*, *Pseudomonas aeruginosa* AND POULTRY MANURE

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ABSTRACT

Tomato (*Solanum lycopersicum* L.) is an economically important crop that requires proper nutrient management for optimal growth and yield. Many of arable soil types in Nigeria are low in total nitrogen and available phosphorus, which cause poor growth and remarkable reduction in tomato yields. Application of bio-fertilizers appears as a sustainable mean of reducing the amounts of chemical fertilizers use in tropical agroecosystem, but Information is sketchy on their effects of in improving performance of tomato in the region. This study investigated growth, yield and biomass distribution of tomato in response to poultry manure application, *Bacillus subtilis* and *Pseudomonas aureginosa* inoculants on marginal soil. The experiment was carried out at the rooftop garden of the Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan. The pot experiment was laid out in a completely randomized design with six replicates. Seven treatments, comprising: poultry manure, *Bacillus subtilis, Pseudomonas aeruginosa,* a combination of poultry manure and *P. aeruginosa,* combination of poultry manure and *B. subtilis,* single superphosphate combined with Urea, while unamended soil served as control. Data on number of leaves, plant height and stem diameter, were collected to assess performance of tomato in response to the applied amendments. Days to flowering, days to fruiting, numbers of fruit and weight of fruits were also determined. The data were analysed with ANOVA and means were separated with Duncan's multiple range test. Tomato plants on soil fertilized with a combination of urea and single super phosphate produced the highest number of leaves (22.25±7.21), which was not significantly different from the number of leaves (19.33±4.36) produced by plant grown on soil augmented with a combination of poultry manure and *P. aeruginosa*. However, tomato plants grown on soil amended with the combination of poultry manure and *P. aeruginosa* were tallest (46.58±8.21 cm), while tomato plant on soil amended with the poultry manure recorded the highest stem diameter (0.95±0.12 cm). In addition, the shortest day to flowering (29±2.48 days) was observed in tomato plant grown on soil amended with combination of poultry manure and *P. aeruginosa,* while the shortest day to fruiting (71±0.41 days) was observed in tomato plant grown on soil amended with a combination of urea and single super phosphate. Highest number of fruits (4±2.53) and fruit mass (52.83±22.47 g) was recorded in tomato plants grown on soil amended with combination of poultry manure and *P. aeruginosa.* Combination of poultry manure and *Pseudomonas aeruginosa* improved growth and yield of tomato.

Keywords: Tomato yield, Poultry manure, Bio-fertilizer, *Bacillus subtilis*, *Pseudomonas aeruginosa*, Soil amendment.

FLORISTIC ATTRIBUTES OF SEED BANKS OF SOILS UNDER CONVENTIONAL AND ORGANIC FARMING SYSTEMS IN IBADAN, SOUTHWEST NIGERIA

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ABSTRACT

Soil seed banks (SSB) contribute to productivity, diversity and dynamics of agro-ecosystems. In spite of their ecosystem functions, there are conflicting reports about their comparative ability to replace standing vegetation under conventional and organic farming systems. This study aimed at determining variations in floristic attributes of standing vegetation and SSB under these two farming systems in Ibadan, Nigeria. Four conventional and four organic farms were purposively selected in Ido and Akinyele local governments in Ibadan, Nigeria. Ten quadrats (50 cm X 50 cm) were laid in each farm for floristic enumeration using random sampling technique. All flora rooted within each quadrat were identified, enumerated and classified. Soil samples randomly collected at two soil depths (0-15 cm and 15-30 cm) from each farm were monitored in six seed trays three replicates laid in completely randomized design. Seedlings emergence were monitored for three months to evaluate the community structure of the SSB. Data were analyzed using relative importance values (RIV), Shannon-Wiener (SW) and Jaccard indices (J). Seedling emergence profile showed that family Poaceae had the highest number of species (8 and 11) in conventional and organic bank respectively. *Tridax procumbens* had the highest RIV (15.47 and 9.89) for conventional and organic farm respectively. *Ageranthum spinosus* had the lowest RIV (0.37) for conventional farms while *Cyperus esculentus* has the lowest (0.46) for organic farms. SW diversity index, was higher (3.192) for organic than conventional farms (2.739). The J indicated low percentage relationship (25.3%) between the SSB and standing vegetation of organic and conventional farms. The SSB of the studied organic farms were richer in species composition and diversity than those of conventional farms in Ibadan, Nigeria. While the two SSB were comparatively less associated, the SSB of organic farms had better prospect to replace standing vegetation and hence more resilient than those of conventional farms.

Keywords: Organic farms, Conventional farms, Standing vegetation, Soil seed bank, Ecosystem resilience.

GROWTH, YIELD AND PROXIMATE COMPOSITION OF *Celosia argentea* L. IN RESPONSE TO *Pseudomonas aeruginosa*, POULTRY MANURE AND UREA FERTILIZER APPLICATION

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ABSTRACT

The intensive usage of artificial N fertilizers in agriculture causes rapid decline in soil fertility and crop productivity which indeed is a great hindrance to achieving food sufficiency. The application of organic fertilizers and biofertilizers present a more sustainable method of food production. Nonetheless, there is scanty information on the effect of biofertilizers on improving nitrogen status of soil used for vegetable production. This study investigated growth, yield and proximate composition of Celosia (*Celosia argentea* L.) as influenced by poultry manure, *Pseudomonas aeruginosa* and urea fertilizer on loamy sand soil. The experiment was carried out at the rooftop garden of the Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan during 2022-2023 growing season. Five treatments comprising four soil amendments- poultry manure, *Pseudomonas aeruginosa*, urea fertilizer and unamended soil served as the control. The pot experiment was laid out in a Completely Randomized Design (CRD) and replicated six times. Data were collected on growth parameters such as number of leaves, leaf area, stem diameter, plant height, number of flowers, and yield parameters such as shoot dry weight, root dry weight, harvest index and proximate composition. Profitability of applying any of the amendment was evaluated using Gross margin analysis. The data were analysed with ANOVA and means were separated with LSD at $p<0.05$. Celosia had significantly higher number of leaves (182.6), leaf area (34.38 cm^2) and stem diameter (1.23 cm) on soil amended with urea but these were not significantly higher than the parameters recorded in Celosia grown on soil amended with combination of *Pseudomonas* and poultry manure. The tallest plant (84.59 cm) was recorded in Celosia plant on unamended soil, while highest number of flowers (32.57) was recorded in Celosia grown on soil amended with poultry manure. The dry shoot weight (17.22 g) was highest in Celosia sown on soil amended with poultry manure, while the dry root weighed (3.29 g) was highest in Celosia sown on soil amended with combination of *Pseudomonas* and poultry manure. Celosia on soil amended with urea had the highest harvest index (5.50). Composition of crude protein (25.5%) and ash (13.9%) were highest on Celosia from soils amended with poultry manure and urea respectively. A gross margin of ₦58.62/100 g fresh weight was realised from *C. argentea* grown on soil augmented with poultry manure relative to unamended (₦55.83k/100 g) and urea (₦46.29k/100 g) fertilized. Performance of *Celosia argentea* regarding growth, proximate composition and marketable yield was superior on sandy loam amended with combination of *Pseudomonas aeruginosa* and poultry manure.

Keyword: *Celosia argentea*, Biofertilizers inoculants, Inorganic fertilizer, Marketable yield.

COMPARATIVE MINERAL COMPOSITION AND PHYSICAL AND CHEMICAL PARAMETERS OF AFRICAN BUSH MANGO SEED (*Irvingia Gabonensis)* USING AND METHODS

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ABSTRACT

Seeds of African bush mango were collected, cleaned and extracted using Soxhlet extraction method with n-hexane as solvent. Thereafter some physical and chemical parameters of the oil sample were determined. The seeds contained mean concentrations of 45.0±0.04 mg/L and 7.0±0.01 mg/L for potassium and sodium respectively. The analyses gave percentage oil yield as 67.76%, moisture, 1.50%, and 0.92% of ash content. Saponification Ester and peroxide values of 50.49mg/g, value 45.96 mg/g and 2.5 mg/g were obtained respectively. The result also showed that Soxhlet extraction using n-hexane as a solvent gave a better oil yield. The study further revealed that Bush mango seed oil can be used for commercial purposes because the saponification and iodine values obtained indicated their solubility for soap and margarine production.

Keywords: African bush mango, Nutrient composition, *Irvingia garbonensis,* saponification, Oil seeds

ASSESSMENT OF TREE DIVERSITY CONSERVATION IN SCHOOL COMPOUNDS OF KURA LOCAL GOVERNMENT AREA, KANO STATE

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ABSTRACT

Planting and management of trees by schools management, town planners and rural communities contributes to biodiversity conservation. The loss of tree diversity of especially indigenous tree species in Kano state is a global environmental challenge exacerbated by high population growth and increased urbanization. The main aim of this study is to evaluate the contribution of school compounds in tree diversity conservation in Kura local government area of Kano State. Simple random sampling was used in selecting nine (9) schools ranging from primary to secondary schools and then tertiary institutions. Data collection was carried out through ground survey observations where all trees within the school compounds were counted. Tree diversity indices using PAST software was used to analyze the data alongside descriptive statistics. Results showed that *Azadirachta Indica* (*Meliaceae* family) was the dominant species recorded in both primary and secondary schools while *Musa spp* (*Musaceae* family) was the dominant species in the tertiary institutions. Shannon index and Evenness in Primary schools respectively has the highest values (1.02 and 0.93) than that of Secondary Schools (0.9 and 0.82) and Tertiary Institutions (0.67 and 0.65) which indicated more tree diversity in Primary schools. It was found that schools management plant trees species for diverse services with educational (Social) purpose as the focal service followed by Environmental and then Economical. In conclusion, School compounds play a vital role in Tree Diversity Conservation in especially primary schools with exotic species having highest number of trees followed by fruit trees and then indigenous trees. It is recommended that indigenous economic trees should be given extra consideration when establishing a new or maintaining an existing school compound in especially primary schools, this shall also contribute to ecosystem restoration.

Key Words: Tree Diversity, Conservation and Indigenous Trees, *Azadirachta Indica*, Tree management

BIODIVERSITY INVENTORY, RESOURCE EXPLOITATION AND NEED FOR MANAGEMENT IN PARTS OF AKWA IBOM STATE, NIGERIA

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ABSTRACT

Species inventory was conducted around some Local Government Areas of Akwa-Ibom State in two seasons in order to characterize species composition, richness and density, diversity indices, abundance, ecosystem services, indigenous uses of plant resources, IUCN status and protected area, as well as fauna exploitation methods of species among other study objectives. The study was carried out with the aid of a GPS. A 60 x 60-meter line transect was laid in ten habitats each for the seven different habitats respectively, with a total sampling size to 504,000 m^2 for both seasons accounting for 50.40 hectares. A total of 164 and 176 flora species in 70 and 71 taxonomic families was recorded for both seasons. Secondary forest recorded the highest species richness and diversity with mangrove forest and freshwater recording the least for species richness and diversity respectively. The Shannon index was 4.86 with equitability index of 0.95 and 4.84 with equitability index of 0.94 for wet and dry seasons respectively. The wet season recorded the highest individual abundance. Eleven threatened flora species was recorded in the Stubbs Creek protected area. A total of 110 and 123 fauna species was reported and Shannon (H) of 4.16 and Equitability index (J) of 0.91 recorded for entire fauna. *Protoxerus stangeri* (African Giant Squirrel) and *Cercopithecus erythrogaster* (White-Throated Monkey) were the most sighted fauna species of a total of 8780 individuals across all fauna groups recorded. Nine threatened, eight migratory and seven raptor species were reported. Traps and poaching were fauna exploitation methods. The pressure of poaching and over-exploitation of T/NTR are major threats to species existence; so, laws should be made to conserve gene pool around the study area.

Keywords: Species inventory, biodiversity, ecosystem services, IUCN status, protected area, species exploitation, Stubbs Creek, Akwa Ibom State

BIODIVERSITY STATUS OF NIGERIA'S AQUATIC RESOURCES

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ABSTRACT

Nigeria has a large range of aquatic ecosystems which support a wide variety of plant and animal species.

These various ecosystems and their associated animal and plant assemblage are under serious pressure from numerous human activities. The Nigerian marine fisheries cover extensive coastline of about 960 km and an Exclusive Economic Zone (EEZ) of 320 km created in 1978. Nigeria has an extensive mangrove ecosystem of which great proportion lies within the eight maritime states. The marine resources have been divided into (a) coastal inshore resources, made up of demersal and pelagic fishes; (b) off-shore resources made up of demersal and some pelagic fishes. Nigeria also has a diversity of finfish and shellfish of about 199 species belonging to 78 families in the brackish and marine environments. Nigeria's freshwater profile boasts of inland waters made up of major lakes, rivers, ponds, floodplains. Inland fisheries and catches from inland waters are primarily most significant for rural areas (both commercially and subsistence). The biodiversity status of Nigeria's aquatic resources is currently facing numerous challenges. This paper examines the current status of Nigeria's aquatic resources; exposes the major threats to both the environment and the endemic plant and animals, which are majorly the fisheries resources. Among the major threats is habitat destruction and degradation; pollution courtesy industrial waste, agricultural run-off, inadequate sanitation practices leading to contamination of water bodies with pollutants, such as heavy metals, chemicals, and sewage; overfishing and illegal fishing practices; unsustainable fishing practices like use of destructive fishing gear, and the targeting of endangered species. All these contribute to the depletion of fish stocks and disruption of ecosystem balance. The paper proposed various measures for effective conservation and management of our aquatic resources.

Keywords: Aquatic resources, Endangered species, Exclusive Economic Zone, Habitat destruction, Biodiversity

BIOLOGICAL GARDENS: A CORNERSTONE IN BIODIVERSITY CONSERVATION - A CASE STUDY OF EDE, NIGERIA

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ABSTRACT

The escalating threat to global flora and its habitats necessitates urgent preservation efforts. In-situ conservation is ideal, yet ecological devastation often precludes it. Reintroducing species to designated conservation areas offers hope. Biological gardens, mirroring natural ecosystems, play vital roles in education, research, and conserving native and exotic flora and fauna. Ede, a town in Osun State, which is biodiversity-rich, like every other town in Nigeria is grappled with conservation challenges. A Botanical Garden and Animal House was therefore established at the Federal Polytechnic, Ede, to exemplify a solution. The Botanical Garden encompasses sections for ornamental, medicinal, exotic, and endangered plants, alongside orchards, grasses, herbs, vegetables, citrus, and roses. The Animal House houses rabbits, albino rats, snails, guinea pigs, parrots, and guinea fowls. This initiative showcases Nigeria's diverse flora and fauna, fostering environmental awareness. It provides sanctuaries for endangered species, facilitates breeding programme, and supports research to enhance survival prospects. The Botanical Garden further offers controlled environments and insights for studying ecological impacts of climate change on local ecosystems.

Keywords: Biodiversity conservation, In-situ conservation, Botanical garden, Endangered species, Conservation education, Climate change mitigation.

ETHNIC DIVERSITY AND AQUATIC RESOURCES UTILIZATION IN TWO COASTAL COMMUNITIES IN SOUTH WEST NIGERIA.

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ABSTRACT

At this time when sustainable and orderly exploitation of renewable natural resources of developing countries is most needed, the role of socio-ethnic influences especially in the coastal fragile communities can-not be over-ruled. This study identified the ethnic diversity of two coastal communities in South-west Nigeria, such as Ilaje-Eseodo community in Ondo State and Ere fishing community in Ogun State. In addition, the study, investigated the influences of these communities on the exploitation and management, utilization and preservation of the various aquatic resources in their domain, most especially the fisheries. The different tribes in Ilaje-Eseodo consist of the Ilajes (66%), the Ijaw Arogbos (17%), and the Ijaw Apois (17%) while in Ere Community, the Eguns constitute 80%the Aworis (10%) and the Egbados (10%). The paper identifies the ethno-cultural operations prevailing in these two distinct coastal communities. The influences were significant in several ways such (a) fishing and livelihoods; (b) traditional ecological knowledge; (c) cultural practices and conservation. The paper recommends sustainable resource utilization and measures to mitigate against resource vandalization.

Keywords: Ethnic diversity, Aquatic resources, Cultural practices, Conservation, Coastal communities

CHARACTERIZATION OF GROUNDNUT (*Arachis hypogea*) GENOTYPES USING MOLECULAR AND MORPHOLOGICAL TECHNIQUES

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ABSTRACT

Information on variation in groundnut genotypes is valuable for cultivation and breeding schemes. This study characterized 66 groundnut genotypes using molecular and morphological techniques. Fourteen SSR markers were used for molecular characterization. The marker profile, generated from scoring clear and unambiguous bands was used to calculate polymorphism information content (PIC) and resolving power (RP). The result revealed that, 12 polymorphic markers amplified a total of 30 bands, with 23 (76.6%) of the bands showing polymorphism. PIC of the markers ranged from 0.2 (TC4G10) to 0.9 (IPAHM395) while RP ranged from 0.5 (TC2D06) to 3.5 (TC4G10). The dendrogram based on marker profile generated two major clusters A and B and eight minor ones (AI, AII, AIII, AIV, AV, AVI, BI and BII). The Morphological characterization revealed that, more than 82% of the total variation in the 12 characters was explained by the first eight principal components. The components were considered significant in the assessment of variability among the groundnut genotypes. The dendrogram generated from morphological data also showed two major clusters, A and B, and four minor ones (AI, AII, AIII and BI). The clusters were consistent with clusters obtained from the molecular data suggesting that the two methods are complementary in assessing genetic diversity in groundnut.

Key words: Groundnut, Euclidean distance, Genotypes, Dendogram, Clustering.

INVENTORY AND IMAGERIES OF INDIGENOUS VASCULAR PLANTS OF AESTHETIC POTENTIALS IN SOUTH-WESTERN NIGERIA.

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ABSTRACT

There is presence of indigenous and naturalized vascular plants of aesthetic, decorative or ornamental potentials in South-western Nigeria and they include herbs, lianous, shrubby and tree forms, but they are largely un-exploited, subsisting in the wilds with very little domestication efforts. These aesthetic parts which are the prior attributes in this study are mainly flowers and rarely leaves and fruits. Observations and inventory compilation were from January to December 2022. Prior attributes of attractiveness, common or local names if any, phenology-flowering time or duration emphasis, and individual plant drawback were noted. Pteridophyta – Fern and Angiospermae comprising of 40 Dicotyledoneae and 5 Monocotyledonae species were documented. These plants can further enhance the aesthetic value of our habitable surroundings and also can be massively exploited as starters for Nigerian indigenous floriculture industry as nature's flower bouquets and floral showers for festivities, floral wreaths and even imprinted on postage stamps and on further strengthening can serve as exportable foreign exchange earner /income to Nigerians.

Key words: Vascular plants, Indigenous plants, Angiosperms, Liana, Ornamental Plants

WINNERS AND LOSERS: OCCUPANCY DYNAMICS AND CONSERVATION FOR FOREST LARGE MAMMALS IN OMO-SHASHA-OLUWA LANDSCAPE

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ABSTRACT

Large mammal response to modification in forest landscapes is usually assessed by investigating factors affecting species diversity and distribution. Factors that influence large mammals' diversity and distribution in response to modified landscapes due to human activities is largely unknown within Omo-Shasha-Oluwa. Large mammal occupancy was modelled in Omo-Shasha-Oluwa Forest Reserves landscape to determine habitat characteristics associated with the presence of large mammals. For this study, 52 sites were surveyed for four seasons from March 2014 to March 2016. Occupancy dynamics were estimated using single-species, multi-season occupancy modelling. 12 of large mammals in six families were identified within the forest landscape. Maxwell's duiker had the highest overall occupancy estimate (0.897 ± 0.062) while forest elephant had the lowest overall occupancy estimate (0.115 ± 0.043). Forest buffalo had the highest increase in site occupancy (0.290 ± 0.076 to 0.358 ± 0.098) while mona monkey had the highest decrease in site occupancy (0.713 to 0.651). The occupancy model predicted colonisation and extinction events for only civet ($\Upsilon = 0.347 \pm 0.154$; $\varepsilon = 0.041 \pm 0.031$) and the red river hog ($\Upsilon = 0.158 \pm 0.098$; $\varepsilon = 0.098 \pm 0.059$). The probability that civet cat and red river hog will colonise any forest patch increased with distance from the nearest settlement. This study provides insight into the habitat characteristics that influence large mammal distribution at landscape scale. The focus on dynamic process that influence species distribution is valuable for the conservation of large mammals in forest regions.

Keywords: Large mammals, Occupancy dynamics, Conservation, Tropical forests, Landscape management

TREE SPECIES DIVERSITY AND DENSITY IN THE UNIVERSITY OF CROSS RIVER CALABAR CAMPUS BOTANICAL GARDEN, NIGERIA

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ABSTRACT

The study was carried out to determine the tree species diversity and density in the University of Cross River botanical garden in Calabar main campus. Three plots of 25m x 25m were laid in the study area and species count was carried out in the plots. Qualitative and quantitative methods were used to determine the species abundance and diversity. The Shannon-Wiener Diversity (H') computation was done for each LGA. The ACFOR scale, Shannon-Wiener diversity (H'), Shannon evenness (E) and tree density (D_{ij}) were all computed for the three plots. A total of 96 individual plants of 34 species in 21 families were enumerated, where 17 were in plot A, 45 in plot B and 34 in plot C. In plot A, *Magnifera indica* (3) had the highest number of stands and tree species density (48) and was found in all the plots followed by *persea americana* (2) which is also found in the three plots and other species were all 1 (one) stand each. Shannon diversity (H') was -0.92, Simpson's diversity (D) was 0.03 and tree density (D_{ij}) was 272. In plot B, *Elaesis guinensis* (5) was common, followed by *Musanga cecropoides* (4) and *Leucaena leucocaphila* (4) which were frequently seen. H' was -3.19, D=0.03 and D_{ij}=576. While plot C had *Zanthoxylum caribaeum* (5), *Mangifera indica* (5), *Elaesis guinensis* (5) as the common species and others were rare. H' was -2.65, D=0.08 and D_{ij}=517 respectively. The result indicates that the diversity of tree species and its density in University of Cross River botanical garden Calabar campus are very low. Hence, there is need for more tree planting and conservation of these plants for sustainable utilization.

Keywords: Tree crops, Tree diversity, Sustainable utilization, Botanical garden, Species conservation

DETERMINATION OF THE BACTERIAL AND FUNGAL STATUS OF *P. americana* IN THE USMANU DANFODIYO UNIVERSITY, SOKOTO, NIGERIA

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ABSTRACT

Periplanata americana is pest and a vector of numerous microorganisms of public health importance. A study to determine the microbial and fungal status of *P. americana* was conducted in the Usmanu Danfodiyo University, Sokoto, Nigeria. A bioassay of the mouthparts, abdominal contents and limbs of twelve (12) randomly collected cockroaches was carried out to determine their fungal and microbial loads using standard microbiological techniques. Eleven (11) bacteria and two (2) fungi species were identified from 19 and 16 isolates of bacteria and fungi respectively. Out of the 19 bacteria isolates; 3(15.8%) were *Corynebacterium kutsceri*; 4(21.1%) were *Acinetobacter* spp.; 7(36.8%) were *Streptococcus* spp., 2(10.5%) were *C. xerosis*, 1(5.3%) were *Neisseria* spp. and 2(10.5%) were *Staphylococcus* spp. Site specific abundance showed that the mouthparts had the highest abundance of microorganisms; 7(36.8%) and 6(37.5%); followed by the abdomen; 6(31.6%) and 5(31.3%) and the legs had, 6(31.6%) and 5(31.3%) loads of bacteria and fungi respectively. Bacterial speciation showed that *Bacillus* spp., had 5(12.8%) *Acinetobacter* spp., 4(10.3%); *Neisseria* spp., 1(2.6%); *C. xerosis*, 2(5.1%); *C. kutsceri*, 3(7.7%); *Micrococcus varians,* 4(10.3%); *Staphylococcus* spp., 7(17.9%); *Streptococcus* spp., 10(25.6%); *Escherichia coli*, 1(2.6%); *Citrobacter freundii*, 1(2.6%) and *Erwinia chrysanthemi,* 1(2.6%). The study showed that cockroach is a veritable vector of microorganisms of public health importance and recommends proper sanitary interventions to reduce the spread and abundance of *P. americana* and its attendant consequences in households in Sokoto State, Nigeria.

Keywords: *Periplanata Americana*, vector, microorganisms, bacteria, fungi.

A SURVEY OF GAME BIRDS DISTRIBUTION AND ABUNDANCE IN SANAGI VILLAGE (Fadama area) JEGA LOCAL GOVERNMENT KEBBI STATE NIGERIA

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ABSTRACT

This project was carried out to study the Distribution and abundance of game birds species at Sanagi village, Jega Kebbi State, Nigeria. To assess the distribution and abundance of game birds species and to identify the dominant species of game birds in the study area (Fadama, area). Morning observation was made between the hours of 06:00am and 10:00am, while the evening visit is from 04:30pm to 06:30pm when the temperature was relatively cool and the birds activities were high. From table 1. A total number of 14 birds were identified from nine (9) species of birds in the study area (Fadama,). From the result, it was observed that speckled pigeon has the dominant numbers of game birds species (41) and the least numbers of game birds species was White face duck (8). More studies should be carried out so as to remark this work and give a much clearer picture of composition of game birds in the study area.

Keywords: Game birds, Bird diversity, Bird abundance, Bird distribution, Avian species.

A SURVEY OF THE TERRESTRIAL ANGIOSPERMIC FLORA OF COLLEGE OF EDUCATION CAMPUSES, AGBOR, DELTA STATE, NIGERIA

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ABSTRACT

A survey was embarked upon to document plant species found on the College of Education (now called University of Delta) Campuses, Agbor, Delta State. The continuous development and disturbance of the sites by human activities necessitated this study. The composition of plant species, similarity index, frequency, density and abundance were evaluated on the campuses. A total of 48 species were recorded on Campus I, and 54 species were recorded on Campus II, belonging to 20 and 26 families respectively. On campus I, the family Poaceae had the highest number of plant species of 12, representing 25% of the entire taxa followed by Asteraceae and Euphorbiaceae which had 6 species each and both contributed 25%, Cyperaceae and Amaranthaceae had 12.5% while the remaining (18) had 37.5%. On campus II, the family Asteraceae had the highest plant species of 14.81%, Poaceae 11.11% and Euphorbiaceae 9.26%. Cyperaceae, Mimosaceae and Rubiaceae contributed 5.56% each, while others contributed 48.15%. *Andropogon gayanus* had the highest relative abundance on campus II while on campus I, *Gomphrena celosiodes* recorded the highest relative abundance. *Cyperus difformis* and *Melochia corchorifolia* had the highest frequencies. Based on habits on both campuses, herbs were represented by 19 and 26 spp., shrubs 10 and 13 spp., grasses 12 and 6 spp., climbers 3 and 3 spp., sedges 3 and 3 spp. and trees 1 and 3 spp. on old and new sites (Campus I and II) respectively. Twenty-six plant species were common to both campuses and Jaccard's similarity coefficient between both campuses was 0.366. The results clearly depicted varying degrees of human interference on both campuses altering species composition and vegetation structure. This suggests that decisive efforts should be taken to conserve the plant species.

Keywords*:* College of Education, Agbor; Conservation; Delta State; Plant species.

ABUNDANCE AND DISTRIBUTION OF FISH SPECIES IN ELEYELE LAKE, OYO STATE

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ABSTRACT

Monitoring and evaluating species composition provide information that are necessary for sustainable management of aquatic ecosystems. Eleyele Lake is one of the major lakes though constructed primarily for the supply of domestic water has been a major source of freshwater fish for human consumption and has been under constant pressure both by fishers and other users, this study is necessitated by the need to assess it present status for better management for sustainability. The lake was partitioned into three Zones (A, B, and C), with monthly collection of water and fish species for a period of 12 months (September 2018 – October 2019). Temperature, pH, dissolved oxygen, and ammonia were measured from the water samples collected. The fish species were identified and sorted into taxonomic groups using identification keys; the information on standard length, total length and weight were taken and condition factor were calculated from the data. Mean temperature (26.70 ± 0.01^{o}C), dissolved oxygen (5.59 ± 2.21 mg/L) and pH (7.00 ± 0.01) were within recommended levels while ammonia (0.26 ± 0.00 mg/L) was higher than the recommended levels. A total number of 453 individuals comprising of 15 species, belonging to 9 families were identified. The family Cichlidae with 6 species was the most abundant (84.50 %), followed by Mochokidae (two species), 4.4 %, while others Gymnarchidae and Polypeptidae were the least. Of the family Cichlidae, the most abundant was *Oreochromis niloticus* (38.00 %), followed by *Coptodon. zilli* (24.50 %) and the least was *Sarotherodon galileaus* (0.40 %). Fish species were most abundant in June (12.10 %), followed by February (10.80 %) while September had the least. Species diversity was highest between August and November (H= 2.66 respectively), while the least diverse diversity occurred in June (H = 2.40), Zone A had the highest number of fish species (13 species representing 38.85 %) and the least diversity value (H = 1.5) , followed by Zone C with 11 species (34.00 %) and diversity value H = 2.5; the least was Zone B with 10 species (27.15 %) and had the highest species diversity value (H = 4.6). The Fish species in the lake were in good condition and condition factors were slightly above 1showing that growth is multidimensional. The species identified are indicators of a healthy freshwater ecosystem.

Keywords: Fish composition, Water quality, Eleyele lake, Aquaculture, Species composition.

VANISHING BEAUTY; THE STATE OF RARITY IN BUTTERFLY SPECIES.

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ABSTRACT

Butterflies are among the most studied groups of insects in the order Lepidoptera, with approximately 20,000 species described worldwide. Many butterfly species are rare and threatened; their rarity has important ecological and conservation implications. The rarity of butterfly species can result from geographic range, population size, ecological specialization, and human impact, with ecological specialization also contributing to the rarity of the species. Anthropogenic activities are major drivers of rarity in butterflies, as habitat loss, fragmentation, and degradation are common causes of species decline, and extinction alongside climate change, pollution, overhunting, and invasive species also threaten butterfly populations and can increase their risk of rarity and extinction. Butterfly rarity has important ecological and conservation implications as the taxa play unique roles in ecosystem balancing, such as pollination, seed dispersal, or ecological interactions with other species. Their loss can negatively affect the ecosystem and lead to biodiversity loss.

Keywords: Lepidoptera, ecological specialization, climate change, overhunting, invasive species.

BIODIVERSITY AND BIOINDICATOR POTENTIALS OF CLIMBERS IN ASSOCIATION WITH HOST TREE IN SELECTED FOREST TYPES IN IBADAN, NIGERIA

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ABSTRACT

Tropical forests are life lines of the planet, and Ibadan city contains different types of forests. The crucial ecological roles of a forest are dependent on a remarkable array of plant species and dynamics that exist among them. Climbers as a group of enigmatic organisms whose pivotal roles within forest ecosystems are often overlooked. This study explores the interplay of biodiversity, ecological functions and bioindicator potentials of climbers and their associations with host trees in selected forest types in Ibadan. Three distinct forest types (Rainforest, Secondary and Derived Forest) at the Forestry Research Institute of Nigeria were assessed for this study. All trees with a diameter at breast height (DBH) ≥5 cm was surveyed for the presence of climbers. Floristic and edaphic data were systematically collected from two plots (400 m^2 each) per forest. The data were described and analyzed using Multivariate and cluster models. The study revealed a total of 18 climber species spanning 17 genera and 14 families within the study area. The Apocynaceae family emerged as the most prevalent, followed by the Moraceae and Menispermaceae. The climber species were found in four categories based on their climbing mode. The most abundant classes were those exhibiting twining (5spp) and tendrils climbing modes (5spp), followed by hook (4spp) and woody climbing modes (4spp) Secondary Forest had the highest number (74) of climbers, while Rainforest had the least (34). Basal area was indicated as the indicator taxon for climber-host tree association, with *Carya grandiofolia* having highest climber association, while climbers displayed preferences for specific soil properties, except *Antiaris Africana* with no climber association across all forest types. Results from Canonical Correspondence Analysis (CCA) showed that edaphic factors had significant influence ($p<0.05$) on distribution and stability of climbers across the selected forest types. In addition to enhancing our comprehension of the intricate interactions within forest ecosystems, this study provides valuable insights for management and conservation decisions. The forests of Ibadan, Nigeria, with their woody climbers, represent a vital ecological realm and ensuring their continued existence and diversity would provide a nature-based solution to their management.

Keywords: Biodiversity, Climbers, Tropical forests, Ecological Functions, Bioindicator potentials, Host-Tree Associations.

OCCURRENCE OF NEMATODES AND PROTISTS COMMUNITIES IN VERMICAST AND EARTHWORM AND THEIR IMPLICATION ON PUBLIC HEALTH

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ABSTRACT

Despite several control measures against Soil Transmitted Helminths (STH), it has been difficult to completely eradicate their infections. This research was directed at determining the protists and nematodes communities in vermicasts and earthworms and their implication on public health in two residential communities of Osogbo, Olorunda and Odo-Otin Local Government Areas of Osun State, Nigeria. Vermicasts and Earthworms samples were collected randomly from these communities using the quadrant technique. The vermicast was analysed with the Bearmann's extraction technique while the earthworm were macerated and processed using normal saline and floatation techniques. A total of Two hundred and sixty seven (267) organisms comprising: protozoans 51 (19.1%) and nematodes 216(80.9%) were extracted from both vermicast and the earthworm. The vermicast has more parasites; 151 (56.6%) than the earthworm's gut; 116 (43.4%). The parasites comprises genera of nematodes; *Ascaris lumbricoides*, S*trongyloides* Spp., P*ratylenchus S*pp., *Paratylenchus S*pp., *Longidorus S*pp., *Hemicyclophora S*pp., *Rotylenchus S*pp., *Meloidogyne* Spp. and genera of protists; *Entamoeba S*pp. and *Coccidia* Spp. There was no statistical difference in the prevalence of nematodes and protists (P>0.05). The faunal structure shows more plant parasitic nematodes (PPN) 107 (53.5%) than obligate helminths 82 (41.0%) and obligate protists 51(25.5%). This research reveals that the vermicast and earthworm's gastrointestinal tracts and harbored both plant parasitic nematodes of agricultural significance and zooparasites of public health importance which shows that vermicast and earthworm can be an absolute agent of the spread of public health important STHs, including safe handling of vermicast and earthworm in its existing control measures could enhance eradication.

Keywords: Protists, Vermicast, Earthworm, Soil Transmitted Helminths, Nematodes, Public Health.

EFFECT OF CLIMATE-SMART AGRICULTURAL PRACTICES ON FOOD SECURITY OF RURAL FARMING HOUSEHOLDS IN SOUTHWEST, NIGERIA

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ABSTRACT

The study aimed at the effect of Climate-Smart Agricultural (CSA) practices on the food security of rural farming households in Nigeria. Multi-stage sampling technique was used to select 480 rural farming households across three selected states in Southwest, Nigeria. The data were analyzed using descriptive and inferential statistics – Household Dietary Diversity Scores (HDDS) and Logit regression analysis. The results revealed that the majority (80.0%) of the respondents were married, while mean age, household size and farm size were 48 years, 6 persons and 4.2 hectares respectively and 80% of the farming households spent less than $10 on food weekly. Mixed cropping is the most practised CSA in the study area. Also, 65.0% of the farming households are food secured, while 35.0% are food insecure. The depth food insecure and severe food insecurity among the sampled farming households were 0.1913 and 0.0711 respectively. The logistic regression result showed that the food security status of rural farming households is significantly affected by gender, farm size, contact with extension agents and CSA practice. The study concluded that the food security status of rural farming households in Nigeria was indeed influenced by CSA practised in crop farming. Government and all stakeholders should promote and encourage the adoption of CSA practices that will ensure agricultural sustainability in agrarian communities by mitigating the effect of climate change.

Keywords: Climate Smart, Agriculture, Crop diversification, Food security, Regression

ASSESSMENT OF VULNERABILITY AND ADAPTATION TO THE IMPACT OF CLIMATE CHANGE IN SOME PARTS OF YOBE STATE, NIGERIA

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ABSTRACT

This paper assessed the vulnerability and adaptation strategies to impact of climate change in some areas of Yobe State, Nigeria. Socio-demographic characteristics and relationship between vulnerability and adaptation strategies, effectiveness of the adaptation strategies to the impact ofwere assessed. Primary and secondary data were collection. It was found that 61% were male between the ages of 20-80 years, 80% of the respondents have a household size of more than 10 members with no access to formal education. Sixty nine percent (69%) of the respondents were aware of the most vulnerable groups as women (both pregnant and non-pregnant), elderly persons and children, 62% of the respondents held that the vulnerability may be as a result of socio-economic and ecological and political factors. Whereas, 64% of the respondents held that they do not have control over critical livelihoods resources, 62% of the respondents believed thatwomen and other marginalized groups had no equal access to information, skills and other services. However, 66% thought that there is no equal right among women and other marginalized vulnerable groups in the study area. Low community awareness (13%) on vulnerability exposes the communities to lack of infrastructures to more vulnerable impacts by climate change in the state as negative. It is recommended that government and concerned organizations create awareness on sustainable development of proper environmental conservation to inhabitants; environmental laws should be enacted in the state by the major stakeholders, nontechnical approaches on climate change adoption, vulnerability and mitigation strategies.

Keywords: Adaptation, Adaptive capacity, Climate change, Mitigation, Vulnerability.

THE EFFECTIVENESS OF EDUCATIONAL TECHNOLOGY IN THE TEACHING AND LEARNING OF CHEMISTRY IN SELECTED SECONDARY SCHOOLS IN MARU LGA, ZAMFARA STATE.

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ABSTRACT

There is a huge challenge of failure in chemistry or difficulty in understanding some topics in chemistry among secondary school students, that is why the study in hand was conducted to explore the effectiveness of implementation of technology in the teaching and learning of chemistry at secondary students as one of best practice beyond the usual approaches of teaching chemistry which is theory. Educational technology plays a vital and crucial role in facilitating teaching and learning process and makes it interesting, effective and successful. The main objectives of the study were to explore the roles of educational technology in the teaching of chemistry at secondary level Maru local government area of Zamfara State. A total of total population of 100 respondents; Out of the total population, 60 students of SS I, II and III were selected as the sample of the study and 40 chemistry teachers. The schools include Government Girls Secondary School Maru, Girls Focal Primary School Maru, Muslim Students Society Secondary School Maru and Government Day Secondary School Maru. They were divided into control group and experimental group, each group comprised of 30 students. Research questions were utilized to identify challenges and possible solutions for effective use of educational technology in the teaching and learning of chemistry. Results showed that educational technology plays a crucial role in teaching of chemistry in secondary schools in Maru LGA, Zamfara State. Its use helped in clarifying concepts that students identified to be difficult. The students of experimental group showed extraordinary performance while using technology to disseminate information, with increased motivation. It was concluded that, the use of educational technology in teaching of chemistry makes it more effective, successful and productive.

Keywords: Educational technology, chemistry as a subject, effective teaching and learning, Secondary School education, Government Science Secondary Schools

IMPACTS OF BIGDATA ON CHALLENGES AND THREATS POSED BY CLIMATE CHANGE

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ABSTRACT

Climate change refers to a drift from the normal pattern of weather condition to harmful and adverse trend which in turn has a negative effect on the environment. As weather condition is known to be classified into a mild temperature, warm and wet depending on the season and/ or geographical location. The emergence of bigdata has potential to revolutionize the way we understand, monitor and tackle climate change challenges and bring an expected change. As bigdata has been characterized in term of its large volume, variety, veracity and significant roles this played in handling environmental challenges among which is climate change. This has several applications which can be used to solve climate change problem such as climate modelling and predictions, environmental monitoring, carbon emission reduction, renewable energy optimization among others. Remote Sensing Data, internet of Things (IOT) and social media and crowdsourcing as well as government records are bigdata methods used to solve climate challenge. Summarily, bigdata helped decision makers gain a valuable insight from such a varied and rapidly changing data to put a necessary measure in place so as to control and avert any harmful climate change would have brought.

Keywords: climate change, environment, bigdata, challenges, decision makers

PHYTOREMEDIATION POTENTIALS OF SUNFLOWER (*HELLIANTHUS ANNUS* L) AND WORMWOOD (*Artemisia annua* L) ON SOIL CONTAMINATED WITH CARBOFURAN

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ABSTRACT

Phytoremediation is the use of plants to remove contaminants from the environment. Carbofuran insecticide-polluted soil was phytoremidiated using *Hellianthus annus* (sunflower) and *Artemisia annua* (wormwood) plants. The phytoaccumulation capabilities and biotranslocation factors of both plants were determined from soil containing mean concentration value of 6.0mg/kg of the carbofuran insecticide. Concentration of carbofuran in soil and plant tissues was determined using High Performance Liquid Chromatography (HPLC) with UV detector. Height, stem girth, number of leaves and weight of the plants grown in the contaminated soil were measured at 2 weeks intervals, for 12 weeks. Substantial accumulation of carbofuran insecticide recorded in the root, stem, and leaf tissues with phytoaccumulation values of 4.42 mg/kg and 1.11 mg/kg for sunflower and wormwood plants respectively. Biotranslocation factors of the two plants showed significant difference ($P<0.05$) with mean values of 0.18 and 0.89 for both sunflower and wormwood plants. The reduction percentage of carbofuran insecticide in the contaminated soil was 72% and 23% for sunflower and wormwood respectively, ($P<0.05$). Highest values of 115 cm and 97 cm (height), 5 cm and 2 cm (stem girth), 95 g and 102 g (weight after harvest) for sunflower and wormwood plants were obtained. The highest number of leaves was recorded in sunflower. The study indicated sunflower and wormwood are potential plants for phytoremediation.

Keywords: Phytoremediation, Carbofuran, *Helianthus annus*, *Artemesia annua.*

ENZYME AND ANTIOXIDANT ACTIVITIES OF *Vigna subterraenea* (L.) Verdc GROWN UNDER CADMIUM STRESS AS AFFECTED BY FOLIAR APPLICATION OF CERIUM OXIDE NANOPARTICLES

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ABSTRACT

This study was carried out to investigate the enzyme and non-enzyme antioxidant activities of *Vigna subterraenea* grown under different concentrations of cadmium with foliar application of cerium oxide (CeO_2) nanoparticles. Seeds of Bambara nut used for the study were collected from Genetic resource center, IITA, Moniya, Ibadan, Nigeria. The seeds were sown in the nursery and transplanted to soil already spiked with different concentrations of Cadmium (0, 20, 50 and 100mg/L) after establishment. Fourteen days after transplanting, plants in each pot in the different treatment regimes were sprayed with 25mL of 200mg/L of cerium oxide (CeO_2) nanoparticles. This was done for six weeks at fourteen days interval. At harvest, plants from the different treatment regimes were harvested and separated into leaves and roots. Enzyme analysis of Catalase (CAT), Superoxide dismutase (SOD), Polyphenol dismutase (POD), Ascorbate peroxidase (APX) and Glutathione peroxidase (GPX) were carried out in the leaves and roots of the harvested plants. Antioxidant like Flavonoids, Sugar, Proline, Ascorbic acid and Phenols were also carried out in the leaves and roots of the plants. Data obtained from the study were subjected to two-way analysis of variance and means were separated using t-test. Results obtained from the study showed that application of cerium oxide (CeO_2) nanoparticles enhanced the enzyme as well as antioxidant activities in the root of the three cultivars of Bambara nut under Cd stress. Meanwhile, there were variations in the concentration of the antioxidants in the leaves as influenced by cerium oxide (CeO_2) nanoparticles under different concentrations of cadmium. It is concluded that in the three cultivars of Bambara nut used, enzyme as well as antioxidant activities of the stressed plants were enhanced by foliar application of cerium oxide (CeO_2) nanoparticles.

Keyword: *Vigna subterraenea*, Antioxidants, nanoparticles, Foliar application, Bambara nut.

SOIL REMEDIATION: THE POTENTIALS OF *Leuceana leucocephala* (Lam.) DE WIT IN CRUDE OIL-POLLUTED SOIL REHABILITATION AND RE-VEGETATION

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ABSTRACT

The adverse effects of crude oil and its derivatives on soil is enormous. Phytoremediation is a cheaper and sustainable method of addressing this menace. Therefore, the remediating potential of *Leuceana leucocephala* (LL) on crude oil-contaminated soil was investigated in Wilberforce Island, Nigeria. Varying concentrations of crude oil (0, 25, 50, 75, and 100 ml) were applied to LL seeds (n=10) in Petri dishes arranged in completely randomised design (r=5). Germination Percentage-GP was determined at day 10. Two weeks after contamination, LL seedlings were planted in plant bags (containing oil-contaminated soil) and arranged in completely randomised design (r=10). Plant Height-PH (cm), Plant Girth-PG (mm) were determined at 4, 8, 12 and 16 Weeks After Planting-WAP while Number of Leaves-NL and Number of Nodules-NN at 16 WAP only. The physicochemical parameters of the soil were determined following standard procedures. The LL seedlings contaminated with 75 and 100 ml crude oil had GP of 62 and 56%, respectively which were significantly lower than 92% (control). At 16 WAP, the PH and PG of LL seedlings ranged from 41.80±6.50 (100 ml) to 58.30±4.75 (25 ml) and 0.19±0.04 (100 ml) to 0.34±0.03 (25 ml) respectively, which were significantly lower than 73.70±4.40 and 0.54±0.03 (control). The NL and NN of LL seedlings ranged from 6.00±2.00 (100 ml) to 16.00±2.00 (25 ml) and 2.00±1.00 (100 ml) to 10.00±2.00 (50 and 25 ml) respectively, which were significantly lower than 24.00±3.00 and 18.00±3.00 (control) at 16 WAP. The pH of the polluted soil ranged from 5.22 (0 ml) to 5.03 (100 ml) when compared to an aggregate of 5.72–5.31 (control). Although there was a decline in the attributes of the growth parameters, *L. leucocephala* was able to endure in crude oil contaminated soil. The tolerance of *L. leucocephala* in crude oil-contaminated soil may indicate the soil rehabilitation and re-vegetation potential of *L. leucocephala* in the oil-rich area of Nigeria.

Keywords: Phytoremediation, crude oil, leguminous plant species, polluted soil.

PHYTOREMEDIATION POTENTIALS OF SUNFLOWER (*HELLIANTHUS ANNUS* L) AND WORMWOOD (*ARTEMISIA ANNUA* L) ON SOIL CONTAMINATED WITH CARBOFURAN

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ABSTRACT

Phytoremediation is the use of plants to remove contaminants from the environment. Phytoremediation of Carbofuran insecticide polluted soil using *Hellianthus annus* and *Artemisia annua* plants was carried out. The phytoaccumulation capabilities and biotranslocation factors of both plants were determined from soil containing mean concentration value of 6.0mg/kg of the carbofuran insecticide. Concentration of carbofuran in soil and plant tissues was determined using High Performance Liquid Chromatography (HPLC) with UV detector. Height, stem girth, number of leaves and weight of the plants grown in the contaminated soil were measured at regular intervals of 2 weeks, for a total period of 12 weeks and the result was recorded. The result of the study indicated substantial accumulation of carbofuran insecticide by the root, stem, and leaf tissues with phytoaccumulation values of 4.42mg/kg and 1.11mg/kg for sunflower and wormwood plants respectively. Biotranslocation factors of the two plants showed significant difference ($P<0.05$) with mean values of 0.18 and 0.89 for both sunflower and wormwood plants. The reduction percentage of carbofuran insecticide in the contaminated soil was 72% and 23% for sunflower and wormwood respectively, ($P<0.05$). Highest values of 115cm and 97cm (height), 5cm and 2cm (stem girth), 95g and 102g (weight after harvest) for sunflower and wormwood plants. The highest number of leaves was recorded in sunflower. The study proved that both sunflower and wormwood are credible plants for phytoremediation.

Keywords: Phytoremediation, Carbofuran, *Helianthus annus, Artemesia annua*, biotranslocation

PYTOREMEDIATION POTENTIALS OF SELECTED *JATROPHA* PLANTS ON HEAVY METAL-POLLUTED SOIL FROM DANGOTE CEMENT FACTORY, GBOKO, BENUE STATE, NIGERIA

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ABSTRACT

Cement factory waste are soil pollutants which are repositories of heavy metals leading to wash off into agro-environments. This study evaluated a few chosen Jatropha plants' potential for cleaning up contaminated soil. Total of ninety six soil pots 3x 4 x 8 factorials. 3 plants variety, 4 treatments and replicates were arranged in a complete randomized design. Soil pots treatment composition T_0 (30kg undisturbed soil and 0 kg cement waste), T_1 (30kg undisturbed soil and 1kg cement waste), T_2 (30kg undisturbed soil and 2kg cement waste), T_3 (30kg undisturbed soil and 3kg cement waste). The plant seeds were cultivated after investigation of eight heavy metals (Mg, Cr, Pb, Co, Fe, Ca, Ni, and Hg). 36 samples of soil, roots, and shoots was taken for digestion and subsequently analysed for heavy metals using an atomic absorption spectrophotometer. For heavy metals, data were collected in duplicates. For descriptive and inferential statistics. Mean, standard error of the mean, ANOVA, mean separation (post-hoc analysis was done using LSD method at 95% confidence limit. Result of the preliminary and post soil shows significant concentration level reduction in Mg, Cr, Pb, Co, Fe, Ca, Ni and Hg. (Pb 0.651 - 0.404 mg/l) (Cr 0.728- 0.459mg/l) (Ni 12.930 -5.895mg/l) (Co 0.649- 0.317mg/l), (Mg 30.270- 14.417mg/l), (Hg 0.649- 0.0005mg/l), (Ca 53.560- 28.864mg/l). Soil pH, Ec and CEC showed significant increase. Uptake of heavy metals from the soil by *Jatropha curcas* (Ca 11.040mg/l) showed greater efficacy than in *Jatropha podagrica and gossipifolia*. However, Nickel uptake, *Jatropha podagrica* showed greater efficacy of (1.684mg/L) while Cobalt level concentration in the three Jatropha species is significantly not different. Control soil (T_o) effect showed significant higher amount of calcium above T_1, T_2, and T3. Mg, Pb, Co, Fe, Ca, Ni and Hg were accumulated in the roots except chromium translocation from root to shoots. Pollution index, Bioconcentration index and Translocation index exceeds WHO Permissible level of 1.00. In conclusion, *J. curcas, J. podagrica* and *J. gossipifolia* shows great economical values and efficacy in clean-up of polluted soil. They can serve as viable ornamental plants around industrial polluted areas.

Keywords: Cement waste. Soil contaminant, Heavy metals, Phytoremediation, Jatropha

OIL PALM HUSK WASTE BIOCHAR AS A REPLACEMENT FOR MINERAL FERTILIZER IN EGGPLANT PRODUCTION AND POLLUTION REDUCTION IN OKITIPUPA, SOUTHWEST NIGERIA

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ABSTRACT

Environmental protection and food availability are becoming important factors in food production systems; thus, there should be a continuous, resilient strategy for food production systems. Efficient use of crop and other farm wastes, like oil palm husk waste converted to biochar for soil amendment, is a beneficial way to improve degraded agricultural soils, increase soil fertility, reduce pollution risk, and mitigate climate change through soil carbon sequestration and a reduction in greenhouse gas emissions. An experiment was carried out to evaluate the growth and yield response of *Solanum melongena* L. using a combination of organic (oil palm Husk biochar, pig slurry) and inorganic fertilizers (NPK) at Teaching and Research Farm, from 2021 to 2022 cropping seasons in a RCBD replicated thrice. Phenology and yield data were assessed using analysis of variance at P = 0.05. The result showed that response to growth and physio-morphological characteristics, yield attributes, and yield of eggplant were positively and significantly influenced by the application of Biochar with the recommended NPK and Biochar with Pig Slurry with the recommended. The T6 (50% Biochar + 50% recommended doses of fertilizer) treatment performed better. However, maximum yield of eggplant (78.02t ha^{-1}) was obtained from T6, and the lowest yield of eggplant (42.36 t ha^{-1}) was obtained from treatment T7. Recommended doses of fertilizer treatment (T6) proved more beneficial and sustainable for the cultivation and obtaining a better yield in eggplant. T4 facilitated the proper vegetative growth of eggplant plants, which could be attributed to physiological changes, and helped develop fruit clusters. Its potential to lead to healthier environmental, societal, and economic growth would enhance sustainability in a global context.

Keywords: Organic Amendment, Soil Properties, Eggplants, Growth, Yield, Biochar, Sustainable Agriculture

SIZE STRUCTURE, SEX RATIO AND GONADOSOMATIC INDEX OF *Chrysichthys nigrodigitatus* IN ASEJIRE RESERVOIR, SOUTHWEST NIGERIA

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ABSTRACT

The scientific management for sustainable utilization of fish stock through adequate and in-depth study of their reproductive mechanism is essential. Thus, this study was undertaken to provide the information on the size structure, sex ratio, gonadosomatic index of *Chrysichthys nigrodigitatus* in Asejire Reservoir. A total of 251 samples of *C. nigrodigitatus* were randomly collected from fishers' catch for seven months covering wet (February – April, 2022) and dry (May – July, 2022) seasons, respectively and categorised into sexes and sizes. The size structure, sex ratio and Gonadosomatic Index were determined following standard procedures. Data were analyzed using descriptive and inferential statistics at $\alpha 0.05$. Samples examined had a joint ratio of 1:1.5 indicating a more dominant female population across both seasons. However, there was only a slight difference in seasons sex ratio. The total length ranged from 17.00–56.30cm (wet), 16.40–52.60cm (dry) while the total body weight ranged between 62.00–546.00g (wet) and 25.00–443.00g (dry) $p<0.05$. The Gonadosomatic Index value ranged from 0.53–9.75 and 0.31–10.69 in wet and dry season respectively. The correlation coefficient between the GSI and body weight was 0.45(wet) and 0.20(dry) while the correlation coefficient between the GSI and length was 0.42 across both seasons. The relationship revealed that GSI on length had a similar pattern in the two seasons but slightly different in weight. The result revealed a positive correlation across all relationships except between the GSI and weight in the dry season, indicating an increase in weight and length will subsequently increase the GSI of *C. nigrodigitatus*. The study provides crucial reproductive insights for managing *C. nigrodigitatus* and suggests exploring its aquaculture potential through additional research.

Keywords: Biology, size, sex, gonadosomatic index, Management

MAPPING URBAN GREEN SPACES AT THE METROPOLITAN LEVEL USING GEOSPATIAL TECHNOLOGIES.

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ABSTRACT

Urban green spaces (UGSs) offer crucial environmental benefits for both society and ecological health. UGSs present significant management problems, especially in rapidly expanding urban regions, because of the continuous environmental, social, and economic alterations that cities undergo. It is now possible to optimise the capture of UGS in satellite imagery thanks to developments in geospatial technologies. This study assesses the relationship between land surface temperature variability and the spatial distribution of UGS in UGS's spatial distribution in Osogho LGA. The 'heavy vegetation' class makes up 1043.82 hectares (10%) of the entire research area. This category is synonymous with the city's peri-urban green spaces, which are primarily found there. The entire "No vegetation" class has a total area of 1966.50 ha (35%), which has the highest Normalised Difference Built-up Index (NDBI) score. The built-up portions of the city spread out in several directions from its (CBD). The "low temperature" class is seen in heavily forested areas. It took up 1028.16 ha (19%) of the study area in total. With temperatures between 28.89 and 30.68 ^{o}C, 1605.78 hectares (or 29%) fall into the "moderate temperature" category. The largest class of LST took approximately 958.95 hectares (17%) of the study region in terms of physical space. According to the study, there is a significant positive association between LST and NDBI (0.944). On the other hand, LST and NDVI have a significant negative association (-0.974).

Keywords: urban green spaces; imagery, ecosystem, geospatial, biodiversity

ETHNOMEDICINAL STUDY OF SELECTED PLANTS USED BY THE IBIBIO IN AKWA IBOM STATE, NIGERIA

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ABSTRACT

Medicinal plants have been an integral part of human society from the dawn of civilization because of their effectiveness in the treatment of diseases. Identification and documentation of some medicinal plants used by the Ibibio was carried out in three communities (Ibiaku Uruan, Eman Uruan and Mbiaya Unruan) in Uruan Local Government Area of Akwa Ibom state, Nigeria. Medicinal plants were identified with their local name, common name, scientific name, family, parts used, medicinal value and method of usage. The results showed that different plant parts were used to treat various ailments. The percentage of plant part value (PPV) showed that Leaves (72%) is the most widely used parts, followed by roots (38%), Bark (10%), Stem (6%) and Fruits (4%). The various ailments treated with the medicinal plants included: Skin disease, Malaria, Typhoid and Cough (18.42), Swollen stomach (15.8%), Gonorrhea (10.52%), Stomach pain, Sore throat, Detox, Diarrhea and Healing of wound (7.8%), Convulsion, Anemia, Belt and Whitlow (5.2%), Eye pain, breast cancer, Abortion, Swollen leg, Broken feet, Hydration, Rheumatism, Local binder, Cholera, Numbness, Ease labor pain, Fungal infection, Abscess, Internal heat, Ulcer, Ease child birth, Neutralizes poison, Dysentry, Toothache, Galactorrhea, Appendicitis, Ear pain, Belt and Elephantias (2.63%). The most used method of preparation is squeezing. The study has provided a veritable source of information for medicinal plant researchers which may lead to discovery of new modern drugs.

Keywords: Medicinal value, Medicinal Plants, Ethnobotanical Treatment, Plant Parts, Ibibio

CONTRIBUTION OF NON-TIMBER FOREST PRODUCTS TO FOOD SECURITY IN EKITI STATE, NIGERIA

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ABSTRACT

Non-timber forest products from forest and forest lands are important sources of livelihood in many rural areas of Nigeria. Their contribution to food security has not been widely investigated. Therefore, the main objective of this study was to assess the contribution of non-timber forest products to food security in Ekiti State. Ten (10) respondents were selected randomly in each of sixteen community in Ekiti State. They were interviewed with semi- structured questionnaire matrix. The finding of revealed that majority of the respondents interviewed were male (69%) while few were female (31%). Almost half of the respondents interviewed were within the age of 31- 50 years. List of NTFPs identified by include honey (71%), bush meat (54%) palm wine (83%), snails (59%), mushroom (86%), cassava (100%), vegetables (100%), palm Kernel (96%), bamboo, yam (90%), locus beans (83%) and bitter kola (61%). The study also revealed negative human impact through the activities of poachers that usually carry out illegal felling of timber and indiscriminate bush burning in the dry season while hunting for wild animals. Respondents faced challenges in marketing their products and high cost of transportation. It is recommended that collectors and the consumers of the products should be educated on the ways by which these products can be conserved through sustainable harvesting practices.

Keywords: Non-timber forest products, Food security, Forest degradation, Tropical forests, Forest lands

WATER PURIFICATION AND ANTIMICROBIAL EFFICACY OF *Moringa Oleifera* DRIED AND MACERATED SEED

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ABSTRACT

Moringa oleifera is an economically important plant with multipurpose benefits. The seed of this plant has been known as a coagulant as well as an antimicrobial agent in water treatment. Availability of clean drinking water is still a major concern in most developing countries especially in rural areas. A simple and cost-effective method for water purification is required for rural communities. The method involves the use of moringa seed both dried and macerated in purifying borehole and well water in the community. Experiments in this study are conducted using jar test set up at varying times and concentrations. The water samples were subjected to purification studies and treated with dried and macerated moringa seed. Treated water samples were subjected to bacteriological analysis using most probable number technique. The total mesophilic bacteria, total mesophilic fungi, and total coliforms of borehole water after treatment with moringa seed are 190×10^1 cfu/ml, 6×10^1 cfu/ml, and 2 MPN/ml respectively, while the total mesophilic bacteria, total mesophilic fungi, and total coliforms of well water after treatment is 210×10^1 cfu/ml, 10×10^1 cfu/ml and 425 MPN/ml respectively. The pH and the temperature of the treated water fall between WHO standards. Thus, this study evaluates the efficacy of *Moringa oleifera* dried and macerated seed as an antimicrobial agent in water treatment and purification.

Keywords: *Moringa*, antimicrobial properties, water, microorganisms

ENVIRONMENTAL SUITABILITY FOR FISHES IN EKO-ENDE RESERVOIR, NIGERIA

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ABSTRACT

Eko-Ende reservoir is one of the oldest reservoirs in Osun state, which is encompassed with diverse human activities. This study therefore aimed to assess the abundance and diversity of fish species about human activities and sustainable management of the reservoir. Three sampling points (A–C) were selected with monthly sampling of water quality, and fish samples for one year. The fish length (cm), and weight (g) were collected and the condition factor (K) was calculated. The Shannon-Wiener (H), Evenness (E), and Simpson's index were calculated. The mean values for temperature (26.36 ± 0.02ºC), pH (7.01 ± 0.00), dissolved oxygen (4.19 ± 0.01mg/L), and ammonia (0.02 ± 0.16mg/L) were within the recommended limits. A total of 1279 individuals belonging to 5 families and 9 species were identified. *Coptodon zillii* and Cichlidae were the most abundant species (17.6%) and family (60.3%) respectively. The length-weight relationship values were positive for *Oreochromis niloticus* (b = 0.03), *C. marie* (b = 0.02), and *Alestes baremose* (b = 0.07; p = 0.01), and negative for *C. zilli* (b = -0.35), *Sarotherodon galileaus* (b = -0.85; p = 0.00) and *Chrysichthys nigrodigitatus* (b = -0.23). The growth pattern for all the fish species showed a negative allometric pattern because the b-values were less than 3. The H (and D - values indicated a high diversity, and species were fairly even (2.12). The study presented the reservoir as a good haven for fish species, based on the water quality parameters measured. With this, increased fishing pressure and human activities are expected around the reservoir, which can lead to a significant effect on the fish biodiversity. Regular awareness regarding the control of human activities and fishing activities around the reservoir must be of the utmost for sustainability. Keywords: Fish composition, growth pattern, morphometric characteristics, sustainability

SEASONAL VARIATION IN HAEMATOLOGICAL PARAMETERS OF *Clarias. gariepinus* AND *Oreochromis niloticus* FROM RIVER JAMA'ARE, NIGERIA

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ABSTRACT

The study was conducted to determine the influence of season on haematological parameters of *C. gariepinus* and *O. niloticus* caught from River Jama'are. A total of 20: five each of matured fish species were obtained in dry and wet seasons. Blood samples were collected from the cardiac vein of the fishes using separate heparinized dispensable syringes and hypodermic needles. Some physicochemical parameters of the water were determined. The data collected were analysed by two-sample t-test. Temperature was statistically significant with the mean values of 25.90^0C in dry season and 25.70^0C in the raining season in River Jama'are. The same trend was observed in Dissolved Oxygen (DO) with mean value of 5.90 mg/L in dry season while in the raining season was 5.30 mg/L in. The mean pH of 8.30 was higher during raining season than 7.80 in the dry season. The WBC, Hb and MCHC were statistically significant between raining and dry seasons while RBC, PVC, MCV and MCH were statistically not significant in both wet and dry seasons. All the haematological parameters were statistically not significant between *C. gariepinus* and *O. niloticus* in River Jama'are. Similar research should be carried out on other species of fishes in the River.

Key Words: Haematological Parameters, *Clarias gariepinus*, *Oreochromis niloticus*, River Jama'are

QUALITY ASSESSMENT OF WATER FROM SELECTED BOREHOLE LOCATIONS IN ADO EKITI, EKITI STATE, SOUTHWEST NIGERIA.

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ABSTRACT

Borehole water is an underground water which is commonly believed to be pure and safe to drink. However, due to the indiscriminate drilling of boreholes, the water may be subjected to pollution and may not be as pure as it is generally assumed. The present study assessed the quality of borehole water by selecting ten different borehole locations within Ado -Ekiti. This was carried out by assessing the physiochemical parameters, microbial and heavy metal contamination using standard procedures. The physiochemical parameter results showed that Temperature ranges between 25.99^0C-26.60^0C, EC ranges between 41.62µs/cm-202.54 µs/cm, pH ranges between 6.81-7.57, TDS ranges between 28.15mgl - 116.22mgl, TSS ranges between 0.09mgl-1.27mgl, Turbidity ranges between 0.12NTU-0.71NTU, Total Hardness ranges between 29.64mg/l - 80.61mg/l, Total Alkalinity ranges between 20.97mg/l - 65.42mg/l and all values were within WHO permissible limits. The bacteria count of borehole water sample ranged from 10.66 ± 0.03 Cfu/ml to 12.56 ± 0.03 Cfu/ml. Highest fungi count of the borehole water sample was in the value ranges from 8.27 ± 0.00 Sfu/ml to 9.63 ± 0.02 Sfu/ml. The highest coliform detected in the borehole sample ranges from 5.33 ± 0.58 Cfu/ml to 8.67 ± 8.56 Cfu/ml. The bacteria, fungi and coliform count result observed in this study was higher than the WHO recommended limits. The metals occurred in the samples in this order Cr >Fe > Pb > As > Cd. The heavy metals were present in quantities higher than WHO recommended limit in some of the samples which is indicative of potential health hazards through the water consumption. These results showed that the borehole water is not as pure as it is popularly assumed to be, hence there is need to closely monitor the quality of borehole water samples to ensure the safety of health of consumers.

Keywords: Borehole Metals Physiochemical Fungi Bacteria Coliform

VARIATIONS IN THE GROWTH PERFORMANCE OF *S. anguivi* Lam AS AFFECTED BY DIFFERENT TYPES OF SOIL AND WATERING REGIMES

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ABSTRACT

S. anguivi planted in three different soil samples were subjected to three watering treatments toexamine the effect of soil types and watering regimes on the early seedling growth of *S. anguivi*an important green leafy vegetable consumed in South West Nigeria. The growth of *S. anguivi* performed best in fallow soil with highest values in plant height (33.43 cm) ; mean number of leaves (9.25), leaf area (423.25 cm 2); stem girth (6.12 mm); dry root weight (0.23 g) and dry shoot weight (0.53 g) respectively with daily watering. The degraded soil has the least values in all the growth parameters studied. Statistical analysis (ANOVA ≤ 0.05) revealed that the types of soil and watering regimes have no significant difference on the plant heights; number of leaves; leaf area with dry root and shoot weights at 5% level of significance. However, the stem girth ofplants grown on fallow and cultivated soils with everyday watering showed significant differences to plants watered every three days. It is suggested that fallow soil might be a good option for the cultivation of S. anguivi. However, further studies on the optimum fallow period that would enhance optimum yield production should be carried out particularly now that most agricultural land is being converted to non-agricultural purposes.

Keywords: Watering regime, soil types, *S. anguivi*, Vegetable, Growth performance

ELEMENTAL INPUT ACCUMULATED ON FOREST FLOOR LITTERS IN RIPARIAN FORESTS IN OSUN STATE, NIGERIA

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ABSTRACT

Litter inputs in forest floor provides key elements returns to the soil which is important to sustainability of species endemic in riparian forest ecosystems. Among the tropical forest ecosystems studied in Nigeria, the floor litters of riparian forests are often neglected. The litter standing crop was sampled at peak of rainy and dry season. Five (5), 1 m × 1 m quadrats were randomly laid within each sampling plot for a total of 25 quadrats per site. Samples collected were sorted into components and were oven–dried at 70 ^{o}C to a constant weight. The dried samples were ground; pass through a 0.5 mm sieve for chemical analyses. The weights were used to evaluate the amount of litter and total nutrient content was also determined. The values of litters in the forest floor at the peak of seasons was (3.48-3.94 t ha^{-1}), being higher in the dry season. Elemental concentrations especially C and N were positively correlated among the components of litters in the floor across study sites. The amount of C deposited (77.26 Kg ha^{-1}) was highest and P (0.52 Kg ha^{-1}) the lowest. The positive correlations of key elements in the litter components and nutrient deposition in the forests floor indicated that ecosystems are being sustained, increasing biodiversity by acting as vector for energy replacement in food web and nutrient returns to the soil.

Key words: elemental concentrations, litter standing crop, nutrient deposition, peak of seasons sustainability

IMPACT OF TEMPERATURE AND GROWTH MEDIUM ON THE GROWTH AND YIELD OF *Alternaria porri* AND *Penicillium digitatum* IN ONION AND CITRUS ECOSYSTEMS FOR ENSURING ECOSYSTEM HEALTH

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ABSTRACT

A laboratory experiment was conducted at the Mycology Laboratory of Usmanu Danfodiyo University in Sokoto, Nigeria. The study aimed at assessing the optimal temperature and growth medium for cultivating and enhancing the yield of the fungal species *Alternaria porri* and Penicillium *digitatum*. These fungi were cultivated on two distinct growth media, namely Onion Dextrose Agar (ODA) and Czapek-Dox Agar (CDA), across a range of five temperature settings 27±3°C, 35°C, 40°C, 45°C, and 50°C. The experimental layout followed a complete randomized design (CRD) and was replicated three times. The data collected were subjected to analysis of variance (ANOVA) and the mean separated by least significance difference (LSD). Results indicated that at 27±3°C on both growth media (CDA and ODA), *Alternaria porri* had the most substantial and statistically significant ($p<0.05$) mean growth of 65.7000 mm, while *Penicillium digitatum* had a lower mean growth of 48.4648 mm. Among the growth media, Onion Dextrose Agar (ODA) recorded the highest significant ($P<0.05$) mean growth of 62.4778 mm, followed by Czapek-Dox Agar (CDA) with a mean growth of 51.6870 mm. *Alternaria porri* thrived well in ODA with a least square mean growth of 68.8667mm, whereas *Penicillium digitatum* had poor growth in CDA with a least square mean growth of 40.8407mm. The fungal growth was notably hindered at the high temperature of 50°C. The findings established that the most favorable temperatures for fostering the growth of both fungal were 27±3°C and 35°C, with implications for practical applications. The application of fungicides on onion seedlings should should be carried out at temperatures of 27±3°C or 35°C, corresponding to the periods when the performance of *Alternaria porri* is most vigorous.

Keywords: *Alternaria porri*, *Penicillium digitatum*, Citrus, onion seedlings.

ASSESSMENT OF VULNERABILITY AND ADAPTATION TO THE IMPACT OF CLIMATE CHANGE IN PARTS OF YOBE STATE, NIGERIA

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ABSTRACT

This paper assessed the vulnerability and adaptation strategies to impact of climate change in some areas of Yobe State, Nigeria. Socio-demographic characteristics and relationship between vulnerability and adaptation strategies, effectiveness of the adaptation strategies to the impact ofwere assessed. Primary and secondary data were collection. It was found that 61% were male between the ages of 20-80 years, 80% of the respondents have a household size of more than 10 members with no access to formal education. Sixty nine percent (69%) of the respondents were aware of the most vulnerable groups as women (both pregnant and non-pregnant), elderly persons and children, 62% of the respondents held that the vulnerability may be as a result of socio-economic and ecological and political factors. Whereas, 64% of the respondents held that they do not have control over critical livelihoods resources, 62% of the respondents believed thatwomen and other marginalized groups had no equal access to information, skills and other services. However, 66% thought that there is no equal right among women and other marginalized vulnerable groups in the study area. Low community awareness (13%) on vulnerability exposes the communities to lack of infrastructures to more vulnerable impacts by climate change in the state as negative. It is recommended that government and concerned organizations create awareness on sustainable development of proper environmental conservation to inhabitants; environmental laws should be enacted in the state by the major stakeholders, nontechnical approaches on climate change adoption, vulnerability and mitigation strategies.

keywords: Adaptation, Adaptive capacity, Climate change, Mitigation, Vulnerability.