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VARIATION IN SPECIES COMPOSITION AND DIVERSITY OF A SOIL SEED BANK: A DUMPSITE AND A FALLOW FIELD

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ABSTRACT

Soils are natural storage house for seeds. Seeds are deposited through several means and stored at different depths. Ecological zones vary in seed composition and quantity. This study was designed to investigate species composition and diversity of soil at a dumpsite and a fallow field. It also evaluated the effects of anthropogenic activities on the species composition of the dumpsite. Seedling emergence method was used to identify seeds to species level using a field guide. Eight soil samples were each collected from both dumpsite and fallow field at three depths (0-5 cm, 5-10 cm, and 10-15 cm) using standard techniques. Soil samples were transferred using bags to Centre for Ecological Studies, University of Port Harcourt, where the soil samples were sieved, 100g weighed, replicated twice in a plastic plate, watered daily and kept in the greenhouse. Seedling emergence was monitored, recorded, and identified for four weeks using a field guide. Data generated were subjected to statistical analysis using one-way ANOVA at $\alpha_{0.05}$. *Species diversity index was calculated using Paleontological Statistics. From both areas, Oldenlandia corymbosa, Sedges, and Lindernia sp. were the most abundant while Celosia leptostachya, Cynodon dactylon,* Croton *sp., and Sida sp. had the least abundant. Fallow field soil had higher number of seedling emergence, but was not significantly different from dumpsite at all depths. Fallow field had both highest and lowest species diversities at 0-5 cm and 10-15 cm respectively across all depths. Anthropogenic activities at the dumpsite had minimal effect on the viability of the seeds as they only needed favourable conditions to sprout. This study shows that soil seed bank is a natural storage medium for varieties of plant species across various depths for fallow field and dumpsite. The presence of these plant species in the soil reveals the regenerative potential of both areas, particularly the dumpsite.*

Keywords: Dumpsite, fallow field, seed bank, species diversity, soil.

INTRODUCTION

A dumpsite is commonly known as a waste disposal area and is characterized by the burial of waste materials in the soil layers. Dumpsites otherwise known as landfills have adverse effects on living organisms and their environments. Notable among these effects is the pollution of the soil, atmosphere, water bodies, loss of biodiversity, and many more. Similarly, soil texture and structure have been altered by a variety of human activities and this leads to mixed horizons, foreign materials, and thin topsoil (Civeira and Lavado, 2010; Poschlod and Rosbakh, 2018). This, therefore, implies that the vegetation cover of a dumpsite is poor and it could affect the soil seed bank. A fallow field is a piece of arable land that is left without sowing for few vegetative seasons. This act enables the soil to regain its organic nutrient naturally while maintaining its moisture contents (Traba and Morales, 2019). Fallow periods are important in biodiversity studies, and weed management. During such periods, the soil seed bank produces large varieties of plant species and aid in the storage of dormant seeds (Major and Dessaint, 1998).

Studies on soil seed banks have gained immense interest due to their importance in the preservation of biological diversity, ecological restoration, plantation renovation, vegetation succession, diffusion processes, and other areas of vegetation (Zhang, 2006; Lu et al., 2010; Jiang et al., 2013). In addition, Wang et al. (2013) reported that soil seed bank is an important component of ecosystem resilience and it represents the regeneration potential of many plant communities. Simpson et al. (1989) defined soil seed bank as all viable seeds present on or in the soil or associated litter. This comprises seeds that recently fell onto the soil surface and viable seeds that have accumulated in the soil over several years (Menalled and

Schonbeck, 2011). Recent investigations have revealed that soil seed bank is an indicator for past, present, and future vegetation of plant population and/or ecosystem, storage medium for varieties of plant species (Sanderson et al., 2007; Fisher et al., 2009; Anyanwu et al., 2019) based on the available plant species at various soil depths (Dalling et al., 1995). Through this medium, plant species diversity is preserved and information on their dynamics and structure is maintained (Anyanwu et al., 2019).

There exist vast definitions for soil seed banks based on field and experimental studies. INHF (2001) defined soil seed banks as a network of seeds present in the soil and are needed for survival. Before this, Robert (1981) and Simpson et al. (1989) described soil seed bank as the viable seed reservoir accessible to the soil. Baker (1989) further added that the reservoirs contain seeds not germinated but are capable of supplanting the annual and perennial adult plants. The potential of soil seed bank to act as a reservoir (natural storage) explains its ability to affect the continuity of plant species through upcoming vegetation (Alemu, 2016) and provide data on the vegetation status and regenerative potential of an ecosystem (Li et al., 2009).

An understanding of the population dynamics of buried viable seeds is of some practical importance in agriculture, forestry, and conservation (Lu et al., 2010; Wang et al., 2013). According to Major and Pyott (1966), a complete description of the plant community must contain the buried viable seeds because of their high species composition comparable to the above-ground species. This implies that the soil seed bank reflects the vegetation history or evolutionary memory of an ecosystem. The seeds present within the soil are spread across the soil profile (Singh et al., 2012; Begum et al., 2006) thereby making seeds available at any depth.

In the studies of the soil seed bank, two methods are commonly utilized. These methods involve either collecting a sample of the seed itself and undertaking an identification process (physical separation methods) which is also called manual seed extraction or growing the seed itself and identifying the seedlings thereafter (seedling emergence) (INHF, 2001). Seed extraction and seedling emergence methods are necessary to identify the species composition. Taking this fact into consideration, Gonzalez and Ghermandi (2012) proposed that in explaining the seed banks and improving the illustration of the results, both methods were necessary.

The soil seed bank studies of various ecosystems have been evaluated ranging from forests, deserts, and crude polluted sites, to wetlands with scanty information available on dumpsites and fallow fields. To this end, this study uses an ecological and systematic approach to examine the composition of the species diversity and impact of the dumpsite and fallow land on the soil seed banks. It also investigates the regenerative potential of these areas based on their species diversity.

MATERIALS AND METHODS

Study area

The study area comprises two locations namely; the university park dumpsite and the fallow field within the Agricultural farm, both at the University of Port Harcourt. Frequent anthropogenic activities along with large amount of waste are deposited at the dumpsite which results to the poor or scanty vegetation cover of the dumpsite. In the fallow field, there is high species diversity due to the absence of habitat disturbance. Soil auger was used to collect the samples from these locations randomly at three depth levels (0-5 cm, 5-10 cm, and 10-15 cm) and bagged into properly labelled polythene bags. The GPS (Global Positioning System) device provided the geographic location and coordinates of the sample collection sites (Table 1).

Table 1. GPS point of the study sites

Location/Sites	Northing's (Latitude)	Easting's (Longitude)
Dumpsite	4.9084418	6.9169499
Fallow field	4.9064281	6.9152419

GPS Device: Garmin GPSMAP 64S

Soil Preparation

The collected soil samples were transferred to the Center for Ecological Studies (Green House) at the University of Port Harcourt. Forty-eight (48) samples were collected from both locations and replicated two (2) times to derive a total of Ninety-six (96) plates. The soil samples were air-dried, sieved to remove stones and debris, and 100 g was weighed and poured into well-labelled perforated plates. Whatman filter paper was placed at the base of the plastic plate to control the moisture content of the soil.

Seed Enumeration

The soil samples were subjected to a seedling emergence test to determine the seed viability, density, and species composition across the depth levels and different locations. Soil samples were monitored weekly for four (4) weeks and the emerging seedlings were identified, recorded, and discarded. The identification was done using a field guide (Akobundu et al., 2016) while unknown species were transferred to the field, monitored, and later identified.

Data Analysis and Sampling Design

Data collected from this study were analyzed using one-way analysis of variance (ANOVA) to ascertain the significant difference within factors. The experimental design used was Completely Randomized Design (CRD) and descriptive statistics such as mean and standard deviation was employed. Paleontological Statistic was used to calculate the species diversity for both areas. Species composition was determined using margalef's index, species diversity using Simpson index of diversity while species evenness was determined with evenness index.

RESULTS

Soil Seed Bank and Species Composition

From this study, a total of nine hundred and thirty-four (934) seedlings emerged from the two (2) study sites within the four (4) weeks of soil sampling. Four hundred and Sixty-Three (463) emerged seedlings and four hundred and seventy-one (471) emerged seedlings were identified from the dumpsite and fallow field respectively.

Based on species diversity, twenty-four (24) plant species from fourteen (14) families were identified and recorded. Poaceae had four (4) species while Asteraceae had three (3) plant species from the study. Rubiaceae, Euphorbiaceae, Amaranthaceae, and Lamiaceae had two (2) species each while Malvaceae, Selaginellaceae, Piperaceae, Phyllanthaceae, Solanaceae, Portulacaceae, and Lindernaceae had the least number of species which is one (1) (Table 2).

Number of individuals at the dumpsite

At depths (5 cm, 10 cm, and 15 cm), there are large quantities of *Oldenlandia corymbosa, Phyllantus sp.* and Sedges in the soil. *Phyllanthus sp.* had more species at 5 cm soil depth than other species. Also, the mean number of species increased with depth for the dumpsite.

Number of individuals at the fallow field

In the fallow field at depths 5 cm, 10 cm, and 15 cm, there are large quantities of persistent seeds of *Odenlandia corymbosa*, Sedges, and *Ageratum conyzoides* species in the soil. The mean number of species decreased with depth for the fallow field.

Table 2. Summary of the total number of emergent seedlings observed across each depth per location.

			Dumpsite			**Fallow Field**		
S/N	**Seed Bank Species**	**Family**	**5cm**	**10cm**	**15cm**	**5cm**	**10cm**	**15cm**
1.	Sedges	Cyperaceae	5	11	29	92	35	20
2.	*Ophismanum burmanii* (Retz.) P. Beauv.	Poaceae	0	0	0	3	2	0

3.	*Oldenladia corymbosa* L.	Rubiaceae	35	74	143	153	42	23
4.	*Acalypha ciliata* Forsk.	Euphorbiaceae	0	0	0	6	0	2
5.	*Lindernia sp.*	Linderniaceae	3	15	5	10	2	2
6.	*Cyathula prostrata* (L.) Blume	Amaranthaceae	0	0	0	5	2	4
7.	*Spermacoce ocymoides* L.	Rubiaceae	0	0	0	6	1	0
8.	*Platostoma africanum* P.Beauv.	Lamiaceae	0	0	1	2	0	0
9.	*Physalis sp.*	Solanaceae	0	0	0	2	0	0
10.	*Solenostemon monostachyus* P.Beauv.	Lamiaceae	0	0	1	12	0	0
11.	*Ageratum conyzoides* L.	Asteraceae	1	1	0	15	6	2
12.	*Croton sp.*	Euphorbiaceae	0	0	0	1	0	0
13.	*Eleutheranthera sp.*	Asteraceae	0	0	0	1	1	0
14.	*Cynodon dactylon* (L.) Pers.	Poaceae	0	0	0	1	0	0
15.	*Aspilia africana* (Pers.) C.D. Adams	Asteraceae	0	0	0	1	1	0
16.	*Axonopus compressus* (Sw.) P. Beauv.	Poaceae	1	0	0	2	0	0
17.	*Talinum triangulare* Jacq.	Portulacaceae	1	3	0	0	0	0
18.	*Phyllanthus sp.*	Phyllanthaceae	63	34	2	0	2	1
19.	*Eleusine indica* (L.) Geartn.	Poaceae	3	0	0	0	1	0
20.	*Peperomia pellucida* Kunth	Piperaceae	0	0	0	0	3	2
21.	*Celosia leptostachya* Benth.	Amaranthaceae	1	0	0	0	0	0
22.	*Sida sp.*	Malvaceae	0	0	0	1	0	0
23.	*Selaginella sp.*	Selaginellaceae	13	11	6	0	0	0
24.	*Digitaria horizontalis* Haller.	Poaceae	1	0	0	1	1	2
	Total number of individual species.		11	7	7	18	13	9
	Total number of plant species.		127	149	187	314	99	58

Difference Between Study Location at Each Depth

There is no significant difference ($p>0.05$) between the number of species at the dumpsite and fallow field for 5 cm, 10 cm, and 15 cm depth. An upward trend in the number of species was observed for dumpsite where soil depth 15 cm had the highest number of species followed by 10 cm and 5 cm (Tables 3 and 4). For the fallow field, there was a downward trend across the soil depths. In this sequence 5 cm (highest number of species), 10 cm and 15 cm (Tables 3 and 4).

Table 3: Difference between field location at each depth

	5cm	10cm	15cm
Dumpsite	5.08±14.09	5.96±16.09	7.48±28.83
Fallow Field	12.56±34.47	3.96±10.58	2.32±5.88
T-Test (p-value)	0.320	0.606	0.385

Species Diversity
The study revealed that species dominance was highest for depth 15 cm followed by 5 cm and 10 cm for both dumpsite and fallow field. In the dumpsite, species richness and diversity were highest in this sequence 5 cm, 10 cm and 15 cm. On the flipside, the species evenness was highest for depth 10 cm succeeded by 5 cm and 15 cm. In the fallow field, species diversity was highest in the sequence of 5 cm, 10 cm and 15 cm but species richness was highest at 5 cm followed by 10 cm and 15 cm. For species evenness, a downward trend was observed from 15 cm down to 10 cm and 5 cm (Table 5).

Table 4: Difference between depths for each nature of field

	Dumpsite	Fallow Field
5cm	5.08±14.09	12.56±34.47
10cm	5.96±16.09	3.96±10.58
15cm	7.48±28.83	2.32±5.88
ANOVA (p-value)	0.918	0.190

Table 5: Species diversity index for dumpsite and fallow field at various depths.

S/N	Diversity Index	Dumpsite			Fallow Field		
		5cm	10cm	15cm	5cm	10cm	15cm
1.	Taxa_S	11	7	7	18	13	9
2.	Individuals	127	149	187	314	99	58
3.	Dominance_D	0.3355	0.3202	0.6107	0.3293	0.3117	0.2872
4.	Simpson_1-D	0.6645	0.6798	0.3893	0.6707	0.6883	0.7128
5.	Shannon_H	1.431	1.413	0.8059	1.558	1.555	1.569
6.	Evenness_e^H/S	0.3804	0.5868	0.3198	0.2638	0.3641	0.5335
7.	Margalef	2.064	1.199	1.147	2.957	2.611	1.97
8.	Fisher_alpha	2.891	1.524	1.435	4.147	4.003	2.982

Table 6: Summary of species diversity for the dumpsite

	5cm	Lower	Upper	10cm	Lower	Upper	15cm	Lower	Upper
Taxa_S	11	11	11	7	7	7	7	7	7
Individuals	127	127	127	149	149	149	187	187	187
Dominance_D	0.3355	0.2734	0.3898	0.3202	0.2682	0.3859	0.6107	0.5347	0.6952
Simpson_1-D	0.6645	0.6101	0.7266	0.6798	0.6138	0.7318	0.3893	0.3048	0.4652
Shannon_H	1.431	1.308	1.636	1.413	1.271	1.54	0.8059	0.6427	0.9522
Evenness_e^H/S	0.3804	0.3363	0.467	0.5868	0.5092	0.6666	0.3198	0.2745	0.3713
Brillouin	1.319	1.199	1.512	1.337	1.198	1.46	0.7559	0.5993	0.8978
Menhinick	0.9761	0.9761	0.9761	0.5735	0.5735	0.5735	0.5119	0.5119	0.5119
Margalef	2.064	2.064	2.064	1.199	1.199	1.199	1.147	1.147	1.147
Equitability_J	0.5969	0.5456	0.6824	0.7261	0.6532	0.7916	0.4141	0.3348	0.4898
Fisher_alpha	2.891	2.891	2.891	1.524	1.524	1.524	1.435	1.435	1.435
Berger-Parker	0.4961	0.4016	0.5669	0.4966	0.4161	0.5772	0.7647	0.7005	0.8235

Chao-1	21	11	21	7	7	8	7.5	7	10

Table 7: Summary of species diversity for the fallow field

	5cm	**Lower**	**Upper**	**10cm**	**Lower**	**Upper**	**15cm**	**Lower**	**Upper**
Taxa_S	18	14	18	13	10	13	9	7	9
Individuals	314	314	314	99	99	99	58	58	58
Dominance_D	0.3293	0.2926	0.3721	0.3117	0.2576	0.3778	0.2872	0.2277	0.3817
Simpson_1-D	0.6707	0.6278	0.7074	0.6883	0.622	0.7422	0.7128	0.6183	0.7723
Shannon_H	1.558	1.394	1.682	1.555	1.295	1.753	1.569	1.226	1.754
Evenness_e^H/S	0.2638	0.2447	0.3362	0.3641	0.3147	0.4559	0.5335	0.431	0.6534
Brillouin	1.475	1.324	1.596	1.395	1.168	1.581	1.377	1.081	1.549
Menhinick	1.016	0.7901	1.016	1.307	1.005	1.307	1.182	0.9191	1.182
Margalef	2.957	2.261	2.957	2.611	1.959	2.611	1.97	1.478	1.97
Equitability_J	0.539	0.5035	0.5965	0.6061	0.5376	0.6867	0.7141	0.6074	0.8028
Fisher_alpha	4.147	3.005	4.147	4.003	2.777	4.003	2.982	2.082	2.982
Berger-Parker	0.4873	0.4299	0.5414	0.4242	0.3636	0.5253	0.3966	0.3448	0.5345
Chao-1	21.75	14.25	32	15	10.75	31	9	7	15

DISCUSSION

Soil seed banks are natural storage reservoirs that are paramount to the natural environment of many ecosystems. In this study, nine hundred and thirty-four seedlings emerged after four weeks from two study locations namely; dumpsite and fallow field. The fallow field had more emergent seedlings of four hundred and seventy-one compared to the dumpsite with four hundred and sixty-three. Twenty-four plant species were observed and recorded from fourteen plant families.

Species diversity, population, and distribution

The use of species diversity to calculate species composition and/or a variety of a plant community has played important role in soil seed bank studies (Anyanwu et al., 2019). In this study, a similar approach was adopted for the two locations at soil depths 0-5 cm, 5-10 cm, and 10-15 cm. The higher the margalef and Fisher_alpha diversity indexes, the higher the plant diversity at the various depths. The Dominance index revealed areas with high species dominance particularly dumpsite (15 cm depth) at 0.6107 and fallow field (5 cm depth) at 0.3293 respectively.

High population density and diversity were observed for sedges, *Oldenlandia corymbosa* and *Lindernia* sp. at various soil depths when compared to above soil vegetation, particularly for *Oldenlandia corymbosa*. This could be as a result of high species dominance at the study locations and large seed production. The species with the lowest population density are *Celosia leptostachya*, *Cynodon dactylon*, *Croton* sp., and *Sida* sp., and at 5 cm soil depth for both locations.

Both study locations (dumpsite and fallow field) gave a high abundance of plant species but at varying depths. At 5 cm depth, the fallow field had high species abundance and diversity but this decreased progressively down the depths (10 cm and 15 cm). The dumpsite showed a relatively even distribution of species but higher abundance at 15 cm depth while 5 cm depth had higher species diversity. Progression in species abundance increased downwards for the dumpsite which was different for the fallow field. Sedges, *Oldenlandia corymbosa*, and *Lindernia* sp. were found at both locations and distributed across all the soil depths. The presence and abundance of this species are similar to the works of Anyanwu et al. (2019) but on spent engine oil-polluted sites. In the same accord, the distribution of seeds (weeds) across the soil profile as observed in this study confirms the findings of Begum et al. (2006)

and Singh et al. (2012). This implies that these plant species can flourish in vast soil irrespective of the nature of anthropogenic activities carried out. Contrary to this, *Celosia leptoclada, Cynodon dactylon, Croton* sp., and *Sida* sp. were the least represented species and scanty across the soil profile. Interestingly, a difference exists in the species composition of both locations. *Ophismanum burmanii*, *Acalypha ciliata*, *Cyathula prostrata*, *Spermacoce ocymoides*, and *Physalis sp.* were only found at the fallow field while *Talinum triangulare* and *Celosia leptostachya* were found only at the dumpsite.

Anthropogenic effects on the dumpsite

The deposition of large waste materials (both biodegradable and non-biodegradable) at the dumpsites have resulted in very scanty vegetation cover and loss of biodiversity. This occurrence affirms the report of Magaji (2012). Contrary to this, the rate of anthropogenic activities on the dumpsite did not have much effect on the viability of the seeds as the seeds only needed favourable conditions to sprout after periods of dormancy. A variety of seedlings were observed at various soil depths and these show the regenerative potential and re-vegetation structure of the area. The frequent human and animal activities have submerged the soil and seeds thereby resulting in more abundance of seeds at the lowest depth (15 cm). On the other hand, high species abundance and diversity were observed at the fallow field as there was a relative representation of the surface vegetation at the seedlings from the soil seed bank. The fallow field has a high abundance of seedlings and species diversity at 5 cm depth. This is similar to the reports of Lopez-Toledo and Martinez-Ramos (2011) stating the regeneration potential of an abandoned tropical pasture, and Menalled and Schonbeck (2011) stating that agricultural soil contains a high number of weed seeds and at least twelve vegetative weed propagates per square foot. From the study, we observed a similar representation between the species composition of the soil seed bank and the vegetation cover of both study locations. This, agrees with the findings of Sanderson et al. (2007) and Wang et al. (2013).

Following the report of Poschlod and Rosbakh (2018) and later confirmed in this study, the seeds in the soil seed bank of the dumpsite and fallow field are transient due to their ability to grow under favourable conditions. The fallow field is said to be consistent in the species diversity as similar species were observed at the soil depths and vegetation cover. This was different to the dumpsite with varying species diversity. In view of this, the soil seed bank of the dumpsite maintained good species diversity amid the anthropogenic activities against its habitat.

Soil seed bank as a tool for biogeography

It is worthy to note that the soil seed bank could be a component of biogeography and reveal species which were absent on the vegetation cover. The availability or presence of species at various depths of the soil seed bank pinpoints the locations, depths, and ecological zones plant species can be found. From this study, *Croton* sp., *Physalis* sp. and *Sida* sp. were absent on the vegetation cover but present at 5 cm depth at the fallow field. Similar investigation could be done in areas where certain species have been tagged extinct or endangered, as soil seed bank could unravel species presence or absence within an ecosystem. The temporal absence of such species on the vegetation cover but present within the soil could be referred to as dormancy period.

CONCLUSION

The soil seed banks of the dumpsite and fallow field are key tools for ecological restoration and vegetation succession of an ecosystem and has proven useful in this study. Systematically, it gives detailed information on the diversity, weed flora, and biogeography of the species that were naturally stored in the soil over a period of time.

Through this study, the authors recommend that more research on soil seed banks should be considered for biogeography as it could unravel plant species that have been termed extinct but might be naturally stored in the soil and undergoing dormancy.

CONFLICT OF INTEREST

The authors hereby declare that there is no conflict of interest.

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REFERENCES

Akobundu, I.O., Ekeleme, F., Agyakwa, C.W., and Ogazie, C.A. (2016). A Handbook of West African Weeds. Third edition, Revised and Expanded. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

Alemu, M.M. (2016). Soil seed bank and Natural Regeneration of trees. Journal of sustainable development 9(2): 73-77. http://dx.doi:10.5539/jsd.v9n2p73

Anyanwu, F.U., Ochekwu, E.B., Ndukwu, B.C. and Ogazie, C.A. (2019). Soil weed seed bank studies in spent engine oil sites in some communities in Rivers State, Nigeria. International Research Journal of Applied Sciences, Engineering and Technology 5(12): 33-46.

Baker, H.G. (1989). Some aspects of the natural history of seed banks In; Leck M.A., Parter V.T. and Simpson R.L. (eds.). Ecology of soil seed bank. Academic Press, San Diego, pp. 9-21.

Begum, M., Juraimi, A.S., Rastan, S.O.B.S., Amartalingam, R. and Man, A.B. (2006). Seed bank and seedling emergence characteristics of weeds in rice field soils of the Muda granary area in North-West peninsular Malaysia. Biotropia 13(1): 11-21.

Civeira, G. and Lavado, R.S. (2000). Nitrate losses, nutrients and heavy metal accumulation from substract assembled for Urban soils reconstruction. Journal of Environment Management 88: 1619-1623. PMID: 17904270 doi: 10.1016/j.jenvman.2007.08.005

Dalling, J.W., Swaine, M.D. and Garwood, N.C. (1995). Effect of Soil Depth on Seedling Emergence in Tropical Soil Seed-Bank Investigations. Functional Ecology 9(1): 119-121. https://doi.org/10.2307/2390098

Fisher, J., Loneragan, W., Dixon, K. and Veneklaas, E. (2009). Soil seed bank compositional change constrains biodiversity in an invaded species rich woodland. Biological Conservation 142(2): 256–269. https://doi.org/10.1016/j.biocon.2008.10.019

Gonzalez, S.L. and Ghermandi, L. (2012). Comparison of methods to estimate soil seed banks; The role of seed size and mass community. Ecology 13(2): 238-242. https://doi.org/10.1556/ComEc.13.2012.2.14

INHF (Iowa Natural Heritage Foundation), (2001). Secret of the seed bank: Tiny Clues to a Landscape past and future. Des Moines. IA 50309-2321.

Jiang, D., Wang, Y., Oshida, T., Luo, Y., Wang, H. and Zhou, Q. (2013). Review of research on soil seed banks in desert region. Disaster advances 6(1): 315-323.

Li, H.Y., Mo, X.Q. and Hao, C. (2009). A review of study on soil seed bank in the past thirty years. Ecology and Environmental Science 18(2): 731-737.

Lopez-Toledo, L. and Martinez-Ramos, M. (2011). The soil seed bank in abandoned tropical pastures: source of regeneration or invasion? Revista Mexicana de Biodiversidad 82: 663-678.

Lu, Z.J., Li, L.F., Jiang, M.X., Huang, H.D. and Bao, D.C. (2010). Can the soil seed bank contribute to revegetation of the drawdown zone in the three Gorges reservoir region? Plant Ecology 209(1): 153–165. https://doi.org/10.1007/s11258-010-9732-y

Magaji, J.Y. (2012). Effects of waste dump on the quality of plants cultivated around Mpape dumpsite FCT Abuja, Nigeria. Ethiopian Journal of Environmental Studies and Management 5(4): 567-573. https://doi.org/10.4314/ejesm.v5i4.S17

Major, J. and Pyott, W.T. (1966). Buried viable seed in two California bunch grass sites and their bearing on the definition of a flora. Vegetatio 13; 253-82. https://doi.org/10.1007/BF00643329

Major, J.P. and Dessaint F. (1998). Influence of weed management strategies on soil seed bank diversity. Weed Research 38(2): 95-105. https://doi.org/10.1046/j.1365-3180.1998.00075.x

Menalled, F.D. and Schonbeck, M. (2011). Manage the weed seed bank minimize “Deposits” and maximize “Withdrawals”. Organic Agriculture 1(8): 1-24.

Poschlod, P. and Rosbakh, S. (2018). "Mudflat species: Threatened or hidden? An extensive seed bank survey of 108 fish ponds in Southern Germany". Biological Conservation 225: 154-163. doi:10.1016/j.biocon.2018.06.024.

Robert, H.A. (1981). Seed bank in soil. Advances in Applied Biology 6:1-55.

Sanderson, M.A., Goslee, S.C., Klement, K.D. and Soder K.J. (2007). Soil seed bank composition in pastures of diverse mixtures of temperate forages. Agronomy Journal 99(6): 1514. http://dx.doi.org/10.2134/agronj2006.0371

Simpson, R.L., Leck M.A. and Parker, V.T. (1989). Seed banks: General concepts and methodological issues. In: Leck M.A., Parker V.T., Simpson R.L. (eds.). Ecology of soil seed banks. 3-8. London: Academic press.

Singh, A., Kaur, R., Kang, J.S. and Singh, G. (2012). Weed dynamics in rice-wheat cropping system. Global Journal of Biology, Agriculture and Health Science 1(1): 7-16.

Traba, J. and Morales, M.B. (2019). The decline of farmland birds in Spain is strongly associated to the loss of fallow land. Scientific Reports 9 (1): 9473. doi:10.1038/s41598-019-45854-0. PMC 6603185. PMID 31263119.

Wang, Y., Jiang, D., Toshio, O. and Zhou, Q. (2013). Recent advances in soil seed bank research. Contemporary Problems of Ecology 6: 520-524. http://dx.doi.org/10.1134/S1995425513050181

Zhang, Z.Q. (2006). Soil Seed Bank. Department of Biology, Life Science School, Zhongshan University, Guangzhou.

FOLIAR CHARACTERISTICS AND PHENOLOGY OF SOME SELECTED OF MELIACEAE PLANT FAMILY CULTIVATED IN MINI PLANTATION AT HUMID FOREST RESEARCH STATION, UMUAHIA, NIGERIA.

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ABSTRACT

In Nigeria, little studies have been carried out on the members of the family meliaceae at plantation level.The study on foliar, field characteristics and phenology of some species in the family meliaceae were carried out at plantation site, The investigated species were: Lovoa trichiloides, Cederela odorata, Entandrophragma cylindricum., Khaya senegalensis and K. grandifoliola. The species were planted in the same year. Data were collected directly from field observation Quantitative and qualitative foliar morphology were studied. Some of the characteristics investigated during this study include the phenology of those species, their susceptibility to mistletoes and diseases at plantation site, and their maturity age. The results showed that the five species are petiolate. The mean leaf length of C. odorata and E. cylindricum were 83.5 and 77 cm long, respectively. Also C. odorata and E. cylindricum had same greenish colour of foliage, while other three species were reddish colour. Lovoa trichiliodes differed from other four species due to semi-circle shape of its petiole. The two khaya species were found to be susceptible to diseases but K. grandifoliola was not host to mistletoes. Entandrophragma cylindricum., K. senegalensis and K. grandifoliola had long reproductive age. There were notable differences in their foliar morphology and C. odorata had highest growth rate among the five species. Their behaviour and characteristics were distinctly different. This study would serve as basis for comparison with the same species in the natural habitats or in another domesticating site particularly in eastern part of Nigeria.

Key words: Meliaceae, morphology, phenology, diseases, mistletoes, precocity age.

INTRODUCTION

Meliaceae, the mahogany family is a flowering plant family of mostly trees and shrubs (and a few herbaceous plants) in the order spindales. The family includes about 53 genera and about 600 known species (Byng, 2016). Some common species in the family Meliaceae found in Nigeria include *Azadiracta indica*, *Khaya senegalensis*, *K. grandifoliola*, *K. ivorensis*, *Cederela odorata*, *Pseudocedrela kotschyi*, and *Lovoa trichiloides*, They are characterized by alternate usually pinnate leaves without stipules and by syncarpous, apparently bisexual (but mostly cryptically unisexual) flowers borne in panicles, cymes, spikes or clusters. The fruit is fleshly and coloured or a leathery capsule. A few members of meliaceae have edible fruits. Most species are evergreen, but some are deciduous, either in dry season or in winter. In taxonomy, a family is a group of related genera that exhibit similarities among the individuals of various genera but mere differences among its species (Sharma, 2008). The members of a family which grow in the same ecological zone will be influenced by the same environmental factors such as light, humidity, water etc. These environmental factors influence the characteristics and behaviour of the plants. The sources of taxonomic information for phenetic classification include herbarium, natural forest, domesticating site such as botanical gardens, plantation, parks. The behaviour and characteristics displayed by many members of angiosperm families domesticated outside their natural ecosystem have not been well studied and documented in Nigeria. In fact, studies and research to date has been dominated by laboratory studies such as, palynology, anatomy, karyotyping, phytochemistry etc. This study was therefore carried out to examine the behaviour and characteristics of domesticated members of meliaceae in Umuahia, eastern part of Nigeria.

MATERIALS AND METHODS

Study area

The Forestry Research Institute of Nigeria, Humid Forest Station, Umuahia Abia State, which lies on latitude 5^0 32 N and longitude 7^0 27 at an altitude of over 122 m above sea level was the study site. The rainfall pattern is bimodal with peak around June to July and September to October. Annual rainfall is 2238 mm. Minimum and maximum temperature are 23^0 C and 30^0 C respectively with relative humidity is 86.4 % (Joseph and Joy, 2015). The vegetation has been described as high forest and soil type is sandy loam (Okeke *et al*., 1995).

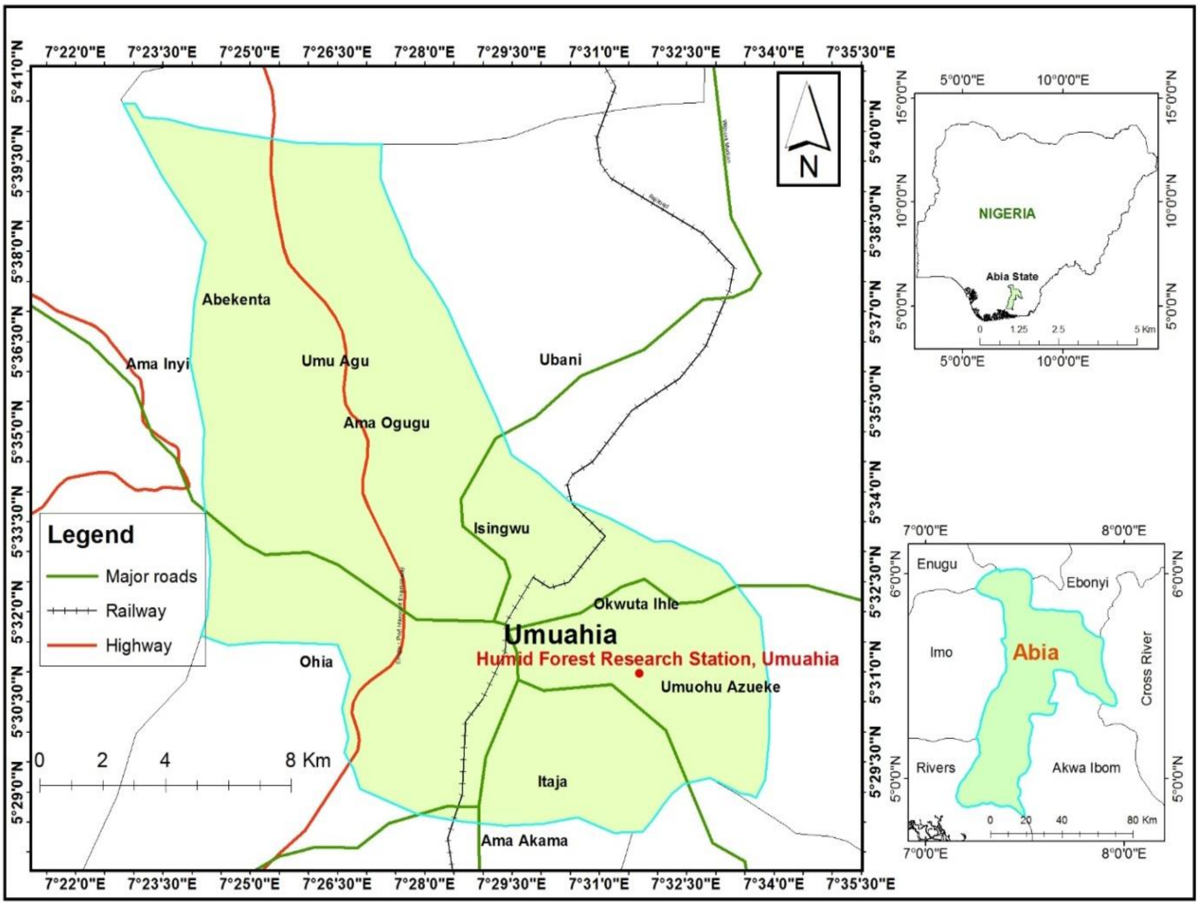

Plate 1: Map showing the study area

Brief history about the domesticated members of meliaceae.

The plantation of the selected tree species in the family Meliaceae were established at FRIN, Humid Forest Research Station Umuahia in June 2012. The size of the experimental layout for the

five species were 20x25 m^2 for *Khaya* species, 20x30 m^2 for *C. odorata,* 25x30 m^2 for *L. trichiloides*, and 25x40 m^2 *E. cylindricum*. They were replicated 3 times. The spacing were not the same due to their growth, habit and management objectives. The spacing at which they were planted were 2.5, 3, 4 and 5 cm for *Khaya species, Cedrela odorata, Lovoa trichiloides* and *Enthradrophyragma cylindricum* respectively.

Data collection on leaf morphology.

From the mini plantation of each selected species ten stands were picked from the middle of the plantation randomly. From each tree, five mature leaves were plucked for their morphological studies. The parameters which were taken from the leaf included quantitative and qualitative characters. The quantitative parameters taken were; the number of leaflets per leaf, petiole length, number of secondary veins, distance between the leaflets, width of leaflets, length of leaflets, leaf length, stem girth and height of the trees. The qualitative parameters include; arrangement of leaf to the stem (phyllotaxy), arrangement of leaflets to leaf rib, nature of petiole, colour of leaf, colour of mature leaf, nodal nature and nature of the leaf surface. Quantitative parameters were measured using ruler.

Phenological data collection.

Observation on phonological study was made on mature trees in the mini plantation of the five species used for this study. The period of the year when phenological processes occurred in each species were taken. The periods include; the period of defoliation and shedding of leaves, the period of leaf formation and development, the period of fruit formation and development, the period of fruit maturity and absicision.

Assessment of species susceptibility to diseases and mistletoes (parasitic plants)

Their interaction with the biotic factor were monitored consistently through the visual examination of the five species in the study area. The diseases were identified through the literatures. Also the interaction of the four species with the mistletoes (parasitic plants) was assessed through visual examination of those trees, that is, manual inventory was used to assess the host range (Carnegies et al., 2009).

Assessment of maturity age of the species

The maturity age of the selected species was assessed. This was done by monitoring the age at which one of the individuals species started flowering. The number of months or years which the selected species spent in the nursery before taking to the field for planting were added to the numbers of the years they have spent at the plantation before they were started fruiting at the domesticating site (plantation).

RESULTS AND DISCUSSION

Foliar characteristics and growth of the selected members of the family Meliaceae

The quantitative morphological characters are depicted in (Table1) with the range and mean of those characters in the five species selected for the studies. Their leaf length ranged between 20- 114 cm. The length of leaflet ranged from 5 to 30 cm, with longest leaflet obtained in *E. cylindricum*. The distances between leaflet among the five species ranged between 2-10 cm. The width of leaflet also ranged from 3-10 cm. The five species were petiolate with shortest petiole length of 7 cm and longest petiole 19cm recorded among the species. The number of leaflet found on them ranged between 10-28. The number of secondary veins were between 7-36. The stem girth were ranged between 16-120 cm with the maximum girth obtain in *Cedrella odorata* and the height that were taken also ranged from 3.4-13 m with maximum height recorded also from *C. odorata.* The mean value of leaf length of *C. odorata, E. cylindricum,AA BB* and *K. grandifoliola* were in the same range. This justified closeness. Also the mean value of leaf length of *L trichloides* and *K. senegalensis* were within the same range and this justified their similarity. On the basis of length of leaflets, *C. odorata* and *K. senegalensis* are similar, the same character also makes *L. trichiloides, E. cylindricum,* and *K. grandifoliola* to be in the same group they had the mean value 17.5, 19, and 22 cm respectively. The mean petiole length of *L. trichloides* which was *8* cm and that of K. senegalensis was 11.25 cm justified their similarity. *L. trichloides* had highest mean value in terms of number of secondary veins that were present in the leaf of the selected species.

The other four species had the value within the same range. Hence, the number of secondary veins that were present in *L. trchiloides* delimit it from other four species. The mean height and girth value obtained from the five species showed that *C. odorata* is a fast growing species while the other four species are slow growing species.

The qualitative morphological characters of the leaves of the five species assessed in the family meliaceae are shown in Table 2. The phyllotaxis of the five species investigated were *whorl*. The arrangement of leaflet to leaf rachis are opposite and sub-alternate. Two major colours were observed in their foliage, greenish and reddish colour during the leaf formation and the colour turned to mature green after 30 to 35 days. The nature of adaxial surfaces was glabrous and smooth.

In taxonomic studies morphological characters have always been useful in delimiling taxa (Akinsulire *et al.*, 2017). Morphological characters have also been used by other researchers to enhance the taxonomy of different taxa (Smith and Ashton, 2006; Adedeji and Faluyi, 2006).

According to Sharma (2008) the morphologicaly data of plants are easily observable and obtainable, and are thus used most frequently in taxonomic studies. They are widely used in both the classification and identification. The data collected for this study was at generic levelA definitely differences are bound. One of the distinct differences among the selected species is the nature of the petiole. The species *K. senegalensis*, *K. grandifoliola*, *Cederela odorata*, and *Entandrophragma cylindricum* had a round petiole. But *L trichiloides* which also belong to the same family meliaceae has its petiole as semi- circle in nature. This feature makes *L. trichiloides* to be distinct from other four species (Table2). According to Sharma (2008), families, genera, and even species in some cases may be identified by petiole characters such as its position on stem, presence or absence of stipules, its vascularization, nodal structure, number of trace etc.

The incidence to diseases and parasitic plants (mistletoes) at the study site.

Based on the physical observation made on those selected species in the family Meliaceae, the two species assessed in the genus *Khaya* were observed to be infected with two different diseases. The organs that were infected were leaves, twigs and stems. The diseases include target leaf spot of leaves and Cancer of cortices or bark. Falesi and Baena (1999) reported that target leaf spot is a fungus disease called *Thanatephorus cucumeris* (Frank) Donk, formerly known as Pellicularia filamentous (Langford, 1962), "Target leaf spot of leaves of *Khaya*" they could be seen on the leaflets. The evolution of the stain is slow, progressing with the time, drying-up and perforating the affected site, resulting in a reduction of the leaf area and, consequently, the physiological activities of the plant. The control can be done through application of Cupric fungicides, such as Pencianol, whose trade name is Moncenven-25 wettable powder. Infection on *Khaya* species with this diseases shows that they may be susceptible to the target leaf spot, but the other three species, *C. odorata*, *L. trichiloides* and *E. cylindericum* from the same family were probably resistant to the disease (target leaf spot).

Table 1: The quantitative morphological leaf characters

Parameters	*L. tricihiloides (cm)*	Mean	*C. odorta (cm)*	Mean	*E. cylindricum (cm)*	Mean	*K. grandifoliola (cm)*	Mean	*K. senegalensis (cm)*	Mean
LL	20 – 36	28	53 – 114	83.5	56 – 98	77	45 – 70	57.5	28 – 45	36.5
LLT	8.5 – 26.5	17.5	5 – 16	10.5	12 – 26	19	14 – 30	22	8 – 16	12
DBL	2 – 4.5	3.25	4 – 8	6	4 – 6	5	6 – 10	8	3 – 6	4.5
WLT	3 – 7.5	5.25	3 – 5	4	5 – 10	7.5	6 – 10	8	3.5 – 4.5	4
PL	7 – 9	8	14 – 16.5	15.25	17 – 22	19.5	14 – 19	16.5	7.5 – 15	11.25
NLT	10 – 12	11	20 – 28	24	20 – 24	22	10 – 16	13	12 – 14	13
NSV	24 – 36	30	12 – 16	14	10 – 15	12.5	10 – 13	11.5	7 – 9	8
SG	38-84	61	54-120	87	30-65	47.5	16-56	36	16-47	31.5
TH (m)	8-38	5.9	13-17	15	5-10.5	7.75	10-3.4	6.7	4-7	5.5

LL = Leaf Length, LLT = Length of leaflets, DBL = Distance between leaflets, WLT = Width of leaflet, PL = Petiole Length, NLT = Number of leaflets, NSV = Number of secondary Vein, SG = Stem girth, TH = Tree Height.

Table 2: Qualitative morphological leaf characters

Parameters	*L. tricihiloides (cm)*	*C. odorta (cm)*	*E. cylindricum (cm)*	*K. grandifoliola (cm)*	*K. senegalensis (cm)*
Arrangement of leaf on stem	Whorl	Whorl	Whorl	Whorl	Whorl
Arrangement of leaflet on leaf rachis	Opposite/sub alternate	Opposite/sub-alternate	Opposite	Opposite/sub alternate	Opposite
Shape of petiole	Semi-circle	Round	Round	Round	Round
Colour of foliage leaf	Reddish	Greenish	Greenish	Reddish	Reddish
Nature of leaf surface	Smooth	Smooth	Smooth	Smooth	Smooth

.**Table3**: Showing Host range and the Mistletoes species in the study area.

Family	**Tree species**	**Mistletoes specie**
Meliaceae	*C. odorata*	*Phragmenthera capitata*
	E. cylindricum	*Agelanthus pungu*
	L. trichiliodes	*Phragmenthera capitata*
	K. senegalensis	*Agelanthus pungu*
	K. grandifoliola	None

This is an indication that *K. grandifoliola* offers an environment which does not favour the germination of the seed of species of all the mistletoes found in the study area. . Because the environmental conditions offered by the host trees represent the immediate environment that the seed propagule must germinate and differences in host resources quality (Watson 2001), growth rate (Hautier *et al*.,2010), and resistance to parasitism (Seel, 2007, Hautier *et al.*, 2010), affect parasite performance The compatibility which occurred between some members and parasitic plants indicates that there are common traits among those families which allow the mistletoes to forage and grow on them (Press and Graves, 1995; Downey 1998). Although diverse factors influence mistletoes-host compatibility but host traits influence the establishment and survival of mistletoes and these traits further affect the distribution of mistletoes among host trees (Desale *et al*., 2016). The *K. grandifoliola* has traits that made it not to be parasitized by the species of mistletoes and those traits were destitute in the other four species, hence they were susceptible to the mistletoes attack.

Phenological study

Phenology which is the study of natural phenomena ocurring periodically in plants and of the relationship of these phenomena to seasonal changes and climate. Flowering, fruiting, fruit fall, leaf formation, shedding of bark, defoliation, are the common phonological events that recurring in mature trees. In some tree species, it occurs annually or alternately.

In the study area, *L. trichloides* and *C. odorata*, were observed to be flowering between the month of February and April. Despite the fact that they were flowering within the same period of time. *L. trichloides* produced mature seeds faster than *C.odorata*. The period of fruit and seed maturity was shorter in *L. trichloides* compared to *C. odorata* (Table 4). This is one of the field characteristics that makes *L. trichloides* different from *C. odorata*. The tree that disperses its seed in the month of August and September may have its seed germinated from the forest floor and surround areas where the seeds have dispersed. But at that period of the year, the seed may suffer from fungi attack that may destroy the seed as a result of high humidity.

Defoliation is a common phonological characteristics of deciduous trees which leads to the formation of the new leaf and flower in some species. The selected members of the family Meliaceae engage in shedding of leaf annually but the mode of defoliation were not the same. *L. trichloides*, *K. grandifoliola,* and *K. senegalensis* engage in partial defoliation whereby leaves are fall based on their maturity age.

Table 4: Showing the period of phenological events

Species	Leaf formation	Defoliation period	Flowering period	Seed Dispersal
L. richiloide	February-October	Ever green	February -April	August -September
C. odorata	Feb-April	Feb-April	March-April	January –March
E. cylindricum	Feb-April	Feb-April	Not yet	Not yet
K. grandifoliola	Feb-Oct	Ever green	Not yet	Not yet
K. senegalensis	Feb-Oct	Ever green	Not yet	Not yet

Although they have their peak period of defoliation .which is dry season and this characteristic makes these 3 species to be similar but makes them to be different from *C. odorata* and *E. cylindricum* that engage in total defoliation between February and April whereby the whole tree would defoliate the entire leaves on it. The profuse fall and total defoliation of the leaves of *C. odorata* and *E. cylindricum* within a few month shows that auxins production stop in all the leaf within that period of time which leads to a total defoliation

Assessment of Precocity study of the species.

Among the selected members of Meliaceae the age at which they started flowering are varied (Table 5). The species *C. odorata* and *L.* trichloides attained their fruiting age at 8 and 7 years respectively. The other 3 species are yet not fruiting. This reflects that the gene that responsible for reproductive maturity manifest earlier in *C. odorata* and *L. trichloides* than the other three species.

Table 5: The fruiting age of assessed tree species

Species	Seedling age	Planting year	Maturity year	Total age at fruiting
Khaya senegalensis	1year	2012	Not yet	-
K. grandifoliola	1 year	2012	Not yet	-
Cedrela odorata	2 years	2012	2018	8
Lovoa trichiloides	2 year	2012	2017	7
Entrandrophragma cylindricum	2 years	2012	Not yet	-

Different trees species attaining their reproductive maturity age at different age in their life cycle due to different genetic make-up in the individual tree species. It was reported that *K. senegalensis* attains its reproductive age between 20 to 25 years (Usman, 2011). The perennial nature of trees allows them to spend several years, building their vegetative skeleton before attaining reproductive maturity (Wareing 1959).

The characteristic of short maturity age makes *C. odorata and L. trichiloides* to be different from other three selected species. In order to reduce the juvenility age of forest species, a scientific intervention from plant breeder is necessary.

CONCLUSION

This study has highlighted some common characteristics of the selected species in the family meliaceae. The study showed that *C. odorata* and *E. cylindricum* strongly share common characteristics in terms of the leaf length, the colour of foliage leaf and pattern of defoliation. The growth in *C. odorata* plantation is faster than any of the other four species. The petiole of *L. trichiloides* is distinctly different from the petiole of other four selected species due to its semi-circle shape. Among the investigated species, *Khaya* species had long juvenility period and they are susceptible to diseases but *K. grandifoliola* was not susceptible to parasitic plants (mistletoes).

REFERENCES

Adedeji, O.A., and Faluyi, J.O. (2006). Morphological, agrobotanical and reproductive studies in 35 acessions of *Panicum Maximum.* Jacq. In Southern Nigeria. *Research Journal of Botany*, 1(2): 64 – 74.

Akinsulire, O.P., Oladipo, T.T., Illoh, H.C. and Mudasiru O.M. (2018). Vegetative and reproductive morphological study of some species in the Family Combretaceae in Nigeria. *Ife Journal of Science*, 20(2).

Amold, R, (2004). *Khaya senegalensis*: current use from its natural range and its potential in Sri Lanka and elsewhere in Asia. Paper presented at the workshop Prospects for high-value hardwood timber plantation in the dry tropics of northern Australia. 19-21 October 2004, Mareeba, Australia. 9 pp.

Byng, J.W. (2016). The number of known plants species in the world and its annual increase. *Phytotaxa*, 261(3):201-217. doi:10.11646/phytotaxa.261.3.1

Rene, I. A, and Judy, L. (2014). The role of forest genetic resources in responding to biotic and abiotic factors in the context of anthropogenic climate change. *Forest Ecology and Management* 333:76-887 https://doi:.org/10.1016/j.foreco.2014.04.006.

Sharma, O.P. (2008). Taxonomy and Systematics: synonyms or independent branches. *Plant Taxonomy*. Tata McGraw-Hill. New Delhi. Pp 482.

Carnegies, A.J., Bi, H.Q., Anorld, S., Li, Y. and Binns, D. (2009). Distribution host preference and impact of parasitic mistletoes (Loranthaceae) in young Eucalypt plantations in New South Wales. *Australia Botany* 87:49 – 63.

Desale, Y.O, Griffiths M.E and Ward D. (2016). Host specificity in parasitic plants-perspectives from mistletoes. *AoB PLANTS 8*: Plw069;doi:10.1093/aobpla/piw069.

Downey P.O (1998). An in inventory of host species for each aerial mistletoe species (Loranthaceae and Viscaceae) in Australia. *Cunninghamia* 5:685-720

Falesi I.C. (2011). Goiania: Seedling Noble. Lecture in Workshop of African Mahogany, 2011, 26 P.

Joseph, O. A and Joy L.H. (2015). Preliminary Investigation on Flowering and Fruiting pattern in a plantation grown *Afzelia africana* Sm stand in Umuahia, Nigeria. *American Journal* of *Plant Science* 6:219-227

Lucy R., Shaanker R., and Jasoury G., (2011). The spatial distribution of mistletoe in a southern Indian tropical forest at multiple scale. *Biotropica* 43(1):50-57

Okeke, A.I, Asiegbu, J.E and Ariwaodo, J.O. (1995). The effect of spacing on the growth and yield of *Pinus caribea* Morlet and *Gmelina arborea* Roxb in a Pine Gmelina plantation. *Nigeria Journal of Forestry*. 1(2):75-82

Press M.C and Graves J (1995). Parasitic plants. London, UK: Chapman and Hall

Smith, C. and Ashton, P.A. (2006). Distinction between the sedges *Carex vulpine* L. and *Cotrubae Podp.* And the potential for identification of hybrids. *Watsonia,* 26:15 – 25.

Urbez-Torres, J.R, Leavitt, G.M, Guerrero, J.C., Guevara, J., and Gubler, W.D. (2008). Identification of *Lasiodiplodia theobromae* and *Diplodia seriata*, the causal agents of bot canker disease of grapevines in Mexico. *Plant Disease,* 92(4):519-529.

Usman D. (2011). *Khaya senegalensis*:. An important naturalized plant in the Savanna. *BeeWorld* 88(44):92-95.

Wareing, P.F. (1959). Problem of juvenility and flowering in trees. *Journal of Society of London.* 56:282-289

Watson, D.M (2001). Mistletoes- a keystone resource in forest and woodlands wordwide. Annual Review of Ecololgy and Systematics, 32:219-249

Xiao-Li, F, Wei-Min N, and Hong-wei, X. (2006). Auxin Flow in Anther Filaments is critical for Pollen Grain Development through Regulation Pollen Mitosis. *Plant Molecular Biology* 61:215-226.

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Evaluation of allelopathic potential of different parts of *Alternanthera brasiliana* on germination of okra (*Abelmoschus esculentus* (*L.*) Moench) seed.

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ABSTRACT

A good number of plants designated as weeds in arable field have been reported to have allelopathic potentials. Many of those weeds are usually found in cultivated fields where they associate with crops. This association might be inhibitory or stimulatory. Some of these weeds such as Alternanthera brasiliana and a good number of others, have the potential of becoming invasive under certain cropping system and environmental conditions. This in vivo, experiment was conducted to evaluate the effect of water extract of leaf, stem and root of Alternanthera brasiliana on the germination of okra seeds. It was laid out in a completely randomized design (CRD) and replicated three times. Three concentrations (10%, 20% and 40 w/v) each of the ground plant parts were evaluated while distilled water was used as control. Five (5mL) of the aqueous extracts of the plant parts and control were applied in each Petri dishes containing seeds (ten) to check its effect on the germination in each Petri dish. Data were collected on number of germinated seeds daily, from 3 to 8 days after treatment application. Also, length of plumule and radicle were measured and recorded at 8 days after treatments application on five randomly selected germinated seeds. Results obtained showed that germination percentage, length decreased with increasing concentrations. Reduction in germination, length of plumule and radicle were more pronounced in the leaf aqueous extract.

Keywords— *Alternanthera brasiliana*, allelopathy, okra, leaf and root.

INTRODUCTION

Generally, plants interact with others in natural environment (ecosystem), an individual plant can have a depressive effect on surrounding neighboring or companion plants. Ngonadi and Awodoyin, (2019) reported the adverse effect as "interference". Interference is the association between two organisms in which one or both suffer(s) some set back. This may be in the form of competition, parasitism and allelopathy. According to Winer, *et al.*, (2008) the potential causes of interference include competition, which is the depletion of one or more resources required for growth while allelopathy is the addition of chemical toxins by one or more species in association. The term "allelopathy" expresses the harmful or stimulatory effect that one plant species has on another through the formation of chemical retardants escaping into the environment (Ngonadi, *et al.*, 2020).

The International Allelopathy Society defined allelopathy as any process involving secondary metabolites produced by plants, micro-organisms, viruses, and fungi that influence the growth and development of agricultural and biological systems, including positive and negative effects. Chemicals released from plants that impose allelopathic influences are termed allelochemicals or allelotoxins (Ngonadi, *et al.*, 2020). These chemicals are present in different parts of plants such as stem, leaves, roots, flowers, fruits and seeds (Ngonadi, *et al.*, 2020). These allelochemicals are usually released from the plants through volatilization, leaching, exudation and decomposition of plant residues (Ngonadi and Awodoyin, (2019). *Alternanthera brasiliana* (L.) Kuntze is commonly called Brazilian joy weed. Scandent shrub about 1.5 - 4m tall. Stems are mainly-branched, sub glabrous below, strigose to pilose in upper parts. While the Leaves are narrowly ovate, usually 3-8 cm long, 1-2.5 cm wide, more or less strigose, apex acute or acuminate, base cuneate to round, petioles usually 0.3-1 cm long (Saawan *et al.*, 2011).

The plant aggressively grows in forests, gardens and wastelands Ahmed *et al.*, (2007). It is obnoxious and a ruderal weed that poses serious problem to flora because of their toxic substance and allelochemical compounds potential. Although several researches have so far worked on the invasion than the allelopathic effects of Joy weed on various agricultural crops, there is need to focus and do more research on the latter.

MATERIALS AND METHODS

Okra seeds (AK-2) were the test crop and were collected from National Horticultural Research Institute (NIHORT) Ibadan. *A. brasiliana* was the donor plant, while it's stem, leaf and root aqueous extracts were used as the allelochemicals.

Preparation And Application Of Aqueous Extracts

The aqueous extracts were prepared using the method described by Edris & Farahbakhsh, (2011) with slight modifications. The collected plant materials were sorted into three parts (root, stem and leaf) and air-dried in the laboratory at 25ºC for twenty-one (21) days. The air-dried plant materials were then ground with Thomas bench top milling machine and stored in well labeled envelopes. The plant materials were ground then 10g, 20g and 40g were weighed and soaked separately in distilled water made up to 100 ml in beakers to have 10%, 20% and 40% (w/v) concentrations respectively. The beakers were covered with aluminum foil and extraction was kept at room temperature (25ºC) for 24 hours, while extracts were obtained by filtering with a muslin cloth. The allelopathy was separately compared by plant parts. Ten (10) seeds of okra were placed in petri-dishes lined with Whatman No 1 filter paper and 5mL of each treatment was applied to each petri-dish using a syringe.

Experimental design and data analysis

The experiment was laid out in a completely randomized design (CRD). The treatments consisted of the aqueous extracts of the leaf, stem and root each at 10%, 20% and 40% w/v.

The treatments were replicated three times.

Data collection

The seeds were observed for germination, from three days after plating and application of treatment, by the protrusion of radicle and plumule. Germination was observed on daily basis for eight days. On the 8th day after application of the treatments, the number of seeds that germinated was counted in each of the treatment. Also, plumules and radicles were measured using meter rule. Five germinating seeds were randomly picked in each petri-dish for growth parameter. Data were analyzed using analysis of variance (ANOVA) of Gen-stat Release 10.3 statistical software and different means were separated with the Duncan's Multiple Range Test (DMRT), at 5% probability level.

RESULTS AND DISCUSSIONS

Germination of okra seeds exposed to varying concentrations of leaf, stem and root aqueous extracts of *Alternanthera brasiliana*.

Germination of okra seeds exposed to varying concentrations of plant parts aqueous extracts, was significantly different at all concentration levels especially when compared with control (distilled water), germination decreased with increasing concentration of aqueous extract. Germination percentage varied from 56.7% in the leaf extracts, to 73.3% at 10% concentration according to (Table1). Leaf extract shows highest inhibition effect at 20% and 40% concentration levels (26.7% and 16.7% respectively) compared to stem and root extracts.

Effects of aqueous extract of *Alternanthera brasiliana* parts on length of radicle

Different concentrations of aqueous extracts have significant difference on length of okra seeds radicle with radicle recording 4.00 cm in leaf extract at 10% but varied in stem and root extracts (5.60cm and 5.52cm) respectively. Reduction in radicles length increased with the increase in the concentrations of the extracts thus suggesting that the effect of the extracts is concentration-dependent.

Plate1. ***Alternanthera brasilian***

Plate2. ***Alternanthera brasiliana*** **dry and ground stem part.**

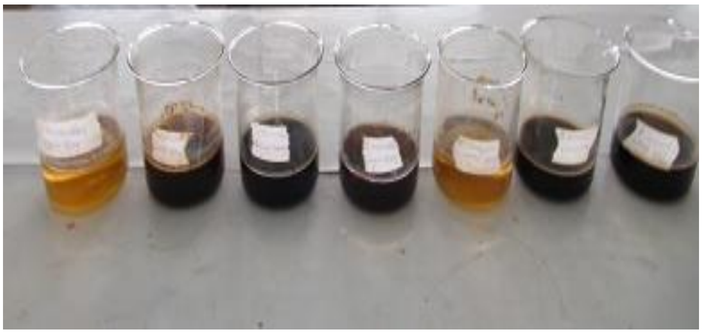

Plate 3. ***Alternanthera brasiliana*** **extracted filtrate**

Table 1: Germination percentage of okra seeds treated with varying concentrations of different parts of *Alternanthera brasiliana*

	Germination (%)		
	Aqueous Extracts		
Concentrations (w/v)	**Leaf**	**Stem**	**Root**
Distilled water	100.0a	100.0a	100.0a
10%	56.7d	73.3c	73.3c
20%	26.7e	60.0e	61.2e
40%	16.7f	46.7g	47.0g

Percentage values with the same letters under a column are not significantly different according to Duncan's Multiple Range Test (DMRT), at 5%level.

Table2: Mean radicle length of germinating okra seeds treated with varying concentrations of different parts of *Alternanthera brasiliana.*

	Radicle Length (cm)		
	Aqueous Extracts		
Concentrations (w/v)	**Leaf**	**Stem**	**Root**
Distilled water	7.77a	7.80a	8.00a
10%	4.00c	5.60b	5.52b
20%	3.50d	4.55c	4.35c
40%	2.06e	3.46d	3.44d
CV (%)	11.37	9.50	11.16

Percentage values with the same letters under a column are not significantly different according to Duncan's Multiple Range Test (DMRT), at 5%level.

Effects of aqueous extract of *Alternanthera brasiliana* parts on length of plumule.

The plumule length of the germinated seeds of okra varied among the various plant parts at different level of concentrations, recording 4.30cm in leaf extract to 6.60cm and 6.52cm in stem and root respectively (Table 3). The highest reduction in length of plumule was recorded in leaf aqueous extract at 20% and 40% concentration.

Table3: Mean plumule length of germinating okra seeds treated with varying concentrations of different parts of *Alternanthera brasiliana*.

	Radicle Length (cm)		
	Aqueous Extracts		
Concentrations (w/v)	Leaf	Stem	Root
Distilled water	7.77a	7.80a	8.00a
10%	4.30c	6.60b	6.52b
20%	3.50d	4.55c	4.35c
40%	2.06e	3.46d	3.44d
CV (%)	11.37	9.50	11.16

Percentage values with the same letters under a column are not significantly different according to Duncan's Multiple Range Test (DMRT), at 5%level.

CONCLUSION

Many plants and their root residues have been reported to have allelopathic effect on agricultural crops. This study revealed that aqueous extracts of the selected *A. brasiliana* contained water soluble allelochemicals which cause inhibitory effects on germination attributes of okra seed. The aqueous leaf extracts showed higher inhibitory effect on the seed germination with increase in concentration. This study

showed that the leaf extracts of *A. brasiliana* showed significant inhibition of okra seed compared to the control treatment at all concentrations. This is a confirmation of observation of Ahmed, *et al.,* (2007) on allelopathic effects of *A. brasiliana* on some agricultural crops. Results obtained from this work are similar to that of other researchers, in relation to inhibitory effects of leaf extracts of *Ageratum conyzoids* on seed germination of rice

REFERENCES

Ahmed, R., Uddin, M.B., Khan M.A., Mukul S.A. and Hossain, M.K. (2007). Allelopathic effects of *Lantana camara* on germination and growth behavior of some agricultural crops in Bangladesh. *Journal of Forestry Resources.* 18 (4): 301-304.

Aziz, A., Tanveer, A., Ali, A., Yasin, M., Babar, B.H. and Nadeem, M.A. (2008). Allelopathic effect of cleavers (*Galium aparine*) on germination and early growth of wheat (*Triticum aestivum*). *Allelopathy Journal of Science* 22 (1): 973-986.

Edrisi, S. and Farahbakhsh, A. (2011). Germination of barley as affected by the allelopathy of *sisymbrium* irio L. and descurainia sophia (L.) schur, *World Academy of Science, Engineering and Tecnology*,6 (3) 68-74.

Eze, J.M.O. and Gill, L.S. (1992). *Chromolaena odorata* - a problematic weed. *Compositae Newsletter* 20: 14-18.

Malla, B. (2003). Allelopathic Potential of *Ageratum* species M. Sc. Dissertation Central Department of Botany, Tribhuvan University, Kirtipur, Nepal.

Ngonadi, E.N. and Awodoyin, R.O. (2019). Evaluation of allelopathic potential of *Lantana camara* and *Tithonia diversifolia* on seed germination Attribute of cowpea (*Vigna unguiculata* (L.) Walp) *IOSR Journal of Environmental Science, Toxicology* *and Food Technology*.13 (5) 11: 34 – 38.

Ngonadi, E.N., Worlu, C.W. and Onyeyirim, S.O. (2020). Evaluation of allelopathic potential *of Lantana camara* vegetative parts on seed germination Aatributes of maize (*Zea Mays* L.). *International Journal of Environment, Agriculture and Biotechnology*. 4 (5) 1304-1307.

Poudel, P. (2004). Phytochemical Screening and Allelopathic Effect of *Arimisia dubia Wall.* Ex. Besser on seedling of Rice and Barnyardgrass. M. Sc. Dissertation, Central Department of Botany, Tribhuvan University, Kirtipur, Kathmandu, Nepal. pp 44-51

Saawan, K., Pradeep, S., Garima, M., Saurabh, S.K. and Khosa, R.L. (2011). Phytopharmacological review of *Alternanthera brasiliana, Asian Journal of Plant Science and Research.*1: (1) 41-47.

Weiner, J., Kristensen, L. and Olsen, J. (2008). Crop density, sowing pattern, and nitrogen fertilization effects on weed suppression and yield in spring wheat. *Journal of Weed Science*. 56: 97-102.

Harnessing agroforestry wastes for the production of edible mushroom (*Pleurotus ostreatus* (Jacq.) P. Kumm)

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ABSTRACT

Pleurotus ostreatus is one of the most widely cultivated oyster mushrooms worldwide. Agroforestry wastes are commonly disposed of through burning in Nigeria and this activity engenders environmental pollution which is harmful to the ecosystem. There is dearth of information on most of these often neglected agricultural residues and forest by-products as substrates for edible mushroom production. Therefore, this study investigated the suitability of eight agroforestry wastes in Nigeria for the cultivation of P. ostreatus. Six agricultural wastes and two forest by-products were collected from farms and sawmills, respectively. Substrates were fermented for seven days using the short composting method. Pasteurization, spawning and inoculation of substrates were done following standard procedures. Sawdust substrate had the fastest colonization rate of 19 days, which was significantly ($p<0.05$) lower than other treatments, while rice and wheat bran had the longest ramification rate of 34.1 and 35.1 days, respectively. Corncobs produced the highest single mushroom fruit body of 50.33 g which was significantly ($p<0.05$) higher than other treatments, while the lowest weight (31.50 g) was recorded in wheat bran substrate. Three of the substrates, sawdust, corncobs and banana leaves produced five flushes consecutively. Corncobs produced the highest cumulative yield of 262.88 g, while the lowest yield (50.22 g) was obtained from wheat bran. Also, corncobs had the highest biological efficiency (BE) of 61.18%, followed by sawdust with 57.8% which was significantly ($p<0.05$) higher than other treatments. Sawdust, corncobs and wheat bran contained the highest amount of lignin (25.07%), Carbohydrate (60.88%) and crude protein (32.11%), respectively. Although all the treatments contained minerals in varying amounts, the concentration of P and K were significantly ($p<0.05$) higher than other nutrients in rice bran treatment. Corncobs and sawdust produced the best yield and BE among the substrates in this study and are, therefore, recommended for commercial mushroom cultivation.

Keywords: *Agroforestry, Pasteurization, Pleurotus ostreatus, Substrates, Wheat bran*

INTRODUCTION

Oyster Mushrooms (*Pleurotus* spp.) are macrofungi that can grow across various agroecological zones where they utilize lignocellulosic materials from plants for growth. They have inherent enzyme systems capable of degrading naturally occurring organic compounds in agroforestry (Muchena *et al.,* 2021). *Pleurotus ostreatus* (Jacq.) P. Kumm) is a white-rot fungus reputed for its efficient biodegradation of lignocellulose in matured tree crops and forest plantations (Muswati *et al.,* 2021). Various agroforestry wastes and by-products can be harnessed for the production of *P. ostreatus*. They are useful agents in ago-wastes recycling, which could otherwise pollute the environment, especially through combustion. Mushroom production is a promising income-generating enterprise, especially for developing countries and mycoremediation of the environment (Sardar *et al.,* 2017). Hence, its cultivation can play a vital role in managing organic wastes whose disposal is laborious and time-consuming. It is an efficient and relatively short biological process of producing food proteins from lignocellulosic materials, by degrading the substrates. *Pleurotus* species are a rich source of protein, minerals and vitamins and also have medicinal value (Hoa *et al.,* 2015; Dania *et al*., 2016).

The choice of substrates for higher yield from a variety of agricultural crop residues and forest wastes is an important factor in oyster mushroom cultivation among farmers. The type of substrate, spawn quality and supplements influence characteristics such as rate of aeration, water retention ability, degree of mycelial ramification and ultimate yield of mushroom (Tesfaw *et al*., 2015, Pokhrel, 2016). Cheung (2013) and Yao *et al.* (2019) reported that mycelial colonization tends to be slow and poor in tightly or loosely packed substrate bags and tends to stop if incubated in chambers with elevated temperatures or hot environments Also, nutrient requirements among species belonging to the same genus may differ considerably in their response to climatic variables. Important factors that may affect the choice of substrate for mushroom cultivation include cost, availability, degradability, weight and proximity of the mushroom farm to substrate procurement sites (Mutema *et al*., 2019; Tavarwisa *et al.*, 2021).

Sawdust which is commonly available in sawmills across Nigeria could be a cheaper option for growing oyster mushrooms than other substrates such as cottonseed wastes and oil palm chaff which are generally not available in sufficient quantities to mushroom producers. A limited quantity of supplements such as wheat bran, rice bran and lime are often added to the lignocellulose-based substrates to increase the nutrient status and encourage higher yield (Bellettini *et al*., 2019; Besufekad, 2020). The application of wheat bran helps to increase nitrogen content, while liming regulates the substrate pH. The various types of substrates used in cultivating mushrooms may affect the chemical and the organoleptic characteristics of mushrooms. Protein, ash, iron and phosphorus contents have been reported to be significantly higher in mushrooms cultivated on cowpea haulms compared to wheat straw (Michael *et al*., 2011). Mushroom cultivation could be an important avenue forconverting huge quantities of agroforestry wastes to consumable biomass of high nutrient value and ensuring a cleaner environment. Although these lignocellulosic residues abound in Nigeria, their potential in the production of edible mushrooms has not been fully explored. This study evaluated the comparative yield and nutrient constituents of *Pleurotus ostreatus* cultivated on different agroforestry wastes.

MATERIALS AND METHODS

Preparation of mushroom spawn

Sorghum seeds purchased from the open market were used to prepare *Pleurotus ostreatus* spawn otherwise referred to as mushroom seeds. Five kilogrammes of the seeds were soaked in water overnight. The excess water was decanted and the seeds were sterilized using an autoclave for 1 h at 121°C. Thereafter, 300 g grains were filled into sterile polypropylene bags and inoculated with a pure culture of *Pleurotus ostreatus* under aseptic conditions in the laminar flow hood to avoid contamination. Inoculated grains were incubated at 27-29°C for 14 days. Pure spawn at full ramification was stored in the refrigerator until when required for use.

Treatments and substrate preparation

The experiment consisted of eight treatments: T1=Sawdust, T2=Palm chaff, T3=Corn cobs, T4=Cowpea haulms, T5=Rice bran, T6=Banana leaves, T7= Wood shavings, T8=Wheat bran. The experiment was laid out in a completely randomized design with five replicates. The treatments were subjected to the short composting method for one week. Lime and sugar supplements were added to each compost at the rate of 1% actual weight and sufficiently mixed with tap water until moderately moist. They were then covered with black polythene sheets for a week to generate the heat necessary for substrate fermentation. The substrates were air-dried for 24h to eliminate any inherent odour before mixing and bagging. About 600g substrate was filled into each of the replicate nylon bags.

and tied with rubber bands to ensure firmness. Pasteurization was done using a drum powered by fuelwood for 5 hours and substrates were allowed to cool overnight preparatory to inoculation.

Spawning, mycelial ramification and harvest

After pasteurization, the substrate bags were allowed to cool at room temperature and inoculated with pure spawn produced in transparent white nylon bags. Each substrate bag was inoculated with 15 g spawn per 600 g substrate under aseptic conditions and incubated in a disinfected darkroom at 27-29ºC for one month. Mycelial ramification was measured weekly for 30 days as the length of the mycelium between the proximal and distal ends of substrate bags. At full mycelial growth, the substrate bags were opened in the growth chamber and watered consistently daily to create requisite optimal relative humidity (70-90 for fruiting, which commenced at 10-14 days after opening. Sprouting mushroom pinheads were allowed to grow for three to four days and harvested from the substrate at maturity with well-developed fruit body and broad caps. The clusters of the mushrooms were harvested by handpicking the stipes at the base and twisting lightly. Morphological characteristics such as ramification rate, stipe length, thickness and pileus diameter were recorded. Yield was determined by weighing the fruiting bodies, while biological efficiency (B.E.) was calculated according to Oliveira *et al*. (2007) and Holtz *et al*. (2007):

$$\text{B.E. (\%)} = \frac{\text{Fresh weight of mushroom (g)}}{\text{Dry weight of substrate (g)}} \times 100$$

Proximate analysis of *Pleurotus ostreatus*

Mushroom samples were oven-dried at 60 ºC for 72 h, powdered using a rotary blender model MP 7433G Japan and stored in a refrigerator at 4 ºC prior to biochemical analyses. Crude protein, cellulose and lignin content were analysed using the official method of AOAC (2005). Carbon, nitrogen and C: N ratio was calculated using the modified method of Nelson and Sommers (1982). The pH was determined by adding 10 g of fresh substrate to 50 ml of 0.01 mol/L $CaCl_2$. The mixture was stirred for 30 min and measured using a pH meter model EW-58825-08 USA. Total carbohydrate was estimated indirectly by difference (FAO, 2003). Mineral content was determined by digesting, 1g of wet sample in a mixture consisting of 18 M H_2SO_4, 12M Perchloric acid and 16 M HNO_3 in the ratio 0.5:1:0.5 v/v. The mineral constituents were evaluated by measuring atomic absorption (Milner and Whitside (1981).

Data analysis

Data collected were analysed using analysis of variance (ANOVA) with SAS 9.0 version, while differences in treatment means were separated using Duncan Multiple Range Test (DMRT) at $p < 0.05$.

RESULTS

Effect of agroforestry wastes on morphological characteristics of *Pleurotus ostreatus*

Fully ramified bags for each of the substrates turned white which gradually turned brown with age (Plate 1a-h). Ramification time varied between 19.43 and 13.01 days depending on the substrate. Sawdust had the fastest colonization rate of 19.43 days, which was significantly ($p<0.05$) lower than other treatments, while rice and wheat bran had the slowest ramification rate of 34.11 and 35.08 days, respectively (Table 1). However, the first flush was obtained from mushroom cultivated on cowpea haulms substrate at 41.24 days of cultivation. This was followed by harvest from sawdust substrate at 44.23 days. Time to harvest was longest in wheat and rice bran which produced first flush at 55.05 and 56.81 days, respectively. Stipe length varied from 29.34-41.55 mm among the substrates. Mushroom grown on banana leaves and corncobs had the highest pileus diameter of 81.72 mm and 98.17 m, respectively, while the number of fruit body produced per substrate ranged between 5.36-22.43. Corncobs produced the highest single mushroom fruit body weight of 50.33 g which was significantly ($p<0.05$) higher than other treatments, while the lowest weight (31.50 g) was recorded in wheat bran substrate.

Corncobs produced the highest yield of 85.24 g at first flush followed by banana leaves which yielded 79.28 g, while the lowest yield of 50.22 g was recorded on wheat bran (Table 2). Although the treatments differed significantly ($P<0.05$) in yield at first harvest, there was no significant ($P>0.05$) difference between the mushroom yield on oil palm chaff and wood shavings. Mushroom yield decreased progressively from flushes 1-5. Three of the substrates, sawdust, corncobs AND banana leaves produced five flushes consecutively. Three flushes were obtained from each of oil palm chaff and wood shavings, while cowpea haulms produced four harvests. Mushroom cultivated on rice and wheat bran produced two and one flushes, respectively which was the lowest among the substrates. Corncobs substrates produced the highest cumulative yield of 262.88 g, while the lowest yield (50.22 g) was recorded on wheat bran substrate. Similarly, corncobs had the highest biological efficiency (BE) of 61.18%, which was significantly higher than other substrates, while wheat bran produced the lowest BE of 5.12%.

Proximate analysis of *Pleurotus ostreatus*

Pleurotus ostreatus cultivated on rice bran substrate had the highest amount of P (218.7g/mg) and Mg (88.2 g/100 mg on dry weight basis. Oil palm chaff recorded the highest K and lowest Mg content of 1841.33 and 58.05 g/100 mg, respectively (Table 3). Mushroom harvested from all the substrates contained a significant amount of all the micronutrients evaluated. The biochemical constituents such as lignin, cellulose, and nitrogen of *P. ostreatus* differed significantly ($p<0.05$) in their various concentrations among the substrates (Table 4). Sawdust contained the highest lignin content of 25.07%, while wheat bran had the lowest (8.22%). Cellulose concentration was also highest in sawdust (46.06%). Corncobs yielded the highest amount of carbohydrate (60.88%), while cowpea haulms recorded the lowest (49.32%). Crude protein content ranged between 17.32 and 32.11%. The highest amount of protein was recorded in wheat substrate. Treatments differed significantly ($p<0.05$) in their nutrient composition. However, there was no significant ($p>0.05$) difference among the substrates in pH concentration which varied between 6.37-6.92.

DISCUSSION

The selection of the appropriate substrate to be used in mushroom cultivation is of paramount importance because it significantly determines growth performance, primordia formation and ultimate yield. Although lignocellulosic-based substrates are generally high in carbon but low in protein, this attribute does not often correspond to obtainable yield (Muswati *et al*., 2021). Sawdust recorded the fastest ramification rate among the test substrates, but this did not correspond to yield, which implies that mycelial growth and yield of mushrooms have different requirements (Zhang *et al*., 2014). Conversely, mycelial growth was slowest in wheat, attaining full ramification in 35 days. Wheat bran substrate has high plasticity and compact texture which impede water drainage and aeration, hence it's mainly used sparingly as an additive and not as a primary substrate (Bonatti *et al*., 2004; Patar *et al*., 2018). Yang *et al*. (2013) also reported that treatments with wheat straw recorded longer mycelial growth rate but the lowest emergence of mushroom pin heads. Authors submitted that the trend may be due to high N content of the substrate which could inhibit mushroom growth, especially when applied in excess of substrate threshold. Excessive application of wheat bran as substrate supplement emits an offensive odour which attracts houseflies and maggots (Yang *et al*., 2013; Dania and Ekpo, 2016).

Table 2. Effect of various agroforestry wastes on *Pleurotus ostreatus* yield

Substrate	Flush 1 (g)	Flush 2 (g)	Flush 3 (g)	Flush 4 (g)	Flush 5 (g)	Total yield (g)	BE (%)
Sawdust	77.74b	66.03b	43.50b	31.50a	22.41b	241.14b	57.84b
Oil palm shaft	70.23c	55.22d	37.17d	0.0d	0.0d	162.92e	42.19d
Corncobs	85.24a	71.44a	50.76a	32.77a	25.67a	262.88a	62.18a
Cowpea haulms	67.61d	52.65e	35.41e	26.17b	0.0d	181.84e	47.80c
Rice bran	62.11e	44.77f	0.0f	0.0d	0.0d	106.88	14.43d
Banana leaves	79.28b	62.44c	41.53c	20.87c	15.4c	219.52d	41.96d
Wood shavings	71.66c	61.11c	44.55b	0.0d	0.0d	177.32c	46.15c
Wheat bran	50.22f	0.0g	0.0f	0.0d	0.0d	50.22f	5.12e

*=Ramification. Means with the same alphabet along the column are not significantly different using Duncan Multiple Range Test (DMRT) at $p < 0.05$.

Table1. Effect of agroforestry wastes on morphological characteristics of *Pleurotus ostreatus* fruiting body

Substrate	Ram* rate (days)	Days to first harvest	Stipe length (mm)	Pileus diameter (mm)	Stipe thickness (mm)	No. of fruiting body	Fresh weight (g)
Sawdust	19.43e	44.23d	37.08b	50.33g	12.41f	12.20b	40.77b
Oil palm shaft	23.12d	47.03c	33.77c	72.94d	19.30d	9.04c	42.01b
Corncobs	30.77b	50.22b	38.71b	98.17a	15.22e	22.43a	50.33a
Cowpea haulms	26.61c	41.24e	41.55a	70.33e	26.80c	12.33b	37.21c
Rice bran	34.11a	56.81a	31.21c	77.19c	18.12d	13.41b	33.22d
Banana leaves	22.71d	50.33b	38.44b	81.72b	27.88c	8.60c	41.55b
Wood shavings	20.18e	51.24b	40.68a	66.41f	38.11a	9.03c	38.09c
Wheat bran	35.08a	55.07a	29.34d	72.91d	35.04b	5.36d	31.50e

*=Ramification. Means with the same alphabet along the column are not significantly different using Duncan Multiple Range Test (DMRT) at $p < 0.05$.

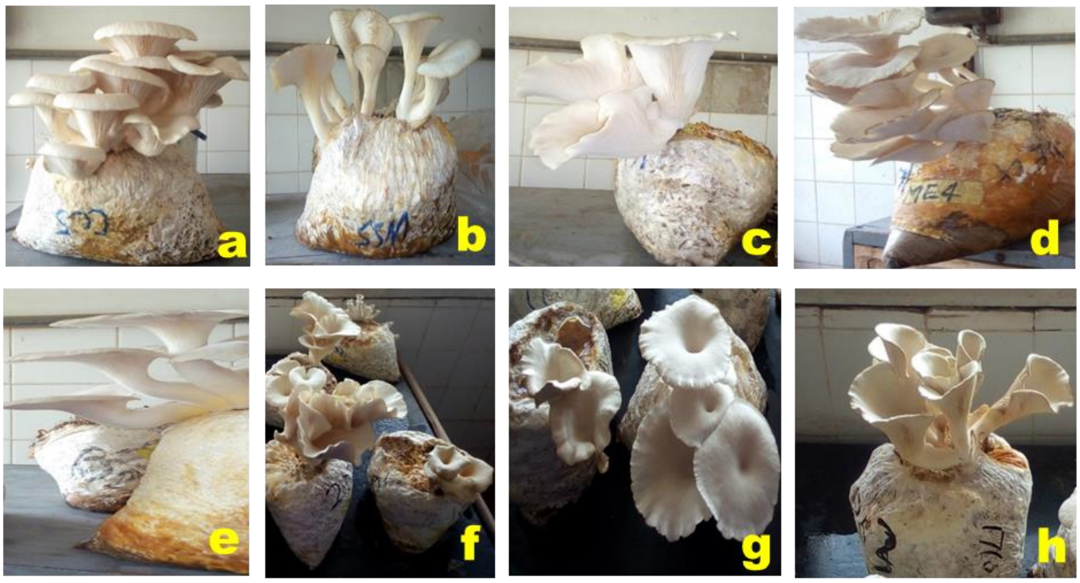

Figure 1. Fruiting bodies of *Pleurotus ostreatus* grown on different agroforestry wastes in substrate bags, a=Sawdust, b=Oil palm shaft, c=Corncobs, d=Cowpea haulms, e=Rice bran, f=Banana leaves, g=Wood shavings, h=Wheat bran

Effect of agroforestry wastes on *Pleurotus ostreatus* yield

There were significant ($p < 0.05$) differences in morphological characteristics of fruit bodies at full maturity in this study, which suggests that the substrate mushroom type is an important determinant in the expression of phenotypic characters in oyster mushrooms. Sanjel *et al.* (2021) found that substrates containing a high proportion of cellulose, hemicelluloses, and lignin would produce low yield if the cultivated mushroom does not produce the requisite lignin-degrading enzymes. Mushroom yield was significantly p<0.05) highest in composted corncobs followed by sawdust than in other treatments.

All the substrates contained mineral elements in varying amounts, but the concentration of P and K was significantly (p<0.05) higher than other nutrients. Phosphorus and potassium have been reported as the most abundant mineral constituents in *P. sajor-caju* fruit bodies cultivated on corncobs (Oyetayo, 2005). Similarly, Hoa *et al*. (2016) and Maheswari *et al*. (2020) recorded potassium as the most predominant mineral nutrient among different species of oyster mushrooms. The disparity in mineral constituents among cultivated mushrooms could be attributed to the rate and pattern of accumulation and adsorption of minerals from the substrates.

The C/N ratio, pH and mineral composition in a substrate are major determinants of ramification rate, sprouting and growth of fruiting bodies (Hoa *et al*., 2015). Sawdust and corncobs had the highest C/N ratio with a corresponding maximum yield of 241.1 g and 262 g, respectively among the substrates. This implies that the substrates with higher C/N ratio performed better in terms of yield and biological efficiency (BE). This result agrees with the findings of Girmay *et al*. (2016) who reported that the decrease in formation of mushroom pinheads was directly related to the availability of carbon and nitrogen from lignocellulose substrate. Similarly, Veira and Nogueirs-Andrade (2016) submitted that cellulose with high organic carbon was one of the most suitable substrates for the production of oyster mushrooms.

Table 3. Mineral composition of *Pleurotus ostreatus* at g/100 mg dry wt cultivated on various substrates

Substrate	P	Zn	Ca	Mg	Mn	Cu	Fe	K
Sawdust	201.44d	4.46a	307.03f	77.13b	6.03d	1.22a	53.44c	1720.12d
Oil palm shaft	183.99f	4.08a	331.24d	58.05e	5.94d	0.77b	49.91d	1841.33b
Corncobs	203.31c	3.77b	338.09c	71.54c	6.88c	1.43a	60.44a	1777.44c
Cowpea haulms	209.32b	2.88d	341.07b	72.06c	8.51a	0.88b	52.31c	1508.38g
Rice bran	218.70a	3.01c	333.33	88.22a	8.04a	1.02a	48.12d	1940.21a
Banana leaves	192.09e	2.79d	347.11a	60.07d	7.45b	0.96b	43.72e	1670.55e
Wood shavings	211.33b	4.44a	328.66e	61.10d	7.01b	0.84b	61.33a	1677.05e
Wheat bran	205.22c	3.09c	329.05e	71.32c	6.55c	0.77b	56.60b	1556.44f

*=Ramification. Means with the same alphabet along the column are not significantly different using Duncan Multiple
Range Test (DMRT) at $p < 0.05$.

Table 4. Biochemical composition of substrates used in the cultivation of *P. ostreatus*

Substrate	Lignin (%)	Cellulose (%)	Carbohydrate (%)	C (%)	N (%)	C: N ratio	pH	Crude protein (%)
Sawdust	25.07a	45.03a	55.5b	40.22c	1.04a	92:1	6.72a	17.35d
Oil palm chaff	22.03b	40.33b	51.22c	29.03f	0.83b	60:1	6.85a	23.09c
Corncobs	13.08e	38.77c	60.88a	40.22c	0.72b	90:1	6.78a	28.67b
Cowpea haulms	20.14c	36.01d	49.32d	34.11e	1.02a	28:1	6.45a	20.33d
Rice bran	16.32d	32.11e	48.52d	42.27b	0.96b	21:1	6.87a	24.13c
Banana leaves	24.03a	41.92b	55.11b	36.92d	0.77b	60:1	6.92a	29.44b
Wood shavings	15.33d	46.06a	52.41c	48.21a	1.06a	18:1	6.37a	31.08a
Wheat bran	8.22f	14.03f	58.07a	33.33e	1.01a	21:1	6.80a	32.11a

*=Ramification. Means with the same alphabet along the column are not significantly different using Duncan Multiple Range Test (DMRT) at $p < 0.05$.

Substrates with a high proportion of lignin and phenolic compounds reduced cellulase bioactivity, but less lignin increased enzyme action and which resulted into higher fruit body yield and BE (Maheswari et al. 2020). A positive correlation exists between mycelium running rate and the C/N ratio of the substrate (Bonatti *et al*., 2004).

Corncobs had the highest BE of 61.18%, which was significantly ($p<0.05$) higher than other substrates, while wheat bran produced the lowest BE of 5.12%. Varying BE potentials have been reported for lignocellulosic materials used as substrates for the cultivation of oyster mushrooms (Liang *et al*., 2009). Peksen and Yakupoglu (2009) showed a positive correlation among yield, N content of substrate and BE. Crude protein content ranged between 17.32 and 32.11% among the substrates. Bonatti- Chaves *et al*. (2004) reported 20.28% crude protein content for *Pleurotus ostreatus* cultivated on cotton waste. The difference in protein and amino acid composition of *Pleurotus* spp. could be attributed to genetic variation and substrates used in commercial cultivation (Mendez *et al.,* 2005).

The pH of the lime-amended substrates varied between 6.37 and 6.92. This result is consistent with the previous findings of MushWorld (2004) who reported that optimal substrates' pH ranges between 6 and 8 depending on mushroom species. Mukherjee and Nandi (2004) submitted that although the optimum pH value for mycelial growth, primordia initiation and fruit formation varies from 5-6.5, substrate ramification stops at less than pH 4. The optimal pH values recorded for substrates in this study may be attributed to the application of 1% w/w lime supplement. Liming reduces substrate acidity level and enhances microbial biodegradation during composting.

CONCLUSION

The short composting technique adopted in this study produced significant mushroom yield, increased BE and reduced environmental pollution through burning of these agroforestry wastes at farm sites. Also, it ensured timely composting and harvest of cultivated mushrooms to meet market demand. The growth, yield and proximate composition of *P. ostreatus* differed significantly ($p<0.05$) among substrates that were used in their cultivation. Generally, treatments that produced higher mushroom yield had corresponding BE. Corncobs and sawdust produced the best yield and BE in substrate utilization potential among the substrates. The efficient performance of both substrates was also observed in their corresponding BE of 62.18%, and 57.84%, respectively. The cellulose content of both substrates notwithstanding, *P. ostreatus* also showed high degrading ability of the lignocellulosic content which translated to the higher yields obtained. Corncobs and sawdust showed promising potential and are, therefore, recommended as substrates for commercial production of *P. ostreatus*.

REFERENCES

AOAC (2005). Official method of Analysis. 18th Edition, Association of Officiating Analytical Chemists, Washington DC, Method 935.14 and 992.24.

Bellettini, M.B., Fiorda, F.A., H. A. Maieves *et al*. (2019). "Factors affecting mushroom *Pleurotus* spp," *Saudi Journal of Biological Sciences* 26(4):633–646.

Besufekad, Y., Mekonnen, A., Girma, B., *et al*., (2020). Selection of appropriate substrate for production of oyster mushroom (*Pleurotus ostreatus*). *Journal of Yeast and Fungal Research* 11 (1):15–25.

Bonatti, M., Karnopp, P., Soares, H.M. and Furlan, S.A. (2004). Evaluation of *Pleurotus ostreatus* and *Pleurotus sajor-caju* nutritional characteristics when cultivated on different lignocellulosic wastes. *Food Chemistry* 88: 425 - 428.

Bonatti-Chaves, M., Karnopp, P., Soares, H.M. and Furlan, S.A. (2004). Evaluation of *Pleurotus ostreatus* and *P. sajor-caju* nutritional characteristics when cultivated in different lignocellulosic wastes. *Food Chemistry* 88:425-38.

Cheung, P.C.K. (2013). Mini-review on edible mushrooms as source of dietary fiber: Preparation and health benefits. *Food Science and Human Wellness* 2(3-4):162–166.

Dania, V.O. and Ekpo, E.N. (2016). Evaluation of growth and nutritional value of *Pleurotus* sajor-*caju* (F.) Springer cultivated on sawdust of different wood species. *Ibadan Journal of Agricultural Research* 12(2): 85-96.

Girmay, Z., Gorems, W., Birhanu, G. and Zewdie, S. (2016). Growth and yield performance of *Pleurotus ostreatus* (Jacq. Fr.) Kumm (oyster mushroom) on different substrates, *AMB Express* 6(1): 1–7.

Food and Agriculture Organization (2003). Food and Nutrition paper, 77, ISSN 0254-4725 . Food energy–methods of analysis and conversion factor, Report of the Technical Workshop, Rome, 2002 Dec 3-6.

Hoa, H.T., Wang, C. and Wang, C. (2015) The Effects of different substrates on the growth, yield, and nutritional composition of two oyster mushrooms (*Pleurotus ostreatus* and *Pleurotus cystidiosus*).*Mycobiology*43(4):423-434.

Holtz, M., Borges, G.M., Furlan, S.A. and Wisbeck, E. 2007. Cultivation of *Pleurotus ostreatus* using cotton residues of textile industry. *Reviata Ciênc Amba* 3 :(1): 37-45.

Liang, Z., Wu, C., Shieh, Z. and Cheng, S. (2009). Utilization of grass plants for cultivation of *Pleurotus citrinopeleatus*. *International Biodeterioration and Biodegradation Journal* 63: 509-514.

Maheswari, S., Rajarajan, P., Pandian M.P., Sheeba, E. and Bayineni, V.K. (2020). Influence of different substrates on growth and yield of *Pleurotus ostreatus*. *Journal of Applied Horticulture* 22(3): 215-219.

Mendez, L.A., Castro, C.A.S., Casso, R.B. and Leal, C.M.C. (2005). Effect of substrate and harvest on the amino acid profile of oyster mushroom (*Pleurotus ostreatus*). *Journal of Food Composition and Analysis* 18: 447 - 450.

Michael, H.W., Bultosa G.G. and Pant, L.M. (2011). Nutritional contents of three edible oyster mushrooms grown on two substrates at Haramaya, Ethiopia, and sensory properties of boiled mushroom and mushroom sauce. *International Journal of Food Science and Technology* 46(4): 732 - 738.

Milner, B.A. and Whitside, P.J. (1981). An Introduction to atomic absorption spectrophotometry, Pye Unicam Ltd.,York Street, Cambridge, England, CBI-2px., 75-78pp.

Muchena, F.B., Pisa, C., Mutetwa, M., Govera, C. and Ngezimana, W. (2021). Effect of spent button mushroom substrate on yield and quality of baby spinach (*Spinacia oleracea*)," *International Journal of Agronomy* 12: 22-29.

Mukherjee, R. and B. Nandi (2004). Improvement of *in vitro* digestibility through biological treatment of water hyacinth biomass by two *Pleurotus* species. *International Biodeterioration and Biodegradation* 53(1)7-12.

MushWorld (2004). Mushroom Growers' Handbook 1. Oyster Mushroom Cultivation, Republic of Korea. 300 pp

Muswati, C., Simango, K., Tapfumaneyi, L., Mutetwa, M. and Ngezimana, W. (2021). The Effects of different substrate combinations on growth and yield of oyster mushroom (*Pleurotus ostreatus*). *International Journal of Agronomy* 12: 1-10.

Mutema, M., Basira, K., Savadye, D. and Paravira, W. (2019). Assessment of oyster mushroom production and profitability in Harare urban and periurban areas (RUWA), Zimbabwe, *Tanzania Journal of Science* 45(1):114-130.

Nelson, D.W. and Sommers, L.E. (1982). Total carbon, organic carbon, and organic matter. In: Page, A.L., Miller, R.H. and Keeney, D.R. (eds.). Methods of soil analysis Part 2. Chemical and microbiological properties. Agronomy monograph 9. Madison (WI): *American Society of Agronomy* 539-79pp

Oliveira, M.A., Donega, M.A., Peralta, R.M. and Souza, C.G.M. (2007). Spawn production of the edible mushroom, *Pleurotus pulmonarius*, from agro-industrial. *Ciência e Tecnologia de Alimentos* 27: 84-87.

Oyetayo, F.L. (2005). Nutritional and toxicological studies on cultivated and wildly obtained edible mushroom, *Pleurotus sajor-caju*. PhD thesis, Federal University of Technology, Akure. 123pp.

Patar, U.R., Chandra, R. and Dhakad, P.K. (2018). Comparative study on growth parameters and yield potential of two species of *Pleurotus* mushroom (*Pleurotus florida* and *Pleurotus sajor-caju*)," *International Journal of Current Microbiology and Applied Sciences* 7: 2319–7706.

Peksen, A. and Yakupoglu, G. (2009). Tea waste as a supplement for the cultivation of *Ganoderma lucidum*. *World Journal of Microbiology and Biotechnology* 25(4): 611-618.

Pokhrel, C.P. (2016). Cultivation of oyster mushroom: A sustainable approach of rural development in Nepal. *Journal of Institute of Science and Technology* 21(1): 56-60.

Sanjel, P., Shrestha, R.K. and Shrestha, J. (2021). Performance of oyster mushroom (*Pleurotus ostreatus*) grown on different finger millet husk substrates. *Journal of Agriculture and Natural Resources* 4(1): 291–300

Sardar, H., Ali, M.A. Anjum, M.A., Nawaz, F., Hussain, S., Naz, S. and Karimi, S.M. (2017). Agro industrial residues influence mineral elements accumulation and nutritional composition of king oyster mushroom (*Pleurotus eryngii*). *Scientia Horticulturae* 225: 327-334.

Tavarwisa, D., Govera, C., Mutetwa, M. and Ngezimana, W. (2021). Evaluating the suitability of baobab fruit shells as substrate for growing organic oyster mushroom (*Pleurotus ostreatus*). *International Journal of Agronomy* 12:33-37.

Tesfaw, A., Tadesse, A. and Tadesse, A. (2015). Optimization of oyster (*Pleurotus ostreatus*) mushroom cultivation using locally available substrate and materials. *Journal of Applied Biology and Biotechnology* 3(1): 15–20.

Vieira, F.R. and Nogueira de Andrade, M.C. (2016). Optimization of substrate preparation for oyster mushroom (*Pleurotus ostreatus*) cultivation by studying different raw materials and substrate preparation conditions (composting: phases I and II). *World Journal of Microbiology and Biotechnology* 32:189-198.

Yao, H., Liu, Y., Ma, Z.F. *et al*., (2019). Analysis of nutritional quality of black fungus cultivated with corn stalks. *Journal of Food Quality* 11:1-5).

Yang, W, Guo, F. and Wan, Z. (2013). Yield and size of oyster mushroom grown on rice/wheat straw basal substrate supplemented with cotton seed hull. *Saudi Journal of Biological Sciences* 20 (4): 333–338.

Zhang, Y., Geng, W., Shen, Y. Wang,Y. and Dai, Y.C. Edible mushroom cultivation for food security and rural development in China: Bio-innovation, technological dissemination and marketing. *Sustainability Journal* 6(5): 2961–2973.

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ASSESSMENT OF EARLY GROWTH PERFORMANCE OF *PERICOPSIS ELATA* HARMS AS INFLUENCED BY DIFFERENT WATERING REGIMES

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ABSTRACT

Pericopsis elata Harms is a valuable timber species occurring in moist semi-deciduous African forests which suffers from lack of regeneration over time with little information on its water requirement for optimum growth rates at nursery. In this study, the influence of different regimes of water on the growth of Pericopsis elata was assessed. Completely randomised design was the experimental design used in investigating the growth response of the species to the treatments in this study. Five watering regimes (two times daily, once daily, once in two days, once in 3 days and once in 4 days) were applied to the seedlings. Fortnight measurements of seedling collar diameter, number of leaves and height were carried out. Data collected were analysed using descriptive statistics and ANOVA at 5% level of significance. Seedling height was not significantly affected by watering regimes during the period of assessment but at 8 Weeks After Transplanting (WAT) seedlings watered once in 3 days had highest mean value (24.27±6.88 cm) while once in 2 days had the least (21.03±5.19 cm). Once a day and once in 3 days watering regimes produced seedlings with highest mean collar diameter (0.74±0.16 and 0.74±0.14 mm respectively). Significant variation was observed in number of leaves as seedlings watered once in 4 days produced highest number of leaves (4.08±0.88 leaves) which was not significantly different from once a day and once in 2 days (3.9±0.98 and 3.9±0.81 respectively). In conclusion, the young seedlings P. elata of 3 months old did not require frequent watering at nursery stage as watering the seedlings once in 3 or 4 days did not affect the seedlings negatively but gave optimum growth rate.

Keywords: Nursery. *Pericopsis elata*, Timber species, watering regime

INTRODUCTION

Pericopsis elata Harms belongs to the *Fabaceae* family. It is among the valuable timber species in Africa which plays an or Afromos according to Dickson *et al.* (2005), Hawthorne and Jongkind(2006) and Vivien and Faure(1985) is Cameroon, the Republic of Congo, Democratic Republic of the Congo, Ivory Coast, Ghana, Nigeria and western Uganda. It was listed among the threatened species through habitat loss at 1992 Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Pericopsis elata is a species of legume. It produces one of the most highly valued timber of tropical Africa. The wood is marketed internationally mainly for furniture and as decorative veneer. It is highly valued, and also used for interior and exterior joinery, stairs, flooring and boat building. According to Anglaaere (2008), it is considered a substitute important role in economic development and ecological sustainability. It is known to as African teak as English name. The origin and geographic distribution of African teak

for teak and commonly called 'African Teak'. The tree is valued for the high quality of its wood, and its exploitation started morethan 50 years ago, minly in Ghana and Côte d'Ivoire (Bourland, 2013). It is also suitable for heavy and light construction, railway sleepers, vehicle bodies, interior trim, handles, ladders, agricultural implements, sporting goods, musical instruments, toys, novelties, boxes, crates, carvings, turnery and draining boards.

In traditional medicine in Congo, the pulped from the bark is rubbed into scarifications as an anodyne. The methanol extracted from the leaves showed moderate *invitro* antiplasmodial activity against multiresistant strains of *Plasmodium falciparum*, (Fern, 2014). Ajaiyeoba *et. Al* .(2004) reported that the wood contains stilbene derivatives with antibiotic, anti-malaria and blood-sugar reducing properties. They also play a role in the colour development of the wood.

The large-scale selective exploitation coupled with slow growth rate which makes its timber plantations economically non-viable has resulted in poor regeneration and in serious reduction of populations, whereas the remaining larger populations are still under much pressure from indiscriminate logging. Although the critical status of *Pericopsis elata* has been recognized by including it in international and national lists of endangered species, protection is still not adequate (African Regional Workshop, 1998). This calls for serious sustainable silvicultural system in order to restore this prominent timber species. There is still little information on growth rates, propagation and appropriate management techniques to develop models for sustainable exploitation (Appiah, 1994; Asare, 1994).

Plants need water supply at appropriate frequency to grow well as lack of it or excess can cause stress to them. Water controls the rate of transpiration, inflow of nutrient solution and other mineral elements (Isah *et al,* 2013; Aderounmu *et al., 2017*) thereby dictating the growth, development and productivity (Ogidan *et al.,* 2018; Adelani, 2019). Water requirement depends on tree species, growth stage and time of the year in the nursery. Information on optimal water requirements of most indigenous tree species differ and also limited. Though there was a report that young *Pericopsis* seedlings are drought resistant (Betti *et al*, 2012) but this has not been established by research. There is need to validate the report in the face of climate change and unavailability of water as this may help in recommending the species to areas with little water or rain supply. This work focused on studying the response of *Pericopsis elata* species to different watering regimes. The result could serve as baseline information to the species nursery management and field establishment.

MATERIALS AND METHODS

Experimental site and climatic conditions

The experiment was conducted in Tree improvement nursery section t Forestry Research Institute of Nigeria Jericho hill Ibadan. The area lies between Longitude 07^{o} 26$^{'}$ 15$^{''}$ N to 07^{o} 25$^{'}$46$^{''}$ N and Latitude 03^{o}54’ 22$^{''}$ E to 03^{o}53’ 40$^{''}$ E. The climatic condition of the area is characterised by annual rainfall range from 1400-1500mm and the average temperature is about 31.2^{o}C, the dry season usually commences from November to March and the rainy season start from April to October (FRIN Meteorological station, 2015).

Assessment of early growth performance using different watering regimes

The seeds of *Pericorpsis elata* were collected from the premises of Forestry Research Institute of Nigeria (FRIN), Jericho, Ibadan, Oyo State from the ground under the mother tree. The seeds were then processed and sown in germination tray filled with washed sterile river sand. Sterile river sand was used to germinate in order to reduce infections from microorganism and also reduce root damage during seedling pricking. These were watered once daily till germination occurred. Thirty seedlings with good vigour and relatively uniform growth were randomly selected from germinated seeds. They were pricked and transplanted into 1 kg capacity poly pots (16 x 7x 0.05 cm) filled with forest top soil at one week after germination. Five watering regimes namely; two times daily, once daily, once in two days, once in 3 days and once in 4 days (modified method of Osaigbovo and Orhue, 2012) were applied to the seedlings. The seedlings were subjected to same volume of water (300ml). The experiment was arranged in completely randomized design and replicated 6 times (single plant replicate). The seedlings were allowed to adjust to the watering regimes for 2 weeks before data collection. Growth parameters considered were seedling height determined by meter rule by measuring from the base to the apex of the seedling, collar diameter determined by veneer caliper placed at the natural ground or collar of the seedling and number of leaves by counting. Data was collected at 2 weeks interval for 8 weeks.

Statistical analysis

Data collected was subjected to descriptive statistics and Analysis of Variance (ANOVA). The least square difference (LSD) was used to separate the means at 5% probability level.

RESULTS

Effect of watering regimes on Seedling Height of *Pterocarpus elata*

Watering regimes produced different seedling height during the weeks of assessmentThe highest height was in the plants subjected to watering once in three days with 22.58 ±5.83 cm, this was followed by 21.97 ± 4.94 cm of the plants subjected to watering once daily. The least plant height was found in the plants that are watered once in two days with 20.18±4.59 cm. However, it was observed that the height of the seedling was not significantly affected by watering regimes during the period of assessment the seedling height. The highest height was observed at 8 weeks after transplanting (WAT) in seedlings watered once in a day with 24.27±6.88 cm, then followed by seedlings at 6 WAT in seedlings watered once daily with 22.47±5.64 cm and the least value of height waat 2 WAT of seedlings watered once in four days with value 21.92±2.21 cm, (Table 1).

Effect of watering regimes on Collar diameter of *Pericopsis elata* seedlings

There was no significant difference at 5% probability level in the collar diameter of *Pericopsis elata* when the seedlings were subjected to different watering regime at different period but different values were observed. The highest mean value of collar diameter was found in seedlings subjected to watering once a day and once in 3 days with values of 0.80 ±0.16 mm and 0.77±0.14 mm respectively 8 WAT. The least value was found in the plants watered once in two days with 0.69±0.07 mm, (Table 2).

Effect of watering regimes on Number of Leaves of *P. elata* seedlings

Watering regimes and assessment weeks significantly affected number of leaves produced at 5% probability level by *Pericopsis elata*, (Table 1). The highest number of leaves was recorded in the seedlings watered once in four days at 8 WAT with 4.5±0.84 leaves followed by seedlings watered once in two days with mean value 4.7±0.55 leaves. The least number of leaves produced was recorded in seedlings watered once daily at 8 WAT with 4.3±0.82 leaves, (Table 2).

Table 1: Mean values for the different watering regimes of *Pericopsis elata* assessed for 8 weeks

Growth parameters	Watering regimes	Period of assessment				Means
		2 WAT	4 WAT	6 WAT	8 WAT	
Seedling height	Twice a day	17.92±4.68^{ns}	19.50±5.36^{ns}	21.48±3.67^{ns}	24.15±2.93^{ns}	20.76±4.63^{ns}
	Once a day	20.37±5.42^{ns}	19.78±3.71^{ns}	21.67±5.69^{ns}	22.47±5.62^{ns}	21.07±4.94^{ns}
	Once in 2 days	18.93±4.36^{ns}	19.73±4.52^{ns}	21.0±5.17^{ns}	21.03±5.19^{ns}	20.18±4.59^{ns}
	Once in 3 days	19.70±5.21^{ns}	22.58±5.21^{ns}	23.77±6.29^{ns}	24.27±6.88^{ns}	22.58±5.83^{ns}
	Once in 4 days	19.68±1.97^{ns}	20.92±2.16^{ns}	21.75±2.05^{ns}	21.92±2.21^{ns}	21.07±2.16^{ns}
Collar diameter	Twice a day	0.62±0.20$^{\mathbf{a}}$	0.64±0.19$^{\mathbf{a}}$	0.81±0.18$^{\mathbf{b}}$	0.83±0.17$^{\mathbf{b}}$	0.72±0.20$^{\mathbf{ab}}$
	Once a day	0.68±0.14$^{\mathbf{a}}$	0.69±0.16$^{\mathbf{a}}$	0.80±0.16$^{\mathbf{b}}$	0.80±0.16$^{\mathbf{b}}$	0.74±0.16$^{\mathbf{a}}$
	Once in 2 days	0.64±0.06$^{\mathbf{a}}$	0.66±0.07$^{\mathbf{a}}$	0.69±0.07$^{\mathbf{b}}$	0.69±0.07$^{\mathbf{b}}$	0.67±0.07$^{\mathbf{a}}$
	Once in 3 days	0.68±0.15^{a}	0.74±0.15$^{\mathbf{b}}$	0.76±0.14$^{\mathbf{b}}$	0.77±0.14$^{\mathbf{b}}$	0.74±0.14$^{\mathbf{b}}$
	Once in 4 days	0.65±0.05^{a}	0.68±0.06^{a}	0.70±0.08^{ab}	0.73±0.09^{b}	0.69±0.68$^{\mathbf{ab}}$
Number of leaves	Twice a day	3.0±0.63^{a}	3.0±0.63^{a}	4.0±0.63^{b}	4.5±0.55^{b}	3.6±0.88^{a}
	Once a day	2.8±0.75^{a}	2.8±0.75^{a}	3.8±0.75^{b}	4.3±0.82^{b}	3.9±0.98^{b}
	Once in 2 days	3.3±0.52^{a}	3.3±0.52^{a}	4.5±0.55^{b}	4.7±052^{b}	3.9±0.81^{b}
	Once in 3 days	3.12±072^{a}	3.12±0.72^{a}	4.0±1.1^{b}	4.3±1.2^{b}	3.67±1.05^{a}
	Once in 4 days	3.67±0.82^{a}	3.67±0.82^{a}	4.5±0.84^{b}	4.5±0.84^{b}	4.08±0.88

Legend: WAT = Weeks after Treatment

DISCUSSION

According to the result of this study, leaf production varied significantly at 5% probability as seedling watered once in 4 days recorded highest number of leaves. This significant difference in leaf production due to watering regime agrees with Isah *et al*. (2012) findings who reported significant difference in *Acacia senegal* leaf production subjected to different watering regimes. Also, Fredrick *et al*. (2018) reported significant variation in all growth parameters assessed including leaf production of *Annona muricata* seedlings subjected to different watering regimes. Period of assessment was significant for all the growth parameters assessed. This implies that the growth of the seedlings was steady. This indicated that, for the period of study, the seedlings did not show any sign of decline in growth.

Seedlings of *Pericopsis* watered at every 3 days had highest height value. Likewise seedlings watered once daily recorded the highest diameter value but not significantly different from other treatments. Sale (2015) reported non-significant difference in seedling height of *Parkia biglobosa* which is consistent with the result of this study.he reaction of the species towards varied watering regime showed that it needs stable moderate moisture for its survival.

CONCLUSION

Pericopsis elata seedlings showed varied responses to different watering regimes applied. The tallest seedlings with highest number of leaves were recorded in watering regimes once in 3 day and once in 4 days respectively. The result of this study showed that the young *P. elata* seedlings can withstand shortage supply of water at the nursery stage as assessed for 8 weeks. Therefore, the watering quantity required and other silvicultural requirements of *P. elata*should be adopted for its plantation establishment and conservation.

REFERENCE

Adelani, D.O. (2019). Effect of watering regimes on the growth and nutrient uptake of Citrus Tangelo J.W. seedlings grown in a mixture of sand and pulverized *Jacaranda mimosifolia* D.Don leaves. *Journal of Research in Forestry, Wildlife and Environment* 11(3) :172-179

Aderounmu, A.F, Adenuga, D.A, Ogidan, O.A. and Alonge, O.O. (2017). Effect of different watering regimes on early growth of *Terminalia superba* Engl and Diels. In: Adekunle, V.A.J, Ogunsanwo, O.Y. and Akinwole, A.O. (eds). Harnessing the uniqueness of forest for sustainable development in a diversifying economy. *Proceedings of the 39th annual conference of the Forestry association of Nigeria.* Pp183-189

African Regional Workshop (Conservation and Sustainable Management of Trees, Zimbabwe) (1998). Pericopsis elata. In: IUCN. 2007 IUCN Red list of threatened species. [Internet] http://www.iucnredlist.org. Accessed December 2007.

Ajaiyeoba, E., Ashidi, J., Abiodun, O., Okpako, L., Ogbole, O., Akinboye, D., Falade, C., Bolaji, O., Gbotosho, G., Falade, M., Itiola, O., Houghton, P., Wright, C. and Oduola, A. (2004). Antimalarial ethnobotany: *In vitro* antiplasmodial activity of seven plants identified in the Nigerian Middle Belt. *Pharmaceutical Biology* 42(8): 588–591.

Anglaaere, L.C.N.(2008). *Pericopsis elata*(Harms) Meeuwen. [Internet] Record from Protabase. Louppe, D., Oteng-Amoako, A.A. and Brink, M. (Eds). PROTA (Plant Resources of Tropical Africa / Ressources végétales de l'Afrique tropicale), Wageningen, Netherlands. < http://database.prota.org/search.htm>. Accessed 15 July 2010.

Appiah, B.K.(1994). Initial growth performance of *Pericopsis elata* in different potting media and fertilizer treatments. B.Sc. Natural Resources Management degree thesis, Institute of Renewable Natural Resources, Kwame Nkrumah University of Science and Technology,Kumasi, Ghana. 49pp.

Asare, A.E. (1994). The effect of different levels of chemical fertilizer (NPK) on the initial growth performance of *Pericopsis elata* seedlings. B.Sc. Natural Resources Management degree thesis, Institute of Renewable Natural Resources,

Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. 42 pp.

Betti, J. L, Belinga, S. J. and Samba D. (2012). Sustaining *Pericopsis elata* (Harms) Van Meeuwen in Tala Tala Forest, North Congo. *Global Research Journal of Agricultural And Biological Sciences 3(4):*336-346accessed online on 15thApril 2022 at http://www.globalresearchjournals.org /?a=journal&id=grjabs

Bourland, N., 2013. Dynamic of a long-lived light demanding timber species in a changing world: the case of Pericopsis elata (Harms) Meeuwen (Fabaceae)in southeastern Cameroon. A PhD Thesis. DOI: 10.13140/RG.2.1.4943.9206. Researchgate.

Fredrick C., Chima, U.D and Bamalo, U.M. (2018). Effect of watering regimes on the germination and early seedling growth of *Annona muricata*Linn. *Production Agriculture and Technology* (PAT)*14*(1): 66-72. ISSN: 0794-5213

Gbadamosi, A. E. (2014). Effect of watering regimes and water quantity on the early seedling growth of *Picralima nitida* Stapf. *Sustainable Agriculture Research*3(2): 35-42.

Isah, AD., Bello, A.G., Maishanu, HM and Abdullahi, S. (2013). Effect of watering regime on the early growth of *Acacia senegal* (Linn) wild provenances. *International Journal of Plant, Animal and Environmental Sciences* 3(1): 52-56.

Ogidan, O.A., Olajire-Ajayi, B.L. and Adenuga, DA. (2018). Assessment of watering regimes on seedling growth performance of *Kigelia africana* (Lam) Benth. Biodiversity conservation and national development potentials and challenges. In: Gabrial, S.U., Folaranmi, D.B. and Edem, A.E. (eds). Proceedings of 6th Nigeria chapter of society for conservation biology (NSCB) biodiversity conference pp 18: 341-345.

Sale, F.A.,(2015). Evaluation of watering regimes and different pot sizes in the growth of *Parkia biglobosa* (Jacq) Benth seedlings under nursery condition. *European Scientific Journal*11(2): 313-325.

Umunay, P.M.; Covey, K.R.; Makana, J. and Gregoire, T.G. (2017). Effect of light, fire and weed control on establishment of *Pericopsis elata* Harms regeneration. New Forests, Springer Science.

Vivien, J. and Faure J.J. (1985). Trees of central African forests ministry of foreign relations, cooperation and development- cultural and technical cooperation agency (ACCT), Paris, p 551.

PERCEIVED EFFECT OF CLIMATE CHANGE ON FOOD CROP PRODUCTION IN OGUN STATE

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ABSTRACT
The study assessed the perceptions of climate change effect on food crop production in Ogun State, Nigeria. Multistage sampling was used to select 240 farm households from the two ADP zones (Ilaro and Abeokuta). Data on socioeconomic characteristics of the respondents and perceived climatic parameters that influenced climate change were collected with the use of a structured questionnaires. Data were analyzed using descriptive statistics and Stochastic Production Frontier (SPF) at α=0.01. The results showed that majority (62.0%) of the respondents were married with mean age and household size of 44 years and 6 persons, respectively. Also, majority (95.83%) were aware of climate change, sourced information about climate change from radio (95.83%) and local Newspaper/Magazine/Flyer (55.00%), while 25.00% sourced from extension agents. Climatic parameters perceived to have indicated climate changed were sunshine (60.00%), rainfall (19.17%), temperature (8.33%) and wind (4.17%) while 81.67%, 75.00% and 54.17% of the respondents claimed that decrease in numbers of rainy days, many days of high temperature coupled with low humidity indicated trends in climate change. Cost of agrochemicals (β=0.0740), number hired labour (β=0.0142), farm size (β=0.3101), perceived amount of rainfall (β=-0.0752) and perceived rate of sunshine (β=-0.1183) had significant influence on food crop production. It is concluded that major parameter that influence climate change in the study area as perceived by the respondents is sunshine which also have significant effect on food crop production in the study area. The study recommends that government should provide necessary resources needed such as information needs and capital resources, this will help the farmers to cope with adverse effect of climate change.

Keywords: Climate Change, Humidity, Newspaper, Stochastic Production Frontier

INTRODUCTION

Over time the concept of food security has kept on changing, it has been earlier defined as both physical and economic access to food that meets people's dietary needs as well as their preferences (FSIN, 2019). It is built on four major pillars; availability, accessibility, utilization and sustainability. Availability means sufficient quantities of food are available on a consistent basis in a place at a particular point in time. Accessibility on the other hand involves having sufficient resources to obtain appropriate foods that are available for a nutritious diet while utilization guarantees the ability of the concerned people to put the available and accessible foods into appropriate use. This shows that they have basic nutrition and health care that include adequate water and sanitation required for healthy living. In the other hand, sustainability on its own means that the earlier three factors availability, accessibility and utilization are sustainable for a record period. Food policy that centered on increased production to meet the consumption needs of the people has always been the focus among the stakeholders in the food sector (FAO, 2019).

Although considerable achievements in the global reduction of hunger and poverty have been made, progress in Africa so far has been very limited. At present, a third of the African population faces widespread hunger and chronic malnutrition and is exposed to a constant threat of acute food crisis and famine (FAO 2018b). The most affected are rural households whose livelihood is heavily dependent on traditional rain fed agriculture.

During the period 2012–2016, there were more than 850 million chronically undernourished people worldwide (FAO 2018a). The sub-Saharan Africa accounts for 25% of the global Plate of chronically undernourished people. Many countries experience food insecurity with inadequate food supplies to maintain their citizens' per capita consumption (Stern, 2017). Stephen (2018) also found that ub-Saharan Africa was the most vulnerable region of all the food distressed countries of the world. The average amount of food available per person per day in the region is 1,300 cal compared to the world wide average of 2,700 cal. Stern

(2017) reported that food security is widely seen as access by all people at all times to enough food for an active life, while food insecurity is the inability of households or individuals to meet the required consumption levels in the face of fluctuating production, price and income.

Global climate conditions and patterns have recently been changing and thus have a severe implication on food availability and accessibility. As seen in most countries in the sub-Saharan Africa region and beyond suffering from perpetual droughts. Increasing temperatures have taken their toll on crops, water bodies and in some instances led to heavy rains that have resulted in floods. This has compounded the fate of a continent suffering from a myriad of development challenges where, for example, malnutrition is responsible for several deaths every year. Increase in average global temperature will have several effects on agricultural production, including variations in growing seasons, the length of time that soil temperature and soil moisture conditions appropriate for crop evolution (Darwin, 2011). The Earth's oceans will expand, raising sea levels and reducing the amount of land available for agriculture. Extreme weather hazards, such as storms and floods, may also increase in frequency (Darwin, 2011).

Developing countries are more vulnerable to climate change due to their low adaptive capacity and growing dependence on resources sensitive to changes in climate. Climate change will weaken development efforts in Africa and the rest of the developing world; this will affect the poorest and most vulnerable sections of society severely (Sibhatu and Qaim, 2018). The author also argued that climate change will further deepen the development crisis faced by developing countries. Climate change "threaten to reverse the gains of sustainable development and put additional pressure on already overstretched human and financial resources in developing countries". The perennial challenges faced by the sub-Saharan countries being, poverty, burden of diseases, conflict, environmental degradation, malnutrition among others, risk getting aggravated by climate change (Stephen, 2018)

The problem haunting small-scale farmers in Nigeria is the changing climate that has adversely affected crop production. There has been an obvious decline in seasonal rainfall, as well as an increase in temperatures conditions that are not favourable to crop production. Therefore, low rainfall and increased temperatures have drastically reduced food production capacity resulting in an increase to the incidence of household food insecurity. Food insecurity in Nigeria have associated with conflict, policy, and resource management as causative factors. Rahim (2011) argued that "hunger results, not from a decline in cumulative food accessibility, but from a lack of clear political commitment to social security provisions due to an alienation of rural land, loss of labour power, a loss of employment, and a fall in wages". A vicious cycle of conflict and food insecurity makes alleviation of poverty in rural areas of the most vulnerable countries intractable. Having more people to feed, with less land and water, more variable climate, and greater food price volatility increases stress on livelihoods (World Bank, 2010). It is against this background that an in-depth qualitative study will be conducted to establish relationship between climate change and food crop production in farming households in Nigeria. Hence, the study examined the effect of climate change on food crop production in Ogun State.

MATERIALS AND METHODS

Study Area

The study was carried out in Ogun State, South Western Nigeria. It is an inland state in south-western Nigeria, with its capital at Abeokuta. 16409.26 km2. It has an estimated population of 3,751,140 (Nigeria Population Census 2006). The state was carved out of the old western region in by the Military Government of the Federation in 1976 and its name is derived from the Ogun River and it is characterized commercially by a dual economic focus, the bourgeoning industrial sector and a dominant agricultural sector

Sampling techniques and Sample size

The population of the study comprises food crop farming households in Ogun state, Nigeria. A multistage sampling technique was used to select 240 rural farming households in the study area. Stage one involved purposive selection of 2 zones (Abeokuta and Ilaro) from 4 zones of the Agricultural Development Programme of the state because they are major food crop producing zones in the study area. Stage 2 involved random selection of 3 blocks each from Abeokuta and Ilaro. Stage 3 comprised the random selection of 4 cells from the selected 6 blocks, making 24 cells. The fourth stage involved random selection of 10 respondents from each of the 24 cells, giving us a total of 240 respondents. Primary data were collected using structured questionnaire.

Data Analysis

Data were subjected to various analytical techniques such as descriptive statistics and Stochastic Production Function (SPF) regression analysis.

RESULTS AND DISCUSSION

Demographic distributions of the respondents

The demographic distribution showed background information of the sampled respondents. The distribution of age of the food crop farmers in Table 1 showed that 91.83% of food crop farmers were aged below 50 years of age with an average age of 44 years (SE=5.81). This result is in conformity with the finding of (Sibhatu and Qaim, 2018) who pointed out that individuals are more active under the age of 50 years. This indicated that majority of the household heads were still at their active productive age. In addition, the food crop farmers in the study area had an average of 6 persons (SE = 1.32) in their household with about 63.0% of them married. This is a large family size points to the need of knowledge of family planning in rural households (Sibhatu and Qaim, 2018).

The distribution of the respondents according to belief showed that the majority (55.0%) are Muslims. In terms of distribution of food crop farmers by educational status, the majority (79.17%) had formal education as against 20.83% with no formal education, with the mean farming experience estimated at 13 years (SE = 2.57). This is contrary to Ibok (2016) who reported that many rural farming households lack basic elementary education. Furthermore, the mean farm size was estimated at 4.3 hectares (SE = 1.09). Also, a high proportion (88.1%) of the farm size fell between 0.1 and 5.0 hectares for the food crop farmers, clearly showing the subsistence nature of farming in Nigeria. This tallies with Amare et al. (2018) who reported that the majority of Nigeria's farmers are still subsistence in nature.

4.2 Distribution of respondents according to awareness about climate change in the study area

Table 2 shows the distribution of respondents according to awareness about climate change in the study area. Majority (95.83%) of the respondents were aware of climate change while only 4.17% of the respondents claimed they were not aware. This indicates that farmers had perceived climate change which enhanced their awareness. This is not surprising because different sources of climate change information, awareness and practices are being shared among the farmers in the recent years. This result conformed with Buba (2004), in a study conducted in Sahel Savannah agro-ecological zone of Borno State, Nigeria, that the majority of farmers were aware of climate change and its consequences.

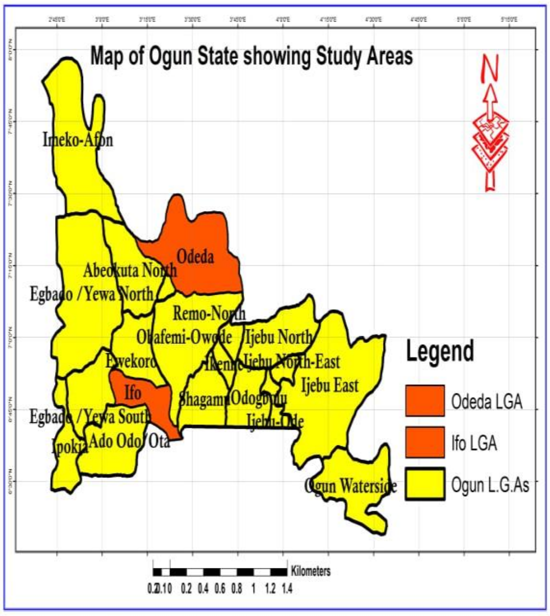

Plate 3.3: Map of Ogun state showing Selected LGAs study areas

Table 1: Socio-economic distribution of food crop farmers

Variable	Frequency	Percentage	Mean	Standard Error (SE)
Age				
25	11	9.17		
26-30	22	18.33		
31-37	9	7.50		
38-45	62	51.66	44	5.81
46-50	5	4.17		
Over 50	11	9.17		
Marital status				
Single	21	17.50		
Married	75	62.50		
Widowed	22	18.33		
Divorced	2	1.67		
Sex				
Male	70	58.33		
Female	50	41.67		
Educational level				
Primary	56	46.67		
Secondary	23	19.17		
Tertiary	16	13.33		
No formal	25	20.83		
Household size				
Less than 5	15	12.50		
5 – 9	75	62.50	6	1.32
Above 9	30	25.00		
Farm size				
Less than 5	75	62.50	4.3	1.09
5-10	30	25.00		
Above 10	15	12.50		
Farm experience				
Less than 6	5	4.17		
6-10	52	43.33		
Above 10	63	52.50	13	2.57
Religion				

Christianity	47	39.17
Islam	66	55.00
Traditional	7	5.83
Others		
Total	120	100.00

Table 2: Distribution of respondents according to awareness about climate change in the study area

Awareness	Frequency	Percentage
Yes	115	95.83
No	5	4.17
Total	120	100.00

Distribution of the respondents according to source of information on climate change

The source of information on climate change as presented in Table 4.16 reveals that most of the respondents (95.83 percent) sourced information on the radio. Respondents who sourced information from local Newspaper/Magazine/Flyer and extension agents were 55% and 25.50% respectively, while 4.17% of the respondents received or had no source of information on climate change. These findings are supported by Munonye et al. (2008), who reported that local radio is the major source of information received by small-scale farmers in Africa.

Table 3: Distribution of the respondents according to source of information on climate change

Information Source*	Frequency	Percentage
Extension Agent	30	25.50
Friends/Neighbour	56	46.67
Radio	115	95.83
Television	15	12.50
Worship centers	75	62.50
Mobile phones	30	25.00
Local Newspaper/Magazine/Flyer	65	55.00
No response	5	4.17

* Multiple response

4.3 Distribution of respondents according to the perceived climatic parameters that influence climate change in the study area

Table 4 shows the perceived climatic parameters that influence climate change in the study area by the respondents. The result indicated that majority (60.00%) of the respondents perceived sunshine as the climatic parameter that influence climate change while 19.17%, 8.33%, 4.17% of the respondents reported that rainfall, temperature and wind respectively were the climatic parameters that brought about climate change in the area respectively. This claim was supported by Bareja (2011) that climatic factors such as rainfall and water, light and temperature are the factors that influence plant growth and development. It was also in line with the claim that climate variability is a long-term shift in weather conditions identified by changes in temperature, precipitation, wind and other indicators (Oyekale et al., 2009).

Table 4: Distribution of Respondents according to the perceived Climatic Parameters that Influence Climate Change in the Study area

Climatic Parameters	Frequency	percentage
Rainfall	23	19.17
Temperature	10	8.33
Wind	5	4.17
Sunshine	72	60.0
Humidity	5	4.17
None	5	4.17
Total	120	100.

Perceived Trends in Climate Change among farmers in the study area

The distribution of the respondents according to perceived trends in climate change in the study area is presented in Table 5. The results showed that majority (81.67 %) of the respondents claimed that decrease in numbers of rainy days as a trends in climate change. Also, 75.00%, 63.33% and 54.17% of the respondents claimed to perceived late arrival of rainfall, high temperature causes wilting of crops and many days of high temperature coupled with low humidity as a trends of climate. You have only explained your results in Table 5 but no discussion. Please discuss the implication of your results.

Table 5: Perceived trends in climate change among farmers in the study area

Trends in climate change*	Frequency	Percentage
Increase in temperature	23	19.17
Many days of high temperature and low humidity	65	54.17
High temperature causes wilting	7	5.83
Decrease in number of rainy days	98	81.67
Inadequate rainfall leads to crop failure	44	36.67
Unstable rainfall pattern reduces yield	76	63.33
Late arrival of rain delays planting	90	75.00
Destructive wind is common	21	17.50
Wind causes damages to crop	15	12.50
Increase in temperature	7	5.83
Many days of high temp.	10	8.33
None	5	4.17

* Multiple responses

Maximum Likelihood Estimates of the Stochastic Production Function of food crop farmers

Table 6 presents the maximum likelihood estimates (MLE) of the production function of food crop farmers in Ogun State. The variance parameter for sigma-square for food crop farmers was estimated at 0.512. The sigma-square attests to the goodness of fit and correctness of the distributional form of the model while the gamma value (0.601) which was significant at 1% indicated the systematic influences that were unexplained by the production function and the dominant sources of random error. It implies that about 60% percent of the variance in output of food crop farmers in Ogun state was due to the differences in their technical efficiencies.

The result showed that cost of agrochemicals (β=0.0740), hired labour (β=0.0142) and farm size (β=0.3101) in hectares had positive significant influence on food crop production at 1% level of significance. However, the finding showed that other variables such as fertilizer and cost of planting materials/input didn't exert any significant influence food crop production in the study area. The contribution of farmers' personal characteristics such as age, years of education, farming experience, household size and sex, perceived rainfall, perceived sunshine and perceived humidity were also examined. However, all the variables examined in the inefficiency model are not significant except perceived rainfall (β=-0.0752) and perceived sunshine (β=-0.1183) that had negative influence on farmers' inefficiency model. It implies that rainfall and sunshine are predominant factors in food crop production in the study area.

Table 6: MLE of production function of farmers in the study area

Variables	Coefficient	Standard error	t-value
Constant	0.5531***	0.2221	2.49
Farm size	0.3101***	0.0982	3.16
Number of Labour (Man days)	0.0142***	0.0099	1.43
Fertilizer (Kg)	0.5981	0.4421	1.35
Agrochemicals (Kg)	0.0740***	0.0289	2.56
Planting material/input (₦)	0.1120	0.3211	0.35
Inefficiency Model			
Constant	1.1321**	0.9736	1.16
Sex	0.1176	0.1123	1.05
Age	0.1023	0.1132	0.90
Education	0.1721	0.2721	0.63
Farm Experience	-0.2217	0.4439	-0.50
Household size	-0.1974	0.2310	-0.85
Perceived change in rainfall	-0.0752***	0.0522	-1.44
Perceived change in sunshine	-0.1183***	0.2316	-0.51
Perceived change in humidity	0.3210	0.4321	0.74
Diagnostic Statistics			
Stigma-square (δ^2)	0.512	0.286	0.467
Gamma (γ)	0.601**	0.311	2.061
Log Likelihood	-92.32		
Chi Square	18.11***		

***, **, * denote significant at 1%, 5% and 10% respectively

CONCLUSION AND RECOMMENDATION

It can be concluded from the findings that majority of the farmers are young and expected to be productive. Also, majority of the rural farmers obtained information about climate change from extension agents, radio and local newspaper. The climate parameters influencing climate change as perceived by the respondents are rainfall, sunshine and temperature. The SPF analysis shows that farming output in the study area is a function of farm size, number of labour, agrochemicals used, amount of rainfall and sunshine. Moreover, the stochastic production function reveals that inefficiency exists among the food crop farmers. The study recommends that role of government is much necessary to supply the resources needed such as infrastructural resources, structural resources, and capital resources. This can help the farmers to cope with an event of climate variability. In addition, the government can put in place, agricultural disaster insurance system or policy to compensate in the case of losses

REFERENCE

Amare, M., Jensen, N., Shiferaw, B. and Cissé, J. 2018. Rainfall shocks and agricultural productivity: implication for rural household consumption. Agricultural Systems, 166: 79–89;

Buba, A. D. (2004): Climate Change and Water in Chad Republic. *Journal* of environment 3(2): 35-42 m (NEST) held at Hotel Millennium, Abuja, Nigeria 8-9th October, 2008. P. 2-4

Darwin. 2011. “Food access indicator review”, Food and Nutrition Technical Assistance(FANTA) Project, Academy for Educational Development (AED), Washington, D

FAO. 2018a. The State of Food and Agriculture in the World 2017. Leveraging food systems for inclusive rural transformation. Rome

FAO. 2018b. The State of Food and Agriculture in the World. Leveraging food systems for inclusive rural transformation. Rome.

FSIN. 2019. Global Report on Food Crises 2019 [online]. [Cited 24 April 2019]. http://www.fsinplatform.org/sites/default/files/resources/files/GRFC_2019f

Ibok. 2016. The Integrated Food Security Strategy in Africa: an institutional analysis. *Agrekon*. 49(3):316–337.

Munonye, J., Okoli, V. and Nwajiuba, C.U. (2008): Rainfall Variabilty and Arable Crops Production in the Humid South of Nigeria. In Doppler, W. and Baner, S. (Eds.) Farming and Rural Systems Economics. Pp. 45-51

Oyekale A.S, Bolaji M.B and Olowa O.W (2009): The Effects of Climate Change on Cocoa Production and Vulnerability Assessment in Nigeria. *Agricultural Journal*, Volume 4, Number 2. Pp 77-80

Sibhatu, K. and Qaim, M. 2018. Rural food security, subsistence agriculture, and seasonality. PLoS One, 82(19): e1076406.

Stephen N. 2018. Climate Change Adaptation Strategies: Water Resources Management Options for Smallholder Farming Systems in Sub-Saharan Africa. UNON, Publishing Services Section, Nairobi

Stern, N. 2017. How Climate Change Will Affect People Around World. In: The Economics of Climate Change: The Stern.Review(Pp. 171-273). Cambridge University Press

World Bank. 2010. UNICEF-WHO, The World Bank: Joint child malnutrition estimates – Levels and trends (March 2019 edition). https://data.unicef.org/topic/nutrition;

ASSESSMENT OF THE RESISTANCE OF *Gmelina aborea* TREATED WITH CASHEW NUTSHELL LIQUID TO TERMITE ATTACK

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ABSTRACT

An assessment was carried on the resistance of Gmelina aborea treated with Cashew Nut Shell Liquid (CNSL) against termite attack. The study was based on the use of natural plants extract from cashew nutshell as alternative to insecticide. The treatments were laid out in a completely randomized design (CRD) with four replicates using sixteen billets. Gmelina aborea wood of 2 x 2 inches thickness were cross – cut into billets, 18 inches in length. The sample billets were installed into termite's mound located within the Polytechnic premises near Forestry Department Plant Nursery. A hoe was used to dig a hole of 10-15cm depth down the ground level and the sample billets where inserted. Treatments included painting of the billets with 50 (T_1), 100 (T_2) and 150 mL (T_3) of (CNSL) using a brush. The untreated billets T_4 served as the control. Incidence of termite attack, severity of damage and weight loss of billets were recorded at interval of 21 days for 63 days. Data obtained were subjected to analysis of variance at 5% level of probability. The study revealed that 150ml of (CNSL) was more effective in causing significant reduction in termite attack than other treatments probably due to the amount used and the toxicity/anti-feedant properties to termite. There was no significant difference in incidence of termite attack and severity of damage, while there was significant difference in number of furrows and weight loss of billets.

Keywords: Wood damage, Insect resistance, Termite attack.

INTRODUCTION

Wood products in use throughout the world are subject to infestation by insect pests, and termites are by far the greatest economic importance in this regards. Termites destroy wood by feeding on its components, thereby reducing its structural ability and appearance (Bowyer *et al.,* 2003). Cellulose being the principal food of termite, wood and wood products such as paper, fabrics and wood structures are avidly consumed and hence, a constant effort is directed towards their control (Peralta *et al.,* 2004).

Natural resistance is the inherent ability of some wood species to resist the attack of bio-deteriorating agents without treatment with chemical preservatives. The term 'natural durability' refers to the degree of resistance of wood to bio-deteriorating agents. The natural resistance exhibited by some species is the resultant effect of the presence of extractives in the heart region. Milton (1995) stated that the sapwood of all known tree species is very susceptible to decay, regardless of any natural resistance of the heartwood. Unless sapwood is entirely removed or impregnated with preservatives, decay is likely to occur even in durable species. Trees with more toxic natural chemicals deposited during the transformation have very durable heartwood that is highly resistant while some may be moderately resistant and other have no resistance to insect attack (Adam *et al.,* 2002). The broad objective of the study is to assess the resistance of *Gmelina aborea* treated with cashew nut shell liquid to termite attack while the specific objective are to examine the incidence of attack by termites, severity of damage to billets by termites, number of furrows on the billets and weight loss of billets.

Finding safe alternative to synthetic pesticides/insecticides to protect/preserve wood from pest infestation are highly desirable. Recently, alternative has been given to the possible use of plant products or plant derived compounds as promising alternative to synthetic pesticides in controlling insect pests of wood products (Rao *et al 1990*). The essential minimum requirements for pesticides to be a more sustainable alternative for insects pests control is that they should be produced from renewable raw materials and that their uses could have lower negative environmental impacts (Henning, 2006).

The broad objective of the study is to assess the resistance of *Gmelina aborea* treated with cashew nut shell liquid to termite attack while the specific objective are to examine the incidence of attack by termites, severity of damage to billets by termites, number of furrows on the billets and weight loss of billets.

MATERIALS AND METHODS

Study Area

The experiment was carried out in Federal Polytechnic Bauchi. Bauchi State has a land area of 49,259.01 km^2 with a population of 4.6 million people and located between latitude 9^0 30$^'$ North of the equator and longitude 8^0 50$^'$ and 11^0 East of the Greenwich Meridian. The state has a typical tropical climate clearly marked by the dry and rain seasons. The average annual rain fall is 700mm in the Northern parts and 1300 mm in the Southern parts. The wettest month is August and dry season starts in November and ends in April; this a period of harmmatan, when the dust loaded North East trade wind from Sahara desert has a marked drying effect on the vegetation and the general climate of the state. Bauchi State is one of the states in Northern part of Nigeria that span three distinct vegetation zones, namely; Northern Guinea Savannah, Sudan Savannah and Sahel Savannah with Sudan Savannah dominating. Northern Guinea Savannah become manifest as one moves along a belt that stretches from extreme western part of the state to the extreme southern part covering Local Government Areas of Toro, Tafawa Balewa, Dass and Bogoro. The Sudan Savannah type of vegetation covers Local Government Areas of Ningi, Warji, Darazo, Ganjuwa, Kirfi, Alkaleri and Bauchi. The Sahel zone also known as Semi – desert type becomes manifest on the middle of the State as one moves from south to the north. (Bauchi State Official Diary, 2014).

Extraction from cashew nut shell liquid CNSL

The extraction of the cashew nut shell liquid was done by using the procedure of Gandhi et al., (2013a, 2013b). The extraction of cashew nut shell liquid (CNSL) from cashew nut shell Cashew nut shell liquid was applied at the rate of 50, 100 and 150mL representing three levels of treatments. Each billet sample was thoroughly polished with the cashew nut shell liquid using a brush to ensure maximum penetration of the cashew nut shell liquid into the sample billets.

(CNS) was done by using soxhlet extractor. Ethanol was used as solvent for extraction of CNSL from shells. Five hundred milliliters (500 mL) of solvents was charged into the round bottom flask of soxhlet apparatus. 50g of crushed cashew nut shell was charged into the thimble and fitted into the soxhlet extractor. The solvent in the set-up was heated 80^{0}C for 5 minutes and the vapors produced were subsequently condensed by water flowing in and out of the extraction set-up. This process of heating and cooling continued until a sufficient quantity of CNSL was obtained. At the end of the extraction, the thimble was removed while the remaining solvent in the extractor was recharged into the round bottom flask for a repeat of the process. Finally, the setup was then re-assembled and the solvent were recovered from a simple distillation method. The process was repeated five times in which 400g of the Cashew Nut Shell (CNS) was used to produce 40g of the CNSL.

Preparation of the Billets

Gmelina aborea wood of 2 x 2 inches thickness were cross – cut into billets, 18 inches in length. The initial weight of the billets was determined using an electronic balance and was recorded.

Experimental Design

The experiment was set up in a completely randomized design (CRD). This comprised four treatments including the control (T_1, T_2, T_3, and T_4) which were replicated four times to have (4 x 4) samples (16 billets) and the Cashew Nut shell liquid at a dose of 50ml, 100ml and 150ml respectively.

T_1-Treated with 50mL of cashew nut shell liquid

T_2-Treated with 100mL of cashew nut shell liquid

T_3-Treated with 150mL of cashew nut shell liquid

T_4-No treatment (control)

Treatment of samples with the cashew nut shell liquid CNSL

Installation of billets into the termite mound.

The sample billets were installed into termite's mound located within the Polytechnic premises near Forestry Department Plant Nursery. A hoe was used to dig a hole of 10-15cm depth down the ground level and the sample billets where inserted.

Data collection procedures.

In order to get detail information that will satisfy the objectives of this research, inspection and evaluation of the sample billets was made by visual assessment after every 21 days for sign of termite attack for a period of 63 days. The sample billets were removed from the mound and cleaned, and then the damage was assessed. The incidence of termite attack was recorded as follows: 1 representing attacked; and 0 representing not attacked. The severity of the damage was recorded as follows: 1 representing less than 1% of total wood volume eaten; 2 for 1 – 20% of total wood volume eaten; 3 for 21 – 40%; 4 for 41 – 60%; and 5 representing above 60% of the total wood volume eaten respectively.

Data Analysis.

The data obtained were determined by analysis of variance (ANOVA) test using IBM® SPSS® Statistics 20 to determine the statistical difference. The results with P=0.05 were considered to be the significantly different.

RESULTS AND DISCUSSION

Incidence of Termite attack on the billets

The incidence of termite attack on the billets after the experiment (63 days) at 21 days interval as represented in Table 1. The results showed that, the highest incidence of attack was on T_4 (control) compared to the lowest recorded in T_2 and $T_{3.}$ This revealed that cashew nutshell extract has significant effect on termite control.

Table 1: Incidence of termite attack on the billets of *Gmelina aborea*

Treatment/ Replicate	A			B			C			D		
	21 days	42 days	63 days	21 days	42 days	63 days	21 days	42 days	63 days	21 days	42 days	63 days
T_1	0	0	1	0	0	1	0	1	1	0	1	1
T_2	0	0	0	0	0	0	0	0	1	0	0	0
T_3	0	0	0	0	0	0	0	0	0	0	0	0
T_4	0	1	1	1	1	1	0	1	1	0	0	1

Severity of damage to the billets by termites

The severity of damage to the billets by termites is presented on Table 2, After 63 days T_4 attack of termite was more severe on T_4 compared to T_2 and T_3 with less severity. This implies that CSNL at these volumes is effective in the control of termites.

Weight loss of billets

The weight loss of billets 63 days after treatment indicated that T_4 had highest weight loss (22.03) relative to the other treatments, treatment T_3 with 28.89 against the initial weight of 30.92 shows that there was significant difference (p=0.05). This could be due to the concentration of insect repellant and anti-feedant properties CNSL contains**.**

Table 2: Severity of damage to the billets by termites

Treatment/ Replicate	A			B			C			D		
	21 days	42 days	63 days	21 days	42 days	63 days	21 days	42 days	63 days	21 days	42 days	63 days
T_1	1	1	1	1	1	2	1	1	1	1	1	2
T_2	1	1	1	1	1	1	1	1	1	1	1	1
T_3	1	1	1	1	1	1	1	1	1	1	1	1
T_4	1	2	2	1	1	2	1	2	3	1	3	3

Table 4: Weight loss of billets 63 days treatment

Treatments	Initial Weight	Final Weight
T_1	30.56	24.03
T_2	31.92	29.09
T_3	30.92	28.89
T_4	32.86	22.03

CONCLUSIONS

Several oil extracts from seeds have been claimed to have anti-feedant properties which help in curtailing the outbreak of insect pest by altering the normal feeding habit and sometimes causing death (Rao *et al.*, 1990).

The present study investigate and ascertains the resistance of *Gmelina aborea* wood species treated with cashew nut shell liquid (CNSL) to termite attack. The high termite vulnerability attack revealed by T_4 (control) in this research study indicated that *Gmelina arborea* is not durable, and as such requires preservative treatment to prolong its longevity. The findings of the study showed that termite attack on *Gmelina arborea* can be reduced with increase concentration of preservatives.

RECOMMENDATION

- Base on the potentials of this tree species (Cashew) Government and Non-Governmental Organisation should established more plantation in the Forestry Sector.
- Pesticides makers (industries) should be encourage to undertake a massive production of Cashew Nut Shell Liquid in order to reduce the use of hazardous Chemicals.
- Further studies should be carried out on the possible use of Cashew Nut Shell Liquid as an energy replacement.

REFERENCES

Adam, M.T., Barbara, L.G & Joffrey, J.M. (2002). *Heartwood and Natural durability* – A review. Wood and fibre Science 34(4):587 – 611

BSGOD (2014). Bauchi State Government Official Diary

Bowyer, J.L Shmulsky, R, Hay – Green, J.G. (2003). *Forest products and wood science*, an introduction. 4th edition. Lowa State press. USA. 552p

Gandhi, T.S, Patel, M. & Dholakiya, B. (2013b). *Synthesis and characterization of different types of epoxide-based Mannich polyols from low-cost cashew nut shell liquid*. DOI:10.1007/ s11164-013-1034-2

Henning R. K. (2008). *Jatropha curcas L.* in Africa. An Evaluation Unit for Underutilised Species (GFUUS) Weissenberg, Germany.

- Milton, F. T (1995). *The Preservation of wood.* A self-study Manual for wood Treaters. Minnesota Extension Service, BU-6413-S. University of Minnesota, College of Natural Resources. Pp 100

Peralta, R.C.G, Menzes, E. B., Carvalho, A.G Aguiar – Menezes, E.L (2004). *Wood consumption rates of forest species by subterranean termites* (isopteran) under field condition R. Arvore 28(2):283-289.

Rao, S. M., Chitra, K.C., Gunekhar, D and Kameswara R. P. (1990). *Anti-feedant properties of certain plant extracts against second stage larvae of Henosepilachna vigitioctopunatata* Fab. Indian Journal of Entomology 52(4):681-685

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EMPIRICAL ANALYSIS OF THE EFFECTS OF CLIMATE CHANGE AND SMART AGRICULTURAL PRACTICES IN GOAT PRODUCTION

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ABSTRACT

This study analyzed climate change effects and smart agricultural practices in goat production in Bassa Local Government Area of Plateau state, Nigeria. Multistage sampling technique was adopted for this study. Primary data were collected from 96 respondents using structured questionnaires and analyzed using Weighted Average Index (WAI). The results revealed that the most critical effects of climate change on flock performance were indicated through pest and disease infestation (3.44), parasite incidence (2.37), irregular appetite (2.21), increased mortality (2.17) and decreased birth rate (2.02). Also, the factors that critically affected grazing land were indicated through irregular rainfall pattern (3.37), prevailing temperature (2.98), drought (2.32), and flood occurrence (2.23). Furthermore, the prevalent practices adopted in the area include; semi-extensive systems (3.51), adoption of improved breeds (2.35), fodder trees (2.29) and use of feed/fodder supplements (2.04); however the level of adoption of agricultural practices was relatively low among the respondents. This study therefore recommends; improved farmer sensitization on coping mechanisms; access to extension services, subsidized production inputs, climate information and adoption of smart agricultural practices to mitigate the adverse effects of climate variability on livestock performance and pasture land management.

Keywords: Adoption, climate variability, flock performance, goat farmer, pasture lands, smart practices

INTRODUCTION

There is an interrelationship between climate change and livestock production (FAO, 2006). Livestock plays a critical role in the livelihoods of many rural communities; acting as a source of both credit and savings in agrarian communities that are remote from financial services, providing food and cash income for the urban as well as the rural poor and for many people, offering a route out of poverty (FAO, 2006). Also, FAO (2006) stated that major livestock systems like goat farming are credited with providing environmental services, including promoting rangeland health (and total biomass) and thereby helping to capture atmospheric carbon and mitigate climate change. Studies by Deressa *et al*. (2009) and Apata *et al*. (2009) indicated that Africa is generally acknowledged to be the continent most vulnerable to climate change. The weather is erratic and unreliable to livestock farmers. Todaro and Smith (2009) concluded that the worst impact of climate change is felt by livestock farmers. Butt *et al*. (2005) predicted future economic losses and increased risk of hunger due to climate change. It seems clear that high climatic variability associated with goat production will constitute important production constraint (Adger *et al*., 2003). Climate smart agricultural practices refer to the adjustments in ecological, social, and economic systems as well as response to climatic conditions and their effects. The capacity of goat farmers to adapt to climate change can be significantly influenced by their level of awareness about the adverse effects of climate change in their communities. There is great need for farmers to develop strategies to cope with the stress and damage climate change can impose on agricultural production (Pinto *et al*. 2012). The development and implementation of climate smart agricultural practices will go a long way to help offset the unpredictable nature of the climate for sustainable livestock production. Livestock farmers in developing countries are especially vulnerable to these impacts of climate change. It is against this backdrop that this study researched into these questions:

1. What are the perceived effects of climate change on flock performance?

2. What are the climate parameters that affect grazing land?
3. What are the smart agricultural practices adopted to mitigate these effects?

METHODOLOGY

Study Area

The study was conducted in Bassa Local Government Area (LGA) of Plateau State; with a land mass of 1,776 kilometers. Bassa LGA comprises nine districts and the major ethnic groups include Miango, Amo, Rukuba, Gashish and Buji (NPC, 2006). It has an average monthly temperature of 25.5ºC and rainfall of about 161mm. Rainfall in Bassa LGA is generally conventional with the occasional torrential storm that is accompanied by hailstones (PADP, 2014).

Sampling Procedure

A multistage random sampling technique was employed in selecting the respondents used for the study. In the first stage, three (3) districts, i.e. Miango, Amo and Rukuba were purposively selected due to the prevalence of goat farmers in the area. In the second stage, two (2) villages were randomly selected from each of the selected districts; the last stage involved the systematic random selection of respondents from the selected villages using a list of goat farmers compiled by the local enumerators. Using a constant sampling proportion of 0.08 (8%) a sample size of 102 respondents was selected from a sample frame of 1,275 goat farmers. However, only 82 questionnaires were retrieved and used for the purpose of this study.

Data Collection

Primary data was collected using well-structured questionnaires.

Method of Data Analysis

The analytical technique used for this study was the Weighted Average Index (WAI).

Weighted average index

Weighted average index (WAI) analysis is an index ranking method that was used to evaluate the effects of climate change on flock performance and grazing land in the study area. To determine the weight of each scale, each item was calculated by multiplying the frequency of each response pattern by its appropriate nominal value and dividing the sum by the number of respondents to the items. Responses for the components are rated by using a three-point scale with the scoring order. Given that; 1= low (L), 2 = moderate (M) and 3 = high (H). A weighted average index (WAI) analysis was then estimated as adapted from [10] and presented in equations 1 and 2:

$\sum f_i w_i \div N$ ………… (1)

$WI \div N$ ……………. (2)

Where:

$\sum$=Summation; F_i = frequency of 'i' occurrence; W_i = weight of each scale; WI = weighted index; and

N = number of respondents

The benefits were therefore ranked using their average weight. This was estimated in equation (3);

Average weight (WA) = $\Sigma s / r$ ……………. (3)

Where: s= scoring order; r = scale rating (3-point scale); $\sum$=Summation;

$\sum s = 1+2+3=6$

$=6 \div 3=2$; thus, weighted average index ≥ 2 will be considered to be critical.

RESULTS AND DISCUSSION

Effects of Climate Change on Flock Performance

Table 1 revealed that the perceived effects of climate change on flock performance are very critical as indicated through pest and disease infestation (3.44), parasite incidence (2.37), irregular appetite (2.21), increased mortality (2.17), and decreased birth rate (2.02). This was reflected by their weighted average index. Climate change is a major threat to the viability and sustainability of livestock production systems in many regions of the world (Gaughan *et al*., 2009). Anticipated rise in temperature due to climate change is likely to aggravate heat stress in livestock, adversely affecting their productive performance, types of disease and parasite outbreaks among animal population and even death in extreme cases (Elsa Lamy *et al*., 2012). With higher temperatures, livestock become more vulnerable to the incidence of emerging diseases and adversely affects animal feed intake and feed conversion rates (Thompson, 2010). Low temperatures resulting from particularly cold weather can cause economic losses from increased animal morbidity to mortality (Mader, 2003). This result corroborates the findings of Apata *et al*. (2009); and Royal Society (2005) who reported similar effects of climate variability on livestock performance.

Table 1: Perceived Effects of Climate Change on Flock Performance

Perceived Effects	$\sum f_i w_i$	WI	Rank
Pest and disease infestation	282	3.44	1st
Incidence of parasite	194	2.37	2nd
Irregular appetite	181	2.21	3rd
Increased mortality rate	178	2.17	4th
Decreased birthrate	166	2.02	5th
Pregnancy abortion	157	1.91	6th
Irregular growth rate	143	1.74	7th

Source: Field Survey (2019)

Climate Parameters and Grazing Land

Table 2 revealed the perceived effects of climate change on grazing land as posited by the respondents. These effects are very critical as indicated through irregular rainfall pattern (3.37), prevailing temperature (2.98), drought (2.32), and flood occurrence (2.23). This was reflected by their weighted average index. Climate factors have great influence on pasture and food resources availability cycle. Some of the greatest impacts of global warming will be visible in grazing systems in arid and semi-arid areas (Hoffman and Vogel, 2008). The predicted negative impact of climate change on agriculture would also adversely affect livestock production by aggravating the feed and fodder shortages. Increasing temperatures and decreasing rainfall reduce yields of rangelands and contribute to their degradation.

This result supports the findings of Royal Society (2005); and (Pinto *et al*. 2012) who reported similar effects of climate variability on pasture lands.

Smart Agricultural Practices

Table 3 revealed Smart Agricultural Practices adopted by the goat farmers. The prevalent practices adopted include; semi-extensive systems (3.51), adoption of improved breeds (2.35), fodder trees (2.29) and use of feed/fodder supplements (2.04). However, the level of adoption of smart agricultural practices among the goat farmers was relatively low. This was reflected by their weighted average index. High temperatures may increase production costs by the building of adapted housing and the use of cooling devices; development of energy-saving programs may also result in increased energy prices. Moreover, further research on smart agricultural practices, adoption of appropriate management techniques and veterinary services is germane for sustainability in livestock farming system, especially in hot humid climatic regions (FAO, 2009). This result supports the findings of Adger *et al*. (2003); and Deressa *et al*. (2009) who also reported similar occurrence in agricultural practices.

Table 2: Climate Parameters that Affects Grazing Land

Parameters and its Effect	$\sum F_i w_i$	Wi	Rank
Irregular pattern of rainfall affects pasture availability	276	3.37	1st
Prevailing temperature also affects grazing land	244	2.98	2nd
Drought is a common occurrence that mitigates pasture growth	190	2.32	3rd
Flood occurrence also hinders pasture growth	183	2.23	4th
Hailstones degrade rangeland	142	1.73	5th

Source: Field Survey (2019)

Table 3: Distribution Based on Agricultural Practices Adopted to Mitigate Effects of Climate Change

Smart Agricultural Practices	$\sum F_i w_i$	Wi	Rank
Semi-extensive systems	288	3.51	1st
Adoption of cold tolerant breed of goat	193	2.35	2nd
Planting fodder trees	188	2.29	3rd
Provision of supplement feed/fodder	167	2.04	4th
Pest and disease control	147	1.79	5th
Charcoal pots	133	1.62	6th
Irrigation of pasture during dry season	112	1.36	7th

Source: Field Survey (2019)

CONCLUSION AND RECOMMENDATIONS

This study analyzed climate change effects and smart agricultural practices in goat production. The results of the study revealed that climate variability critically affected flock performance and pasture lands as indicated by the results of the weighted average index. Furthermore, several smart agricultural practices were adopted by the respondents to mitigate the adverse effects of climate change on goat farming; however, the level of adoption of these practices remained relatively low among goat farmers. In view of the above findings, the following recommendations are suggested;

1. Improved farmer sensitization on the effects of climate variability.
2. Formulation of policies that will facilitate the adoption of management practices for pasture lands.
3. Improving farmer's access to extension services and climate information.
4. Increasing farmers access to improved production inputs and technology at subsidized costs.
5. Increased sensitization of livestock farmers on the benefits of smart practices as coping mechanisms.

REFERENCES

Adger, W.N., Huq, S., Brown, K., Conway, D. & Hulme, M., (2003). Adaptation to climate change in the developing world. *Progress in Development Studies* 3: p.179–195.

Apata, T.G., Samuel, K.D. & Adeola, A.O., (2009). Analysis of Climate Change Perceptions and Adaptation among Arable Food Crop Farmers in South Western Nigeria: *Paper Presented at the International Association of Agricultural Economists Conference, Beijing, China.*

Butt, T.A., McCari, B.A., Angerer, J., Dyke, P.T. & Stuth, J.W., (2005). The economic and food security implications of climate change in Mali. *Journal of Climatic change* 6(8) p.355-378.

Deressa, T.T., Hassan, R.M., Ringler, C., Alemu, T. & Yesuf, M., (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change report* 19: p.248-255.

Devkota, R.P., Cockfield, G., Maraseni, T.N. (2014). Perceived community-based flood adaptation strategies under climate change in Nepal. *International Journal of Global Warming*, 6:113-124.

Elsa Lamy, Sofia van Harten, Elvira Sales-Baptista, Maria Manuela Mendes Guerra and André Martinho de

Almeida (2012). *Factors Influencing Livestock Productivity*. Technical paper.

Food and Agricultural Organization (FAO) (2009). *The state of food and agriculture: Livestock in the balance*. Annual report.

Food and Agricultural Organization (FAO) (2006). *World Agriculture Interim Report 2030-2050*, Global Perspective Studies Unit. Rome, Italy.

Gaughan, J.G., Goopy, J., and Spark, J. (2009). *Excessive heat load index for feedlot cattle. In: Meat and livestock Australia project report*, FLOT. 316. MLA Ltd, locked bag 991, Sydney, NSW, 2059 Australia.

Mader, T.L. (2003). Environmental stress in confined beef cattle. *Journal of Animal Science*, 81 (2): 110-119.

Nigerian's Population Census (NPC) (2006). Arranged by State (Wikipedia). Retrieved 2nd July 2019.

Pinto, D.A., Demirag, U., Haruna, A., Koo, J. & Asamoah, M., (2012). Climate

Change, Agriculture and Food crop production in Ghana. Accra; *International Food Policy Research Institute (IFPRI) report.*

Plateau Agricultural Development Project (PADP) (2014). *Bulletin & Annual report*: 2014.

Rowlinson, P. (2008). Adapting livestock production systems to climate change – temperate zones. Livestock and global change. Proceedings of an international conference, Hammamet, Tunisia. Cambridge, UK, Cambridge University Press 61-63.

Royal Society (2005). Impact of Climate Change on Crops. http://royalsociety.org/news. Retrieved 2nd July, 2019.

Thompson, L.G. (2010). Climate change: the evidence and our options. *Association for Behavior Analysis International* 33(2): 153–170.

Todaro, M.P. & Smith, S.C., (2009). *Economic Development 10th Edition.* Addison-Wesley, London: Pearson Education Ltd. Publishers.

HEAVY METALS ASSOCIATED WITH SELECTED WILD MUSHROOMS COLLECTED FROM THE UNIVERSITY OF IBADAN AND OKI, IBADAN, NIGERIA: A HUMAN HEALTH RISK ASSESSMENT

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ABSTRACT

Mushrooms are undeniably rich in nutritive and therapeutic compounds; nevertheless, they are excellent bio-accumulators of hazardous substances in contaminated conditions. This study aims at investigating the potential human health risk associated with the consumption of mushrooms from two locations in Ibadan, Nigeria. The concentrations of Pb, Cd, Cr, Cu, Zn, Ni and Al in six species of wild mushrooms collected from University of Ibadan Campus and Oki in Ibadan, Nigeria were determined using Atomic Absorption Spectrometry. The mean concentration (mgkg^{-1}) of heavy metals in the mushrooms ranged from (6.33 – 8.33) for Pb, (1.08 – 1.62) for Cd, (2.93 – 4.81) for Cr, (4.26 – 17.95) for Cu, (1.68 – 5.78) for Ni, (21.63 – 134.40) for Zn, (3.72 – 8.10) for Al. Lenzites betulina recorded the highest concentration for most of the heavy metals studied (Cd, Cu, Ni, Zn, Al) while Pleurotus ostreatus recorded the least concentration for most of the heavy metals (Pb, Cu, Ni, Zn). The Estimated Daily Intakes of the heavy metals in the mushrooms were all within the PTDI limit set by JECFA and WHO. The Target Hazard Quotient values of the heavy metals were all <1, however, the hazard indices of the mushrooms were all >1, indicating health risk. The Carcinogenic Risk values of Cd, Cr, and Ni exceeded the acceptable limit of 1E-04 as set by USEPA with the highest range value (2.92 – 4.37E-03) recorded in Cadmium. Therefore, this study suggests that the consumption of mushrooms collected from metal-polluted substrates increases carcinogenic and non-carcinogenic health risk of mushroom consumers in the study locations.

Keywords: Carcinogenic risk, hazard quotient, metal pollution, mushrooms, Nigeria

INTRODUCTION

Edible mushrooms are globally recognized as potent sources of protein, vitamins, low cholesterol, fibre and minerals (Nakalembe *et al*., 2015). In addition to the nutritional value of mushrooms, they exhibit various therapeutic properties. Numerous studies have confirmed mushroom bioactivities including anti-inflammatory, antioxidant, antiviral, antibacterial, antifungal, anticancer, immuno-regulatory, anti-diabetic and cholesterol-lowering activities (Moro *et al*., 2012; Kosanic *et al*., 2016; Nowakowski *et al*., 2020; Nowakowski *et al*., 2021). About 8-10 different mushroom species are consumed by individuals in Nigeria (Igbiri *et al*., 2018).

However, despite the beneficial characteristics of mushrooms, their ability to bio-accumulate pollutants from contaminated environments is a limitation to the consumption of mushrooms (Igbiri *et al*., 2018). Mushrooms are notable for accumulating heavy metals (Kalac and Svoboda, 2000), which are injurious to human health. Mushrooms possess effective mechanisms that enable them to readily take up some metals from the ecosystem compared to green plants growing in similar environments (Svoboda *et al*., 2000). Mushrooms, through their mycelium, absorb toxic elements embedded in substrates into their fruiting bodies (Siric *et al*., 2016). The most recent and worst incidence of heavy metal (lead) poisoning in Zamfara, Nigeria was reported to claim the lives of 500 children within seven months in 2010 (Galadima and Garba, 2012).

The consumption of heavy metal-laden mushroom is one of the many ways in which these heavy metals find their way into the human body system (Singh *et al*., 2011). According to the Nigeria Cancer Statistics, at least 102,100 people are diagnosed of new cancer while at least 71,600 people die from cancer annually (Igbiri *et al*., 2018). Mushroom consumption (both wild and cultivated) among the Nigerian populace is a prominent act, hence, the need to understand the human health risk associated with the consumption of mushrooms in Nigeria. The present paper focuses on determining the carcinogenic and non-carcinogenic health impact associated with the consumption of metal-laden mushrooms from two specific locations in Ibadan, Nigeria.

MATERIALS AND METHODS

Sample Collection and Identification

Six wild mushroom species were collected between July and September, 2021 from the University of Ibadan Campus and Oki in Ibadan, Nigeria. The mushrooms were harvested from dead logs of wood as a substratum. The identification of the mushrooms was done by comparing morphological characteristics of harvested mushrooms with that of taxonomic literatures including: Mcknight and Mcknight, 1987; Hall *et al*., 2003; Schwab, 2010 and Loyd *et al*., 2017. Table 1 shows the mushroom samples and their respective sampling sites.

Digestion of Samples

The mushroom samples were air dried in the laboratory for 14 days and grinded to powder form in preparation for digestion. 0.5 grams of each sample was digested using the nitric-per chloric acid digestion method in accordance to the recommendation of AOAC (1990).

Analysis of Heavy Metals

The concentrations of Lead (Pb), Cadmium (Cd), Chromium (Cr), Copper (Cu), Nickel (Ni), Aluminum (Al) and Zinc (Zn) in the digested samples were analyzed in triplicates using a Buck Scientific Atomic Absorption Spectrometer model 210/211 VGP.

Health Risk Assessments

In this study, the USEPA model and their threshold values were used to evaluate the potential carcinogenic and non-carcinogenic health risks posed by heavy metal contamination.

Estimated Daily Intake (EDI)

The Estimated Daily Intake is an index used to assess the transfer of elements into the human body through consumables (Nowakowski *et al*., 2021). The EDI of the studied metals were calculated using the formula as follows:

$$EDI = \frac{Cmetal \times Dintake}{BWa}$$

Where; Cmetal is the concentration of each metal in a mushroom sample, Dintake is the average daily consumption of mushroom estimated at 30g/day (Nnorom *et al*., 2020), BWa is the average body weight of an adult estimated at 70kg (Igbiri *et al*., 2018).

Target Hazard Quotient (THQ)

THQ is used to assess the non-carcinogenic health risk posed by heavy metals in consumables (Nnorom *et al*., 2020). It is the ratio of the determined dose of a pollutant to a reference level considered toxic (Igbiri *et al*., 2018). THQ values higher than 1 indicates that the consumption of a particular substance could yield detrimental health effects (Nowakowski *et al*., 2021). THQ of the heavy metals were estimated using the formula:

$$THQ = \frac{\text{Estimated Daily Intake of metal}}{(RfDo)}$$

RfDo represents Oral reference dose for a specific metal: Pb = 0.004, Cd = 0.001, Cr = 0.003, Ni = 0.02, Zn = 0.3, Cu = 0.04, Al = 1, Co = 0.0003, Mn = 0.14, Fe = 0.7 (USEPA, 2021).

Hazard Index (HI)

Hazard Index is the sum of individual THQs of the studied elements in a substance (Igbiri *et al*., 2018). A HI value higher than 1 is considered a substantial risk and danger to health (Nowakowski *et al*., 2021). The HI index is calculated as follows:

$$HI = \sum_{THQs}' n$$

Where; THQ is the target hazard quotient estimated for each toxic element

Carcinogenic Risk (CR)

Carcinogenic Risk is a measure of the likelihood of developing cancer during a lifetime as a result of exposure to carcinogens (Nowakowski *et al*., 2021). A CR value below 10^{-4} is considered an acceptable risk while above that means an increased risk of carcinogenic effect (USEPA, 2011). The CR is calculated as follows:

$$CR = EDI \times Csf$$

Csf represents the oral slope factor of a specific carcinogen: Pb = 0.0085, Cd = 6.3, Cr = 0.5, Ni = 0.84 (USEPA, 2011).

Table 1: MUSHROOM SAMPLES AND SAMPLING SITES.

Mushroom samples	Sampling site	Sampling coordinates		Common name
		Latitude	**Longitude**	
Lenzites betulina	Amina way, University of Ibadan	7^0 26’54.6’’N	3^0 54’2.7’’E	Birch maze-gill, Gilled polypore
Pleurotus ostreatus	Eketa Omo Street, Oki, Ibadan	7^0 25’13.4’’N	3^0 59’57’’E	Oyster
Calocybe indica	Obong Road, University of Ibadan	7^0 27’0.8’’N	3^0 54’11.3’’E	Milky white mushroom
Pleurotus pulmonarius	Eketa Omo Street, Oki, Ibadan	7^0 25’13.4’’N	3^0 59’57’’E	Lung Oyster
Ganoderma sessile	Amina way, University of Ibadan	7^0 26’54.6’’N	3^0 54’2.7’’E	____
Ganoderma applanatum	Ijoma Road, University of Ibadan	7^0 26’58.9’’N	3^0 54’13.1’’E	Artist’s conk

RESULTS

Concentration of heavy metals

The mean concentration of the heavy metals ranged from 6.33 – 8.33 for Pb, 1.08 – 1.62 for Cd, 2.93 – 4.81 for Cr, 4.26 – 17.95 for Cu, 1.68 – 5.78 for Ni, 21.63 – 134.40 for Zn and 3.72 – 8.10 for Al (**Table 2**). *L. betulina* recorded the highest mean concentrations for most of the studied metals i.e. Cd, Cu, Ni, Zn, and Al while *P. ostreatus* recorded the lowest mean concentrations for Pb, Cu, Ni and Zn. In this study, the concentrations of zinc and cadmium were recorded to be the highest and lowest respectively in all of the mushroom samples (Table 2).

Estimated Daily Intake (EDI)

The EDI (µg/kg/day) of the heavy metals in the studied mushrooms ranged from 2.71 – 3.57 for Pb, 0.46 – 0.69 for Cd, 1.26 – 2.06 for Cr, 1.83 – 7.69 for Cu, 0.72 – 2.48 for Ni, 9.27 – 57.6 for Zn and 1.59 – 3.47 for Al (Table 3). Zn and Cd recorded the highest and lowest values respectively. The EDI of all the heavy metals in the studied mushrooms were within the Permissible Tolerable Daily Intake (PTDI) set by JECFA, 2021 (Table 3).

Target Hazard Quotient (THQ)

The THQ of the metals ranged from 0.68 – 0.89 for Pb, 0.46 – 0.69 for Cd, 0.42 – 0.69 for Cr, 0.05 – 0.19 for Cu, 0.04 – 0.12 for Ni, 0.03 – 0.19 for Zn, 0.0016 - 0.0035 for Al (Table 4). Lead and Aluminum recorded the highest and lowest values in all of the mushroom samples respectively (Table 4). *Lenzites betulina* recorded the highest THQ for all of the heavy metals with the exception of Chromium that recorded its highest value in *Pleurotus ostreatus*. *Pleurotus ostreatus* recorded the lowest THQ for Pb, Cu, Ni and Zn while *Pleurotus pulmonarius* recorded the lowest THQ for Cd and Cr (Table 4).

Table 2: Mean heavy metal concentrations in mushrooms collected from University of Ibadan and Oki, Ibadan (mgkg^{-1})

Mushroom samples	Pb	Cd	Cr	Cu	Ni	Zn	Al
Lenzites betulina	8.26±0.25 (8.0 – 8.5)	1.62±0.06 (1.56 – 1.68)	4.21±0.13 (4.06 – 4.30)	17.95±0.22 (17.7 – 18.1)	5.78±0.18 (5.60 – 5.95)	134.4±2.35	8.1±0.2 (7.90 – 8.30)

						(132.0 – 136.7)	
Pleurotus ostreatus	6.33±0.29 (6.0 – 6.5)	1.13±0.07 (1.08 – 1.21)	4.81±0.31 (4.50 – 5.11)	4.26±0.05 (4.2 – 4.30)	1.68±0.03 (1.64 – 1.70)	21.63±0.15 (21.5 – 21.8)	4.28±0.25 (4.01 – 4.50)
Calocybe indica	8.07±0.21 (7.9 – 8.3)	1.24±0.06 (1.19 – 1.31)	3.14±0.22 (2.96 – 3.38)	6.38±0.08 (6.3 – 6.45)	2.18±0.11 (2.08 – 2.30)	28.7±0.52 (28.1 – 29.0)	3.72±0.19 (3.51 – 3.89)
Pleurotus pulmonarius	8.33±0.42 (8.0 – 8.8)	1.08±0.06 (1.01 – 1.13)	2.94±0.10 (2.85 – 3.05)	6.83±0.06 (6.8 – 6.9)	2.32±0.15 (2.14 – 2.41)	38.5±0.87 (38.0 – 39.5)	5.37±0.38 (5.1 – 5.8)
Ganoderma sessile	7.83±0.83 (6.9 – 8.5)	1.31±0.03 (1.29 – 1.34)	2.93±0.05 (2.90 – 2.98)	13.37±0.25 (13.1 – 13.6)	3.28±0.11 (2.97 – 3.22)	36.3±0.44 (36.0 – 36.8)	7.27±0.21 (7.1 – 7.5)
Ganoderma applanatum	6.57±0.40 (6.1 – 6.8)	1.52±0.04 (1.48 – 1.56)	3.14±0.11 (3.02 – 3.22)	11.29±0.46 (10.9 – 11.8)	2.96±0.11 (2.84 – 3.06)	37.1±0.96 (36.0 – 37.8)	4.47±0.29 (4.3 – 4.8)

* mean of triplicate determinations±S.D; values in parentheses represent minimum – maximum

TABLE 3: Estimated daily intake of heavy metals in mushrooms (µg/kg/day)

Mushroom samples	Pb	Cd	Cr	Cu	Ni	Zn	Al
Lenzites betulina	3.54	0.69	1.80	7.69	2.48	57.60	3.47
Pleurotus ostreatus	2.71	0.48	2.06	1.83	0.72	9.27	1.83
Calocybe indica	3.46	0.53	1.35	2.73	0.93	12.30	1.59
Pleurotus pulmonarius	3.57	0.46	1.26	2.93	0.99	16.50	2.30
Ganoderma sessile	3.36	0.56	1.26	5.73	1.41	15.60	3.12
PTDI **(JECFA, 2021)**	-	0.83	3.33	500	5	300 – 1000	140

PTDI – Permissible tolerable daily intake, JECFA – Joint FAO/WHO Expert Committee on Food Additives

Table 4: TARGET HAZARD QUOTIENT AND HAZARD INDEX OF HEAVY METALS IN MUSHROOMS

	L. betulina	***P. ostreatus***	***C. indica***	***P. pulmonarius***	***G. sessile***	***G. applanatum***
Pb	0.89	0.68	0.87	0.89	0.84	0.71
Cd	0.69	0.48	0.53	0.46	0.56	0.65
Cr	0.6	0.69	0.45	0.42	0.42	0.45
Cu	0.19	0.05	0.07	0.07	0.14	0.12
Ni	0.12	0.04	0.05	0.05	0.07	0.06
Zn	0.19	0.03	0.04	0.06	0.05	0.05
Al	0.0035	0.0018	0.0016	0.0023	0.0031	0.0019
Hazard Index (∑THQ)	2.69	1.96	2.00	1.96	2.09	2.05

Hazard Index

The Hazard indices of the mushrooms ranged from 1.96 – 2.69. The highest value (2.69) was recorded in *L. betulina* while the lowest value (1.96) was recorded in both *P. ostreatus* and *P. pulmonarius* (Fig. 1). The HI of all the mushrooms exceeded the threshold of 1 (Fig. 1).

Carcinogenic Risk

The Carcinogenic Risk (CR) of the heavy metals is represented in Table 5. The CR of the heavy metals ranged from 2.30 – 3.04E-05 for Pb, 2.92 – 4.37E-03 for Cd, 6.3E-04 – 1.03E-03 for Cr, 6.05E-04 – 2.08E-03 for Ni (Table 5). *L. betulina* recorded the highest values for Cadmium and Nickel (Table 5). *P. ostreatus* and *P. pulmonarius* recorded the highest values for Chromium and Lead respectively (Table 5). On the other hand, *P. ostreatus* recorded the lowest value for Lead and Nickel while *P. pulmonarius* recorded the lowest value for Cadmium and Chromium (Table 5). The range of values recorded for Cadmium was distinctly higher than that of other studied carcinogens.

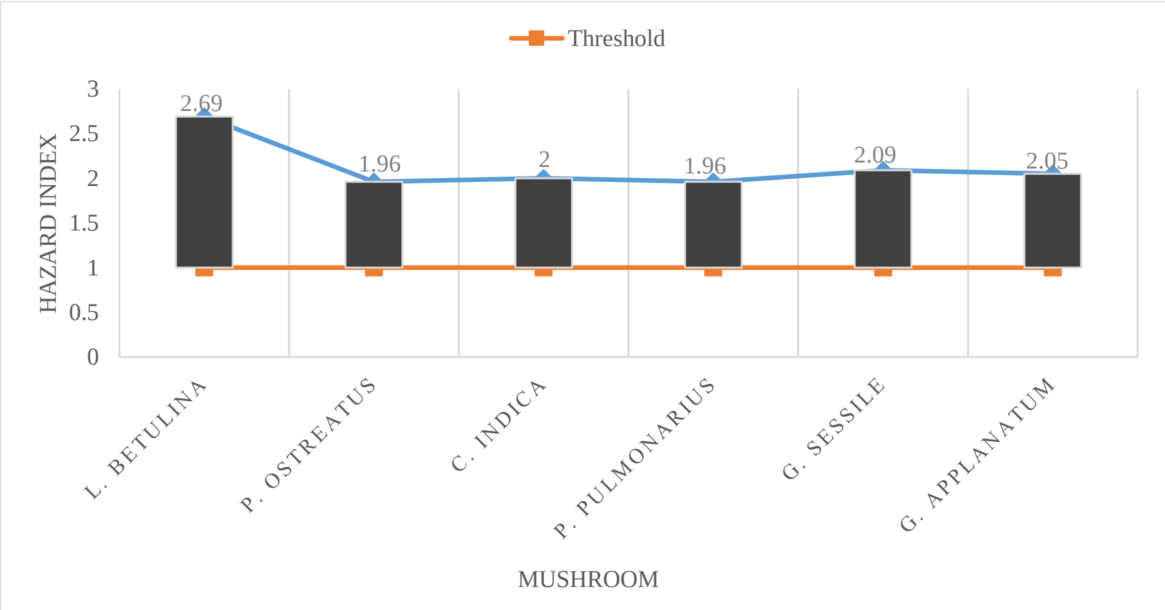

Plate 1: Hazard indices of mushroom samples in comparison with the acceptable limit

TABLE 5: Carcinogenic risk of heavy metals in mushroom samples

Mushroom Sample	Pb	Cd	Cr	Ni	Tolerable limit
L. betulina	3.01E-05	4.37E-03	9.00E-04	2.08E-03	
P. ostreatus	2.30E-05	3.05E-03	1.03E-03	6.05E-04	
C. indica	2.94E-05	3.35E-03	6.75E-04	7.85E-04	
P. pulmonarius	3.04E-05	2.92E-03	6.30E-04	8.35E-04	1E-06 - 1E-04
G. sessile	2.86E-05	3.53E-03	6.30E-04	1.18E-03	
G. applanatum	2.40E-05	4.10E-03	6.75E-04	1.07E-03	

DISCUSSION

Concentration of Heavy Metal

In the present study, the mean concentration of heavy metals in the experimentally analysed mushrooms ranked in the following order Zn > Cu > Pb > Al > Cr > Ni > Cd. The variability in metal concentrations of different mushroom species can be related to the ecosystem-determined composition of substrates and the differences in the absorption of individual metals by mushroom species. (Udochukwu *et al*., 2014, Nnorom *et al*., 2020). Zinc is a micronutrient that is readily absorbed by mushrooms, therefore, its high content in wild mushrooms can be attributed to its essentiality (Arvay *et al*., 2019). The average Zn content in mushrooms from uncontaminated conditions has been reported by literatures to range from 25 – 200 $mgkg^{-1}$ DW (Arvay *et al*., 2015: Arvay *et al*., 2019). The observation of Zinc to have the highest concentration in mushrooms is similar to the findings of Arvay *et al*., 2015; Igbiri *et al*., 2018; Arvay *et al*., 2019. Copper is also an essential trace element and has a usual content that ranges from 20 – 100 $mgkg^{-1}$ in the fruiting bodies of mushrooms from unpolluted areas (Arvay *et al*., 2015; Gebrelibanos *et al*., 2016; Arvay *et al*., 2019). In the present study, the mean concentration of Cu in the mushrooms ranged from 4.26 – 17.95 $mgkg^{-1}$, hence, there was no exceedance of 100 $mgkg^{-1}$ in any of the samples. This finding is in corroboration with that of Udochukwu *et al*., 2014; Arvay *et al*., 2019, Gebrelibanos *et al*., 2016 but contrary to the findings of Adebiyi and Adeyemi, 2020, which reported a Cu range of 487.42 - 797.34 $mgkg^{-1}$.

The lead content in wild-growing mushrooms from uncontaminated areas ranges from 1 – 10 $mgkg^{-1}$ (Arvay *et al*., 2019). In this study, Pb concentration in the mushroom samples ranged from 6.33 – 8.33 $mgkg^{-1}$. This finding corroborates with that of previous studies that reported a Pb concentration between 0.1 – 40 $mgkg^{-1}$ (Chen *et al*., 2009; Igbiri *et al*., 2018; Arvay *et al*., 2019; Adebiyi and Adeyemi, 2020; Nnorom *et al*., 2020). The fruiting bodies of mushrooms are capable of accumulating lead in considerable amounts, especially in habitats near roadways (Nowakowski *et al*., 2021) as this was the case for majority of the sampling sites in this study. Aluminium is one of the toxic elements with varying concentration in mushrooms (Arvay *et al*., 2019). The concentrations of Al in the present study is relatively low in comparison with that of Arvay *et al*., 2019 that reported an average concentration of 394 $mgkg^{-1}$. The Cr concentrations determined in this study is in agreement with those reported by Nnorom *et al*., 2020 (1.10 – 3.99 $mgkg^{-1}$) but lower than that of Adebiyi and Adeyemi, 2020 (28.67 – 94.98 mg/kg). The concentrations of Ni in this study agrees with the range of values obtained by Igbiri *et al*., 2018 (0.03 – 10.14 $mgkg^{-1}$) and Udochukwu *et al*., 2014 (2.5 – 5.75 $mgkg^{-1}$) but contradicts that of Adebiyi and Adeyemi, 2020 (24.95 -49.92 $mgkg^{-1}$).

Cadmium is known to pose the most risk to human health (Arvay *et al*., 2015) as its toxicity is linked to a wide range of health issues, including terminal diseases such as cancer, heart disease and diabetes (Igbiri *et al*., 2018). The concentrations of Cd obtained in the present study is higher than those reported by Igbiri *et al*., 2018 (0.01 – 0.55 $mgkg^{-1}$) but lower than the report of Udochukwu *et al*., 2014 (2.25 – 4.88 $mgkg^{-1}$) and Adebiyi and Adeyemi, 2020 (16.21-34.92 $mgkg^{-1}$).

Lenzites betulina recorded the highest concentrations for most of the studied metals (Cd, Cu, Ni, Zn, Al) while *Pleurotus ostreatus* recorded the least concentrations for most of the heavy metals (Pb, Cu, Ni, Zn). This observation may be attributed to the significant contribution of environmental (pH, metal concentration in substrate) and fungal (species, morphological part of fruiting body, age of mycelium) related factors (Igbiri *et al*., 2018).

Health Risk Assessment

Human health could be jeopardized by a long-term exposure to toxic elements from mushroom ingestion. In this study, indicators such as EDI, THQ, HI and CR were used to estimate the potential risk of associated with the consumption of metal-laden mushrooms in two locations of Ibadan, Nigeria.

The Estimated Daily Intakes of Pb, Cd, Cr, Cu, Zn, Ni and Al were calculated. In this study, the EDI of all the heavy metals was below the permissible tolerable daily intake (PTDI) set by JECFA, 2021. This finding is similar to those of Igbiri *et al*., 2018 and Nnorom *et al*., 2020.

Target Hazard Quotient denotes the proportion of a contaminant's estimated dose to the reference dose specific to each contaminant (Igbiri *et al*., 2018). THQ value below 1 indicates no significant risk to health while value above 1 indicates significant health risk from oral exposure (Igbiri *et al*., 2018). The Target Hazard Quotient of all the heavy metals in the mushrooms were below 1 indicating that individual metals in the studied mushrooms do not pose non-carcinogenic health risk to mushroom consumers.

The Hazard Index calculated in this study sums up all the THQ of heavy metals in a mushroom sample, hence, is used to investigate the human health risk from exposure to multiple elements in a mushroom sample (Nowakowski *et al*., 2021). The Hazard indices obtained for all mushroom samples exceeded the acceptable limit of 1 indicating a significant threat to the health of mushroom consumers in the study locations. The findings of the HI in this study agree with that of Igbiri *et al*., 2018 but is contrary to that of Nowakowski *et al*., 2021 that reported a value below 1 for majority of mushroom samples.

A cancer risk of one in a million (1×10^{-6}) means that for every million people exposed, one more cancer case is expected (Igbiri *et al*., 2018). Carcinogenic Risk higher than 10^{-4} indicates an increased risk of the carcinogenic effect of an element (Nowakowski *et al*., 2021). In the present study, the CR of Cd, Cr, and Ni exceeded the tolerable limit of 10^{-4} while the CR of Pb was within the satisfactory range of 10^{-6} - 10^{-4}. The CR values obtained in this study were generally higher than those of Nowakowski *et al*., 2021 ($8.37 \times 10^{-10} – 1.90 \times 10^{-5}$). The distinctly high values of Cd in comparison to the other three carcinogenic metals (Ni, Cr, Pb) suggests that it poses the highest carcinogenic risk to mushroom consumers in the study locations.

CONCLUSION

This study determined the heavy metal contents in selected mushrooms from the University of Ibadan Campus and Oki, Ibadan, Nigeria and analyzed them for their potential to induce carcinogenic and non-carcinogenic health risk in humans when consumed using hazard model indices, thereby, filling some knowledge gaps on the health risks associated with consuming metal-laden mushrooms. Although the THQ of all the heavy metals in the experimentally analyzed mushrooms were < 1, the HI revealed a significant health risk as values in all mushrooms were > 1. The Carcinogenic Risk of Cd, Cr and Ni exceeded the tolerable limit set by USEPA with Cadmium posing the greatest threat of cancer in this study. This study suggests that consuming mushrooms collected from metal polluted substrates increases carcinogenic and non-carcinogenic health risk of mushroom consumers in the study locations, thus, encourages the cultivation of mushrooms in heavy metal-free substrates.

REFERENCES

Adebiyi, A. O and Adeyemi, F. P. (2020). Bioaccumulation of Heavy metals in the fruiting bodies of four edible mushrooms collected from polluted areas in Akure, Ondo State, Nigeria. *EAS Journal of Nutrition and Food Sciences* 2(1): 19 – 23.

AOAC, 1990. AOAC official methods of analysis. 15th ed. Associations of Official Analytical Chemists. Arlington, Virginia. Pp. 84 – 85.

Árvay, J, Tomáš, J, Hauptvogl, M, Massányi, P, Harangozo, I, Tóth, T, Stanovič S, Bryndzová, S, Bumbalová, M. (2015). Human exposure to heavy metals and possible public health risks via consumption of wild edible mushrooms from Slovak Paradise National Park, Slovakia, *Journal of Environmental Science and Health*, Part B, 50:11, 833 – 843.

Árvay, J., Hauptvogl, M., Šnirc, M., Gažová, M., Demková, L., Bobuľská, L.; Hrstková, M., Bajčan, D., Harangoz., Bilčíková, J. (2019). Determination of elements in wild edible mushrooms: Levels and risk assessment. *Journal of Microbiology, Biotechnology and Food Sciences*. 8; 999–1004.

Galadima, A., Garba, Z. N. (2012). Heavy metals pollution in Nigeria: Causes and consequences. *Elixir Pollution* 45: 7917 – 7922.

Gebrelibanos M, Negussie M, Abi Taddesse M. (2016). Levels of essential and non-essential metals in edible mushrooms cultivated in Haramaya, Ethiopia. *International Journal of Food Contamination*; 3: 2. Pp 12.

Hall, I. R., Stephenson, S. L., Buchanan, P. K., Yun, W. and Cole, A. L. T. (2003). *Edible and poisonous mushrooms of the world*. Timber Press, Portland, USA. 349pp.

Igbiri S, Udowelle N. A, Ekhator O. C, Asomugha R. N, Igweze Z. N, Orisakwe O. E. (2018). Edible Mushrooms from Niger Delta, Nigeria with Heavy Metal Levels of Public Health Concern: A Human Health Risk Assessment. *Recent Patents on Food, Nutrition and Agriculture*. 9(1):31-41

Kalac P, Svoboda L. (2000). A review of trace elements concentrations in edible mushrooms. *Food Chemistry*; 69: 273-281

Kosanic, M., Rankovic, B., Rancic, A., Stanojkovic, T. (2016). Evaluation of metal concentration and antioxidant, antimicrobial, and anticancer potentials of two edible mushrooms Lactarius deliciosus and Macrolepiota procera.

Journal of Food and Drug Analysis 24 (3), 477–484.

Loyd, A., Smith, J. A., Ritcher, B. S., Blanchette, R. A. and Smith, M. E. (2017). The laccate *Ganoderma* of the Southeastern United States: A cosmopolitan and important Genus of wood decay fungi. *University of Florida EDIS*. 1(6): PP333. 6pp.

Mcknight, K. H. and Mcknight, V. B. (1987). *A field guide to mushrooms of North America (Peterson field guides)*. Houghton Mifflin Company, Boston, New York. 409pp.

Moro, C., Palacios, I., Lozano, M., D'Arrigo, M., Guillamon, E., Villares, A., Martínez, J. A., García-Lafuente, A. (2012). Anti-inflammatory activity of methanolic extracts from edible mushrooms in LPS activated RAW 264.7 macrophages. *Food Chemistry*. 130 (2), 350–355.

Nakalembe, I, Kabasa J. D, Olila D. (2015). Comparative nutrient composition of selected wild edible mushrooms from two agro-ecological zones, Uganda. *Springerplus*. 4: 433.

Nnorom, I. C., Eze, S. O., Ukaogo, P. O. (2020). Mineral contents of three wild-grown mushrooms collected from forests of south Eastern Nigeria: An evaluation of bioaccumulation potentials and dietary intake risks. *Scientific African* 8: 1 – 10.

Nowakowski, P., Naliwajko, S., Markiewicz-Zukowska, R., Borawska, M., Socha, K., (2020). The two faces of Coprinus comatus — Functional properties and potential hazards. *Phytotherapy Research* 1–13.

Nowakowski, P.; Markiewicz-Żukowska, R.; Soroczyńska, J.; Puścion-Jakubik, A.; Mielcarek, K.; Borawska, M. H; Socha, K. (2021). Evaluation of toxic element content and health risk assessment of edible wild mushrooms. *Journal of Food Composition and Analysis*. 96, 103698.

Schwab, A. (2010). *Mushrooming with confidence; a guide to collecting edible and tasty mushrooms*. Skyhorse Publishing, New York. 172pp.

Singh R, Gautam N, Mishra A, Gupta R. (2011). Heavy metals and living systems: An overview. *Indian Journal of Pharmacology*; 43(3): 246-53.

Siric I, Humar M, Kasap A, Kos I, Mioc B, Pohleven F. (2016). Heavy metal bioaccumulation by wild edible saprophytic and ectomycorrhizal mushrooms. *Environmental Science and Pollution Research*; 23(18): 18239-52.

Svoboda, L., Zimmermannova, K., Kalac, P. (2000) Concentrations of mercury, cadmium, lead and copper in fruiting bodies of edible mushrooms in an emission area of a copper smelter and a mercury smelter. *Science of the Total Environment*. 246:61–67.

Udochukwu, U., Nekpen, B. O., Udinyiwe, O. C., Omeje, F. I. (2014). Bioaccumulation of heavy metals and pollutants by edible mushroom from Iselu market, Benin city. *International Journal of Current Microbiology and Applied Sciences* 3(10): 52 – 57.

USEPA (2011). Integrated Risk Information System (IRIS). United States Environmental Protection Agency, Washington DC, USA.

USEPA (2021). Integrated Risk Information System (IRIS). United States Environmental Protection Agency, Washington DC, USA.

DRYING DEFECTS IN WOOD: CAUSES, CASES, CONSEQUENCES AND SOLUTIONS

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ABSTRACT

Wood is a versatile renewable natural resource which is utilized for manufacture of several end products. Drying of wood has been identified as an indispensable treatment which improves workability, finishing and utilization potentials of wood products. Consequently, adequate knowledge on indices involved in wood drying is a step towards successful wood products utilisation. However, lack of understanding on required wood drying techniques is known to increase the susceptibility of wood to drying defects. Drying defects are undesirable developments which cause severe consequences on wood, reduce the utilisation potentials of wood-based products and undermine the relevance of timber for structural and construction applications. Warps and checks are common defects which occur on timber; sometimes, they develop on logs, semi-finished lumber or finished wood products thereby causing negative effects on their utilization potentials, workability, finishing, serviceability and durability. Cases of defects in domestic and industrial wood products have generated concern ranging from losses, accidents, hiding places for unwanted pests, pressure on existing forests, just to mention a few. It is recommended that wood drying defects be reduced to the barest minimum through well planned and properly executed wood drying procedures. Drying of wood prior to its utilisation has the potentials of increasing the relevance of timber for structural and construction industrial, boosting the industrial sector and encouraging a sustainable development of renewable natural resource (wood).

Keywords: Wood products, wood utilization industries, durability, timber.

INTRODUCTION

Drying defects are unwanted or desirable developments which occur in wood during drying. Common drying defects in wood are warps, checks, collapse, wet pocket, stains and discolouration. Defects in wood are major concern in the wood conversion and wood products manufacturing industries which cannot be overemphasized (Getachew *et al.*, 2020). According to Pinchevska *et al.* (2016) defects in wood are caused by a number of factors ranging from wood species composition, timber sawing method, wood drying environment, drying methods and techniques used. A topical issue of interest to researchers in the wood products industry has been to reduce drying defects in timber and improve products' quality. This is because efficient utilization of forest products (timber) can be attained through reduction of defects and improvement of value and condition of wood products for sustainable end uses (Gemechu *et al.*, 2018).

In Nigeria, performance of domestic and industrial wood products in service has suffered greatly because of exposure to drying defects. This has tarnished the reputation of timber for structural and constructional application. The effects of drying defects on timber used in internal or external applications is more pronounced because unseasoned wood is used (Ashkin, 2013; Amoo-Onidundu *et al.*, 2017). Some of the consequences of wood drying defects which have been identified include: deformation of wood products, accident, pressure on existing forest, devaluation of wood products and wastages of wood products (Amoo-Onidundu *et al.*, 2019).

According to Wengert (2006) almost all defect types can be prevented by proper operation of the dryer. Hence, it should be ensured that appropriate equipment is used for drying and acceptable drying condition is enhanced. The key to controlling defects and ensuring quality control program is through appropriate drying techniques, practices and environmental conditions.

Types of drying

Warps: The first type of drying defects is warps. According to Cown *et al*. (1996) warp is distortion or deviation of timber from normal plane. It is categorized into cup, bow, twist and crook. Warp is a major wood defects caused by wood characteristic features.

Checks: Checks are fissuring or breaking apart of fibres in wood. Checks in wood include: end checks, surface checks and internal checks (honey combing).

Wet pockets: Wet pockets are portions in a timber in which moisture is excessively present and localized. The MC in wet pockets could be about 10% above other regions in a timber. Wet pockets is a defect which is common with fast growing plantation species (Getachew *et al.*, 2020).

Collapse: Collapse is a defect that often occurs in wood of high moisture content. It involves of shrinking of wood cells to a point of collapse (Bond and Espinoza, 2016).

Stain or discoloration: Stain or discoloration in wood is a type of defect which appears as patches on surfaces of wood. For instance, blue stain (Moya *et al.* 2013; Bond and Espinoza, 2016).

What are causes of wood drying defects?

According to Bond and Espinoza (2016) presence of juvenile wood in fast growing species has been recognised as common factor which increase the tendency of wood to warp on drying. This is due to the presence of features such as low density, high spiral grain, diagonal grain, growth stresses, high longitudinal shrinkage, high knot volume, microfibril angle and reaction wood in commonly utilised species such as *Gmelina arborea* and radiata pine. More so annual growth ring curvature has been recognised as having great impact relative to grain angle and tangential shrinkage.

Checks occur as a result of uneven drying stresses which develop during drying. Drying at the ends and surfaces of boards is more pronounced compared to drying at the core of boards. On drying, the shrinkage of the outer layers is restricted by the moist wood core. Hence, drying stresses at boards surface or ends develop leading to tearing apart of fibres which is referred to as checking. This happens when stresses across the grain exceeds the strength across the grain- fibre to fibre bonding (Keey *et al.*, 2000). More so, growth site and the location of the wood within the tree have been identified as factors influencing the percentage of honeycomb or internal checking occurring during wood drying. Wet pockets are majorly caused by anaerobic respiration at the root tip of tree during growth process. Collapse develops when removal of the free water from the lumen is too rapid. This results into collapse of the cell due to capillary forces. Enzymatic or chemical stain in wood is usually caused either by fungal or chemical reaction of components already present in wood or prevailing environment. (Moya *et al.* 2013; Bond and Espinoza, 2016).

Cases of drying defects on wood

Drying defects cause deformation of wood products. It is an anomaly which reduces value, quality and makes wood less appealing to the sense of seeing. Cases of drying defects on finished wood products are shown in Plate 1 to Plate 7.

Warp at the top end of door

Plate 1: Warping in door leave

Opening caused by drying stress

Plate 2: Warping in table-drawer compartment

Warp at the middle

Plate 3: Warping in door post

Warp at the stool top

Plate 4: Warping in stool top

Opening caused by shrinkage

Plate 5: Delamination in stool-top

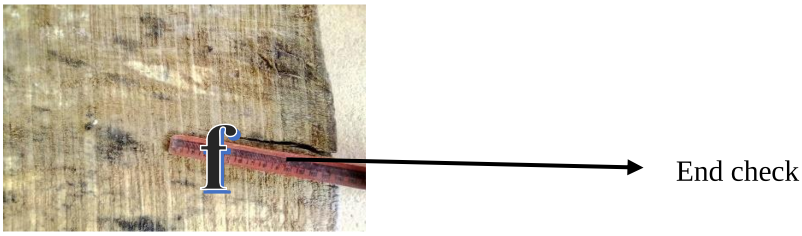

Plate 6: Checking in sawn board

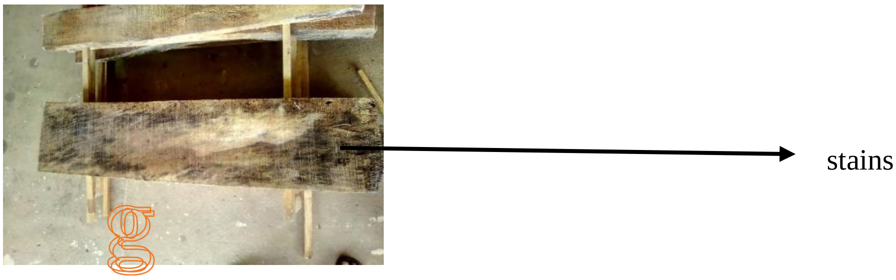

Plate 7: Staining of plank

Source: Authors survey, 2017 (a, b, c, d, e, f and g)

Consequences of wood drying defects

Drying defects deform wood products from their original form. Thereby reducing their aesthetics and making such products less appealing to the sense of sight. More so, due to the fact that wood defects cause degradation on wood, they devalue of products on which they are found. For instance, in an occasion where semi-finished lumber develops defects, the market value reduces drastically. Hence, the price of such an item falls considerably.

Checks and other seasoning defects such as warp cause considerable effect on shape of wood products. Sometimes, they render such items unfit for its original purpose. Consequently, such a products could be untimely discarded, disposed or replaced. This leads to timber resource wastage (Zahid and Majeed, 2005; Weihuan, and Clément, 2008). Replacing disposed wood product or finding an alternative may result into depletion of existing forest or unhealthy deforestation (Zahid and Majeed, 2005). According to Ohagwu and Ugwuishiwu (2011) one of the most disturbing consequences of incidence of drying defects on wood is that it may promote pressure on existing forest.

Emergence of defects on wood-based products may cause serious consequence such as major accident. Splits and checks reduce the strength of wood, particularly in shear. Checks that have closed may escape detection, but the weakness is still present because the bond between the fibers has been broken. Fasteners (such as nails, screws, bolt and nots) and, glue joint holding wood products may give way unexpectedly leading to accident (FRIM, 2011). More so, checking and warps in wood products could loosen fasteners or create crevices which habour insect and pest such cockroaches and ants (Plate 8).

Proper stacking is important for preventing warp and ensuring proper kiln loading and adequate airflow through the kiln charge. Consequently, it is vital that the kiln operator pays close attention to how well the lumber is stacked and to provide feedback to the person supervising the stacking operation. By evaluating snickering and stacking practices after drying, these are known to influence drying quality. Bond and Wiedenbeck (2006) reported that stacking practices have great influence on development of warp. It was observed that using of proper timber stacking practices reduced drying degrade and improved drying qualities of Red Oak (*Quercus rubra*) lumber.

Xiang *et al*. (2012) reported on the use of surface coating in minimizing warp during drying of southern red oak (*Quercus falcata*) and submitted it can be effective in reducing cup if it is applied to the pith side of the tangential face of the specimens. End-coating of timber with pigment has been reported to be an effective measure in reducing end-checks in timber (Pinchevska, *et al.*, 2016).

According to Yang *et al* (2014) the use of an intermittent drying process (drying followed by lower temperature and higher humidity periods) reduced total shrinkage and collapse by one third, compared to a continuous drying process for *Eucalyptus urophylla*. Using of lower temperature or more mild schedules in drying hardwood species resulted into minimal warp. Freeze-drying was reported to completely avoid collapse during drying (Blakemore and Langrish 2008). Fuller (2008) submitted that elevated temperature and liquid flow transport of solutes on the surface chemistry influenced the formation of stain in Maple (*Acer spp*.). The 'Elder process'- which involves heating wood to 120 °F and wet-bulb depression near zero, followed by cooling, was adopted to prevent enzymatic stain in Red Oak (*Quercus falcata*). The process resulted in significant stain reduction (Weihuan, and Clément 2008).

Cockroach hiding under stool- top

Plate 8: Loosened joints in stool members

CONCLUSION AND RECOMMENDATION

The phenomenon of drying defects on semi-finished lumber and wood in service is worthy of note. Having elucidated the various wood drying defects on wood and their consequences, it is imperative to consider the need for wood seasoning as a basic measure in addressing incidence of wood drying defects and reducing the associated consequences which are inimical to utilization of wood products. It is recommended, timber drying should be encouraged in Nigeria and the use of unseasoned lumber for structural and constructional applications should be discouraged.

REFERENCES

Amoo-Onidundu, O. N., Ademola, A. A., Isienyi, N. C. and Izuagbe, M. O. 2017. Solar kiln Technology: Towards solving challenges associated with conventional wood drying processes in Nigeria. Proceedings of the 39th Annual Conference of the Forestry Association of Nigeria. Held in Ibadan between 20th and 24th February, 2017. 264-272.

Amoo-Onidundu, O. N., Areghan, S. E., Olajide, B. O. and Adejoba, A. L. 2019. Combating the menace of drying defects on semi-finished lumber and wood products in-service through solar kiln drying method. Proceedings of the 11th Annual Conference on Environment and 2nd Specialized Workshop for Environmental Health Practitoner. Held at Institute of Ecology Basement Hall, Obafemi Awolowo University, Ile-Ife, Nigeria. 3rd-5th September, 2019.

Ashkin, R. 2013. Innovative building technologies- The social housing angle. Housing Africa conference, Abuja, Nigeria, 14th August, 2013. 1-6.

Blakemore P., Langrish T. A. G. 2008. Effect of pre-drying schedule ramping on collapse recovery and internal checking with Victorian Ash eucalypts. Wood Sci Technology 42(6): 473-92.

Bond H. B, Wiedenbeck J. 2006. Study of overlength on red oak lumber drying quality and rough mill yield. For Prod J. 56(10): 15-9.

Bond, H. B. and Espinoza, O. A 2016. Decade of Improved Lumber Drying Technology. Curr Forestry Rep. 2:106–118 DOI 10.1007/s40725-016-0034-z.

Cown, D. J., Haslett, A. N., Kimberley, M. O. and Mcconchie, D. I. 1996. The influence of wood quality on lumber drying distortion. Annales des sciences forestières, INRA/EDP Sciences 53(6): 1177-1188. hal-00883126.

Forest Research Institute Malaysia-FRIM. 2011. Properties of *Acacia mangium* planted in Peninsular Malaysia: ITTO Project on improving utilization and value adding of plantation timbers from sustainable sources in Malaysia. Project No. PD 306/04 (1): 1- 104.

Fuller J. 2008. Influence of drying method on enzymatic stain and contact angle of maple. Dry Technol. 26(5): 617–9.

Gemechu, K., Tsegaye, B., and Mulugeta, L. 2018. Actual and Potential Industrial Uses of Eucalyptus Wood in Addis Ababa, Ethiopia. The International Journal of Engineering and Science. 7(6): 74-79.

Getachew D., Gemechu K., Anteneh T. and Saifu A. 2020. Seasoning technologies of *Gmelina arborea* Roxb. lumber species grown at Bonga, SNNP, Ethiopia. WNOFNS. 29(3): 269-281.

Keey, R. B., Langrish, T. A. G. and Walker, J. C. F. 2000. Kiln-Drying of Lumber. Springer, Berlin. 1-326.

Moya, R., Urueña, E., Salas, C., Muñoz, F. and Espinoza, O. 2013. Kiln drying behavior of lumber from ten fast-growth plantation species in Costa Rica, Wood Material Science and Engineering. 8(1): 37- 45.

Ohagwu, C. J. and Ugwuishiwu, B. O. 2011. Status of wood processing and storage in Nigeria: Nigerian Journal of Technology. 30 (2): 94-104

Pinchevska, O., Spirochkin, A., Sedliačik, J. and Oliynyk, R. 2016. Quality assessment of lumber after low temperature drying from the view of stochastic process characteristics. Wood Research. 61(6): 871-884

Weihuan, X., Clément C. E. 2008. Prevention of drying defects and drying degrade in hardwood lumber by predrying treatment. For Prod J. 58(6): 29–35

Wengert, E. M. 2006. Principles and Practices of Drying Lumber. *Lignomat* 1-59.

Xiang, Z. Y, Peralta, P., and Peszlen, I. 2012. Lumber drying stresses and mitigation of cross-sectional deformation. Wood Fiber Sci. 44(1): 94–102.

Yang L., Liu H., Cai Y. C, Hayashi, K., Wu Z. H. 2014. Effect of drying conditions on the collapse-prone wood of *Eucalyptus urophylla*. Bioresources. 9(4): 7288-98

Zahid, D. M. and Majeed, A. 2005. Extent of dimensional changes during staggered seasoning in Pakistan-grown Eucalyptus Wood. Australian Journal of Experimental Agriculture. 45: 121-125

IN - SITU BIOREMEDIATION OF CRUDE OIL CONTAMINATED SOIL USING UREA

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ABSTRACT

Crude oil pollution is a threat to the environment specifically in the Niger Delta area of Nigeria. The remediation of oil polluted soil is one of the major focus for most environmental research. The efficacy of urea as an amendment (in-situ remediation) on crude oil polluted soil at Botem -Tai in Rivers State, Nigeria was investigated in this study. A Randomized Complete Block Design (RCBD) was used. The experimental treatments were: B1: polluted soil without Urea; B2: polluted soil with 20 g Urea addition; B3: polluted soil with 40 g Urea addition; B4: unpolluted soil in an area of 2 m^2. Physico-chemical and microbial analyses were done on soil samples from the different treatment plots. At the end of the 4-month study, it was observed that the soil properties improved significantly as against the initial (0 month) with a reduction in hydrocarbon contents of the soil. Total hydrocarbon content (THC) and Total Petroleum Hydrocarbon (TPH) reduced to 1963.67 mg/kg and 1014.37 mg/kg in B1; 193.98 mg/kg and 135.90 mg/kg in B2; 708.13 mg/kg and 615.40 mg/kg in B3 as against the initial of 2926.00 mg/kg and 1189.96 mg/kg respectively. Also, Total Heterotrophic Bacteria (THB) and Hydrocarbon Utilizing Bacteria (HUB) count increased in the urea amended polluted soil (B2 and B3). This is an indication that addition of urea to the polluted soil enhanced bacterial growth and reduction in hydrocarbon. Hence, the use of urea especially at 20g urea/2m^2 in in situ remediated crude oil polluted soil. However, large scale application has not been ascertained.

***Keywords**: Soil, Urea, Hydrocarbon, Pollution, Amendment, Microbial count.*

INTRODUCTION

Petroleum products have been known to be the main source of energy for daily life and industries. With industrialization and economic development, the demand for petroleum products has increased tremendously accompanied with some negative impacts. Accidental spills and leakages usually occur during exploration, refining, transportation and storage of petroleum and its products which later finds its way into the environment (air, soil and water) thus, causing contamination of the environment with petroleum compounds. This is of much concern worldwide (Banks *et al*., 2003; Rojo, 2009). Hydrocarbon contamination from crude oil related activities has serious health, environmental and economic problems which include pollution of ground water (thereby limiting water usage), economic loss, environmental degradation, and decrease in agricultural productivity of the soil (Wang *et al*., 2008).

Though, remediation of crude oil contaminated sites can occur naturally (natural attenuation) but takes a long time. Physical, chemical and thermal processes are general methods for the clean-up of contaminated sites of petroleum compounds (Chorom *et al*., 2010). These methods however, have some negative effects on the environment and are also costly (Milic *et al*., 2009; Chorom *et al*., 2010). Currently, oil removal from contaminated soil by new methods such as bioremediation is necessary. In this method (bioremediation), the recovery of impacted soil is accelerated through addition of microbes or nutrients. Bioremediation of contaminated soil is simpler, less labour intensive and has less disruption to soil structure with higher public acceptance as compared to other methods (Bijay *et al*., 2012; Mosaed *et al*., 2013). Despite its acceptability, bioremediation can be limited by several factors which include; nutrients, oxygen, pH, temperature, moisture, soil characteristics, microorganisms and pollutants concentration.

One of the major challenges of crude oil contamination is nutrient deficiency in the contaminated soil. So nutrient addition is important in the achievement of the nitrogen/carbon balance and successful biodegradation of hydrocarbon. Several researchers have reported that the application of fertilizer on crude oil contaminated soil results in increase in the rate of biodegradation of the pollutant. Urea has been considered as a preferred nitrogen source in enhancing biodegradation of hydrocarbon and this is because of its high nitrogen content and commercial availability. For instance, Chorom *et al*. (2010) reported that application of fertilizers at the rate of 2 tons per acre on oil contaminated soils increased rate of biodegradation after 5 weeks, which indicates that the biodegradation process was facilitated.

This study was therefore, aimed at evaluating the effectiveness of application of different amounts of urea in *in situ* bioremediation of a crude oil contaminated soil. It is expected that results obtained from this study will provide other effective ways of remediating crude oil polluted soil of the Niger Delta area of Nigeria.

MATERIALS AND METHODS

The experiment was conducted at a crude oil polluted site (GPS: N 4°43' 29.56082'') which resulted from an oil spill, and a non-polluted site (E 7°16' 8.382'') with no evidence of crude oil pollution at Botem – Tai in Tai Local Government Area of Rivers State, Nigeria. The oil spill resulted from leakage in corroded oil pipe belonging to Shell Petroleum Development Company (SPDC).

The two different sites (polluted and a non-polluted) were mapped out for the study. The polluted site of area of 14 m x 10 m was subdivided into nine (9) sub-plots of 2 m x 2 m each with an interval of 2 m between them. Then 20 g and 40 g of urea obtained from Agricultural Development Program (ADP) Rumuodomaya, Port Harcourt, Rivers State were dissolved in water and added to the respective subplots. The non-polluted site was located at a distance of 30 m away from the polluted site. This was also subdivided into three (3) replicated plots (Fig.1). The layout followed a Randomized Complete Block Design (RCBD) consisting of four (4) treatments in four blocks; and each treatment replicated three times. The experiment lasted for 4 months. The four (4) treatments were as follows:

B1: polluted soil without Urea

B2: polluted soil with 20 g Urea addition

B3: polluted soil with 40 g Urea addition

B4: non-polluted soil

Soil samples were collected at every 2 months interval (for precise and consistent results, that is, to assess the effect of urea on the rate of hydrocarbon reduction in soil within this period which is enough for the amendment to have incorporated into the soil properly for best performance) from the two sites with a soil auger (at the depth of 0 - 15 cm) for analysis of soil physico -chemical properties (pH, conductivity, Total organic carbon, Total petroleum hydrocarbon and total hydrocarbon content) and microbial population (total heterotrophic bacteria, total fungi, hydrocarbon utilizing bacteria and hydrocarbon utilizing fungi) to ascertain the level of oil biodegradation. A baseline analysis was done before addition of amendment (urea).

Soil pH and conductivity were determined using a pH meter (PHS. 25 Model) and conductivity meter (Labtech Model) respectively. Walkley -Black method cited by Tanee and Jude (2020) was used to determine Total Organic Carbon (TOC) in soil. Microbial population (Total heterotrophic bacteria, total fungi, hydrocarbon utilizing bacteria and hydrocarbon utilizing fungi) of soil was determined using the method of Baath and Anderson (2003). API-RP45 Colorimetric method used by Aigberua *et al.* (2016) was used to determine the Total Hydrocarbon Content (THC) of soil. TNRCC Tx Method 1005 cited by Jude *et al.* (2019) was used to determine the total petroleum hydrocarbon (TPH) in the soil.

Statistical evaluation was done using Means and standard error means. The data generated were further analysed using one -way Analysis of Variance (ANOVA). Least significant difference (LSD) was used to separate means. The results were presented as mean ± standard error (SE) using bar graphs and tables.

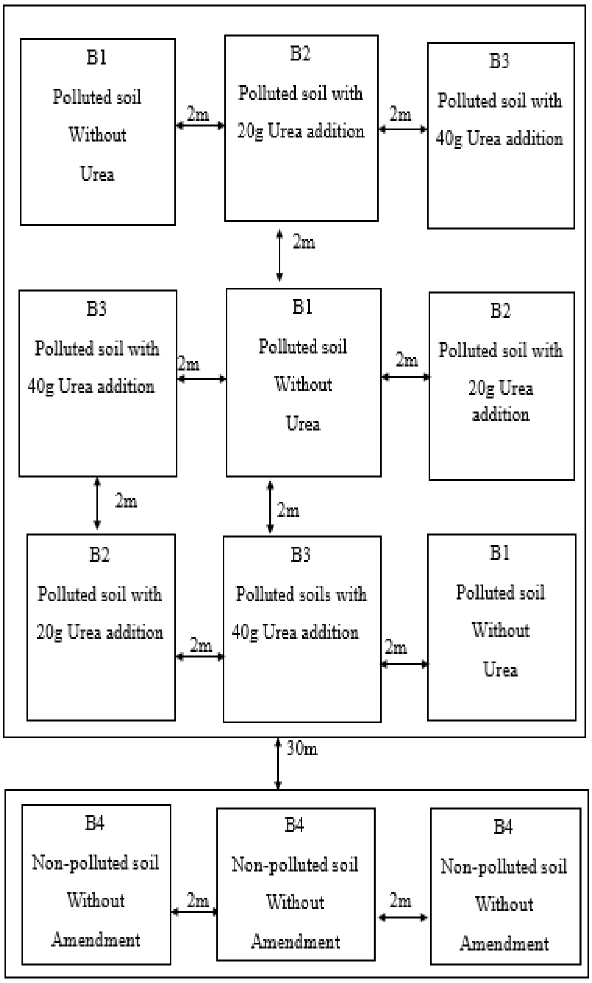
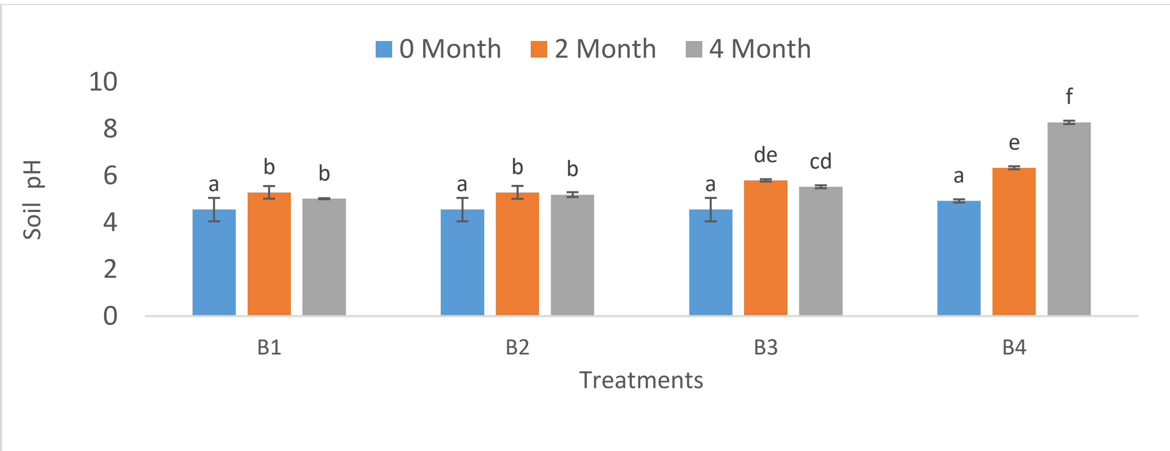


Figure 1: Experimental Layout

RESULTS

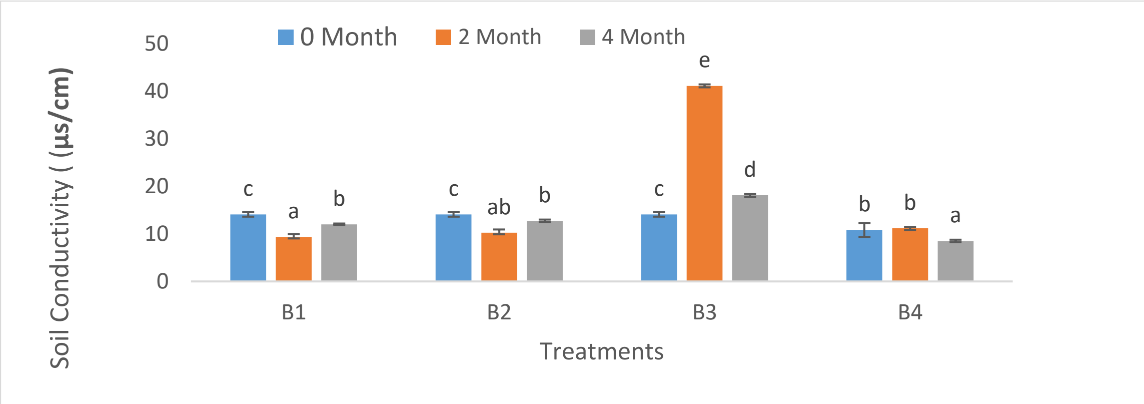
Result for soil pH is presented in Fig.2. The result showed significant increase in soil pH in all the polluted soil after amendment with urea; with the highest increase in soil pH in B3 (polluted soil with 40 g urea addition). The reverse was the case in soil conductivity in which amending the soil with urea caused decrease in the soil conductivity except in B3 where there was a significant increase at 2 months after amendment (Fig.3). Similar result of conductivity was obtained for the Total Organic Carbon (TOC) where amendment (urea) reduced the TOC of the soil except in B3 (Fig.4).

The result presented in Figs. 5 and 6 showed that soil Total Petroleum Hydrocarbon (TPH) and Total Hydrocarbon Content (THC) of the polluted soil were significantly (P = 0.05) reduced in the amended polluted soil with treatment B2 (polluted soil with 20 g urea addition) having the highest reduction while least reduction in soil TPH and THC was observed in polluted soil without urea (B1) at both 2 and 4 months.



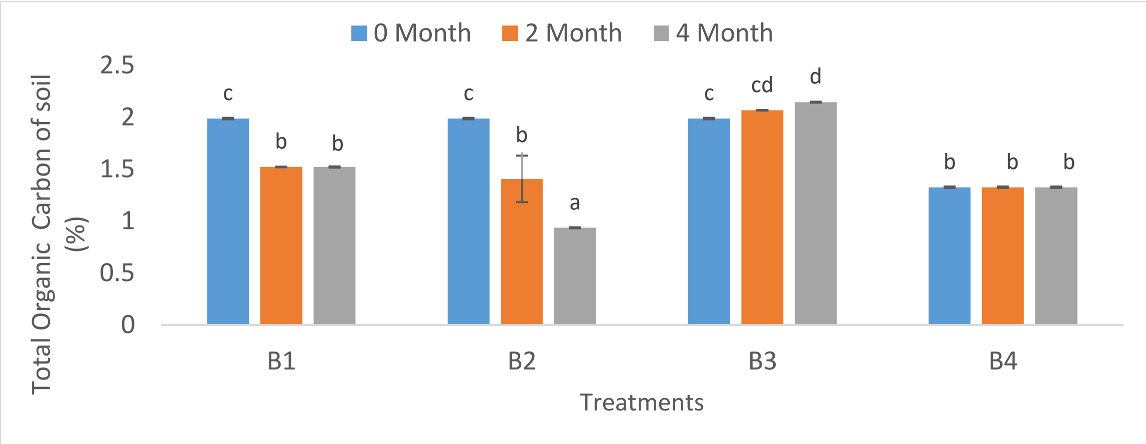
i. B1: polluted soil without Urea, B2: polluted soil with 20 g Urea addition, B3: polluted soil with 40 g Urea addition, B4: unpolluted soil.
ii. Bar with different alphabet shows significant within treatments.

Fig 2: Soil pH in the soils amended with urea in Botem, Rivers state, Nigeria



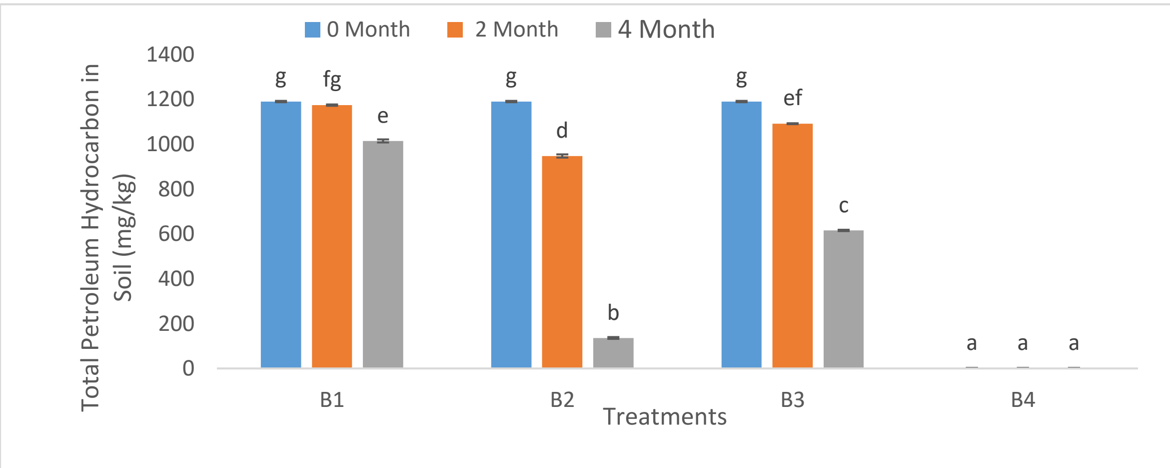
i. B1: polluted soil without Urea, B2: polluted soil with 20 g Urea addition, B3: polluted soil with 40 g Urea addition, B4: unpolluted soil.
ii. Bar with different alphabet shows significant within treatments.

Fig. 3: Soil Conductivity in the soils amended with urea in Botem, Rivers state, Nigeria



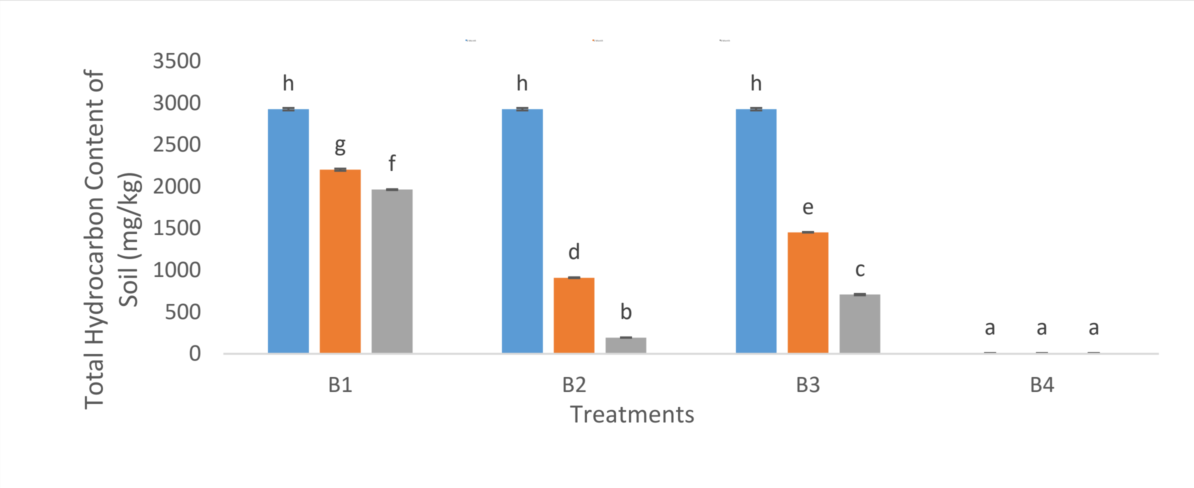
i. B1: polluted soil without Urea, B2: polluted soil with 20 g Urea addition, B3: polluted soil with 40 g Urea addition, B4: unpolluted soil.
ii. Bar with different alphabet shows significant within treatments.

Fig. 4: Total Organic Carbon in the soils amended with urea in Botem, Rivers state, Nigeria



B1: polluted soil without Urea, B2: polluted soil with 20 g Urea addition, B3: polluted soil with 40 g Urea addition, B4: unpolluted soil. Bar with different alphabet shows significant within treatments.

Fig. 5: Total Petroleum Hydrocarbon in the soils amended with urea in Botem, Rivers state, Nigeria



1. B1: polluted soil without Urea, B2: polluted soil with 20 g Urea addition, B3: polluted soil with 40 g Urea addition, B4: unpolluted soil.
2. Bar with different alphabet shows significant within treatments.

Fig. 6: Total Hydrocarbon Content in the soils amended with urea in Botem, Rivers state, Nigeria

The results for microbial count in the different treatments is shown in Table 1. Total heterotrophic bacteria (THB) increase in polluted soil amended with urea (B2, B3) as compared to polluted soil without urea addition (B1) at 2 months. Between polluted soil with urea addition, 40 g urea (B3) had the highest THB population. Polluted soil without urea (B1) had higher fungal population than polluted soil with amendment. At 4 months, increase in TF (total fungi) was observed in polluted soil with 20 g urea addition (B2) while decrease was observed in treatments (B1, B3 and B4). Highest Hydrocarbon Utilizing Bacteria (HUB) count was obtained in polluted soil with 40 g urea addition (B3). At 4 months, decrease in HUB count was observed in polluted soil with urea addition (B2, B3) as compared to polluted soil without urea (B1). Highest HUF population was recorded in polluted soil with 40 g urea addition at 2 months.

Table 1: Microbial Population in the soils amended with urea in Botem, Rivers state, Nigeria

Trt	**THB (cfu/g)**			**HUB (cfu/g)**			**TF (cfu/g)**			**HUF (cfu/g)**		
	0 month	**2 months**	**4 months**	**0 month**	**2 months**	**4 months**	**0 month**	**2 months**	**4 months**	**0 month**	**2 months**	**4 months**
B1	$8.4x10^5$	$8.0x10^4$	$3.8x10^6$	$4.0x10^4$	$4.4x10^5$	$8.5x10^5$	$3.7x10^4$	$4.5x10^6$	$4.0x10^5$	$3.2x10^4$	$7.5x10^5$	$6.3x10^4$
B2	$8.4x10^5$	$3.3x10^6$	$2.5x10^7$	$4.0x10^4$	$1.2x10^6$	$5.5x10^5$	$3.7x10^4$	$1.0x10^4$	$1.1x10^5$	$3.2x10^4$	$1.5x10^5$	$6.4x10^4$
B3	$8.4x10^5$	$6.0x10^6$	$1.2x10^6$	$4.0x10^4$	$1.1x10^6$	$5.4x10^5$	$3.7x10^4$	$6.5x10^4$	$1.6x10^4$	$3.2x10^4$	$5.0x10^6$	$1.4x10^5$
B4	$1.3x10^6$	$1.3x10^6$	$2.6x10^6$	$5.3x10^4$	$5.3x10^4$	$8.5x10^5$	$4.3x10^4$	$4.3x10^4$	$2.7x10^4$	$4.2x10^4$	$4.2x10^4$	$2.3x10^4$

i. B1: polluted soil without Urea, B2: polluted soil with 20 g Urea addition, B3: polluted soil with 40 g Urea addition, B4: unpolluted soil.
ii. THB: Total Heterotrophic Bacteria, HUB: Hydrocarbon Utilizing Bacteria, TF: Total Fungi, HUF: Hydrocarbon Utilizing Fungi

DISCUSSION

Hydrocarbon pollution in soil rendered the affected soil unproductive. Thus, there is need for remediation and subsequent restoration of such land. Though the degradation of this pollutant can occur naturally, but it is slow and takes longer period to recover affected land.

Thus bioremediation using remediating materials which can speed up pollutant degradation process is necessary. Addition of urea which served as a source of nutrient, helped to stimulate naturally occurring or indigenous microorganisms in soil. Samples showed apparent higher rate of hydrocarbon reductions (Buraimoh *et al.* 2017).

In this study the addition of urea to crude oil polluted soil facilitated the degradation of hydrocarbon as higher reductions of total petroleum hydrocarbon and total hydrocarbon content were obtained in polluted soil in which urea was added. This showed that addition of urea enhanced the solubility and removal of the contaminant and improved oil biodegradation rate. Chorom *et al*. (2010) had a similar observation and concluded that fertilizer application increased the degradation of hydrocarbons as compared with the control.

Increase in Soil pH (decrease in acidity) in the amended soil provided a favourable pH for oil-degrading microorganisms to act. This is because most microbial activities occur at a pH closed to neutrality. Increase in Total organic carbon, observed in polluted soil with urea could be attributed to the urea (remediating agent) decomposition (Chinenye *et al*., 2014). This justified urea as an amendment in improving soil properties. Higher TPH and THC reduction were observed. The increase in total organic carbon in the polluted soil with urea addition, supplement the limiting nutrients, thus, providing favourable condition for microbial growth and actions (Tanee and Kinako, 2008). This also confirmed the work of Jude and Tanee (2016) who reported that total organic matter and carbon increase in polluted amended soil.

The application of urea resulted in increase in growth of oil- degrading bacteria that finally led to the degradation of petroleum hydrocarbons. This is an indication that adding a nitrogen source (such as urea) is capable of boosting pollutant biodegradation (Hesnawi and Adbeib, 2013). Similarly, Mosaed *et al*. (2013) reported increase in growth of oil degrading bacteria that subsequently led to the degradation of petroleum hydrocarbons in polluted soil treated with NPK fertilizer.

CONCLUSION

Crude oil reduces soil fertility and productivity in polluted areas. Polluted soils could be remediated. The use of urea as a remediating agent in biodegradation of crude oil polluted sites has been found to be effective as the urea added to the polluted soil enhanced significant biodegradation of petroleum hydrocarbons. This is an indication that remediation by enhanced natural attenuation using urea is efficient and promises to be one of the remedial options in the remediation of crude oil polluted soils.

REFERENCES

Aigberua, A. O., Ekubo, E. T., Azibaola, I. K. and Izah, C. S. (2016). Evaluation of Total Hydrocarbon Content and Polycylic Aromatic Hyrocarbon in an Oil Spill Contaminated Soil in Rumuolukwu Community in Niger Delta. *Journal of Environmental Treatment Techniques,* 4 (4): 130 – 142.

Baath, E. and Anderson, T. H. (2003). Comparison of soil fungal/bacteria ratios in a pH gradient using physiological and PLFA-based techniques. *Soil Biology and Biochemistry* 35: 955-963.

Banks, M. K., Hadessa, M. and Karrie, R. (2003). Rhizosphere Microbial Characterization in Petroleum-Contaminated Soil. Soil and Sediment Contamination 12(3): 371-385.

Bijay, T., Ajay Kumar, K.C. and Anish, G. (2012). A Review on Bioremediation of Petroleum Hydrocarbon Contaminants in Soil. *Kathmandu University Journal of Science, Engineering and Technology*, 8, (I): 164-170

Buraimoh, O.M., Ogunyemi, A.K., Ibrahim, N.H., Adebusoye, A.S., Ilori, M.O and Amund, O.O. (2017). Efficacy of intervention strategies for bioremediation of crude oil in polluted soil microcosm. *Ife Journal of Science* 19 (2): 303 -313.

Chinenye, C., Chijioke-Osuji, Peace N., Ibegbulam-Njoku and Ebenezer J. D. B. (2014). Biodegradation of Crude Oil Polluted Soil by Co-Composting with Agricultural Wastes and Inorganic Fertilizer. *Journal of Natural Sciences Research*, 4(6): 28-39.

Chorom, M., Sharifi, H. S. and Motamedi, H. (2010). Bioremediation of a crude oil-polluted soil by application of fertilizers, *Iran Journal of*

Environmental Health Science and Engineering, 7 (4): 319-326.

Hesnawi, R. M, and Adbeib, M.M. (2013). Effect of nutrient source on indigenous biodegradation of diesel fuel contaminated soil. *APCBEE Proceedings* 5:557–561.

Jude, K., Tanee, F. B. G. and Mensah, S. I. (2019). Enhancing phytoremediation potential of *Andropogon tectorum* (Schumach & Thonn) in petroleum hydrocarbon contaminated soil using cassava peel. *Scientia Africana*, 18 (2):23-36.

Jude, K. and Tanee, F.B.G. (2016). Remediation Trials of Crude Oil Contaminated Soil Using Different Sawdust and Detergent Combination Levels, *Scientia Africana* 15(2): 112-124.

Milic J. S., Beskoski, V. P., Ilic M.V., Ali S. M., GojgicCvijovic G. D. and Vrvic M. M., (2009). Bioremediation of soil heavily contaminated with crude oil and its products: composition of the microbial consortium, *Journal Serbian Chemical Society*, 74 (4): 455–460.

Mosaed H. P., Ardakani, S. S. and Cheraghi, M. (2013) Assessment Bioremediation of Contaminated Soils to Petroleum Compounds and Role of Chemical Fertilizers in the Decomposition Process, *Journal of Chemical Health Risks* 3(1): 4 7 -54.

Rojo, F. (2009). Degradation of Alkanes by bacteria. *Environmental Microbiology*, 11 (10):2477-2490.

Tanee, F. B. G. and Jude, K. (2020). Stimulating the rate of Phytoremediation of *Chromolaena odorata* in Crude Oil Contaminated Soil Using Inorganic Urea, *International Journal of Plant and Soil Science* 32(16): 13-25.

Tanee, F.B.G. and Kinako, P. D.S. (2008). Comparative study of Biostimulation and phytoremediation in the mitigation of crude oil toxicity in tropical soil. *Journal of Applied Science and Environmental Management*, 12(2): 143-147

Wang, J., Zhang, Z. Z., Su, Y.M., He, W., He, F. and Song, H.G. (2008). Phytoremediation of petroleum polluted soil, *Petroleum Science*, 5 (2):167.

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ENVIRONMENTAL DRIVERS OF DESERTIFICATION IN THE WORLD

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ABSTRACT

The environment has been greatly affected by desertification which means land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities. Desertification is a threat to environmental and biodiversity conservation. This paper reviewed the information on the drivers of desertification in the environment, anthropogenic drivers of desertification such as crop land expansion, unsustainable land management practices including overgrazing by livestock, labour mobility as well as institutional, policy and socio-economic drivers of desertification. The thrust of the review further lend credence to the necessity of prevention of desertification which will bring economic and environmental benefits to people in the present and future.

***Key words**: Desertification, Environment, Drivers of desertification, Degradation, Biodiversity, Conservation*

INTRODUCTION

Tropical forests are among the most biodiverse ecosystems on Earth, providing essential ecosystem services to the benefit of society (Wright, 2005, Gardner *et al.*, 2009). Forests in Nigeria are greatly exploited for various resources that satisfy the needs of the people. Some of the needs include timber, food, fodder, firewood, medicine, chemicals, agricultural implements, household utensils and cultural items (Oboho *et al.*, 2015). Oboho *et al.* (2015) stated that all world leaders agree about the fact that the continuous existence of many societies and their livelihoods rest on the sustainability of the biodiversity of their forests as this ensures the availability of more goods and services. However, deforestation is threatening the survival and health of natural forests with man being at risk of losing his resources and benefits too (Oboho *et al.*, 2015). Lapido (2010) puts the deforestation rate in Nigeria at about 3.5%, translating to a loss of 350,000 to 400,000 hectares of forest land per year. The commonest reasons for deforestation include removal of forest to make way for urbanization, infrastructural development, agriculture (especially plantation agriculture) logging and in recent times fires and wars (Oboho, 2014).

Today by human developments and influences of industries and deforestation caused climate change and global warming. Quantity and quality development of forests and forestation is the most important operation against these problems (Taleshi *et al.*, 2009). C I E S (2020) stated that tropical forests are allies in the fight against climate change. Growing trees absorb carbon emissions and store them as woody biomass (C I E S, 2020), help to overcome the challenge of deforestation which eventually leads to desertification. Desertification has been described as the “the greatest environmental challenge of our time” and it greatly influences climate change.

Desertification

The UNCCD set out a definition of desertification in a treaty adopted by parties in 1994. It states that desertification means “land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities” (McSweeney, 2019). McSweeney (2019) stated that rather than desertification meaning the literal expansion of deserts, it is a catch-all term for land degradation in water-scarce parts of the world. This degradation includes the temporary or permanent decline in quality of soil, vegetation, water resources or wildlife. It also includes the deterioration of the economic productivity of the land – such as the ability to farm the land for commercial or subsistence purposes (McSweeney, 2019). Arid, semi-arid and dry sub-humid areas are known collectively as “drylands”. These are, unsurprisingly, areas that receive relatively little rain or snow each year. Technically, they are defined by the UNCCD as "areas other than polar and sub-polar regions, in which the ratio of annual precipitation to potential evapotranspiration falls within the range from 0.05 to 0.65" (McSweeney, 2019).

In simple terms, this means the amount of rainfall the area receives is between 5-65% of how much it loses through evaporation and transpiration from the land surface and vegetation, respectively. Any area that receives more than this is referred to as "humid". McSweeney (2019) stated that drylands encompass around 38% of the Earth's land area, covering much of North and southern Africa, western North America, Australia, the Middle East and Central Asia. Drylands are home to approximately 2.7 billion people, 90% of whom live in developing countries (McSweeney, 2019). Drylands are particularly susceptible to land degradation because of scarce and variable rainfall as well as poor soil fertility. There are numerous ways in which the land can degrade. One of the main processes is erosion, the gradual breaking down and removal of rock and soil. This is typically through some force of nature such as wind, rain and/or waves, but can be exacerbated by activities including ploughing, grazing or deforestation.

McSweeney (2019) reported that a loss of soil fertility is another form of degradation. This can be through a loss of nutrients, such as nitrogen, phosphorus and potassium, or a decline in the amount of organic matter in the soil. For example, soil erosion by water causes global losses of as much as 42m tonnes of nitrogen and 26m tonnes of phosphorus every year. On farmed land, this inevitably needs to be replaced through fertilisers at significant cost. Soils can also suffer from salinization, an increase in salt content and acidification from overuse of fertilisers. Then there are lots of other processes that are classed as degradation, including a loss or shift in vegetation type and cover, the compaction and hardening of the soil, an increase in wildfires, and a declining water table through excessive extraction of groundwater (McSweeney, 2019).

The nature of desertification

Land degradation is a negative trend in land condition, caused by direct or indirect human-induced processes including anthropogenic climate change, expressed as long-term reduction or loss of at least one of the following: biological productivity, ecological integrity or value to humans. Arid, semi-arid, and dry sub-humid areas, together with hyper-arid areas, constitute drylands (UNEP, 1992), home to about 3 billion people. The difference between desertification and land degradation is not process-based but geographic. Although land degradation can occur anywhere across the world, when it occurs in drylands, it is considered desertification. Desertification is not limited to irreversible forms of land degradation, nor is it equated to desert expansion, but represents all forms and levels of land degradation occurring in drylands. Moreover, droughts are not restricted to drylands, but occur both in drylands and humid areas (Wilhite *et al.*, 2014). Drought is defined here as "a period of abnormally dry weather long enough to cause a serious hydrological imbalance".

Dryland populations are highly vulnerable to desertification and climate change because their livelihoods are predominantly dependent on agriculture, one of the sectors most susceptible to climate change (Schlenker and Lobell, 2010; Rosenzweig *et al.,* 2014). Pastoral production systems represent an adaptation to high seasonal climate variability and low biomass productivity in dryland ecosystems (Krätli and Schareika, 2010; Varghese and Singh 2016), which require large areas for livestock grazing through migratory pastoralism (Snorek *et al.*, 2014). Grazing lands across dryland environments are being degraded, and/or being converted to crop production, limiting the opportunities for migratory livestock systems, and leading to conflicts with sedentary crop producers (Abbass, 2014; Dimelu *et al.*, 2016). These processes, coupled with ethnic differences, perceived security threats, and misunderstanding of pastoral rationality, have led to increasing marginalization of pastoral communities and disruption of their economic and cultural structures (Morton, 2010; Elhadary, 2014). As a result, pastoral communities are not well prepared to deal with increasing weather/climate variability and weather/climate extremes due to changing climate (Dong, 2016; López-i-Gelats *et al.*, 2016), and remain amongst the most food insecure groups in the world (FAO, 2018).

Fernandez-Gimenez (2000) reported that the Pastoralists in Mongolia developed indigenous classifications of pasture resources which facilitated ecologically optimal grazing practices. Currently, however, indigenous and local knowledge and practices are increasingly lost or can no longer cope with growing demands for land-based resources (Dominguez, 2014; Kodirekkala, 2017). Unsustainable land management is increasing the risks from droughts, floods and dust storms. Policy actions promoting the adoption of sustainable land management (SLM) practices in dryland areas, based on both indigenous and local knowledge and modern science, and expanding alternative livelihood opportunities outside agriculture can contribute to climate change adaptation and mitigation, addressing desertification, with co-benefits for poverty eradication and food security (*high confidence*) (Stafford-Smith *et al.*, 2017; Cowie *et al.*, 2018).

Processes and drivers of desertification under climate change

Processes of desertification are mechanisms by which drylands are degraded. Desertification consists of both biological and non-biological processes. These processes are classified under broad categories of degradation of physical, chemical and biological properties of terrestrial ecosystems. The number of desertification processes is large and they are extensively covered elsewhere (UNCCD, 2017; IPBES, 2018). Drivers of desertification are factors which trigger desertification processes. Initial studies of desertification during the early-to-mid 20th century attributed it entirely to human activities. "Desertification is purely artificial. It is only the act of the man," (Geist *et al.*, 2004; Reynolds *et al.*, 2007). However, such a uni-causal view of desertification was shown to be invalid (Geist *et al.*, 2004; Reynolds *et al.*, 2007).

Ginoux *et al.* (2012) summarized the drivers, linking them to the specific processes of desertification and land degradation under changing climate. Erosion refers to removal of soil by the physical forces of water, wind, or often caused by farming activities such as tillage. The global estimates of soil erosion differ significantly, depending on scale, study period and method used (García-Ruiz *et al.*, 2015), ranging from approximately 20 Gt yr^{-1} to more than 200 Gt yr^{-1} (Boix-Fayos *et al.*, 2006; FAO, 2015).

i. Invasive plants contributed to desertification and loss of ecosystem services in many dryland areas in the last century (*high confidence*). Extensive woody plant encroachment altered runoff and soil erosion across much of the drylands, because the bare soil between shrubs is very susceptible to water erosion, mainly in high-intensity rainfall events (Pierson *et al.*, 2013; Eldridge *et al.*, 2015). Rising CO_2 levels due to global warming favour more rapid expansion of some invasive plant species in some regions. An example is the Great Basin region in western North America where over 20% of ecosystems have been significantly altered by invasive plants, especially exotic annual grasses and invasive conifers, resulting in loss of biodiversity. This land-cover conversion has resulted in reductions in forage availability, wildlife habitat, and biodiversity (Pierson *et al.*, 2011, 2013; Miller *et al.*, 2013).

ii. The wildfire is a driver of desertification, because it reduces vegetation cover, increases runoff and soil erosion, reduces soil fertility and affects the soil microbial community (Weber *et al.*, 2014; Liu and Wimberly, 2016). Predicted increases in temperature and the severity of drought events across some dryland areas; can increase chances of wildfire occurrence (*medium confidence*) (Jolly *et al.*, 2015; Clarke and Evans, 2018). In semi-arid and dry sub-humid areas, fire can have a profound influence on observed vegetation and particularly the relative abundance of grasses to woody plants (Bond and Keeley, 2005; Balch *et al.*, 2013). While large uncertainty exists concerning trends in droughts globally (AR5), examining the drought data by Ziese *et al.* (2014).

Anthropogenic drivers of desertification under climate change

IPBES (2018) identified cropland expansion, unsustainable land management practices including overgrazing by livestock, urban expansion, infrastructure development, and extractive industries as the main drivers of land degradation. IPBES (2018) also found that the ultimate driver of land degradation is high and growing consumption of land-based resources, e.g., through deforestation and cropland expansion, escalated by population growth.

i. Food production is also a major driver of desertification. Growing demand for food can see cropland expand into forests and grasslands, and use of intensive farming methods to maximise yields. Overgrazing of livestock can strip rangelands of vegetation and nutrients. Fleming (2019) reported that the growing food demand is driving conversion of forests, rangelands, and woodlands into cropland (D'Odorico *et al.*, 2013; Bestelmeyer *et al.*, 2015). Climate change is projected to reduce crop yields across dryland areas. Without research breakthroughs mitigating these productivity losses through higher agricultural productivity, and reducing food waste and loss, meeting the increasing food demands of growing populations will require expansion of cropped areas to more marginal areas (with most prime areas in drylands already being under cultivation) (Eitelberg *et al.*, 2015; Kapović Solomun *et al.*, 2018). Borrelli *et al.* (2017) showed that the primary driver of soil erosion in 2012 was cropland expansion. Although local food demands could also be met by importing from other areas, this would mean increasing the pressure on land in those areas (Lambin and Meyfroidt, 2011).

Climate change will exacerbate poverty among some categories of dryland populations. Depending on the context, this impact comes through declines in agricultural productivity, changes in agricultural prices and extreme weather events (Hertel and Lobell, 2014; Halle gatte and Rozenberg, 2017). There is high confidence that poverty limits both capacities to adapt to climate change and availability of financial resources to invest into SLM (Vu *et al.,* 2014; Way, 2016).

ii. Labour mobility is another key human driver that will interact with climate change. Although strong impacts of climate change on migration in dryland areas are disputed, in some places, it is likely to provide an added incentive to migrate. Out-migration will have several contradictory effects on desertification. On one hand, it reduces an immediate pressure on land if it leads to less dependence on land for livelihoods (Chen *et al.,* 2014; Liu *et al.,* 2016). Moreover, migrant remittances could be used to fund the adoption of SLM practices. Labour mobility from agriculture to non-agricultural sectors could allow land consolidation, gradually leading to mechanisation and agricultural intensification (Wang *et al.*, 2014, 2018).

On the other hand, this can increase the costs of labour-intensive sustainable land management (SLM) practices due to lower availability of rural agricultural labour and/or higher rural wages. Out-migration increases the pressure on land if higher wages that rural migrants earn in urban centres will lead to their higher food consumption. Moreover, migrant remittances could also be used to fund land-use expansion to marginal areas (Gray and Bilsborrow, 2014; Taylor *et al.*, 2016). The net effect of these opposite mechanisms varies from place to place (Qin and Liao, 2016). There is very little literature evaluating these joint effects of climate change, desertification and labour mobility.

iii. There are also many other institutional, policy and socio-economic drivers of desertification, such as land tenure insecurity, lack of property rights, lack of access to markets, and to rural advisory services, lack of technical knowledge and skills, agricultural price distortions, agricultural support and subsidies contributing to desertification, and lack of economic incentives for SLM (Mythili and Goedecke, 2016; Sow *et al.*, 2016). There is no evidence that these factors will be materially affected by climate change, however, serving as drivers of unsustainable land management practices, they do play a very important role in modulating responses for climate change adaptation and mitigation.

iv. Drought, deforestation and climate change. All of these contribute to the extreme global issue known as desertification. According to the environmental campaign Clean Up the World, desertification is the degradation of land in drylands, which affects all continents except Antarctica. Approximately half of the people worldwide who live below the poverty line live in affected areas (Mikaela, 2016).

Prevention of desertification

The creation of a "culture of prevention" can go a long way toward protecting drylands from the onset of desertification or its continuation. The culture of prevention requires a change in governments' and peoples' attitudes through improved incentives. Young people can play a key role in this process. Evidence from a growing body of case studies demonstrates that dryland populations, building on long-term experience and active innovation, can stay ahead of desertification by improving agricultural practices and enhancing pastoral mobility in a sustainable way. For example, in many areas of the Sahel region, land users are achieving higher productivity by capitalizing on improved organization of labor, more extensive soil and water conservation, increased use of mineral fertilizer and manure, and new market opportunities (Zafar *et al.,* 2005).

i. Integrated land and water management are key methods of desertification prevention. All measures that protect soils from erosion, salinization, and other forms of soil degradation effectively prevent desertification. Sustainable land use can address human activities such as overgrazing, overexploitation of plants, trampling of soils, and unsustainable irrigation practices that exacerbate dryland vulnerability. Management strategies include measures to spread the pressures of human activities, such as transhumance (rotational use) of rangelands and well sites, stocking rates matched to the carrying capacity of ecosystems, and diverse species composition. Improved water management practices can enhance water-related services. These may include use of traditional water-harvesting techniques, water storage, and diverse soil and water conservation measures. Maintaining management practices for water capture during intensive rainfall episodes also helps prevent surface runoff that carries away the thin, fertile, moisture-holding topsoil. Improving groundwater recharge through soil-water conservation, upstream revegetation, and floodwater spreading can provide reserves of water for use during drought periods (Zafar *et al.,* 2005).

ii. Protection of vegetative cover can be a major instrument for prevention of desertification. Maintaining vegetative cover to protect soil from wind and water erosion is a key preventive measure against desertification. Properly maintained vegetative cover also prevents loss of ecosystem services during drought episodes. Reduced rainfall may be induced if vegetation cover is lost due to overcultivation, overgrazing, overharvesting of medicinal plants, woodcutting, or mining activities. This is usually coupled with the effect of reduced surface evapotranspiration and shade or increased albedo.

iii. Zafar *et al.* (2005) reported that in the dry subhumid and semiarid zones, conditions equally favor pastoral and cropping land use. Rather than competitively excluding each other, a tighter cultural and economic integration between the two livelihoods can prevent desertification. Mixed farming practices in these zones, whereby a single farm household combines livestock rearing and cropping, allows a more efficient recycling of nutrients within the agricultural system. Such interactions can lower livestock pressure on rangelands through fodder cultivation and the provision of stubble to supplement livestock feed during forage scarcity (and immediately after, to allow plant regeneration) due to within- and between-years climatic variability. At the same time, farmland benefits from manure provided by livestock kept on fields at night during the dry season. Many West African farming systems are based on this kind of integration of pastures and farmland (Zafar *et al.,* 2005).

iv. Use of locally suitable technology is a key way for inhabitants of drylands at risk of desertification to work with ecosystem processes rather than against them. Applying a combination of traditional technology with selective transfer of locally acceptable technology is a major way to prevent desertification. Conversely, there are numerous examples of practices, such as unsustainable irrigation techniques and technologies and rangeland management, as well as growing crops unsuited to the agroclimatic zone that tend to accelerate, if not initiate, desertification processes. Thus technology transfer requires in-depth evaluation of impacts and active participation of recipient communities.

Zafar *et al.* (2005) opined that the local communities can prevent desertification and provide effective dryland resource management but are often limited by their capacity to act. Drawing on cultural history and local knowledge and experience, and reinforced by science, dryland communities are in the best position to devise practices to prevent desertification. However, there are many limitations imposed on the interventions available to communities, such as lack of institutional capacity, access to markets, and financial capital for implementation. Enabling policies that involve local participation and community institutions, improve access to transport and market infrastructures, inform local land managers, and allow land users to innovate are essential to the success of these practices. For example, a key traditional adaptation was transhumance for pastoral communities, which in many dryland locations is no longer possible. Loss of such livelihood options or related local knowledge limits the community's capacity to respond to ecological changes and heightens the risk of desertification (Zafar *et al.,* 2005).

v. Desertification can be avoided by turning to alternative livelihoods that do not depend on traditional land uses, are less demanding on local land and natural resource use, yet provide sustainable income. Such livelihoods include dryland aquaculture for production of fish, crustaceans and industrial compounds produced by microalgae, greenhouse agriculture, and tourism-related activities. They generate relatively high income per land and water unit in some places. Dryland aquaculture under plastic cover, for example, minimizes evaporative losses, and provides the opportunity to use saline or brackish water productively. Alternative livelihoods often even provide their practitioners a competitive edge over those outside the drylands, since they harness dryland features such as solar radiation, winter relative warmth, brackish geothermal water, and sparsely populated pristine areas that are often more abundant than in non-drylands. Implementation of such practices in drylands requires institution building, access to markets, technology transfer, capital investment, and reorientation of farmers and pastoralists (Zafar *et al.,* 2005).

vi. Zafar *et al.* (2005) reported that desertification can also be avoided by creating economic opportunities in drylands urban centers and areas outside drylands. Changes in overall economic and institutional settings that create new opportunities for people to earn a living could help relieve current pressures underlying the desertification processes. Urban growth, when undertaken with adequate planning and provision of services, infrastructure, and facilities, can be a major factor in relieving pressures that cause desertification in drylands.

CONCLUSION

The necessity of information on the drivers of desertification cannot be over emphasized as this helps to identify and discuss the drivers of desertification. Methods of prevention of the challenges of desertification as integrated land and water management, protection of vegetation cover, use of locally suitable technology, availability of alternative livelihood and creating economic opportunities in dry land which were highlighted will make the environment more productive and habitable to people.

REFERENCES

Abbass, I. (2014). No retreat no surrender conflict for survival between Fulani pastoralists and farmers in Northern Nigeria. *European Scientific Journal*, 8: 331–346. doi:10.19044/esj.2012.v8n1p%25p. DOI: http://dx.doi.org/10.19044/esj.2012 . v8n1p%25. p331-346.

Alkire, S and Santos, M.E. (2014). Measuring acute poverty in the developing world: Robustness and scope of the multidimensional poverty index. World Development, 59: 251–274, doi:10.1016/J.WORLDDEV.2014. 01.026..

Balch, J.K., Bradley, B.A., D'Antonio, C.M and Gómez-Dans, J. (2013). Introduced annual grass increases regional fire activity across the arid western USA (1980–2009). *Global Change Biology*, 19:173–183, doi:10.1111/gcb.1204.

Bestelmeyer, B. T., Okin, G.S., Duniway, M.C., Archer, S.R., Sayre, N.F., Williamson, J.C and Herrick, J.E. (2015). Desertification, land use, and the transformation of global drylands. *Frontiers in Ecology and Environment*, 13: 28–36, doi:10.1890/140162.

Boix-Fayos, C., Martínez-Mena, M., Arnau-Rosalén, E., Calvo-Cases, A., Castillo, V and Albaladejo, J. (2006). Measuring soil erosion by field plots: Understanding the sources of variation. *Earth-Science Reviews*., 78: 267–285, doi:10.1016/J.EARSCIREV.2006.0 5.005

Bond, W.J and Keeley, J.E. (2005). Fire as a global 'herbivore': The ecology and evolution of flammable ecosystems. *Trends in Ecology and Evolution*, 20: 387–394. doi:10.1016/j.tree.2005.04.025.

Borrelli, P., Robinson, D. A., Fleischer, L. R., Lugato, E., Ballabio, C., Alewell, Christine., Meusburger, K., Modugno, S., Schutt, B., Ferro, V., Bagarello, V., Van Oost, K., Montanarella, L and Panagos, P. (2017). An assessment of the global impact of 21st century land use change on soil erosion. *Nature Communications*, 8(1):1-13. doi:10.1038/ s41467-017-02142-7.

Cary Institute of Ecosystem Studies (CIES) (2020). Nitrogen-fixing trees help tropical forests grow faster and store more carbon. https://www.sciencedaily.com/relea ses/2020/02/200213124211.htm,pp 1-5.

Chen, R., Ye, C., Cai, Y., Xing, X and Chen, Q. (2014). The impact of rural out-migration on land use transition in China: Past, present and trend. *Land Use Policy*, 40: 101–110, doi:10.1016/J.LANDUSEPOL.2013.10.003.

Clarke, H and Evans, J.P. (2018). Exploring the future change space for fire weather in Southeast Australia. *Theory and Applied Climatology*, 136: 513–527, doi:10.1007/s00704-018-2507-4.

Cowie, Annette. L., Orr, B.J., Castillo Sanchez, V.M., Chasek, P., Crossman, N.D., Erlewein, A., Louwagie, G., Graciela, M.M., SaraMinelli, M., Tengberg, A.E and Welton, S.W.S. (2018). Land in balance: *The Scientific Conceptual Framework for Land Degradation Neutrality, Environmental Science and Policy*, 79: 25–35, doi:10.1016/J.ENVSCI.2017.10.011.

Dimelu, M., Salifu, E and Igbokwe, E. (2016) Resource use conflict in agrarian communities, management and challenges: A case of farmer-herdsmen conflict in Kogi State, Nigeria. *Journal of Rural Studies*, 46:147–154.

D'Odoriocoa, P., Bhattachan, A., Davisa, K.F., Ravib, S and Christiane, W.R.(2013). Global desertification: Drivers and feedbacks. *Advances in Water Resources*, 51:326-344.

Dominguez, P. (2014). Current situation and future patrimonializing perspectives for the governance of agropastoral resources in the Ait Ikis transhumants of the High Atlas (Morocco). In: Herrera P, Davies J, Baena P (eds.). *The Governance of Rangelands. Collective Action for Sustainable Pastoralism. Routledge, Oxon and New York*, pp. 126–144.

Dong, S. (2016). Overview: Pastoralism in the World. In: *Building Resilience of Human-Natural Systems of Pastoralism in the Developing World* [Dong, S., K. A.S. Kassam, J. Tourrand and Boone, R.B. (eds.)]. *Springer International Publishing, Cham, Switzerland*, pp. 1–37.

Eitelberg, D.A., van Vliet, J and Verburg, P.H. (2015). A review of global potentially available cropland estimates and their consequences for model-based assessments. *Global Change Biology*., 21: 1236–1248, doi:10.1111/ gcb.12733.

Eldridge, D.J., Wang, L and Ruiz-Colmenero, M. (2015). Shrub encroachment alters the spatial patterns of infiltration. *Ecohydrology*, 8: 83–93, doi:10.1002/eco.1490.

Elhadary, Y. (2014). Examining drivers and indicators of the recent changes among pastoral communities of Butana locality, Gedarif State, Sudan. *America Journal of Sociology Research*, 4: 88–101.

FAO (2015). Global Soil Status, Processes and Trends. *Food and Agriculture Organization of the United Nations, Rome, Italy*, 605 pp.

FAO (2018). The Impact of Disasters and Crises on Agriculture and Food Security 2017. *Food and Agriculture Organization of the United Nations*, Rome, Italy, 143 pp.

Fernandez-Gimenez, M.E., (2000). The role of Mongolian nomadic pastoralists' ecological knowledge in rangeland management. *Ecological Applications.*, 10: 1318– 1326, doi:10.1890/1051-0761(2000)010[1318:TROMNP]2.0.CO2.

Fleming, E. (2019). How does planting trees control desertification?. SidmartinBio. https://www.sidmartinbio.org/how-does-planting-trees-control-desertification/ Accessed o 31/1/2022. 7 Pp. .

García-Ruiza, J.M., Beguería, S., Nadal-Romero, E., González-Hidalgo, J.C., Lana-Renault, N and Sanjuán, Y. (2015). A meta-analysis of soil erosion rates across the world. *Geomorphology*, 239: 160–173, doi:10.1016/j. geomorph.2015.03.008.

Gardner, T.A., Barlow, J., Chazdon, R., Ewers, R.M., Harvey, C.A., Peres, C.A and Sodhi, N.S., (2009). Prospects for tropical forest biodiversity in a human-modified world. *Ecology Letters*, 12: 561-582.

Geist, H.H.J., and Lambin, E.F. (2004). Dynamic Causal Patterns of Desertification. *Bioscience*, 54: 817–829, doi:10.1641/0006-3568(2004)054[0817:DCPOD]2.0.CO;2

Ginoux, P., Prospero, J.M., Gill, T.E., Hsu, N.C and Zhao, M. (2012). Global-scale attribution of anthropogenic and natural dust sources and their emission rates based on MODIS Deep Blue aerosol products. *Reviews of Geophysics*, 50(3): 1-36. doi:10.1029/2012RG000388.

Gray, C.L and Bilsborrow, R.E. (2014). Consequences of out-migration for land use in rural Ecuador. *Land Use Policy*, 36: 182–191, doi:10.1016/J. LANDUSEPOL.2013.07.006.

Hallegatte, S and Rozenberg, J. (2017). Climate change through a poverty lens. *Nature Climate Change.*, 7: 250–256, doi:10.1038/nclimate3253.

Hertel, T.W and Lobell, D.B. (2014). Agricultural adaptation to climate change in rich and poor countries: Current modeling practice and potential for empirical contributions. *Energy Economics*, 46: 562–575, doi:10.1016/J. ENECO.2014.04.014

IPBES (2018). Assessment report on land degradation and restoration [Montanarella, L., R. Scholes., and A. Brainich. (eds.)]. *Secretariate of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, Bonn, Germany, 686 pp

Jolly, W. M., Cochrane, M. A., Freeborn, P. H., Holden, Z. A., Brown, T. J., Williamson, G. J and Bowman, D. M. J. S. (2015). Climate-induced variations in global wildfire danger from 1979 to 2013. *Nature Communications*, 6:1–11, doi:10.1038/ncomms8537

Kapović Solomun, M., Barger, N., Cerda, A., Keesstra, S and Marković, M. (2018). Assessing land condition as a first step to achieving land degradation neutrality: A case study of the Republic of Srpska. *Environmental Science and Policy*, 90: 19–27, doi:10.1016/j.envsci.2018.09.014.

Kodirekkala, K.R. (2017). Internal and external factors affecting loss of traditional knowledge: Evidence from a Horticultural Society in South India. *Journal of Anthropological Research*, 73: 22–42, doi:10.1086/690524

Krätli, S and Schareika, N. (2010). Living off uncertainty: The intelligent animal production of dryland pastoralists. *European Journal of Development Research*., 22: 605–622, doi:10.1057/ejdr.2010.41.

Lambin, E.F and Meyfroidt, P. (2011). Global land use change, economic globalization, and the looming land scarcity. *Proceedings of the National Academy of Sciences of the United States of America*, 108: 3465–3472, doi:10.1073/pnas.1100480108

Lapido, D. (2010). The State of Nigeria forest in conserving endangered species in Nigeria. *Nigerian Field Society 80th Anniversary*, IITA, Ibadan p. 4.

Liu, Z and Wimberly, M.C. (2016). Direct and indirect effects of climate change on projected future fire regimes in the western United States. *Science of Total Environment*., 542: 65–75, doi:10.1016/j.scitotenv.2015.10.093

Liu, G., Wang, H., Cheng, Y., Zheng, B and Lu, Z. (2016). The impact of rural out-migration on arable land use intensity: Evidence from mountain areas in Guangdong, China. *Land Use Policy*, 59: 569–579, doi:10.1016/J. LANDUSEPOL.2016.10.005

López-i-Gelats, F., Fraser, E.D.G., Morton, J.F and Rivera-Ferre, M.G. (2016). What drives the vulnerability of pastoralists to global environmental change? A qualitative meta-analysis. *Global Environment Change*., 39: 258–274. doi:10.1016/J.GLOENVCHA.2016.05.011.

McSweeney, R. (2019). Explainer: 'Desertification' and the role of climate change. **https://climate-diplomacy.org/magazine/environment/explainer-desertification-and-role-climate-change.** Accessed on 1/02/2022. 3pp.

Mikaela F. (2016). Five Ways to Help Stop Desertification of the World. https://borgenproject.org/stop-desertification/Accessed 1/2/2022. 2pp.

Miller, R.F., Chambers, J.C., Pyke, D.A and Pierson, F.B. (2013). A Review of Fire Effects on Vegetation and Soils in the Great Basin Region: Response and Ecological Site Characteristics. US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Colorado, USA, 126 pp.

Morton, J. (2010). Why should governmentality matter for the study of pastoral development? *Nomadic People*, 14: 6–30, doi:10.3167/np.2010.140102

Mythili, G and Goedecke, J. (2016). Economics of Land Degradation in India. In: *Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development* [Nkonya, E., A. Mirzabaev, and J. von Braun (eds.)]. Springer International Publishing, Cham, Switzerland, pp. 431–469.

Oboho, E. G, Ogedegbe, S. A and Taiwo, O. P. (2015). Effect of fruit ripeness status and netting on the germination and early growth of *Dennettia tripetala* G. Baker seedlings. *Journal of Agricultural and Crop Research*, 3 (8):123-129.

Oboho, E.G. (2014). Silviculture for beginners, Uniben Press, Ekehuan Campus, Benin City, Nigeria. p. 263.

Pierson, F. B., Williams, C. J., Hardegree, S. P., Weltz, M. A., Stone, J. J and Clark, P. E. (2011). Fire, plant invasions, and erosion events on western rangelands. *Rangeland Ecology and Management*, 64: 439–449, doi:10.2111/ REM-D-09-00147.1.

Pierson, F. B., Jason Williams, C., Hardegree, S. P.; Clark, P. E., Kormos, P. R., Al-Hamdan, O. Z. (2013). Hydrologic and erosion responses of sagebrush steppe following juniper encroachment, wildfire, and tree cutting. *Rangeland Ecology and Management*, 66, 274–289, doi:10.2111/REM-D-12-00104.1.

Qin, H and. Liao, T.F. (2016). Labor out-migration and agricultural change in rural China: A systematic review and meta-analysis. *Journal of Rural Studies*., 47: 533–541, doi:10.1016/J.JRURSTUD.2016.06.020

Reynolds, J.F., Stafford Smith, D. M., Lambin, E.F., Turner, B L., Mortimore, M., Batterbury, S. P. J., Downing, T. E., Dowlatabadi, H., Fernández, R. J., Herrick, J. E., Huber-Sannwald, E., Jiang, H., Leemans, R., Lynam, T., Maestre, F. T., Ayarza, M and Walker, B. (2007). Global desertification: building a science for dryland development. *Science,* 316: 847–851, doi:10.1126/science.1131634.

Rosenzweig, C., Elliott, J., Deryng, Delphine, Ruane, Alex C., Müller, Christoph., Arneth A ., Boote, K. J., Folberth, C., Glotter, M., Khabarov, N., Neumann K., Piontek, F., Pugh, T. A.M., Schmid, E., Stehfest, E., Yang, H and Jones, J.W. (2014). Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison. *Proceedings of the National Academy of Sciences of the United States of America.*, 111: 3268–3273, doi:10.1073/pnas.1222463110.

Schlenker, W and. Lobell, D.B. (2010). Robust negative impacts of climate change on African agriculture. *Environmental Research Letters*, 5 (1): 1-8, 14010. doi:10.1088/1748-9326/5/1/014010.

Snorek, J., Renaud, F.G and Kloos, J. (2014). Divergent adaptation to climate variability: A case study of pastoral and agricultural societies in Niger. *Global Environmental Change*., 29: 371–386, doi:10.1016/J.GLOENVCHA.2014.06.014

Sow, S., Nkonya, E., Meyer, S and Kato, E. (2016). Cost, drivers and action against land degradation in Senegal. In: *Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development* [Nkonya E., A. Mirzabaev and J. von Braun (eds.)]. Springer International Publishing, Cham, Switzerland, pp. 577–608.

Stafford-Smith, M., Griggs, D., Gaffney, O., Ullah, F., Reyers, B., Kanie, N., Stigson, B., Shrivastava, P., Leach, M and O'Connell, D. (2017). Integration: The Key to Implementing the Sustainable Development Goals. *Sustainability*

Science, 12: 911–919, doi:10.1007/ s11625-016-0383-3.

Taleshi, S.A.R., Dhumal, K.N., Alipour, A., Espahbodi, K and Ghasemi, O. (2009). Impact of Alder (*Alnus subcordata*) in Fertility of Forest Soil. *Research Journal of Environmental Sciences,* 3: 640-644.

Taylor, M.J., Aguilar-Støen, M., Castellanos, E., Moran-Taylor, M.J and Gerkin, K. (2016). International migration, land use change and the environment in Ixcán, Guatemala. *Land Use Policy*, 54: 290–301, doi:10.1016/J. LANDUSEPOL.2016.02.024.

UNCCD (2017). Global Land Outlook. First. UNCCD, Bonn, Germany, 336 pp.

UNEP (1992). *World Atlas of Desertification* [Middleton, N. and D.S.G. Thomas (eds.)]. UNEP.Edward Arnold, London, UK, 69 pp.

Varghese, N and Singh, N.P. (2016). Linkages between land use changes, desertification and human development in the Thar Desert Region of India. *Land Use Policy,* 51: 18–25, doi:10.1016/J.LANDUSEPOL.2015. 11.001.

Vu, Q.M., Le, Q.B., Frossard, E and Vlek, P.L.G. (2014). Socio-economic and biophysical determinants of land degradation in Vietnam: An integrated causal analysis at the national level. *Land Use Policy,* 36: 605–617, doi:10.1016/J.LANDUSEPOL.2013. 10.012.

Wang, X., Yamauchi, F., Otsuka, K and Huang, J. (2014). Wage Growth, Land holding, and Mechanization in Chinese Agriculture. Policy Research Working Paper No. WPS 7138, World Bank Group, Washington, DC, USA, 43 pp.

Wang, X., Yamauchi, F., Huang, J and Rozelle, S. (2018). What constrains mechanization in Chinese agriculture? Role of farm size and fragmentation. *China Economic Review*, in press, doi:10.1016/J.CHIECO.2018.09.002

Way, S.A. (2016). Examining the links between poverty and land degradation: From blaming the poor toward recognising the rights of the poor. In: Governing Global Desertification: Linking Environmental Degradation, Poverty and Participation [Johnson, P.M. (ed.)]. Routledge, London, UK, pp. 47–62, doi:10.4324/9781315253916-13.

Weber, C.F., Lockhart, J.S., Charaska, E., Aho, K and Lohse, K.A. (2014). Bacterial composition of soils in ponderosa pine and mixed conifer forests exposed to different wildfire burn severity. *Soil Biology and Biochemistry*, 69: 242–250, doi:10.1016/j.soilbio.2013.11.010

Wilhite, D.A., Sivakumar, M.V.K and Pulwarty, R. (2014). Managing drought risk in a changing climate: The role of national drought policy. *Weather and Climate Extremes*., 3: 4–13, doi:10.1016/J.WACE.2014.01.002.

Wright, S.J. (2005). Tropical forests in a changing environment. Trends in Ecology and Evolution, 20: 553-560.

Zafar, A., Uriel, S., David, N., Robin, W., Grégoire, de K., Michael, G., Boshra, S., Bob, S., Maryam, N.F., Simeon, E and Valentine, Y.G. (2005). How can we prevent or reverse desertification. Green Facts. https://www.greenfacts.org/en/desertification/l-3/6-prevention-desertification.htm. Accessed on 1/02/2022. 8pp.

Ziese, M., Schneider, U., Meyer-Christoffer, A., Schamm, K., Vido, J., Finger, P.,Bissolli, P., Pietzsch, S and Becker, A.(2014). The GPCC Drought Index – a new, combined and gridded global drought index. *Earth System Science Data*, 6: 285–295, 2014. www.earth-syst-sci-data.net/6/285/2014/ doi: 10. 5194/essd-6-285-2014.

DEVELOPMENT OF A MARINE NATIONAL PARK IN NIGER DELTA, NIGERIA: STRATEGIES AND CONTRIBUTIONS TO NATIONAL DEVELOPMENT

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ABSTRACT

Nigerian has a coastline which is approximately 853 km long that stretches from the western border with the Republic of Benin to the eastern border with Cameroon. These marine and its coastline environment is of high value for humans as it harbours touristic resorts and contribute to the nation's economy. The estuaries with the presence of large tracts of mangroves that line the channels possess numerous natural resources. This includes native flora and fauna, beautiful landscape and several other attributes that are essential for successful ecotourism. The Niger Delta wetlands have been referred to as largest biodiversity hotspots in Africa that inhabit several species that are endemic in the region. Wildlife conservation and development strategies represent a major challenge facing governments and the donor agencies. Attempts to harness the various resources across the six geopolitical regions of the nation and provide positive incentives to rural communities through alternative income generation have not proven effective. The way forward is through the integration of all the geopolitical zones in the nation's National Park system, hence creation of Marine National Park will go a long way in enhancing the livelihood of the rural people and Nigerians at the long run. Strategies that could help boost Marine National Park development in Nigeria include; Programs to reduce the impacts of effluent, litter and diffuse pollution sources in marine and coastal environments; Programs to re-establish native vegetation to improve the overall condition of land and water resources as well as program on increasing the communities' awareness and understanding of catchment, coastal and marine issues. We reviewed the strategies and contributions of a Marine National Park in Niger Delta, Nigeria to national development. It is recommended that the coastline be properly protected as this area serves as a spawning ground for million organisms in the area.

Keywords: *Marine National Park, Mangrove Forest, Biodiversity, Protection.*

1.0 INTRODUCTION

A Marine Park is a park consisting of an area of sea, sometimes protected for recreational use, but more often set aside to preserve a specific habitat and ensure the ecosystem is sustained for the organisms that exist there. The Marine Park is characterized by warm tropical conditions varying at the surface between 25 °C and 31 °C during the year, stable salinity regimes and moderate nutrient levels (UNESCO, 2018).

According to Ferns (2003), Marine National Parks are areas that, collectively, represent different types of marine environments. The government established them in order to protect and preserve marine biodiversity. They are highly protected, with legislation limiting the activities that can occur in them. Swimming, diving, boating and other sustainable uses such as recreational fishing are allowed, while damaging or illegal extractive activities like, oil and gas exploration, discharging ballast and waste are not usually allowed.

As a result of the quest for a good standard of living by the various communities in the Niger Delta region and the struggle to own the recourses of the land hence the struggle manifests as various levels of protests, occasionally violent demonstration by the aggrieved youths of the Niger Delta areas, particularly oil producing communities. The struggles in the region have been directed towards operators of petroleum and allied industries for provision of alternative employment, healthcare facilities and standard schools in place of destroyed life-supporting mangrove bases. The presence of National Park in the area will go a long way to bridge the gap between the communities and the federal government in protecting the resources of the area, alleviates the living condition of the indigenous communities and also protect the biodiversity of the region. Establishment of a National Park and other protected areas are considered to be an effective tool for harmonizing the troubled relationship between humanity and the rest of nature.

1.1. The main natural habitats of the ocean marine

The marine area of West African region is made up of different natural habitats (Ferns, 2003). These natural habitats include:

i. The Open Sea or ocean waters. It begins in the bottom of the intertidal area towards the ocean at depths of several tens of meters to about 6000 meters. The levels that are closer to the surface are exposed to sunlight, with nutrients in the water, allowing the aquatic vegetation to grow through *photosynthesis*.

ii. The Coastline: The area between the sea and the land. This may appear as cliffs where the sea beats against the coast. The coastline thus provides a number of services. The coastline is also an environment that is of high value for humans because it combines the advantages of sea and earth. It is on the coast that all of the regional capitals are developed that harbours touristic resorts.

iii. The Estuaries: Estuaries are formed by encounters between the sea and a river valley: they are the mouths of coastal rivers and water ways. During the dry season the salt water goes back far into the estuary, a situation that is reversed during the rainy season when freshwater influence extends to the mouth and beyond to the sea. Estuaries in the region are largely fed by rain water. Productivity is reflected in the vegetation by the presence of large tracts of mangroves that line the channels.

1.2. The flora and fauna of the marine habitat

The flora and fauna of the marine habitat includes the following;

Mangroves

The mangrove is a plant community consisting in trees which have the specificity of being able to live with their roots in the sea (International Union for Conservation of Nature –IUCN, 2011).

According to IUCN (2011) six species of mangroves are present on the coast of West Africa have indeed developed amazing adaptations to withstand salt water and mud. Thus, the red mangrove, Rhizophora, has aerial roots or prop roots directly connected to the branches or trunk. The Avicennia is characterized by the presence of *pneumatophores* (or pencil roots) that emerge a few inches over the soil around the tree. The roots help to fix the sediments so that the fine particles of silt would not be easily washed away by currents.

ii. Sea Grass beds

The mudflats and shallow environments are covered with aquatic vegetation which makes them

look like grazing lands under water. Some species like the sea turtles, manatees and some fishes, that directly consume such vegetation are found here.

iii. The Algae

Marine algae that can be observed by the sea side are plants with neither roots, nor stems or leaves. The algae use sunlight to live and reproduce, which is why they are found mostly in shallow depths. From 200 meters deep Fresh or dried, the algae provide a range of wide use.

They are found useful in medicine (rheumatism, vermifuge), agriculture (fertilizer) or even as food for humans and animals. When the coastal area receives input of artificial fertilizers, such as from wastewater discharged into the sea, algae can grow significantly. When large amounts of algae die they decompose, producing bacteria that consume the oxygen in the water, which causes the disappearance of many animals

iv. Molluscs

Crustaceans and fishes are targeted by the commercial fishing communities. The main species like periwinkles, oyster, and other shell fishes play a role in coastal communities' source of food; they even represent their main source of animal protein.

v. Other Marine Mammals including marine turtles and birds are in coastal marine environment and when conserved could also serve as source of animal protein.

1.3 Review Wildlife Conservation Laws

The National Policy on Environment was developed in Nigeria in 1989. (Nigeria Biodiversity and Tropical Forest Assessment-NBTFA 2018) This policy resulted in 14.2% of Nigeria's land mass qualifying as protected area, securing 988 nationally protected reserves and 12 protected areas under international conventions. Despite federally declaring these sites protected, under-regulation and mismanagement has resulted in anthropogenic exploitation of reserve resources. (NBTFA 2018). No National policy has been enacted in Nigeria with the sole purpose to conserve mangrove forests wildlife. The mangrove forest wildlife is not under any known form of protection or laws in Nigeria (Mmom and Arokoyu, 2010). This has led to rapid decimation of the mangrove resources and wildlife in general. Deforestation has been propelled in Niger Delta region by demand for bush meat, timber, and vegetation (NBTFA, 2018).

2.0. Location of Niger delta Marine Environment

The Nigerian coastline is approximately 853 km long stretches from the western border with the Republic of Benin to the eastern border with Cameroon, with mangroves and estuaries extending from 10-150 km inland (USAID, 2008). It lies between latitude 4°15′ to 4°50′ and longitude 5°25′ to 7°37′ with a land mass of about 28000 sq/km (Uzoma and Mgbemena, 2015). The Nigerian coastal area is hot and humid, with an annual temperature range between 26 and 34^{o}C, and the highest temperatures occurring during the dry season- November to March. According to Igu and Marchant (2017) the Niger Delta is predominantly a flat, low-lying sedimentary basin drained by the Niger River with several crisscrossed rivers, streams, creeks, creeklets that emptied into the Atlantic Ocean through the estuaries.

The Niger Delta region is the largest wetland in Africa (Ogbe, 2011) covers 20,000 km^2 within 70,000 km^2 of wetlands and it's the third largest in the world (Izah, 2018). It is among the 14 biomes recognized by the World Wild Life Fund for conservation (Olsen and Dinerstein, 2002). Already there are few existing forest reserves at the Upper Orashi, Nun River, and Lower Orashi, all in Rivers/ Bayelsa state, which comprise a total of 239 km^2., having community protection and restricted to certain species of wildlife. In a number of Lakes crocodiles as well as chimpanzees are being protected (Polidoro *et al*., 2010).

2.1. Fauna and flora of the Niger Delta region

The Niger Delta wetlands have been referred to as largest biodiversity hotspots in Africa that inhabit several species that are endemic in the region including Sclater's guenon (*Cercopithecus sclateri*), Nigerian white-throated guenon (*Cercopithecus erythrogaster pococki*), red-capped mangabey (*Cercocebus torquatus*) *(De-Lange et al*., *1994*). Ogbe (2011) also reported that several biodiversity that are internationally and locally endangered are also found in the Niger Delta region, such as the endangered Nigeria–Cameroon chimpanzee (*Pan troglodytes ellioti*). The endemic Niger Delta Red Colobus monkey (*Procolobus epieni*), and the Nigerian white-throated guenon (*Cercopithecus erythrogaster pococki*) is also found in Apoi creek in Bayelsa state (Wildlife Conservation Society- WCS, 2012). Based on International Union for Conservation of Nature classification *Procolobus epieni* have been rated as 'Critically Endangered (Oates, 2008). Furthermore, WCS (2012) rated the Niger Delta Colobus monkey as among the 25 endangered primates in the world. The freshwater (10,000 km^2) and mangroves are separated by transition wetlands dominated by *Dalburger escatophylum, Machaerum lunatus, Pandanus* sp. and *Nypa fruticans* (Izah, 2018).

2.2. Nigerian National Parks and the vegetation regions they occur

Nigeria is covered by three types of vegetation: forests, savannahs and montane vegetation.

2.2.1. The Forest vegetation in Nigeria can be subdivided into three smaller zones namely:

i.. Evergreen rainforests: The tropical evergreen forests are home to a great number of tree species which are categorized into top, middle and lower layers. The mangrove swamp vegetation: This type of vegetation is limited to the coastal strip of Nigeria. The Saline swamp conditions along with the climate help to grow various types of mangrove vegetation.

iii. Freshwater Swamp Forest: This freshwater comes from the inland rivers and rainfalls.

2.2.2. Savannah vegetation: Savannah is the second biggest type of vegetation found in Nigeria. There are three major savannah belts in Nigeria. Guinea Savannah, Sudan Savannah, and Sahel Savannah, while,

2.2.3. Montane Vegetation: The Montane Vegetation are mainly found in the mountains near the Cameroon border, Adamawa State, Taraba State and Plateau State. Presently the Nigerian National Parks are located in the various vegetations mentioned except the in the marine mangrove environment of the rainforest region as shown in the (Table1).

Table1: Present National Parks and the regions they occur in Nigeria

National Park	Area km^2	Established	Region	State(s)	Geopolitical zones
Chad Basin	2,258	1991	Sudan/ Sahel Savanna	Borno, Yobe	North-East
Cross River	4,000	1991	Rainforest	Cross River	South-South
Gashaka Gumti	6,731	1991	Savanna /Rainforest/Moutane	Taraba, Adamawa	North East
Kainji	5,382	1979	Guinea Savanna	Niger, Kwara	North-Central
Kamuku	1,121	1999	Guinea /Sudanian Savanna	Kaduna	North-West
Okomu	181	1999	Rainforest/Swamp	Edo	Soth-South
Old Oyo	2,512	1991	Savanna	Oyo, Kwara	South-West

2.3. Niger Delta Mangrove Forest

Nigeria has extensive mangrove forests in the coastal region of the Niger Delta. It is considered one of the most ecologically sensitive regions in the world, the Niger Delta mangrove forest is situated within a deltaic depositional environment. Nigeria's mangrove forest which covers an area of about 105,000 hectares is known to be the largest in Africa and the third largest in the world (World Bank, 1995). These mangrove forests serve a critical role in regional ecological and landscape composition, and support subsistence gathering practices, and market-based income opportunities (Giri *et. al.*, 2011). Mangroves are found in all the coastal states of Nigeria namely – Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Lagos, Ogun, Ondo, and Rivers States. Despite expansive geographic coverage, the Niger Delta mangrove forest has approximately 80% of its vegetation distributed in three states (Bayelsa, Delta, and River states). *(James, et. al., 2013)*, Table 1.

2.4. Types of Mangrove Forests in the Niger Delta

According to Abere, and Ekeke (2014) the mangrove forests of Nigeria comprise principally only three families and six species as follows:

i. *Rhizophoraceae* (the red mangrove):- *Rhizophora racemosa*, *R. harrisonii* and *R. mangle.* Among these, *Rhizophora racemosa* is the most abundant taking about 90% of the mangrove forests. It occurs at the outer body of water. It forms a dense growth throughout the region. It is also the biggest of the three species attaining heights of up to 40m and dbh>90 cm at maturity. Being a pioneer, from the water body, it is followed by *R. harrisonii* which attains heights of 5-10m and *R mangle* with heights less than 5m. In their distribution, *R. harrisonii* occurs usually between *R. racemosa* and *R. mangle* the latter occupying the harder parts of the mangrove soil.

ii. *Avicenniaceae* – (white mangrove) *Avicennia africana.*

iii. *Combretacea – Lagancularia racemosa* and *Conocarpus erectus.*

Rhizophora recemosa, being a pioneer grows on the soft muddy banks of the brackish creek. It is

followed by the shorter *R. harrisonii* and *R. mangle*, which progressively prefer drier habitats. *Avicennia africana*, *Laguncularia racemosa* and *Conocarpus erectus* are progressively found on firmer landward grounds (Abere and Ekeke 2014).

Numbere (2018) reported that there are several mangrove species in the region and the most dominant ones are the red (*Rhizophora racemosa*), black (*Laguncularia racemosa*) and white (*Avicennia germinans*) mangroves. Also the Button wood mangroves (*Conocarpus erectus*) are also prominent, Oil palm trees (*Elaeis guineensis*), mangrove fern (*Acrostichum aureum*), grass species such as vines, and sedges are seen. The white mangroves (*Avicennia germinans*) on the other hand, are the next most dominant after the button wood in sandy areas.

Nypa fruticans (Nypa Palm) an exotic palm has spread through the Eastern Delta and is common

around the mouths of the Bonny and Imo Rivers. This exotic species has high national income value in its natural range where it is also cultivated and sustainably managed. In degraded areas, sedges, grasses especially *Paspalum vaginatum* and the fern *Acrostichum aureum* thrive (USAID, 2008).

2.5. *Importance of* Niger Delta *Mangrove forests*

Mangroves are extremely important to the coastal ecosystems they inhabit. Physically, they serve as a buffer between marine and terrestrial communities. Mangrove forests provide a wide range of ecological services like protection of shorelines and riverbanks from erosion, flood regulation, violent storms and hurricanes, maintenance of biodiversity (Patrik, 1999). They contribute to climate change mitigation and afford protection for coastal areas from tidal waves, cyclones and are the most carbon-rich forest in the tropics (Cornforth et al., 2013). They support nutrient and organic-matter processing, sediment control for other inshore habitats (Giri et al., 2011). Wells et al. (2006) observed that mangroves act as carbon sinks and thereby lessen the impact of global warming. Ecologically, they provide habitat for a diverse array of terrestrial organisms, and many species of coastal and offshore fish and shellfish rely exclusively on mangroves as their breeding, spawning, and hatching grounds. (Oates *et al.* 2004). *They also* contribute immensely to the socio-economic wellbeing of the coastal communities (Chima and Larinde, 2016**).**

2.6. Problems facing Niger Delta Mangrove Forest

This important ecosystem of the Niger Delta Region of Nigeria is fast diminishing due to factors which are mainly anthropogenic (Chima and Larinde, 2016). For instance, the growing human population and economic activities have been described as the major factors in mangrove forest depletion (Mmom, 2007). Crude oil exploration and exploitation in the region has equally contributed greatly to the loss of the mangrove forest. James *et. al*. (2007) reported that 210 km^2 of mangroves forest had been removed as a result of oil and gas exploration. Some of the major anthropogenic factors contributing to loss of Niger Delta mangrove Forest include the following:

i. Deforestation

Deforestation of the coastal mangrove vegetation exposes the coast to storm surges, coastal erosion and loss of land. The Nigerian coastline experiences some of the fastest erosion rates in the world averaging about 20-30 m per year in some locations (USAID, 2008). The deforestation and degradation of the mangroves for firewood gathering, the construction of navigational canals, villages, and the activities of oil companies, encourage their replacement by an invasive alien species *Nypa fruticans* (USAID, 2008).

ii. Environmental pollution caused by gas flaring and oil spill

Flaring impacts on the quality of the coastal atmosphere and affects coastal vegetation and human habitation. The mixture of flared gas and precipitation causes acid rain, with harmful effects on the mangrove biota and marine organisms. Gas flaring and oil spillage from pipelines and agrochemical carried by flood causes environmental pollution in the area, these pollutants are threats to the mangrove forest (Nwilo and Badejo, 2005).

iii. Invasive species

Nypa palm (*Nypa fruticans*, Wurmb) invasion is a major threat to mangrove in the Niger Delta (CEDA, 1997). This fast colonizer (*Nypa fruticans*), does not provide the enormous ecological services provided by mangroves (USAID, 2008).

iv. Environmental hazards

The occurrence of mangroves at the tip of the sea predisposes them to the impact of sea-level rise caused by climate change (Gilman *et al*., 2006). Niger Delta States is currently experiencing climate change related impacts such as rising temperature, heat waves, more intense rain/wind storms, more extreme rains, including erosion and landslides, sea level rise, sea surges and coastal inundation (Okoh *et al*., 2010). Recent report on global mangrove forest shows that the current rate of its degradation and disappearance has seriously threatened the fragile ecosystem and reduced its resilience to withstand climate change effect (Ajonina *et al.*, 2005).

v. Land reclamation

Land reclamation of swamps adjoining the coast for the increasing human population and other development activities destroys the nursery, breeding and feeding grounds of marine organisms. It also restricts the distribution of organisms and leads to considerable loss of biodiversity (Ajonina *et al.,* 2005).

3. Wildlife Conservation in Niger Delta' the Way Forward

To sustainably use and conserve oceans and marine resources, United Nation's Sustainable

Development Goals (UNSDG) 14.5 set the target that by 2030, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative. Also, that the ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored. Based on these United Nation's Sustainable Development Goals (UNSDG), it is therefore imperative that, the national government should as a matter of urgency and in recognition of the fragile nature of Niger Delta marine and its mangrove ecosystem consider it as part of national resource area that need to be upgraded into a National Park.~~,~~ This will also help the government in checking and conserving the wildlife species of the area. It will help the people of the mangrove area to benefit from the immense contributions the nation offers through the existence of the National Park in an area, for such as listed in the NPS (National Park Service Act, 2006), for example; (a) The conservation of selected and representative examples of wildlife communities in Nigeria; (b) The establishment of an ecologically and geographically balanced network of protected areas under the jurisdiction and control of the Federal Government; (c) The protection of endangered species of wild plants and animals and their habitats; (d) The conservation of wildlife throughout Nigeria so that the abundance and diversity of their species are maintained at the optimum levels commensurate with other forms of land use. (e) The preservation of outstanding scenic, natural, scientific, recreational and other values in the National Parks and, (f) The protection and maintenance of crucial wetlands and water catchment areas **(**National Park Service Act, 2006).

4. Strategies for Marine National Park Development in Nigeria

Strategies that could help boost Marine National Park development in Nigeria include;

a. Programs to reduce the impacts of effluent litter and diffuse pollution sources in marine and coastal environments; This will ensure that the natural quality of the marine ecosystem is maintained with a view to enhance the survival of varied flora and fauna species found in order to enrich its biodiversity. Regulatory agencies such as NOSDRA and NESREA are saddled with these functions.

b. Programs to control erosion and other processes that may have an impact on water quality or the overall condition of land and water resources; Coastal erosion is a common site in the region. It is therefore of the essence that relevant offices such as the Federal Ministry of Water Resources, Ecological Fund Office in the Presidency etc. should be contacted to remediate coastal erosion sites identified in the region.

c. Programs to re-establish native vegetation to improve the overall condition of land and water resources; Deliberate efforts should be made by agencies of government at all levels to re-establish nature reserves, game sanctuaries, community forests etc. This can be championed by the States Ministry of Environments, that is, states of the Niger Delta region.

d. Best-practice environmental guidelines for dredging activities; This will involve the Federal Ministry of Environment ensuring that Environmental impact assessment are carried out before and after dredging activities.

Improved arrangements for the integration of catchment and coastal management; The involvement of local communities in the management of conservation sites will integrate both the communities and the local government toward efficient biodiversity management.

Increasing community awareness and understanding of catchment, coastal and marine issues;

e. Promotion of training opportunities to enhance integrated catchment, coastal and marine management and technical skills. The National Park Service should extend her conservation education programs to the Niger

Delta Region to create conservation awareness among the locals.

CONCLUSION AND RECOMMENDATIONS

The Niger Delta coastal and marine areas play an important role in the nation's economy as a result of the abundant crude oil. The area also has ample number of wildlife species including the Niger Delta red colobus (*Procolobus badius epieni*), crocodiles, chimpanzees and birds. Several studies in the zone have shown that the forests and animal populations of the delta are under severe threat and presently there are no wildlife define protected areas in the delta region, hence the rapid rates of fauna and flora destruction present a matter of concern for the future of wildlife species in the area and in Nigeria at large. It is therefore recommended that the government should in recognition of Niger Delta marine and its mangrove tries and upgrades the existing forest reserves into a National Park. Finally, the coastline should be properly protected as these areas serve as a spawning ground for the immense population of diverse organisms in the area.

REFERENCES

Abere, S.A and Ekeke B.A. (2014) Proceedings of the 1st International Technology, Education and Environment Conference (c) African Society for Scientific Research (ASSR) National Park Service Act, 2006 Arrangement of Sections [National Park Service (Amendment). pp1-36.

Ajonina, P.U., Ajonina, G.N., Jin, E. Mekongo, F., Ayissi, I. and Usongo, L. (2005).Gender roles and economics of exploitation, processing and marketing of bivalves and impacts on forest resources in the Douala-Edaa Wildlife Reserve, Cameroon. *International Journal of Sustainable Development and World Ecology* 12: 161- 172

CEDA, (1997). Coastal profile of Nigeria. Federal Environmental Protection Agency, Press, Abuja, Nigeria.

Chima, U. D. and Larinde, S. L. (2016*). Deforestation and Degradation of Mangroves In The Niger Delta Region of Nigeria: Implications in a Changing climate. 38th Annual Conference of FAN at:* https://www.researchgate.net/publication/299285693

Cornforth, A., Fatoyinbo, E., Freemantle, P and Pettorelli, N. (2013). Advanced land observing satellite phased array type L-brand SAR (ALOS PALSAR) to inform the Conservation of Mangroves: Sundarbans as a case study. Remote sensing 5, 224-237.

De Lange, W.P. and P.J. De Lange (1994). An appraisal of factors controlling the latitudinal distribution of mangrove (Avicennia marina var. resinifera) in New Zealand. Journal of Coastal Research 10 (3): 539-548.

Dublin-Green, C.O., (1993). The foraminiferan fauna of Bonny estuary, a baseline studies. NIOMR Technical Paper.

Ferns, L. (2003). Victoria's System of Marine National Parks and Marine Sanctuaries: Management Strategy 2003-2010. Level 10, Melbourne, Australia. ISBN 0 7311 83266 https://www.researchgate.net/publication/309414365

Gilman, E.L., Ellison, J. Jungblut, V. Van Lavieren H. and Wilson, L. (2006). Adapting to Pacific Island mangrove responses to sea level rise and climate change. Climate Res., 32: 161-176. DOI: 10.3354/cr032161

Giri, C., (2011). Status and distribution of mangrove forests of the world using earth observation satellite data. Glob. Ecol. Biogeogr. 20, 154–159.

Giri, C., E. Ochieng, L.L. Tieszen, Z. Zhu and Singh, A.., (2011*)*. Status and distribution of Mangroveforests of the world using earth observation satellite data. Global Ecol. Biogeography, 20: 154-159. DOI: 10.1111/j.1466-8238.2010.00584.x

Igu, N.I, and Marchant, R. (2017) Freshwater swamp forest use in the Niger Delta: perception and insights. *Journal of Forest Research*, 22(1):44–52.

IUCN. (2011). Discovering the Coastal and Marine Environment in West Africa – Knowledge Handbook. Regional Program of Environmental Education: IUCN Guinea- Bissau. *pp84.*

Izah, S.C, Seiyaboh, E.I. (2018). Changes in the protected areas of Bayelsa state, Nigeria. *International Journal of Molecular Evolution and Biodiversity*. 8(1):1–11.

Izah, S.C, (2018). Ecosystem of the Niger Delta region of Nigeria: Potentials and Threats. *Biodiversity Int J.* 2018;2(4):338–345. DOI: 10.15406/bij.2018.02.00084

James, G.K., J.O. Adegoke, E. Saba, P. Nwilo and J. Akinyede, (2007). Satellite-based Assessment of the extent and changes in the mangrove ecosystem of the Niger Delta. Marine Geodesy, 30: 249-267. DOI: 10.1080/01490410701438224

*James, G. K., Adegoke, J. O., Osagie, S., Ekechukwu, S., Nwilo, P., Akinyede, J., (2013). "Social valuation of mangroves in the Niger Delta region of Nigeria". International Journal of Biodiversity Science, Ecosystem Services & Management. **9** (4): 311–323. doi:10.1080/21513732.2013.842611. ISSN 2151-3732*

Mmom, P.C. and Arokoyu, S.B. (2010). Mangrove forest depletion, biodiversity loss and traditional resources management practices in the Niger Delta, Nigeria. *Research Journal of Applied Sciences, Engineering and Technology* 2(1): 28-34.

Mmom, P.C. (2007). Impact of Human Density and Economic Activities on the Mangrove Forest of the Niger Delta, Nigeria. Paper presented at the Annual Conference of the International Association for Impact Assessment, held in Seoul South Korea. 1-9th.

NBTFA -Nigeria Biodiversity and Tropical Forest Assessment (2018). Maximizing Agricultural Revenue in Key Enterprises for Targeted Sites (Markets). Publi. no. 620-C-00-05-00077. *Chemonics International Inc*., <http://pdf.usaid.gov/pdf_docs/PNADN536.pdf>.

NDES, (1997). Environmental and socio-economic characteristics, second phase of field re-port. Environmental Resource Manager Limited. Nigeria Country Analysis Brief 2005. Report published by the Energy Information Administration (EIA), USA GDE..

Numbere A. *O*., *(*2018*)*. Mangrove Species Distribution and Composition, Adaptive Strategies and Ecosystem Services in the Niger River Delta, Nigeria. Mangrove Ecosystem Ecology and Function http://dx.doi.org/10.5772/intechopen.79028. https://www.researchgate.net/publication/32879198037 pp 247–266

Nwilo, P.C. and Badejo, O.T., (2005). Oil spill problems and management in the Niger delta. Int. Oil Spill Proc., 2005: 567-570.

Oates, J.F, Bergl, R.A, Linder, J,M (2004). Africa's Gulf of Guinea forests: biodiversity patterns and Conservation priorities. *Adv Appl Biodivers Sci* 6:1–91

Ogbe, M. G. (2011). Managing the environmental challenges of the oil and gas industry in the Niger Delta, Nigeria. *Journal of Life Science*.;1(1):1–17.

Ohimain EI, Otobotekere D, Biriduba W. (2014). Unsustainable Exploitation of Freshwater Wetland Turtles and Tortoises in Central Niger Delta. *International Journal of Environmental Monitoring and Analysis*.;2(2):57–64.

Okoh, R.N., Okoh, P.N., Ijioma, M.A., Ajibefun, I.A., Idehen, K.I., Ajieh, P.C., Nwabueze, A.A., Ovharhe, O.J. and Emegbo, J. (2010). Assessment of vulnerability and impacts of climate change on livelihoods of communities in the Niger Delta States. A research report submitted by Rural Linkage Network (RULIN) to Building Nigeria's Response to Climate Change (*BNRCC)*, 78pp.

Olsen, D.M. and E. Dinerstein, (2002). The global 200: Priority ecoregions for global conservation. Annals Missouri Botanical Garden, 89: 199-224.DOI: 10.2307/3298564

Patrik, R. (1999). The ecological basis for economic value of seafood production supported by Mangrove ecosystems. Department of Systems Ecology, Stockholm University, Stockholm, Sweden. *Ecological Economics*: 29. 235-252.

Polidoro, B.A., Carpenter, K.E., Collins, L. Duke N.C. and Ellison A.M. (2010). The loss of species: Mangrove extinction risk and geographic areas of global concern. *PloS ONE,* 5: e10095-e10095. DOI: 10.1371/journal.pone.0010095

Suman, D.O (2018) Mangrove Management: Challenges and Guidelines. In: GME P, Wolanski E, Cahoon DR, Hopkinson CS (eds) Coastal wetlands. *Elsevier*, Amsterdam, pp 1055–1079

UNESCO (2018). MAB Biosphere Reserves Directory". www.unesco.org. Retrieved 22 September 2018.

USAID (2008). Nigeria Biodiversity and Tropical Forestry Assessment. United States Agency for International Development, 90pp.

Uzoma, A.C. and Mgbemena, O. O (2015). Evaluation Of Some Oil Companies In The Niger Delta Region Of Nigeria: An Environmental Impact Approach International Journal of Environment and Pollution Research Published by European Centre for Research Training and Development UK Vol.3, No.2, pp.13-31, (www.eajournals.org)

Wildlife Conservation Society - WCS (2012). Saving the Niger Delta red colobus monkey from extinction: enlisting the support of local communities to help protect Apoi creek forest reserve. Stakeholder Workshop Report, Yenagoa, Nigeria; 2012.

Wells, S., Ravilious, C. and Corcoran. E. (2006*)*. In the frontline: shoreline protection and other ecosystem services from mangrove and coral reefs. United Nations Programme World Conservation Monitoring Centre, Cambridge, p. 33.

World Bank. (1995*)*. Defining an Environmental Development Strategy for the Niger Delta, Vol. II, Industry and Energy Operations Division (West Central Africa Department), Washington DC.

Waycott, M., C.M. Duarte, T. J. B. Carruthers, R. J. Orth, W. C. Dennison, S. Olyarnik, A. Calladine, J.W. Fourqurean, K.L. Heck, Jr., A. R.Hughes, G.A. Kendrick, W. J. Kenworthy, F. T. Short and S. L. Williams (2009) Accelerating loss of seagrasses across the globethreatens coastal ecosystems. Proceedings of the National Academy of Sciences of the United States of America, 106(30), 12377-12381.

ENVIRONMENTAL DRIVERS OF DESERTIFICATION IN THE WORLD

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ABSTRACT

The environment has been greatly affected by desertification which means land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities. Desertification is a threat to environmental and biodiversity conservation. This paper reviewed the information on the drivers of desertification in the environment, anthropogenic drivers of desertification such as crop land expansion, unsustainable land management practices including overgrazing by livestock, labour mobility as well as institutional, policy and socio-economic drivers of desertification. The thrust of the review further lends credence to the necessity of prevention of desertification which will bring economic and environmental benefits to people in the present and future.

Key words*: Desertification, Environment, Drivers of desertification, Degradation, Biodiversity, Conservation*

INTRODUCTION

Tropical forests are among the most biodiverse ecosystems on Earth, providing essential ecosystem services to the benefit of society (Wright, 2005, Gardner *et al.*, 2009). Forests in Nigeria are greatly exploited for various resources that satisfy the needs of the people. Some of the needs include timber, food, fodder, firewood, medicine, chemicals, agricultural implements, household utensils and cultural items (Oboho *et al.,* 2015). Oboho *et al.* (2015) stated that all world leaders agree about the fact that the continuous existence of many societies and their livelihoods rest on the sustainability of the biodiversity of their forests as this ensures the availability of more goods and services. However, deforestation is threatening the survival and health of natural forests with man being at risk of losing his resources and benefits too (Oboho *et al.,* 2015). Lapido (2010) puts the deforestation rate in Nigeria at about 3.5%, translating to a loss of 350,000 to 400,000 hectares of forest land per year. The commonest reasons for deforestation include removal of forest to make way for urbanization, infrastructural development, agriculture (especially plantation agriculture) logging and in recent times fires and wars (Oboho, 2014).

Today by human developments and influences of industries and deforestation caused climate change and global warming. Quantity and quality development of forests and forestation is the most important operation against these problems (Taleshi *et al.,* 2009). C I E S (2020) stated that tropical forests are allies in the fight against climate change. Growing trees absorb carbon emissions and store them as woody biomass (C I E S, 2020), help to overcome the challenge of deforestation which eventually leads to desertification. Desertification has been described as the "the greatest environmental challenge of our time" and it greatly influences climate change.

Desertification

The UNCCD set out a definition of desertification in a treaty adopted by parties in 1994. It states that desertification means "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities" (McSweeney, 2019). McSweeney (2019) stated that rather than desertification meaning the literal expansion of deserts, it is a catch-all term for land degradation in water-scarce parts of the world. This degradation includes the temporary or permanent decline in quality of soil, vegetation, water resources or wildlife. It also includes the deterioration of the economic productivity of the land – such as the ability to farm the land for commercial or subsistence purposes (McSweeney, 2019). Arid, semi-arid and dry sub-humid areas are known collectively as "drylands". These are, unsurprisingly, areas that receive relatively little rain or snow each year. Technically, they are defined by the UNCCD as "areas other than polar and sub-polar regions, in which the ratio of annual precipitation to potential evapotranspiration falls within the range from 0.05 to 0.65" (McSweeney, 2019).

In simple terms, this means the amount of rainfall the area receives is between 5-65% of how much it loses through evaporation and transpiration from the land surface and vegetation, respectively. Any area that receives more than this is referred to as "humid". McSweeney (2019) stated that drylands encompass around 38% of the Earth's land area, covering much of North and southern Africa, western North America, Australia, the Middle East and Central Asia. Drylands are home to approximately 2.7 billion people, 90% of whom live in developing countries (McSweeney, 2019). Drylands are particularly susceptible to land degradation because of scarce and variable rainfall as well as poor soil fertility. There are numerous ways in which the land can degrade. One of the main processes is erosion, the gradual breaking down and removal of rock and soil. This is typically through some force of nature such as wind, rain and/or waves, but can be exacerbated by activities including ploughing, grazing or deforestation.

McSweeney (2019) reported that a loss of soil fertility is another form of degradation. This can be through a loss of nutrients, such as nitrogen, phosphorus and potassium, or a decline in the amount of organic matter in the soil. For example, soil erosion by water causes global losses of as much as 42m tonnes of nitrogen and 26m tonnes of phosphorus every year. On farmed land, this inevitably needs to be replaced through fertilisers at significant cost. Soils can also suffer from salinization, an increase in salt content and acidification from overuse of fertilisers. Then there are lots of other processes that are classed as degradation, including a loss or shift in vegetation type and cover, the compaction and hardening of the soil, an increase in wildfires, and a declining water table through excessive extraction of groundwater (McSweeney, 2019).

The nature of desertification

Land degradation is a negative trend in land condition, caused by direct or indirect human-induced processes including anthropogenic climate change, expressed as long-term reduction or loss of at least one of the following: biological productivity, ecological integrity or value to humans. Arid, semi-arid, and dry sub-humid areas, together with hyper-arid areas, constitute drylands (UNEP, 1992), home to about 3 billion people. The difference between desertification and land degradation is not process-based but geographic. Although land degradation can occur anywhere across the world, when it occurs in drylands, it is considered desertification. Desertification is not limited to irreversible forms of land degradation, nor is it equated to desert expansion, but represents all forms and levels of land degradation occurring in drylands. Moreover, droughts are not restricted to drylands, but occur both in drylands and humid areas (Wilhite *et al.*, 2014). Drought is defined here as "a period of abnormally dry weather long enough to cause a serious hydrological imbalance".

Dryland populations are highly vulnerable to desertification and climate change because their livelihoods are predominantly dependent on agriculture, one of the sectors most susceptible to climate change (Schlenker and Lobell, 2010; Rosenzweig *et al.*, 2014). Pastoral production systems represent an adaptation to high seasonal climate variability and low biomass productivity in dryland ecosystems (Krätli and Schareika, 2010; Varghese and Singh 2016), which require large areas for livestock grazing through migratory pastoralism (Snorek *et al.*, 2014). Grazing lands across dryland environments are being degraded, and/or being converted to crop production, limiting the opportunities for migratory livestock systems, and leading to conflicts with sedentary crop producers (Abbass, 2014; Dimelu *et al.*, 2016). These processes, coupled with ethnic differences, perceived security threats, and misunderstanding of pastoral rationality, have led to increasing marginalization of pastoral communities and disruption of their economic and cultural structures (Morton, 2010; Elhadary, 2014). As a result, pastoral communities are not well prepared to deal with increasing weather/climate variability and weather/climate extremes due to changing climate (Dong, 2016; López-i-Gelats *et al.*, 2016), and remain amongst the most food insecure groups in the world (FAO, 2018).

Fernandez-Gimenez (2000) reported that the Pastoralists in Mongolia developed indigenous classifications of pasture resources which facilitated ecologically optimal grazing practices. Currently, however, indigenous and local knowledge and practices are increasingly lost or can no longer cope with growing demands for land-based resources (Dominguez, 2014; Kodirekkala, 2017). Unsustainable land management is increasing the risks from droughts, floods and dust storms. Policy actions promoting the adoption of sustainable land management (SLM) practices in dryland areas, based on both indigenous and local knowledge and modern science, and expanding alternative livelihood opportunities outside agriculture can contribute to climate change adaptation and mitigation, addressing desertification, with co-benefits for poverty eradication and food security (*high confidence*) (Stafford-Smith *et al.,* 2017; Cowie *et al.,* 2018).

Processes and drivers of desertification under climate change

Processes of desertification are mechanisms by which drylands are degraded. Desertification consists of both biological and non-biological processes. These processes are classified under broad categories of degradation of physical, chemical and biological properties of terrestrial ecosystems. The number of desertification processes is large and they are extensively covered elsewhere (UNCCD, 2017; IPBES, 2018). Drivers of desertification are factors which trigger desertification processes. Initial studies of desertification during the early-to-mid 20th century attributed it entirely to human activities. "Desertification is purely artificial. It is only the act of the man," (Geist *et al.,* 2004; Reynolds *et al.,* 2007). However, such a uni-causal view of desertification was shown to be invalid (Geist *et al.,* 2004; Reynolds *et al.,* 2007).

Ginoux *et al.* (2012) summarized the drivers, linking them to the specific processes of desertification and land degradation under changing climate. Erosion refers to removal of soil by the physical forces of water, wind, or often caused by farming activities such as tillage. The global estimates of soil erosion differ significantly, depending on scale, study period and method used (García-Ruiz *et al.*, 2015), ranging from approximately 20 Gt yr^{-1} to more than 200 Gt yr^{-1} (Boix-Fayos *et al.*, 2006; FAO, 2015).

i. Invasive plants contributed to desertification and loss of ecosystem services in many dryland areas in the last century (*high confidence*). Extensive woody plant encroachment altered runoff and soil erosion across much of the drylands, because the bare soil between shrubs is very susceptible to water erosion, mainly in high-intensity rainfall events (Pierson *et al.*, 2013; Eldridge *et al.,* 2015). Rising CO_2 levels due to global warming favour more rapid expansion of some invasive plant species in some regions. An example is the Great Basin region in western North America where over 20% of ecosystems have been significantly altered by invasive plants, especially exotic annual grasses and invasive conifers, resulting in loss of biodiversity. This land-cover conversion has resulted in reductions in forage availability, wildlife habitat, and biodiversity (Pierson *et al.,* 2011, 2013; Miller *et al.,* 2013).

ii. The wildfire is a driver of desertification, because it reduces vegetation cover, increases runoff and soil erosion, reduces soil fertility and affects the soil microbial community (Weber *et al.,* 2014; Liu and Wimberly, 2016). Predicted increases in temperature and the severity of drought events across some dryland areas; can increase chances of wildfire occurrence (*medium confidence*) (Jolly *et al.,* 2015; Clarke and Evans, 2018). In semi-arid and dry sub-humid areas, fire can have a profound influence on observed vegetation and particularly the relative abundance of grasses to woody plants (Bond and Keeley, 2005; Balch *et al.,* 2013). While large uncertainty exists concerning trends in droughts globally (AR5), examining the drought data by Ziese *et al.* (2014).

Anthropogenic drivers of desertification under climate change

IPBES (2018) identified cropland expansion, unsustainable land management practices including overgrazing by livestock, urban expansion, infrastructure development, and extractive industries as the main drivers of land degradation. IPBES (2018) also found that the ultimate driver of land degradation is high and growing consumption of land-based resources, e.g., through deforestation and cropland expansion, escalated by population growth.

i. Food production is also a major driver of desertification. Growing demand for food can see cropland expand into forests and grasslands, and use of intensive farming methods to maximise yields. Overgrazing of livestock can strip rangelands of vegetation and nutrients. Fleming (2019) reported that the growing food demand is driving conversion of forests, rangelands, and woodlands into cropland (D'Odorico *et al.,* 2013; Bestelmeyer *et al.,* 2015). Climate change is projected to reduce crop yields across dryland areas. Without research breakthroughs mitigating these productivity losses through higher agricultural productivity, and reducing food waste and loss, meeting the increasing food demands of growing populations will require expansion of cropped areas to more marginal areas (with most prime areas in drylands already being under cultivation) (Eitelberg *et al.,* 2015; Kapović Solomun *et al.,* 2018). Borrelli *et al.* (2017) showed that the primary driver of soil erosion in 2012 was cropland expansion. Although local food demands could also be met by importing from other areas, this would mean increasing the pressure on land in those areas (Lambin and Meyfroidt, 2011).

Climate change will exacerbate poverty among some categories of dryland populations. Depending on the context, this impact comes through declines in agricultural productivity, changes in agricultural prices and extreme weather events (Hertel and Lobell, 2014; Halle gatte and Rozenberg, 2017). There is high confidence that poverty limits both capacities to adapt to climate change and availability of financial resources to invest into SLM (Vu *et al.,* 2014; Way, 2016).

ii. Labour mobility is another key human driver that will interact with climate change. Although strong impacts of climate change on migration in dryland areas are disputed, in some places, it is likely to provide an added incentive to migrate. Out-migration will have several contradictory effects on desertification. On one hand, it reduces an immediate pressure on land if it leads to less dependence on land for livelihoods (Chen *et al.*, 2014; Liu *et al.*, 2016). Moreover, migrant remittances could be used to fund the adoption of SLM practices. Labour mobility from agriculture to non-agricultural sectors could allow land consolidation, gradually leading to mechanisation and agricultural intensification (Wang *et al.*, 2014, 2018).

On the other hand, this can increase the costs of labour-intensive sustainable land management (SLM) practices due to lower availability of rural agricultural labour and/or higher rural wages. Out-migration increases the pressure on land if higher wages that rural migrants earn in urban centres will lead to their higher food consumption. Moreover, migrant remittances could also be used to fund land-use expansion to marginal areas (Gray and Bilsborrow, 2014; Taylor *et al.,* 2016). The net effect of these opposite mechanisms varies from place to place (Qin and Liao, 2016). There is very little literature evaluating these joint effects of climate change, desertification and labour mobility.

iii. There are also many other institutional, policy and socio-economic drivers of desertification, such as land tenure insecurity, lack of property rights, lack of access to markets, and to rural advisory services, lack of technical knowledge and skills, agricultural price distortions, agricultural support and subsidies contributing to desertification, and lack of economic incentives for SLM (Mythili and Goedecke, 2016; Sow *et al.,* 2016). There is no evidence that these factors will be materially affected by climate change, however, serving as drivers of unsustainable land management practices, they do play a very important role in modulating responses for climate change adaptation and mitigation.

iv. Drought, deforestation and climate change. All of these contribute to the extreme global issue known as desertification. According to the environmental campaign Clean Up the World, desertification is the degradation of land in drylands, which affects all continents except Antarctica. Approximately half of the people worldwide who live below the poverty line live in affected areas (Mikaela, 2016).

Prevention of desertification

The creation of a "culture of prevention" can go a long way toward protecting drylands from the onset of desertification or its continuation. The culture of prevention requires a change in governments' and peoples' attitudes through improved incentives. Young people can play a key role in this process. Evidence from a growing body of case studies demonstrates that dryland populations, building on long-term experience and active innovation, can stay ahead of desertification by improving agricultural practices and enhancing pastoral mobility in a sustainable way. For example, in many areas of the Sahel region, land users are achieving higher productivity by capitalizing on improved organization of labor, more extensive soil and water conservation, increased use of mineral fertilizer and manure, and new market opportunities (Zafar *et al.,* 2005).

i. Integrated land and water management are key methods of desertification prevention. All measures that protect soils from erosion, salinization, and other forms of soil degradation effectively prevent desertification. Sustainable land use can address human activities such as overgrazing, overexploitation of plants, trampling of soils, and unsustainable irrigation practices that exacerbate dryland vulnerability. Management strategies include measures to spread the pressures of human activities, such as transhumance (rotational use) of rangelands and well sites, stocking rates matched to the carrying capacity of ecosystems, and diverse species composition. Improved water management practices can enhance water-related services. These may include use of traditional water-harvesting techniques, water storage, and diverse soil and water conservation measures. Maintaining management practices for water capture during intensive rainfall episodes also helps prevent surface runoff that carries away the thin, fertile, moisture-holding topsoil. Improving groundwater recharge through soil-water conservation, upstream revegetation, and floodwater spreading can provide reserves of water for use during drought periods (Zafar *et al.*, 2005).

ii. Protection of vegetative cover can be a major instrument for prevention of desertification. Maintaining vegetative cover to protect soil from wind and water erosion is a key preventive measure against desertification. Properly maintained vegetative cover also prevents loss of ecosystem services during drought episodes. Reduced rainfall may be induced if vegetation cover is lost due to overcultivation, overgrazing, overharvesting of medicinal plants, woodcutting, or mining activities. This is usually coupled with the effect of reduced surface evapotranspiration and shade or increased albedo.

iii. Zafar *et al.* (2005) reported that in the dry subhumid and semiarid zones, conditions equally favor pastoral and cropping land use. Rather than competitively excluding each other, a tighter cultural and economic integration between the two livelihoods can prevent desertification. Mixed farming practices in these zones, whereby a single farm household combines livestock rearing and cropping, allows a more efficient recycling of nutrients within the agricultural system. Such interactions can lower livestock pressure on rangelands through fodder cultivation and the provision of stubble to supplement livestock feed during forage scarcity (and immediately after, to allow plant regeneration) due to within- and between-years climatic variability. At the same time, farmland benefits from manure provided by livestock kept on fields at night during the dry season. Many West African farming systems are based on this kind of integration of pastures and farmland (Zafar *et al.*, 2005).

iv. Use of locally suitable technology is a key way for inhabitants of drylands at risk of desertification to work with ecosystem processes rather than against them. Applying a combination of traditional technology with selective transfer of locally acceptable technology is a major way to prevent desertification. Conversely, there are numerous examples of practices, such as unsustainable irrigation techniques and technologies and rangeland management, as well as growing crops unsuited to the agroclimatic zone that tend to accelerate, if not initiate, desertification processes. Thus, technology transfer requires in-depth evaluation of impacts and active participation of recipient communities.

Zafar *et al.* (2005) opined that the local communities can prevent desertification and provide effective dryland resource management but are often limited by their capacity to act. Drawing on cultural history and local knowledge and experience, and reinforced by science, dryland communities are in the best position to devise practices to prevent desertification. However, there are many limitations imposed on the interventions available to communities, such as lack of institutional capacity, access to markets, and financial capital for implementation. Enabling policies that involve local participation and community institutions, improve access to transport and market infrastructures, inform local land managers, and allow land users to innovate are essential to the success of these practices. For example, a key traditional adaptation was transhumance for pastoral communities, which in many dryland locations is no longer possible. Loss of such livelihood options or related local knowledge limits the community's capacity to respond to ecological changes and heightens the risk of desertification (Zafar *et al.*, 2005).

v. Desertification can be avoided by turning to alternative livelihoods that do not depend on traditional land uses, are less demanding on local land and natural resource use, yet provide sustainable income. Such livelihoods include dryland aquaculture for production of fish, crustaceans and industrial compounds produced by microalgae, greenhouse agriculture, and tourism-related activities. They generate relatively high income per land and water unit in some places. Dryland aquaculture under plastic cover, for example, minimizes evaporative losses, and provides the opportunity to use saline or brackish water productively. Alternative livelihoods often even provide their practitioners a competitive edge over those outside the drylands, since they harness dryland features such as solar radiation, winter relative warmth, brackish geothermal water, and sparsely populated pristine areas that are often more abundant than in non-drylands. Implementation of such practices in drylands requires institution building, access to markets, technology transfer, capital investment, and reorientation of farmers and pastoralists (Zafar *et al.,* 2005).

vi. Zafar *et al.* (2005) reported that desertification can also be avoided by creating economic opportunities in drylands urban centers and areas outside drylands. Changes in overall economic and institutional settings that create new opportunities for people to earn a living could help relieve current pressures underlying the desertification processes. Urban growth, when undertaken with adequate planning and provision of services, infrastructure, and facilities, can be a major factor in relieving pressures that cause desertification in drylands.

CONCLUSION

The necessity of information on the drivers of desertification cannot be over emphasized as this helps to identify and discuss the drivers of desertification. Methods of prevention of the challenges of desertification as integrated land and water management, protection of vegetation cover, use of locally suitable technology, availability of alternative livelihood and creating economic opportunities in dry land which were highlighted will make the environment more productive and habitable to people.

REFERENCES

Abbass, I. (2014). No retreat no surrender conflict for survival between Fulani pastoralists and farmers in Northern Nigeria. *European Scientific Journal*, 8: 331–346. doi:10.19044/esj.2012.v8n1p%25p. DOI: http://dx.doi.org/10.19044/esj.2012. v8n1p%25. p331-346.

Alkire, S and Santos, M.E. (2014). Measuring acute poverty in the developing world: Robustness and scope of the multidimensional poverty index. World Development, 59: 251–274, doi:10.1016/J.WORLDDEV.2014.01. 026..

Balch, J.K., Bradley, B.A., D'Antonio, C.M and Gómez-Dans, J. (2013). Introduced annual grass increases regional fire activity across the arid western USA (1980–2009). *Global Change Biology*, 19:173–183, doi:10.1111/gcb.1204.

Bestelmeyer, B. T., Okin, G.S., Duniway, M.C., Archer, S.R., Sayre, N.F., Williamson, J.C and Herrick, J.E. (2015). Desertification, land use, and the transformation of global drylands. *Frontiers in Ecology and Environment*, 13: 28–36, doi:10.1890/140162.

Boix-Fayos, C., Martínez-Mena, M., Arnau-Rosalén, E., Calvo-Cases, A., Castillo, V and Albaladejo, J. (2006). Measuring soil erosion by field plots: Understanding the sources of variation. *Earth-Science Reviews*., 78: 267–285, doi:10.1016/J.EARSCIREV.2006.0 5.005

Bond, W.J and Keeley, J.E. (2005). Fire as a global 'herbivore': The ecology and evolution of flammable ecosystems. *Trends in Ecology and Evolution*, 20: 387–394. doi:10.1016/j.tree.2005.04.025.

Borrelli, P., Robinson, D. A., Fleischer, L. R., Lugato, E., Ballabio, C., Alewell, Christine., Meusburger, K., Modugno, S., Schutt, B., Ferro, V., Bagarello, V., Van Oost, K., Montanarella, L and Panagos, P. (2017). An assessment of the global impact of 21st century land use change on soil erosion. *Nature Communications*, 8(1):1-13. doi:10.1038/ s41467-017-02142-7.

Cary Institute of Ecosystem Studies (CIES) (2020). Nitrogen-fixing trees help tropical forests grow faster and store more carbon. https://www.sciencedaily.com/relea ses/2020/02/200213124211.htm,pp 1-5.

Chen, R., Ye, C., Cai, Y., Xing, X and Chen, Q. (2014). The impact of rural out-migration on land use transition in China: Past, present and trend. *Land Use Policy*, 40: 101–110, doi:10.1016/J.LANDUSEPOL.2013.10.003.

Clarke, H and Evans, J.P. (2018). Exploring the future change space for fire weather in Southeast Australia. *Theory and Applied Climatology*, 136: 513–527, doi:10.1007/s00704-018-2507-4.

Cowie, Annette. L., Orr, B.J., Castillo Sanchez, V.M., Chasek, P., Crossman, N.D., Erlewein, A., Louwagie, G., Graciela, M.M., SaraMinelli, M., Tengberg, A.E and Welton, S.W.S. (2018). Land in balance: *The Scientific Conceptual Framework for Land Degradation Neutrality*, *Environmental Science and Policy*, 79: 25–35, doi:10.1016/J.ENVSCI.2017.10.011.

Dimelu, M., Salifu, E and Igbokwe, E. (2016) Resource use conflict in agrarian communities, management and challenges: A case of farmer-herdsmen conflict in Kogi State, Nigeria. *Journal of Rural Studies*, 46:147–154.

D'Odoriocoa, P., Bhattachan, A., Davisa, K.F., Ravib, S and Christiane, W.R.(2013). Global desertification: Drivers and feedbacks. *Advances in Water Resources*, 51:326-344.

Dominguez, P. (2014). Current situation and future patrimonializing perspectives for the governance of agropastoral resources in the Ait Ikis transhumants of the High Atlas (Morocco). In: Herrera P, Davies J, Baena P (eds.). *The Governance of Rangelands. Collective Action for Sustainable Pastoralism. Routledge, Oxon and New York*, pp. 126–144.

Dong, S. (2016). Overview: Pastoralism in the World. In: *Building Resilience of Human-Natural Systems of Pastoralism in the Developing World* [Dong, S., K. A.S. Kassam, J. Tourrand and Boone, R.B. (eds.)]. *Springer International Publishing, Cham, Switzerland*, pp. 1–37.

Eitelberg, D.A., van Vliet, J and Verburg, P.H. (2015). A review of global potentially available cropland estimates and their consequences for model-based assessments. *Global Change Biology*., 21: 1236–1248, doi:10.1111/ gcb.12733.

Eldridge, D.J., Wang, L and Ruiz-Colmenero, M. (2015). Shrub encroachment alters the spatial patterns of infiltration. *Ecohydrology*, 8: 83–93, doi:10.1002/eco.1490.

Elhadary, Y. (2014). Examining drivers and indicators of the recent changes among pastoral communities of Butana locality, Gedarif State, Sudan. *America Journal of Sociology Research*, 4: 88–101.

FAO (2015). Global Soil Status, Processes and Trends. *Food and Agriculture Organization of the United Nations, Rome, Italy*, 605 pp.

FAO (2018). The Impact of Disasters and Crises on Agriculture and Food Security 2017. *Food and Agriculture Organization of the United Nations*, Rome, Italy, 143 pp.

Fernandez-Gimenez, M.E., (2000). The role of Mongolian nomadic pastoralists' ecological knowledge in rangeland management. *Ecological Applications.*, 10: 1318– 1326, doi:10.1890/1051-0761(2000)010[1318:TROMNP]2.0.CO2.

Fleming, E. (2019). How does planting trees control desertification?. SidmartinBio. https://www.sidmartinbio.org/how-does-planting-trees-control-desertification/ Accessed o 31/1/2022. 7 Pp. .

García-Ruiza, J.M., Beguería, S., Nadal-Romero, E., González-Hidalgo, J.C., Lana-Renault, N and Sanjuán, Y. (2015). A meta-analysis of soil erosion rates across the world. *Geomorphology*, 239: 160–173, doi:10.1016/j. geomorph.2015.03.008.

Gardner, T.A., Barlow, J., Chazdon, R., Ewers, R.M., Harvey, C.A., Peres, C.A and Sodhi, N.S., (2009).

Prospects for tropical forest biodiversity in a human-modified world. *Ecology Letters*, 12: 561-582.

Geist, H.H.J., and Lambin, E.F. (2004). Dynamic Causal Patterns of Desertification. *Bioscience*, 54: 817–829, doi:10.1641/0006-3568(2004)054[0817:DCPOD]2.0.CO;2

Ginoux, P., Prospero, J.M., Gill, T.E., Hsu, N.C and Zhao, M. (2012). Global-scale attribution of anthropogenic and natural dust sources and their emission rates based on MODIS Deep Blue aerosol products. *Reviews of Geophysics*, 50(3): 1-36. doi:10.1029/2012RG000388.

Gray, C.L and Bilsborrow, R.E. (2014). Consequences of out-migration for land use in rural Ecuador. *Land Use Policy*, 36: 182–191, doi:10.1016/J. LANDUSEPOL.2013.07.006.

Hallegatte, S and Rozenberg, J. (2017). Climate change through a poverty lens. *Nature Climate Change.*, 7: 250–256, doi:10.1038/nclimate3253.

Hertel, T.W and Lobell, D.B. (2014). Agricultural adaptation to climate change in rich and poor countries: Current modeling practice and potential for empirical contributions. *Energy Economics*, 46: 562–575, doi:10.1016/J. ENECO.2014.04.014

IPBES (2018). Assessment report on land degradation and restoration [Montanarella, L., R. Scholes., and A. Brainich. (eds.)]. *Secretariate of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, Bonn, Germany, 686 pp

Jolly, W. M., Cochrane, M. A., Freeborn, P. H., Holden, Z. A., Brown, T. J., Williamson, G. J and Bowman, D. M. J. S. (2015). Climate-induced variations in global wildfire danger from 1979 to 2013. *Nature Communications*, 6:1–11, doi:10.1038/ncomms8537

Kapović Solomun, M., Barger, N., Cerda, A., Keesstra, S and Marković, M. (2018). Assessing land condition as a first step to achieving land degradation neutrality: A case study of the Republic of Srpska. *Environmental Science and Policy*, 90: 19–27, doi:10.1016/j.envsci.2018.09.014.

Kodirekkala, K.R. (2017). Internal and external factors affecting loss of traditional knowledge: Evidence from a Horticultural Society in South India. *Journal of Anthropological Research*, 73: 22–42, doi:10.1086/690524

Krätli, S and Schareika, N. (2010). Living off uncertainty: The intelligent animal production of dryland pastoralists. *European Journal of Development Research*., 22: 605–622, doi:10.1057/ejdr.2010.41.

Lambin, E.F and Meyfroidt, P. (2011). Global land use change, economic globalization, and the looming land scarcity. *Proceedings of the National Academy of Sciences of the United States of America*, 108: 3465–3472, doi:10.1073/pnas.1100480108

Lapido, D. (2010). The State of Nigeria forest in conserving endangered species in Nigeria. *Nigerian Field Society 80th Anniversary*, IITA, Ibadan p. 4.

Liu, Z and Wimberly, M.C. (2016). Direct and indirect effects of climate change on projected future fire regimes in the western United States. *Science of Total Environment*., 542: 65–75, doi:10.1016/j.scitotenv.2015.10.093

Liu, G., Wang, H., Cheng, Y., Zheng, B and Lu, Z. (2016). The impact of rural out-migration on arable land use intensity: Evidence from mountain areas in Guangdong, China. *Land Use Policy*, 59: 569–579, doi:10.1016/J. LANDUSEPOL.2016.10.005

López-i-Gelats, F., Fraser, E.D.G., Morton, J.F and Rivera-Ferre, M.G. (2016). What drives the vulnerability of pastoralists to global environmental change? A qualitative meta-analysis. *Global Environment Change*., 39: 258–274. doi:10.1016/J.GLOENVCHA.2016.05.011.

McSweeney, R. (2019). Explainer: ‘Desertification’ and the role of climate change. **https://climate-diplomacy.org/magazine/environment/explainer-desertification-and-role-climate-change.** Accessed on 1/02/2022. 3pp.

Mikaela F. (2016). Five Ways to Help Stop Desertification of the World. https://borgenproject.org/stop-desertification/Accessed 1/2/2022. 2pp.

Miller, R.F., Chambers, J.C., Pyke, D.A and Pierson, F.B. (2013). A Review of Fire Effects on Vegetation and Soils in the Great Basin Region: Response and Ecological Site Characteristics. US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Colorado, USA, 126 pp.

Morton, J. (2010). Why should governmentality matter for the study of pastoral development? *Nomadic People,* 14: 6–30, doi:10.3167/np.2010.140102

Mythili, G and Goedecke, J. (2016). Economics of Land Degradation in India. In: *Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development* [Nkonya, E., A. Mirzabaev, and J. von Braun (eds.)]. Springer International Publishing, Cham, Switzerland, pp. 431–469.

Oboho, E. G, Ogedegbe, S. A and Taiwo, O. P. (2015). Effect of fruit ripeness status and netting on the germination and early growth of *Dennettia tripetala* G. Baker seedlings. *Journal of Agricultural and Crop Research,* 3 (8):123-129.

Oboho, E.G. (2014). Silviculture for beginners, Uniben Press, Ekehuan Campus, Benin City, Nigeria. p. 263.

Pierson, F. B., Williams, C. J., Hardegree, S. P., Weltz, M. A., Stone, J. J and Clark, P. E. (2011). Fire, plant invasions, and erosion events on western rangelands. *Rangeland Ecology and Management*, 64: 439–449, doi:10.2111/ REM-D-09-00147.1.

Pierson, F. B., Jason Williams, C., Hardegree, S. P.; Clark, P. E., Kormos, P. R., Al-Hamdan, O. Z. (2013). Hydrologic and erosion responses of sagebrush steppe following juniper encroachment, wildfire, and tree cutting. *Rangeland Ecology and Management*, 66, 274–289, doi:10.2111/REM-D-12-00104.1.

Qin, H and. Liao, T.F. (2016). Labor out-migration and agricultural change in rural China: A systematic review and meta-analysis. *Journal of Rural Studies*., 47: 533–541, doi:10.1016/J.JRURSTUD.2016.06.020

Reynolds, J.F., Stafford Smith, D. M., Lambin, E.F., Turner, B L., Mortimore, M., Batterbury, S. P. J., Downing, T. E., Dowlatabadi, H., Fernández, R. J., Herrick, J. E., Huber-Sannwald, E., Jiang, H., Leemans, R., Lynam, T., Maestre, F. T., Ayarza, M and Walker, B. (2007). Global desertification: building a science for dryland development. *Science,* 316: 847–851, doi:10.1126/science.1131634.

Rosenzweig, C., Elliott, J., Deryng, Delphine, Ruane, Alex C., Müller, Christoph., Arneth A ., Boote, K. J., Folberth, C., Glotter, M., Khabarov, N., Neumann K., Piontek, F., Pugh, T. A.M., Schmid, E., Stehfest, E., Yang, H and Jones, J.W. (2014). Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison. *Proceedings of the National Academy of Sciences of the United States of America.*, 111: 3268–3273, doi:10.1073/pnas.1222463110.

Schlenker, W and. Lobell, D.B. (2010). Robust negative impacts of climate change on African agriculture. *Environmental Research Letters*, 5 (1): 1-8, 14010. doi:10.1088/1748-9326/5/1/014010.

Snorek, J., Renaud, F.G and Kloos, J. (2014). Divergent adaptation to climate variability: A case study of pastoral and agricultural societies in Niger. *Global Environmental Change*., 29: 371–386, doi:10.1016/J.GLOENVCHA.2014.06.014

Sow, S., Nkonya, E., Meyer, S and Kato, E. (2016). Cost, drivers and action against land degradation in Senegal. In: *Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development* [Nkonya E., A. Mirzabaev and J. von Braun (eds.)]. Springer International Publishing, Cham, Switzerland, pp. 577–608.

Stafford-Smith, M., Griggs, D., Gaffney, O., Ullah, F., Reyers, B., Kanie, N., Stigson, B., Shrivastava, P., Leach, M and O'Connell, D. (2017). Integration: The Key to Implementing the Sustainable

Development Goals. *Sustainability Science*, 12: 911–919, doi:10.1007/s11625-016-0383-3.

Taleshi, S.A.R., Dhumal, K.N., Alipour, A., Espahbodi, K and Ghasemi, O. (2009). Impact of Alder (*Alnus subcordata*) in Fertility of Forest Soil. *Research Journal of Environmental Sciences,* 3: 640-644.

Taylor, M.J., Aguilar-Støen, M., Castellanos, E., Moran-Taylor, M.J and Gerkin, K. (2016). International migration, land use change and the environment in Ixcán, Guatemala. *Land Use Policy*, 54: 290–301, doi:10.1016/J.LANDUSEPOL.2016.02.024.

UNCCD (2017). Global Land Outlook. First. UNCCD, Bonn, Germany, 336 pp.

UNEP (1992). *World Atlas of Desertification* [Middleton, N. and D.S.G. Thomas (eds.)]. UNEP.Edward Arnold, London, UK, 69 pp.

Varghese, N and Singh, N.P. (2016). Linkages between land use changes, desertification and human development in the Thar Desert Region of India. *Land Use Policy,* 51: 18–25, doi:10.1016/J.LANDUSEPOL.2015.11.001.

Vu, Q.M., Le, Q.B., Frossard, E and Vlek, P.L.G. (2014). Socio-economic and biophysical determinants of land degradation in Vietnam: An integrated causal analysis at the national level. *Land Use Policy,* 36: 605–617, doi:10.1016/J.LANDUSEPOL.2013.10.012.

Wang, X., Yamauchi, F., Otsuka, K and Huang, J. (2014). Wage Growth, Land holding, and Mechanization in Chinese Agriculture. Policy Research Working Paper No. WPS 7138, World Bank Group, Washington, DC, USA, 43 pp.

Wang, X., Yamauchi, F., Huang, J and Rozelle, S. (2018). What constrains mechanization in Chinese agriculture? Role of farm size and fragmentation. *China Economic Review*, in press, doi:10.1016/J.CHIECO.2018.09.002

Way, S.A. (2016). Examining the links between poverty and land degradation: From blaming the poor toward recognising the rights of the poor. In: Governing Global Desertification: Linking Environmental Degradation, Poverty and Participation [Johnson, P.M. (ed.)]. Routledge, London, UK, pp. 47–62, doi:10.4324/9781315253916-13.

Weber, C.F., Lockhart, J.S., Charaska, E., Aho, K and Lohse, K.A. (2014). Bacterial composition of soils in ponderosa pine and mixed conifer forests exposed to different wildfire burn severity. *Soil Biology and Biochemistry*, 69: 242–250, doi:10.1016/j.soilbio.2013.11.010

Wilhite, D.A., Sivakumar, M.V.K and Pulwarty, R. (2014). Managing drought risk in a changing climate: The role of national drought policy. *Weather and Climate Extremes*., 3: 4–13, doi:10.1016/J.WACE.2014.01.002.

Wright, S.J. (2005). Tropical forests in a changing environment. Trends in Ecology and Evolution, 20: 553-560.

Zafar, A., Uriel, S., David, N., Robin, W., Grégoire, de K., Michael, G., Boshra, S., Bob, S., Maryam, N.F., Simeon, E and Valentine, Y.G. (2005). How can we prevent or reverse desertification. Green Facts. https://www.greenfacts.org/en/desertification/l-3/6-prevention-desertification.htm. Accessed on 1/02/2022. 8pp.

Ziese, M., Schneider, U., Meyer-Christoffer, A., Schamm, K., Vido, J., Finger, P.,Bissolli, P., Pietzsch, S and Becker, A.(2014). The GPCC Drought Index – a new, combined and gridded global drought index. *Earth System Science Data*, 6: 285–295, 2014. www.earth-syst-sci-data.net/6/285/2014/ doi: 10.5194/essd-6-285-2014.

HEAVY METALS ACCUMULATION IN PLANTS GROWING IN RECYCLED METAL SLAG WASTE DUMPSITE IN OGIJO, OGUN STATE

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ABSTRACT

Soils in and around slag deposited waste dumpsites have been reported to contain a significant amount of heavy metals, usually difficult to remove from the environment, owing to peculiarity in characteristics of metals. This study was conducted to assess possible concentration of heavy metals in plant in a slag dumpsite in Ogijo, Ogun state and compare their consequent hyper-accumulator capacity. An area of 10 m by 50 m was measured from the base of a large slag heap in the study area. Slag samples were randomly collected from slag heap, soil samples were collected at the base of the heap (0 m) and at 50 m from the base. Mature whole samples of Chromolaena odorata, Alternanthera sessilis and Megathyrsus maximus were collected at approximately 0 m, 10 m and 50 m from the base of heap. All samples were collected in three replicates and analysed for Cu, Fe, Zn, Mn, Pb, Ni, Cd and Cr. Data obtained were subjected to Analysis of Variance and mean separation was done by Duncan's Multiple range test at $P \leq .05$. Results obtained (in mg/kg) showed that there were significant differences ($P \leq .05$) in all metals tested except in Ni, Cd and Cr that were below detectable limits. Lowest mean parameters except Zn were observed in plant samples. Mean Cu, Fe and Pb were significantly highest ($P \leq .05$) in slag with values 81.93±14.19, 421.61±71.94 and 48.73±2.52 respectively, Mn in soil at 0 m with mean value 4.30±0.26 and Zn in C. odorata with a mean of 52.88±5.41. In soil, highest mean heavy metals, except Cu occurred at 0 m, though not significantly different ($P \geq .05$) from those at 50 m. In plants, lowest mean values for Cu (1.31±0.70), Fe (104.59±6.88) and Pb (0.61±0.26) occurred in A. Sessilis, Zn (7.50±0.98) in M. maximus and Mn (1.02±0.46) in C odorata. Highest mean Cu, Fe, Mn and Pb were recorded in M. maximus, with values 30.01±12.01, 255.60±21, 4.28±0.66, and 4.96±1.40 respectively, while Zn (52.88±5.41) occurred in C. odorata. Data from this study showed that among the three plants tested Megathyrsus maximus had the highest hyperaccumulator potential for most metals and therefore is the most suitable plant for phytoremediation of heavy metal from polluted soils.

***Keywords**: Phytoremediation, Hyperaccumulator, Soil pollution, Invasive weeds, Scrap metal, Waste recycling*

INTRODUCTION

Pollution of the natural environment by heavy metals have become a serious problem, because, these metals are indestructible. In addition, most of them have toxic effects on living organisms, when they exceed a certain concentration (Ghrefat and Yusuf, 2006). Although certain metallic elements are required by plants and animals in very small quantities for some physiological processes (WHO, 1996; Hall, 2012), high levels of these elements can become harmful to living organisms ((Uzondu, 2012; Turkdogan *et al.,* 2013). Metals display cytotoxicity and genotoxicity in both animal and plant (Ciriaková, 2019). Pollution by heavy metals may occur through natural or anthropogenic sources. However, pollution by anthropogenic sources is the most widespread (Nazir *et al.*, 2015). The contribution of metals to environmental pollution from industrial, agricultural and mining processes and domestic effluent discharges, solid waste disposal and automobile and other atmospheric emissions from industrial establishments, are some of the major sources of environmental pollution (Onder *et al.,* 2017).

Metal recycling activities are a particularly important source of heavy metal contamination, causing negative impacts on the surrounding environment (Uzondu, 2012). The industrial production of iron and steel in Nigeria stood at 1.91052 million tonnes per year using the capacity utilization of 54.9% released by the Central Bank of Nigeria (CBN, 2016). The production of iron and steel from scrap iron and steel metal recycling industries, yields large amounts of slag as by-products (Gunn, 2015). This slag contains a considerable amount of heavy metal, which makes it one of the main sources of heavy metal pollution in the environment (Beauman, 2017). Iron and steel slag are widespread in Nigeria because the industries producing these by-products are found in the north, south, west and eastern parts of the country (Elijah, 2013). Slag production in Nigeria from this source is estimated at 0.29 tons per ton of steel produced. Therefore, the total estimated production of iron and steel slag in Nigeria is 0.55405 million tonnes per year (Uzondu, 2012). Consequently, recycle iron waste and slag are pollutants which litters some cities and towns in Nigeria (Uzondu, 2012).

Slag is usually a mixture of metal oxides and silicon dioxide and can contain metal sulfides and elemental metals. According to Luxan *et al* (2010), the major components of these slags include the oxides of calcium, magnesium, silicon and iron, with lesser amounts of magnesium, phosphorus, and others depending on the specifics of the raw materials used. Leaching concerns are typically towards non-ferrous or base metal slags, which tend to have higher concentrations of PTEs, but ferrous and ferroalloy slags may also have them, which raises concerns about highly weathered slag dumps (Ettler, and Vítkova, 2021). In recent times, slags are usually transported along with slag tailings to slag dumps. Here, they are exposed to weathering, which generates concerns about leaching of potentially toxic elements (PTEs) and hyper-alkaline runoffs into the soil and water, thereby, endangering the local ecological communities (Potysz *et al.*, 2018; Ettler and Kierczak, 2021). Soils in and around slag deposited waste dumpsites have been reported to contain a significant amount of heavy metals (Ukpebor and Unuigbe, 2013).

Characteristics of heavy metals make them persistent and sometimes difficult to remove from the environment. Currently, several alternative technologies are used to treat environmental heavy metal contamination and these comprise chemical, physical and biological treatments. Most physical and chemical methods are expensive and do not make the soil suitable for plant growth (Marques *et al*, 2009). Biological approach or bioremediation on the other hand is an economical and environmentally friendly approach, because it is achieved through natural processes and encourages the establishment or reestablishment of plants on polluted soils. Phytoremediation is an aspect of bioremediation that uses plants for the treatment of polluted soils (Luxan *et al.,* 2010; Gonzalez and Gonzalez-Chavez, 2016). It involves the use of natural hyperaccumulators, which are plants with very high metal-accumulating ability. Hyperaccumulators accumulate 10 to 500 times more metals than ordinary plant (Chaney *et al.,* 1997); hence, they are very suitable for phytoremediation. An important characteristic which makes hyperaccumulation possible is the tolerance of these plants to increasing concentrations of these metals.

Plant communities in soils contaminated with heavy metals respond differently to the presence of heavy metals in the soil. Heavy metals generally produce common toxic effects on plants, such as low biomass accumulation, chlorosis, inhibition of growth and photosynthesis, altered water balance and nutrient assimilation, and senescence, which ultimately cause plant death (Friedlova, 2010; Turkdogan *et al.,* 2013). Most plants are sensitive to the contaminant even at very low concentrations, while some have developed resistance, either by excluding or accumulating the contaminant (Chaudhry *et al.,* 2008). Works have shown that some common plants have ability of accumulating high level of heavy metals from the soil (El-Sharabasy and Ibrahim, 2010; Zheng *et al.*, 2017). Therefore, whenever a plant species is identified to have capacities to remediate elevated concentrations of heavy metals in the environment, emphases are usually on how to either maximize its remediation abilities (Omoregie *et al.,* 2019) On this basis, it was therefore important for this research to determine concentration of heavy metals in plant and their hyper-accumulator potentials. This study was conducted in a slag dump in Ogijo, Ogun state, to assess heavy metals concentration in slag and soil and compare their accumulation in selected plants growing in the dumpsite.

METHODOLOGY

Description of study site

This study was conducted in slag dumpsite in Ogijo, Ogun state. Ogijo is a town in Ogun state that shares its boundary with Lagos state. It is an industrial area, among whom most recent industries have been the scrap metal recycling factories. Evidence of pollution by these factories is obvious in their immediate surroundings and extends far beyond their vicinities into neighbouring areas. Among these are untreated waste slags generated as by-products of scrap metal recycling process, often deposited indiscriminately in heaps on the soil surface (Plate 1). One of such slag dumpsites was used in this study. The site is located on latitude 60 43’47’’N; longitude 30 31’35”E and 68.9 feet (21 m) above sea level.

Collection of samples

A preliminary survey of site was conducted prior to sample collection. An area of 10 m by 50 m was measured from the base of the large slag heap in the study area. Samples of slag were collected from slag, soil samples were collected from the base of the heap (0 m) and at 50 m from the heap. Three plant species; *Chromolaena odorata*, *Alternanthera sessilis* and *Megathyrsus maximus*; were selected on the basis of availability and abundance of species in the study site. Mature whole plant samples were collected at approximately at 0 m, 10 m and 50 m from the base of heap. All samples were were collected in three replicates and 50 g of each were analysed for; Cu, Fe, Zn, Mn, Pb, Ni, Cd and Cr.

Sample analysis

Reagent grade chemicals were used in all tests. Calibration and Quality Control procedure were from accurate Standard, Inc, except otherwise stated in the procedure. Calibration standard were prepared by diluting the appropriate certified reference standard solutions (1000 m_g /L) with deionized water to containing 0.100-2.00 mg/L of each of the multi-element mix of the standard. The certified reference standard calibration mix is a 1000 mg/L multi-element standard purchased commercially (Accurate Standard, Inc, USA).

Pretreatment of samples

Slag samples were crushed to fine particles. Both soil and crushed slag samples were air dried and sieved with a 2 mm sieve. Plant samples were washed in clean water to remove external impurities

Ashing

Exactly 50.0g of each plant sample was weighed and placed in the glass dish. The sample was oven dried at the temperature of 150 degree centigrade overnight. Dried sample was allowed to cool in the desiccators charged with dehydrated silica gel. The sample was transferred back to the oven and dried for another five hours, after which it placed in the desiccator for cooling and weighed. Exactly 0.1g of the ashed sample of plant and 1.0 g of slag and soil samples were weighed into a pre cleaned borosilicate glass of 250 ml capacity for digestion. Exactly 20 ml of the nitric acid was added into the weighed sample in the beaker. The sample with the digesting solvent was placed on the hot plate for digestion in the fume cupboard.

Digestion of samples

A test portion of 2.0 g of each soil sample was weighed into a 25 ml digestion vial and then 5 ml of 1:1 nitric acid is added to solid sample in the vial. The vial was capped and the mixture heated in a heat block at 90-95^0 C for 15 minutes. Thereafter, 2.5 ml of concentrated nitric acid was added, and the mixture was refluxed for 30 minutes, in the heat block. The sample was then cooled and 2.5 ml of concentrated nitric acid was added again. The sample was refluxed for additional 30 minutes. 0.5 ml of 30% hydrogen peroxide was added to the cooled sample, and the sample was re-heated in the heat block until the sample no longer was effervescing. 1.0 ml of hydrogen peroxide was added to the sample three more times and the sample heated in the heat block between each aliquot addition of 30% hydrogen peroxide. 5 ml of concentrated hydrochloric acid was added, and the sample heated on the heat block for 15 minutes. After cooling, the sample was diluted up to 50 ml with deionized water, and then filtered through whatman #1 filter paper. The filter was saved for the determination of the metals.

The beaker and its contents after the digestion were allowed to collect. Another 20 ml of the digesting solvents was added and digested further in the fume cupboard and the mixture was allowed to cool at room temperature. The mixture was filtered into the 250ml volumetric capacity borosilicate container. The filtrate was made up to the mark with the de-ionized water. All the digested samples were sub-sampled into pre-cleaned borosilicate glass containers for Atomic Absorption Spectrophotometer (AAS) analysis.

Concentration of samples

Sample extracts were concentrated by evaporating the solvent down to a volume of approximately 2 ml. This was achieved using a Buchi R215 Rotary evaporator. The equipment consists of a rot vapor, heating bath, vacuum controller and a re-circulating chiller. The temperature of the water bath was set to about 60 ºC, while that of the chiller was set at 2 ºC. The extract was transferred into a flask and connected to the rot vapor. The rotation speed of the flask to was set to 60 RPM then the evaporating flask was lowered into the heating bath. The vacuum was set using the vacuum controller and press button was switched on. When volume had reduced to required levels, the evaporation was ended by pressing the stop button on the vacuum controller. The flask was removed and content transferred into a glass vial.

Preparation of Standards solutions for metals

Standards Zinc, Lead, Chromium and Iron solutions of 0.2, 0.4, 0.6, 0.8 and 1.0mg/L were made from each of the heavy solutions of 100 mg/L stock solutions of the analyses. The set of standard solutions and the filtrate of the digested samples were analyzed by AAS. The detection limit of the metals ion the samples was 0.0001mg/L by means of Atomic Absorption Spectrophotometer (AAS). Arsenic, Lead, Chromium and Iron cathode lamps were used for the analysis of the respective ions in the standards and the filtrate of the samples, Gas mixtures of compressed air and acetylene were used in the generation of the flame.

Samples were analyzed using Agilent 7890B Gas chromatograph equipped with a flame ionization detector (FID), fitted with a HP-5 capillary column coated with 5% Phenyl Methyl Siloxane (30m length x 0.32mm diameter x 0.25pm film thickness) (Agilent Technologies). One (1) μL of the samples were injected in split less mode at an injection temperature of 220 °C, at a pressure of 14.861psi and a total flow of 21.364ml/min. Purge flow to split vent was set at 15 ML/min at 0.75 minute. Oven was initially programmed at 100°C (2 min) then ramped at 10°C/min to 280 °C (4 min) and then ramped to 300C at 10C/min. FID temperature was 300 °C with Hydrogen: Air flow at 30ml/min: 300ml/min. Nitrogen was used as makeup gas at a flow of 18ml/min. After calibration, the samples were analyzed and corresponding concentrations calculated. The labelled chromatograms were also extracted and reported.

Heavy Metal Determination

The metals were determined on filtrate of sample digested by atomic absorption spectrometry. Test results were validated with calibration curves obtained with certified metal standards. Calibration standard_ were prepared from stock by applying dilution formula C1Vl=C2V2 to obtain working range. Quantitation of metal levels in the soil samples was obtained with Perkin Elmer Win Lab AA software. Levels were converted from mg/1 to mg/kg by the following:

$$Conc.of\ \ in\ mg/kg = Conc.in\ mg/L\ X\ Dilution\ Factor\ X\ volume\ of\ digest\ /\ weight\ of\ sample\ digested$$

…...……………1

Statistical analysis of data

Data obtained were subjected to Analysis of Variance (ANOVA) using the statistical package for the social sciences (SPSS) 25.0 software. Mean separation was carried out mean separation was by Duncan's Multiple range test (DMRT) at $P \leq .05$. In every parameter analysed, results obtained were mean values from three replicates.

Plate 1. The study location showing slag heap (A) and surrounding vegetation (B) (arowed)

RESULTS

Results obtained from concentration of heavy metals (in mg/kg) in slag, soil and plants are presented in Table 1. Results showed that Ni, Cd and Cr that were below detectable limits in all samples tested. However, there were significant differences ($P \leq .05$) in all other metals tested which were; Cu, Fe, Pb, Mn and Zn.

Results showed that mean Cu, Fe and Pb were significantly higher ($P \leq .05$) in slag compared to all other sample, with values 81.93±14.19, 421.61±71.94 and 48.73±2.52 respectively, while highest Zn and Mn occurred in C. *odorata* and soil at 0 m respectively with mean values 52.88±5.41 and 4.30±0.26 respectively, although, concentration of Mn at this point was not significantly different from those in other samples except in *C. odorata* at 10 m.

In soil, highest mean for all metals, except Cu, occurred in 0 m though not significantly different ($P \geq .05$) from those at 50 m. Mean values in soil at 0 m and 50 m respectively were: Cu: 6.96±0.35 and 7.10±0.34; Fe: 220.39±3.19 and 218.09±2.65, Zn: 32.37±1.56 and 30.98±1.17; Mn 4.30±0.26. and 3.48±0.32; Pb: 3.68±0.34 and 3.61±0.21.

In plants, lowest mean values for Cu (1.31±0.70), Fe (104.59±6.88) and Pb (0.61±0.26) occurred in *A. Sessilis*, Zn (7.50±0.98) in *M. maximus* and Mn (1.02±0.46) in *C odorata.* Highest mean values for Cu, Fe, Mn and Pb in plants were recorded in *M maximus* with mean values 30.01±12.01, 255.60±21, 4.28±0.66, and 4.96±1.40

respectively while Zn occurred in C. *odorata* with a mean value of 52.88±5.41.

Lowest mean Cu (1.31±0.70) occurred in *Alternanthera sessilis* at 10 m, but was not significantly lower (*P* ≤ *.05*) than all other samples except concentration in slag and M. maximus at 10 m. Mean Cu was significantly highest in slag (81.93±14.19) compared to other samples. This was followed by mean concentration in *M. maximus* at 10 m from the heap with value 30.01±12.01, which was also significantly higher (*P* ≤ *.05*) than all samples except in *M. maximus* at 50 m with a mean value of 15.72±9.27 (Table 1).

Mean concentration Fe followed nearly a similar pattern to that of Cu. Mean Fe (104.59±6.88) was again lowest in *A. sessilis*, but at 0 m (Table 1). The value was not significantly higher (*P* ≥ *.05*) than all other samples except in slag (421.61±71.94) and *M. maximus* at 0 m (255.60±21.36). Mean concentration in slag was significantly higher (*P* ≤ *.05*) than that found in all samples also followed by that present in *M. Maximus* at 0 m . However, mean concentration in *M maximus* was not significantly higher (*P* ≤ *.05*) than that found in all soil and *C. odorata* samples at all distances from slag heap.

Concentration of Pb in samples followed the exact pattern as those observed in Fe. Lowest and significantly highest (*P* ≤ *.05*) mean Pb occurred in *A. sessilis* at 10 m with a mean value of 0.61±0.26 and in slag with mean value of 48.73±2.52 respectively (Table 1). Highest concentration was followed by that found in *A maximus* at 0 m, which had a mean value of 4.96±1.40, which was not significantly different (*P* ≥ *.05*) from mean concentration of Pb in all samples except the lowest and highest mean values recorded in *A. sessilis* and slag mentioned earlier (Table 1).

In Mn, lowest mean value of 1.02±0.46 occurred in *C. odorata* at 10 m. Results further showed that lowest mean value was not significantly (*P* ≥ *.05*) lower than all samples except in soil at 0 m (4.30±0.26) and 50 m (3.48±0.32), *A maximus* at 0 m (4.28±0.66) and *A. sessilis* at 10 m (3.35±0.78). Highest mean Mn occurred in soil at 0 m with a value of 4.30±0.26 (Table 1).

Results obtained for concentration of Zn in samples are also shown in Table 1. Lowest mean Zn occurred in tissues of *M. maximus* at 10 m (7.50±0.98) This was however not significantly different (*P* ≥ *.05*) from concentration in slag (11.30±1.92), at 50 m (23.50±7.29), *M. maximus* at 50 m (23.37±3.12) and *C odorata* at 0 m (8.15±0.98) and 10 m (8.01±0.83) respectively (Table 1). Highest mean Zn was found in *C. odorata* at 50 m with concentration of 52.88±5.4 which was significantly higher than different from all other samples tested. This was followed by that in *A. sessilis* with a mean value of 36.48±8.43 (Table 1).

Table 1. Mean concentration of heavy metals in slag, soil and plants in slag dumpsite in Ogijo, Ogun state

Sample type	D	Heavy metals							
		Cu	Fe	Pb	Mn	Zn	Ni	Cd	Cr
Slag	NA	**81.93±14.19^{c}**	**421.61±71.94^{d}**	**48.73±2.52^{c}**	3.09±0.37^{ab}	11.30±1.92^{ab}	0.00±0.00	0.00±0.00	0.00±0.00
soil	0 m	6.96±0.35^{a}	220.39±3.19^{bc}	3.68±0.34^{ab}	**4.30±0.26^{b}**	32.37±1.56^{c}	0.00±0.00	0.00±0.00	0.00±0.00
	50 m	7.10±0.34^{a}	218.09±2.65^{bc}	3.61±0.21^{ab}	3.48±0.32^{b}	30.98±1.17^{bc}	0.00±0.00	0.00±0.00	0.00±0.00
M. maximus	0 m	4.87±1.72^{a}	255.60±21.36^{c}	4.96±1.40^{b}	4.28±0.66^{b}	34.57±15.99^{c}	0.00±0.00	0.00±0.00	0.00±0.00
	10 m	30.01±12.01^{b}	147.73±44.40^{ab}	1.80±0.80^{ab}	3.15±1.22^{ab}	7.50±0.98^{a}	0.00±0.00	0.00±0.00	0.00±0.00
	50 m	15.72±9.27^{ab}	144.99±53.14^{ab}	0.67±0.31^{a}	3.00±1.24^{ab}	23.50±7.29^{abc}	0.00±0.00	0.00±0.00	0.00±0.00
A. sessilis	0 m	3.32±0.86^{a}	140.95±21.15^{ab}	3.89±2.61^{ab}	2.34±0.33^{ab}	32.00±6.91^{c}	0.00±0.00	0.00±0.00	0.00±0.00
	10 m	3.95±1.47^{a}	104.59±6.88^{a}	0.61±0.26^{a}	3.35±0.78^{b}	36.48±8.43^{c}	0.00±0.00	0.00±0.00	0.00±0.00
	50 m	1.31±0.70^{a}	140.42±7.14^{ab}	1.34±0.56^{ab}	2.36±0.62^{ab}	23.37±3.12^{abc}	0.00±0.00	0.00±0.00	0.00±0.00
C. odorata	0 m	8.65±2.33^{a}	243.07±32.69^{bc}	3.17±1.07^{ab}	1.99±0.69^{ab}	8.15±0.98^{a}	0.00±0.00	0.00±0.00	0.00±0.00
	10 m	5.19±1.52^{a}	240.04±10.46^{bc}	1.51±0.81^{ab}	1.02±0.46^{a}	8.01±0.83^{a}	0.00±0.00	0.00±0.00	0.00±0.00
	50 m	6.70±1.30^{a}	234.56±21.88^{bc}	2.16±0.22^{ab}	2.26±0.35^{ab}	**52.88±5.41^{d}**	0.00±0.00	0.00±0.00	0.00±0.00
WHO limits for soil		36.0	--	85.0	12.0	50.0	35 0	0.8	100.0
FMinEnv limits for soil		200.0	50,000.0	200.0	--	150.0		1.0	100.0

Mean values of the same parameter along the same column having the same superscripts are not significantly different (DMRT.$P \geq .05$)

NA = Not applicable; D = distance from base of slag heap

DISCUSSION

Metal recycling continues to grow globally due to increasing awareness of resource conservation and economic benefits (Anderson *et al*., 2017). However, the process usually results in generation of heavy metal contaminated liquid and solid slag wastes. Through indiscriminate disposal of these wastes, metal recycling facilities discharge variety of heavy metals into the environment. Common examples of heavy metals that have been reported include lead, aluminium, arsenic, chromium, manganese cadmium, nickel, copper, and zinc are also released by the facilities (Beauman, 2017; O'Connor *et al*., 2019). This agrees with the results from the present study where high levels of heavy metals including iron, lead, copper, manganese, nickel and zinc were observed in samples of slag waste deposited by metal recycling factories in the study area.

Several reports have shown that presence of heavy metal contaminated slag in the environment can lead to heavy metal contamination of immediate soil of the areas (Ettler, and Vítkova, 2021; Ettler, and Kierczak, 2021). Comparing concentration of heavy metal in slag and soil samples at different distances, it was observed that higher concentration of most heavy metals were recorded in slag, followed by soil and plants nearest to slag heap, with much less concentrations in soils located at a reasonably far distant from the slag heap. It can therefore be inferred that slag waste is the source of heavy metal pollution of soil in the study site. This agrees with earlier report that slags transported along with slag tailings to slag dumps, where they are exposed to weathering, may result in leaching of potentially toxic elements such as heavy metals and hyper-alkaline runoffs into the soil and water endangering the local ecological communities (Potysz *et al*., 2018; Ettler and Kierczak, 2021). Thus, heavy metal contamination of soil may pose risks and hazards to humans and the ecosystem (McLaughlin *et al*., 2011). Contamination of biota and groundwater with potentially toxic heavy metals also has important implications for human health (Slaveykova and Cheloni, 2018).

Reports have shown that plants growing in heavy metal-contaminated sites generally accumulate higher amounts of heavy metals in their edible and non-edible parts at quantities high enough to cause clinical problems to both plants, animals and human beings (Uzondu, 2012; Ogundiran and Osibanjo, 2018). This agrees with results obtained in this study, where high concentration of heavy metals was present in all plants samples growing in metal contaminated soil of the study area, especially those plants growing nearer to the source of contamination. Through this mechanism, heavy metals in soil can accumulate in vegetables, which can be transferred to other media through the food chain (Wang *et al*., 2017). Although heavy metal accumulation in edible plants can pose threat to health of plant and animals, the mechanism has been exploited in environmental remediation for removal of pollutants from different environmental media through a process of phytoremediation.

Plants have an advantage growing on metal contaminated soil. Such plants can withstand high accumulation of metals in their aerial tissues (Vesk and Reichman, 2019) and can also eliminate competitive plants (Maestri *et al.,* 2010). These are attributes of common to invasive alien plants and agree with those of the three plants selected for this study. Based on casual observation, these three were the most predominant plants species in the study site. Invasive species are non-native species that have become established in a new region, devoid of natural enemies (Reichard and White, 2001; Fountain, 2016). Such plants are characteristically adaptable, aggressive and have a high reproductive capacity, having escaped natural enemies and herbivores and have dominated native plants through several mechanisms resulting in outbreak of their populations (Florida Exotic Pest Plant Council, 2007). Invasion by all three plants; *Chromolaena odorata, Alternanthera sessilis* and *Megathyrsus maximus;* have been reported (Fan *et al.*, 2013; PIER, 2013; Uyi *et al*. 2013;).

Megathyrsus maximus is a grass species that can suppress or displace local plants on fertile soils in pastures. It is tolerant of fire, resistant to drought is and can dominate the ground after a fire. (Calvert, 2018). These may have contributed to the higher levels of metal accumulation compared to other plants studied. In this study, High levels mean concentration of heavy metals including Cu, Fe, Mn and Pb in plants were recorded in *M maximus,* showing higher accumulation of metals compared to *C. odorata* and *A. sessilis*. However, a study has shown that obvious signs of phyto-toxicity appeared in *M maximus* plants exposed to 120 ppm Pb^{2+} and Cd^{2+}, suggesting that the plant may be a moderate metal accumulator. In the present study, *C. odorata* showed less metal accumulation capacity except for Zn. A study on the remediating capacity of plants revealed that *C. odorata* still thrive heavy metal induced stress that resulted in such disruption of physiological functions and cause morphological deficiencies in other plants (Ciriakova, 2019).

Alternanthera sessilis leaves are rich in protein and are eaten raw as a fresh green leafy vegetable in many countries of South Asia (Alveera *et al.,* 2009). It has been reported that *A. sessilis* has a potential to hyperaccumulate Cd in the leaves (Alveera *et al.,* 2009). In the present study, Cd was not detected in the soil to verify this claim. However, accumulation of heavy metals in *A. sessilis* was lowest among the three plants, significantly reducing the potential risk of the plant to humans on consumption. Higher accumulation of Zn in *C. odorata* at 50 m from base of slag heap observes in the present study. Zinc is one of the most mobile heavy metals in surface waters and groundwater. In addition, zinc readily precipitates under reducing conditions and in highly polluted systems when it is present at very high concentrations, and may co-precipitate with hydrous oxides of iron or Magnesium (Evanko and Dzomback, 1997). Therefore, the highly mobile nature of the metal may have accounted for rapid leaching and movement from the source causing higher concentration at a more distant position from the source.

CONCLUSION

Although all three plant species accumulated heavy metals in their tissues, *Megathyrsus maximus* had the highest heavy metal accumulation potential in all heavy metals assessed except Zn, with *Chromolaena odorata* having highest accumulation capacity for Zn while *Alternanthera sessilis* showed the least potential for heavy metals accumulation. Therefore, among the three plants, *Megathyrsus maximus* is the most suitable plant species for phytoremediation of heavy metal from polluted soils with regards to heavy metals tested in the present study.

REFERENCES

Anderson, H., Cohen, A., Brauer, M., Burnett, R., Frostad, J., Estep, K., and Forouzanfar, M. (2017). "Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015". *The Lancet,* **389**(82): 1907–1918.

Alveera, S. Thangaraj, K. asamy, and Bharti, O. (2009). In vitro propagation of *Alternanthera sessilis* (sessile joyweed), a famine food plant. *African Journal of Biotechnology,* **8**(21): 5691–5695.

Beauman, C. (2017). Steel: Climate change poses stern challenge. *The Financial Times*. 71-76 pp.

Calvert, G. (2018). Weeds -The silent invaders. *Australian Journal of Crop Science*, **28**(5): 98-99.

Central Bank of Nigeria, CBN (2016) *"Nigeria Capacity Utilization 2009-2016, data, chart and calendar*. Retrieved January 16 2022, from http://www.tradingeconomics.com/analytics/ api.aspx.

Chaney, R. L. Malik, M. and Li Y. M (1997) Phytoremediation of soil metals. *Current Opinion in Biotechnology*, 8(3): 279–284.

Chaudhry, T.M., Hayes, W.J. Khan, A.G. and Khoo, C.S. (2008). Phytoremediation– focusing on accumulator plants that remediate metal contaminated soils. *Australasian Journal of Ecotoxicology*, **4**:37-51.

Chaney R. L. and Oliver D. P., (2016). *Sources, potential adverse effects and remediation of agricultural soil contaminants,* Kluwer Academic Publishers, 323–359 pp.

Ciriakova, A. (2019). Heavy metals in the vascular plants of Tatra Mountains. *Oecologia Montana,* **18**: 23-26.

Elijah, I. O. (2013). Scrap Iron and Steel Recycling in Nigeria. *Greener Journal of Environmental Management and Public Safety,* **2** (1): 1-9.

El-Sharabasy, H.M. and Ibrahim A. (2010). Communities of oribatid mites and heavy metal accumulation in oribatid species in agricultural soils in Egypt impacted by wastewater. *Plant Protection Sci*ence, **46**: 159- 170.

Ettler, V. and Kierczak, J., (2021): Environmental Impact of Slag Particulates. In Metallurgical Slags: Environmental Geochemistry and Resource Potential, ed. Piatak, N., Ettler, V., United Kingdom: The Royal Society of Chemistry, Cambridge. 174-193 pp.

Ettler, V. and Vítková, M. (2021). Slag leaching properties and release of contaminants. In: Metallurgical slags: Environmental geochemistry and resource potential. ed. Piatak, N., Ettler, V., The Royal Society of Chemistry, Cambridge. United Kingdom: The Royal Society of Chemistry, 151-173 pp.

Evanko, C. R., and Dzombak, D. A. (1997). Remediation of metals-contaminated soils and groundwater. Technology evaluation report. Ground-Water Remediation Technologies Analysis Center, Carnegie Mellon University, Pittsburgh.

Friedlova M., (2010) The influence of heavy metals on soil biological and chemical properties. *Soil and Water Research*, **5**(1):21–27.

Fan, S. F., Yu, D. and Liu, C. H. (2013). The invasive plant *Alternanthera philoxeroides* was suppressed more intensively than its native congener by a native generalist: implications for the biotic resistance hypothesis. *PLoS ONE*, 8.12:e83619. Retrieved Aug 28, 2021 from http://www.plosone.org/article/info%3Adoi%2 F10.1371%2Fjournal.pone.0083619

Florida Exotic Pest Plant Council, (2007). Invasive species list. Retrieved January 20, 2022 from: http://www.fleppc.org/index.cfm

Fountain, W. M. (2016). *Invasive Species: Understanding the Characteristics*. College of Agriculture Food and Environment, University of Kentucky, Academic Research Extension. Retrieved May 12, 2021 from https://ukntrees.ca.uky.edu/Treetalk/invasive-characteristics.

Friedlova M., (2010) The influence of heavy metals on soil biological and chemical properties. *Soil and Water Research*, **5**(1):21–27.

Gonzalez, R.C. and Gonzalez-Chavez, M.C.A. (2016). Metal accumulation in wild plants surrounding mining wastes". *Environmental Pollution,* **144**:84-92.

Ghrefat H. and Yusuf, N. (2006), Assessing Mn, Fe, Cu, Zn and Cd Pollution in Bottom Sediments of Wadi Al-Arab Dam, Jordan. *Chemosphere*, 65(11): 2114-2121.

Gunn, J. M. (2015). *Restoration and Recovery of an Industrial Region*. New York: Springer-Verlag. 19-25 pp.

Hall, J.L. (2012) "Cellular mechanisms for heavy metal detoxification and tolerance. *Journal of Experimental Botany,* **53**(366): 1-11.

Luxan, M.P., Sotolongo, R., Borrego, F. and Herrero E. (2010). Characteristics of the slags produced in the fusion of scrap steel by electric arc and furnace.

Cement and Concrete Research, **30**: 517-519.

Maestri, E. Marmiroli, M. Visioli, G. and Marmiroli, N. (2010). Metal tolerance and hyper-accumulation: Costs and trade-offs between traits and environment. *Environmental and Experimental Botany*, **68**:1-13.

Marques, A. P. G. C. Rangel, A. O. S. S. and Castro, P. M. L. (2009). Remediation of heavy metal contaminated soils: phytoremediation as a potentially promising clean-up technology. *Critical Reviews in Environmental Science and Technology*, 39(8) 622–654.

McLaughlin M. J., Zarcinas B. A., Stevens D. P., and Cook N., (2011). Soil testing for heavy metals, *Communications in Soil Science and Plant Analysis*, **31**(11–14):161–170

Meitzner, L.S. and Price, M.L. (2016). *Amaranth to zai holes: ideas for growing food under difficult conditions*. North Fort Myers, Florida, USA: ECHO, 52-60 pp.

Nazir, R., Khan, M. Muhammad, M. Hameed, U. R. Naveed U. R. Shahab, S. Nosheen, A. Muhammad, Sajed. Mohib, U. Muhammad R. and Zeenat S. (2015). Accumulation of Heavy Metals (Ni, Cu, Cd, Cr, Pb, Zn, Fe) in the soil, water and plants and analysis of physico-chemical parameters of soil and water Collected from Tanda Dam kohat. *Journal of Pharmaceutical Sciences and Research*, **7**(3):89-97

O'Connor, J. Nguyen, T.B.T. Honeyands, T. Monaghan, B. O'Dea, D. Rinklebe, J. Vinu, A. Hoang, Son A. Singh, G. Kirkham, M.B. and Bolan, N. (2019). "Production, characterization, utilization, and beneficial soil application of steel slag: A review". *Journal of Hazardous Materials.* **419**: 126-128.

Ogundiran, M. and Osibanjo, O. (2018). "Heavy metal concentrations in soils and accumulation in plants growing in a deserted slag dumpsite in Nigeria". *African Journal of Biotechnology*, **7**(17):3053-3060.

Omoregie G. O. Ikhajiagbe B. and Anoliefo Geoffery O. (2019). Phytoremediation Potential of Four Heavy Metals in Soil by *Chromolaena odorata* (L.) King & Robinson at the Phytotoxicity Screening Benchmarks. *Tanzania Journal of Science*, 45(3): 372-381.

Onder, S. Dursun, S. Gezgin, S. and Demirbas E. (2007) Determination of heavy metals pollution in Grass and soil of city centre Green Area (Konya Turkey). *Poland Journal of Environmental studies*, **1**:145-154.

PIER, 2013. *Megathyrsus maximus*. Pacific Islands Ecosystems at Risk., Honolulu, Hawaii, USA: HEAR, University of Hawaii. http://www.hear.org/pier/index.html

Potysz, A., Kierczak, J., Grybos, M., Pędziwiatr, A., van Hullebusch, (2018). Weathering of historical copper slags in dynamic experimental system with rhizosphere-like organic acids. Journal of Environmental Management 222, pp. 325-337.Reichard, S. H. and White, P. 2001. Horticulture as a Pathway of Invasive Plant Introductions in the United States. *BioScience*, 51.2: 103–113.

Slaveykova V. I. and Cheloni G. (2018). Preface: special issue on environmental toxicology of trace metals, *Environments*, **5**(12):138-140.

Turkdogan M.K. Fevzi, K. Kazim, K. Ilyas, T. and Ismail U. (2013). ―Heavy metals in soil, vegetables and fruits in the endemic upper gastrointestinal cancer region. *Environmental Toxicology and Pharmacology*, **13**:175-179

Ukpebor, E.E. and Unuigbe, C.A. (2013). "Heavy metals concentration in the subsoil of refuse dump sites in Benin City, Nigeria". *Ghana Journal of Science*, **43**: 9-15.

Uzondu J (2012). ―The thriving scraps metal business. *International Journal of Environmental Science and Development*, **4**(1):90–97.

Uyi, O. O., Egbon, I. N., Igbinosa, I. B., Adebayo, R. A., Oigiangbe, O. N. (2013) *Chromolaena odorata* in Nigeria: extent of spread, problems and control. In: Zachariades C, Strathie LW, Day MD, Muniappan R (eds), Proceedings of the Eighth International Workshop on Biological Control and Management of *Chromolaena odorata* and other Eupatorieae, Nairobi, Kenya, 1-2 November 2010. ARCPPRI, Pretoria, pp 43

WHO (1996) World Health Organization. Switzerland: Geneva;. Trace Elements in Human Nutrition and Health.

Vesk, P. and Reichman, S. (2019). Hyperaccumulators and herbivores- a *bayesian metaanalysis* of feeding choice trials. *Journal of Chemical Ecology*, **35**:289-296.

Wang, Y. Qiao, M. Liu, Y. and Zhu Y. (2017). ―Health risk assessment of heavy metals in soils and vegetables from wastewater irrigated area. *Journal of Environmental Science,* **24** (4):690-698

Zheng, N. Wang, Q. Zhang, X. Zheng, D. Zhang, Z. and Zhang, S. (2017). Population health risk due to dietary intake of heavy metals in the industrial area of Huludao city, China. *Science of Total Environmental,* **387**:96–104.

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OCCURRENCE AND SPATIAL DISTRIBUTION OF *Irvingia gabonensis* (Aubry-LeComte ex O'Rorke) Baill. IN CROSS RIVER STATE, NIGERIA USING MAXENT MODEL

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ABSTRACT

African bush mango (Irvingia gabonensis (Aubry-LeComte ex O'Rorke) Baill.) is a multi-use species whose edible seeds are commonly used as a soup delicacy across Cross River State, Nigeria. In recent years, there has been growing concern on the effects of global climate change on species and habitats. Knowledge of the spatial and temporal distribution of a species is key to evaluating extinction risks and forecasting possible future threats from factors such as climate change. This study surveyed and documented the occurrence of I. gabonensis using Global Positioning System (GPS) software in 36 forested areas comprising northern, central and southern zones of Cross River State, Nigeria. MaxEnt was used to model the spatial distribution of I. gabonensis at present and in the future under Representative Concentration Pathways (RCP) 8.5 horizon 2070 using 15 Bioclim variables. The performance of the model was evaluated by the area under the receiver operating characteristics (ROC) curve and its related area under curve (AUC), the percentage contribution table of variables and the jackknife charts (Regularized training gain, test gain and AUC) and true skill statistics (TSS). MaxEnt results showed that four Bioclim variables; Bio 6 (Minimum temperature of coldest month), Bio 12 (Annual precipitation), Bio 13 (Precipitation of the coldest month) and Bio 14 (Precipitation of the driest month) were retained as the most important variables contributing to the spatial distribution of the species. Currently, 94.84% of Cross River State is suitable habitat for I. gabonensis, with future projections showing a significant decrease of 79.64% in the suitability of habitats. The suitable habitats (20.36%) fall under few protected areas and are the only areas that will conserve the species. The results obtained highlight the need to protect the species against overexploitation and climate change to minimize the risk of driving into extinction.

Key words: *Irvingia gabonensis, occurrence, climate change, environmental variables, MaxEnt model, Cross River State*

INTRODUCTION

According to Araujo *et al.*, (2011) in recent years, there has been a growing attention from the research community to the effects of global climate change on species and habitats. Bellard *et al.*, (2012) and Mori *et al.*, (2013) reported that climate change has exerted significant biological, spatial and temporal effects on terrestrial habitats. In 2007, the Intergovernmental Panel on Climate Change (IPCC) reported that even in the most optimistic scenario, the past decades' trend of rising carbon dioxide in the atmosphere will continue for several decades, and this is expected to have major effects on animal and plant species (Ferrarini *et al.*, 2014). Also, in recent years, easy access to climate and species distribution data has simplified the use of Ecological Niche Models (ENMs) in ecology research. These models relate the environmental parameters to the presence or absence of plant-animal species by the use of quantitative equations, which are then used to predict the species distribution in sampled or un-sampled areas, the environmental changes and the resulting ecological consequences (Guisan and Zimmermann, 2000; Miller and Rogan, 2007; Elith and Leathwick, 2009; Franklin, 2010). Among several programs for ecological niche modeling and habitat suitability prediction, MaxEnt is one of the most used with respect to the type of data used in this study, species presence-only data. This modeling tool using presence-only data is one of the best performing algorithms among those using climate modeling approaches (Phillips *et al.,* 2006), and is relatively robust for small sample sizes (Pearson *et al.,* 2007). MaxEnt is a machine learning method that estimates species distribution across a study area by calculating the distribution probability of maximum entropy, subject to the constraint that the expected value of each feature under this estimated distribution should match its empirical average (Phillips *et al.*, 2006).

The application of ENMs such as MaxEnt in biodiversity research is well known for some plant species in Europe, America, Middle East and Asia and in West Africa, mostly in Benin Republic. Some of these studies include those of Shivaprakash *et al.*, (2013), Jagadish *et al.,* (2015), Yu-jun *et al.,* (2016), Carvalho *et al.,* (2017), Javad *et al.,* (2018) and in West Africa particularly Benin Republic; Moutouama *et al.,* (2016), Ganglo *et al.,* (2017) and Kakpo *et al.,* (2019). These studies show the usefulness of ENMs approach in providing information that can drive strategies to conserve species, communities, biomes, and biodiversity as a whole at national, regional or more global scales.

Irvingia gabonensis (Aubry-LeComte ex O'Rorke) Baill is a tree species belonging to the family Irvingiaceae and grows to between 30 - 50 m in height. It is indigenous to the humid forest zone of the Gulf of Guinea from Western Nigeria to the Central African Republic and South to Angola and westernmost part of DR Congo; it also occurs in Sao Tome and Principe (Orwa *et al.,* 2009). Its preferred habitat is moist lowland tropical forest below 1000 m altitude and with annual rainfall of 1500 - 3000 mm and mean annual temperature of 25 - 32˚C (Ude *et al.,* 2006). The fruits are eaten as a good source of vitamin in Cross River State besides its economic value as a source of income (Ude *et al.,* 2006). This research provides primary occurrence data for *I. gabonensis* in Cross River State, Nigeria and assesses the current and future spatial distribution of the tree species using MaxEnt (Maximum Entropy Species Distribution Model) for effective management, sustainable use and conservation.

MATERIALS AND METHODS

Study area

The Study was carried out in Cross River State, a coastal state located in Southern Nigeria and named after the Cross River, which flows through the state. The land mass of the State is approximately 20,156 square kilometres. The Cross River State shares boundaries with Benue State to the north, Enugu and Abia States to the west, Cameroon Republic to the east and Akwa Ibom and the Atlantic Ocean to the south (Fig. 1a). The State lies between, latitude 5° 45′N and 6˚ 10˙N and on longitude 8° 30′E and 8˚ 39˙E (Aju and Ezeibekwe, 2010). The study was carried out in thirty-six (36) communities, selected on the basis of their forested areas, located in the Northern, Central and Southern Senatorial Districts of Cross River State, Nigeria (Figure 1b). An eighteen (18) month study to generate field data was undertaken between April 2019 and October 2020. The elevation of the study area ranges between 140 m to 400 m above sea level. The area has a tropical climate with an average annual rainfall of 1250 mm – 2300 mm. The wet or rainy season lasts for approximately seven months. The zone normally experiences a wet climate, and diurnal temperature variations are well marked throughout the year. Two seasons are discernible in the year; the dry season occurring between November and March, and the rainy season which begins in March, reaching its maximum in July and September (FME, 2006). The temperature is high all year round with only small variations. The proximity of the Atlantic Ocean has a moderating effect on temperature with highest average daily maximum of 35 °C and recorded mean actual temperature of 26 °C. The relative humidity is about 80- 90 per cent (NIMET, 2015). The topography is highly undulating and with soils that are generally deep, porous and weakly structured and well drained soils with low to moderate status (NIMET, 2015). The vegetation of the area is a mixture of mangrove, rainforest and savannah. The rainforest is further subdivided into the lowland rainforest and the freshwater swamp forest (Edet *et al.,* 2012).

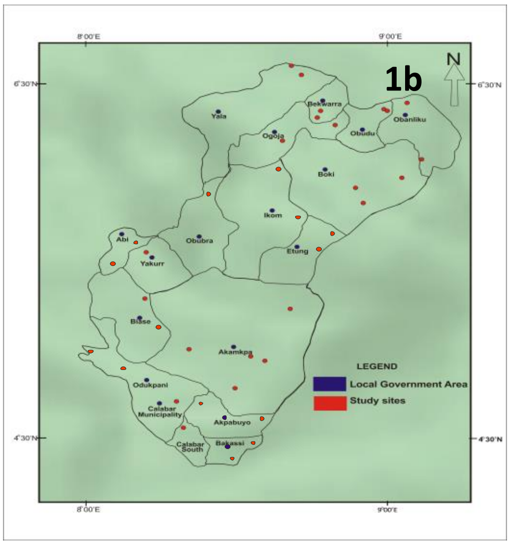

Figure 1a: Location of Cross River State on the geographical map of Nigeria
Figure 1b: Map of Cross River State showing study sites (from data generated during field work)

Occurrence

The coordinates (latitude and longitude) of *Irvingia gabonensis* present in the sampled plots in each study site was recorded using Global Positioning System (GPS) software (GARMIN GPS MAP 78 sc). Furthermore, we authenticated each coordinate and converted it to obtain the decimal latitude and decimal longitude using the site www.gps-coordinates.net. The species name, decimal latitude and decimal longitude of *I. gabonensis* was compiled on Microsoft Excel spreadsheet and saved as a .csv (comma separated value) file and used for Ecological Niche Modelling (Philips *et al.*, 2006) as the maxEnt model only recognizes a .csv file. The final dataset of georeferenced records of *I. gabonensis* was further cleaned using Quantum Geographic Information System (QGIS) software ver. QGIS-OSGeo4W-2.18.1 to eliminate occurrences or coordinates that fell outside the training region.

Impact of climate change evaluation

The impact of climate change on the spatial distribution of *I. gabonensis* in the study area at present and in the future was predicted using the Bioclim variables, Quantum Geographic Information System (QGIS) software ver. QGIS-OSGeo4W-2.18.1 and Ecological Niche Modelling software MaxEnt (Maximum entropy modelling of species geographic distributions ver. Jre-8u191-windows).

Environmental variables (BIOCLIM) used for running MaxEnt model

In this study, we used fifteen (15) substantial bioclimatic variables for forest tree habitat in Africa and Nigeria selected from the WorldClim database (http://www.world clim.org/bioclim – Hijmans *et al.*, 2005). These variables have been derived from monthly temperature and precipitation parameters over the period of 1950-2000 and are closely associated with growth and development of species, thus they are widely used in the assessment of species distribution (Elith *et al.*, 2006, Graham *et al.*, 2008, Warren *et al.*, 2013). Climate data used for prediction (Future_2070_rcp85_bis) was collected from AfriClim database available from the Coupled Model Inter comparison Project Phase 5 (CMIP5) of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment for the years 2070 (average of 2061-2080 period). These data have been predicted using 15 General Concentration Models (GCM) under four greenhouse gas concentration scenarios known as Representative Concentration Pathways (RCPs). According to van Vuuren *et al.*, (2011) RCPs are third generation scenarios and are preferred to the Special Report on Emissions Scenarios (SRES) because they allow more flexibility and reduced costs in modelling processes. Also, RCPs imply collaboration between impacts, adaptation and vulnerability research, and climate and integrated assessment modelling (van Vuuren and Carter, 2014). RCPs scenarios have been developed to explore different combinations of scenario context (demographic, socioeconomic, land use and technology) (Moss *et al.,* 2010). The 15 bioclim variables we used in this study and their keys are presented in Table 1.

Table 1: Bioclimate variables used for running MaxEnt model

S/N	Code	Environmental variables	Unit
1.	BIO1	Annual Mean Temperature	˚C
2.	BIO2	Mean Diurnal Range (Mean of monthly (max temp – min temp)	˚C
3.	BIO3	Isothermality (BIO2/BIO7) (* 100)	-
4.	BIO4	Temperature Seasonality (standard deviation *100)	CV
5.	BIO5	Max Temperature of Warmest Month	˚C
6.	BIO6	Min Temperature of Coldest Month	˚C
7.	BIO7	Temperature Annual Range (BIO5-BIO6)	˚C
8.	BIO10	Mean Temperature of Warmest Quarter	˚C
9.	BIO11	Mean Temperature of Coldest Quarter	˚C
10.	BIO12	Annual Precipitation	mm
11.	BIO13	Precipitation of Wettest Month	mm
12.	BIO14	Precipitation of Driest Month	mm
13.	BIO15	Precipitation Seasonality (Coefficient of variation)	CV
14.	BIO16	Precipitation of Wettest Quarter	mm
15.	BIO17	Precipitation of Driest Quarter	mm

Source: World Climate Database

MaxEnt model calibration

We processed the environmental data for modelling by calibrating environmental layers to Africa and Nigeria using QGIS software (Philips *et al.,* 2006). The environmental layers or Bioclim variables BIO1 - 7 and 10 - 17 (which are Raster files) were loaded on QGIS (Nigeria_disc_shape) one after the other and the occurrence data of the *I. gabonensis* (computed on Microsoft Excel spreadsheet and saved as .csv file) was clipped on the environmental layers and saved as Geo. Tif file. The points of occurrence of the tree species was trimmed to create a polygon shape file using the default value 1 as regularization multiplier (beta value) and saved. We further converted the raster layers saved as .tif format to ascii format using QGIS before they were used to run the MaxEnt model.

MaxEnt model evaluation

MaxEnt uses presence data only by generating random test points. For this analysis, we used the suggested default settings which have been shown to yield robust results as reported by Phillips and Dudik (2008). Maximum iteration was set at 1000, number of replications was set at 10 and the model was evaluated by using the area under the receiver operating characteristic (ROC) curve (Peterson *et al.,* 2008) and its related Area Under Curve (AUC) (Elith *et al.,* 2006), the percentage contribution table of variables and the jackknife charts (Regularized training gain, test gain and AUC) were taken into account to judge the most important contributing variables to the model (Phillips and Dudik 2008). The regularized training gain is used as an index of model fit. The Regularized training gain is a measure of the distance between a multivariate distribution of covariates at randomly selected background sites (i.e., a random sample of the entire landscape that a species could potentially inhabit) and a corresponding distribution of covariates at sites of known species occurrences (Elith *et al.,* 2011). Hence, a large regularized training gain (RTG ≥ 1) indicates an affinity for a narrow range of environmental conditions, relative to the broader landscape, while a small training gain (RTG ≤ 1) suggests a lack of specialized habitat requirements (i.e., the distribution of covariates at occurrence sites mirrors the background distribution; Merow *et al.,* 2013). The test gain is in general an indication of how much better-than-random the model fit is. A high gain ≥ 1for a particular variable therefore means that variable has a greater predictive value. The high gain means that these variables are good predicators for where the species can survive and is biologically meaningful (Elith *et al.,* 2006). The AUC is a probability that a randomly chosen presence point of species will be ranked as more suitable than a randomly chosen absence point (Elith *et al.,* 2006). A model is considered as having a good fit when its AUC is close to 1 (AUC ≥ 0.75) (Elith *et al.,* 2006). Furthermore, the performance of the model was assessed using true skill statistic (TSS) (Allouche *et al.,* 2006; Elith *et al.,* 2006). The TSS is the capacity of the model to accurately detect true presences and true absences. A model with TSS ≤ 0 indicates a random prediction; while one with a TSS close to 1(TSS > 0.5) has a good predictive power (Allouche *et al.,* 2006). To generate the final maps and response curves, the model was run using all data points, i.e., including the test data and run 50 times with bootstrapping as the replicated run type. The remaining options were set to default. While generating response curves, the MaxEnt model estimates the relative effect of each predictor (Khanum *et al.,* 2013). Species presence potential was classified using two probability classes; suitable and unsuitable (Kakpo *et al.,* 2019). To post-process the MaxEnt TSS (validate the model) we used the TSS Excel sheet.

Projection of MaxEnt model

To project the MaxEnt model for *I. gabonensis* we generated another niche model which was projected into climate conditions for the year 2070 (Philips *et al.,* 2006) modelled using the Africlimate ensemble model under the Representative Concentration Pathway RCP 8.5 climate scenario (Future_2070_rcp 85).

RESULTS

Occurrence

A total number of 190 occurrence points for *I. gabonensis* was recorded from the field and used in this study. The coordinates; decimal latitude (˚N) and longitude (˚E) of *I. gabonensis* were recorded in the Northern, Central and Southern geographical zones of Cross River State.

Model validation

The results of Model evaluations indicate its robustness. The average training Area Under Curve (AUC) for the 10 bootstrap replicate runs for was AUC = 0.944 for *Irvingia gabonensis* (O’Rorke) Baill. (Figure 2). The True skill statistics (TSS) value was 0.87 (Figure 3). Therefore, the model showed excellent performance and had a good predictive ability and performed better than random.

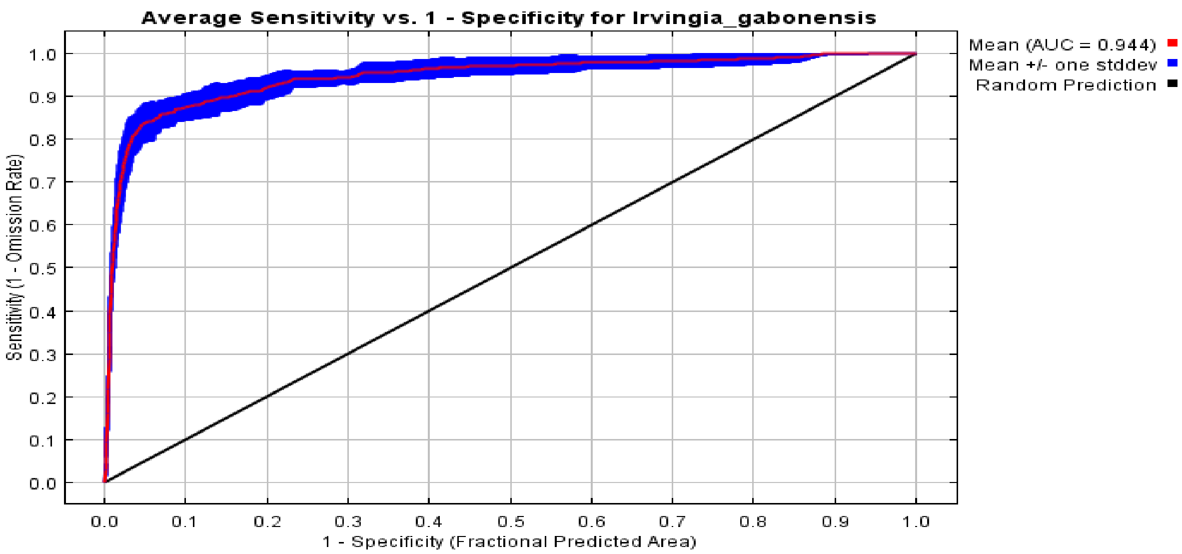

Figure 2: Average Receiver Operating Characteristic (ROC) and related AreaUnder Curve (AUC) for 10 bootstrap replicates using the MaxEnt model for *Irvingia gabonensis*

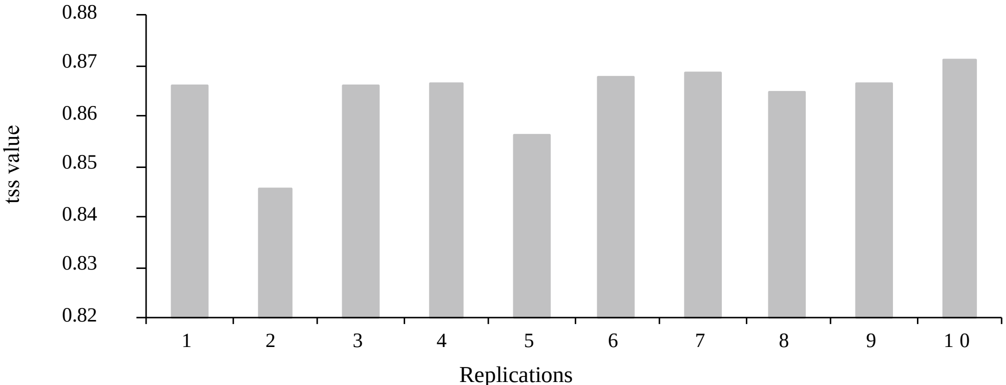

Figure 3: True skill statistics (TSS) value for 10 replicates using the MaxEnt model for *Irvingia gabonensis*

Environmental variables controlling the spatial distribution of *Irvingia gabonensis* across Cross River State

In this study, the Jackknife tests of variable importance (Figure 4A, B and C) and the table of variable contributions (percentage contribution and permutation importance) Table 2: This measure depends only on the final MaxEnt model, not the path used to obtain it. The contribution for each variable is determined by randomly permuting the values of that variable among the training points (both presence and background) and measuring the resulting decrease in training AUC. A large decrease indicates that the model depends heavily on that variable. Variables are normalized to give percentages. Table 3 helped to identify four environmental variables as contributing most to the spatial distribution of *I. gabonensis* across Cross River State, respectively. These are bio 6 (minimum temperature of coldest month), bio 12 (Annual precipitation), bio 13 (precipitation of wettest month) and bio 14 (precipitation of driest month). The Jackknife test of variable importance showed that leaving out any of these four variables did not allow for optimization of the training gain, AUC and test gain levels relative to using the whole set of variables. Consistent with the Jackknife tests, the table of variable importance for *I. gabonensis* (Table 3) shows that bio 13 (precipitation of the wettest month) was the most important contributing variable among the four variables retained in the model. Bio 14 (Precipitation of the driest month) decreased the gain the most when omitted and appears to be the most informative variable of the model.

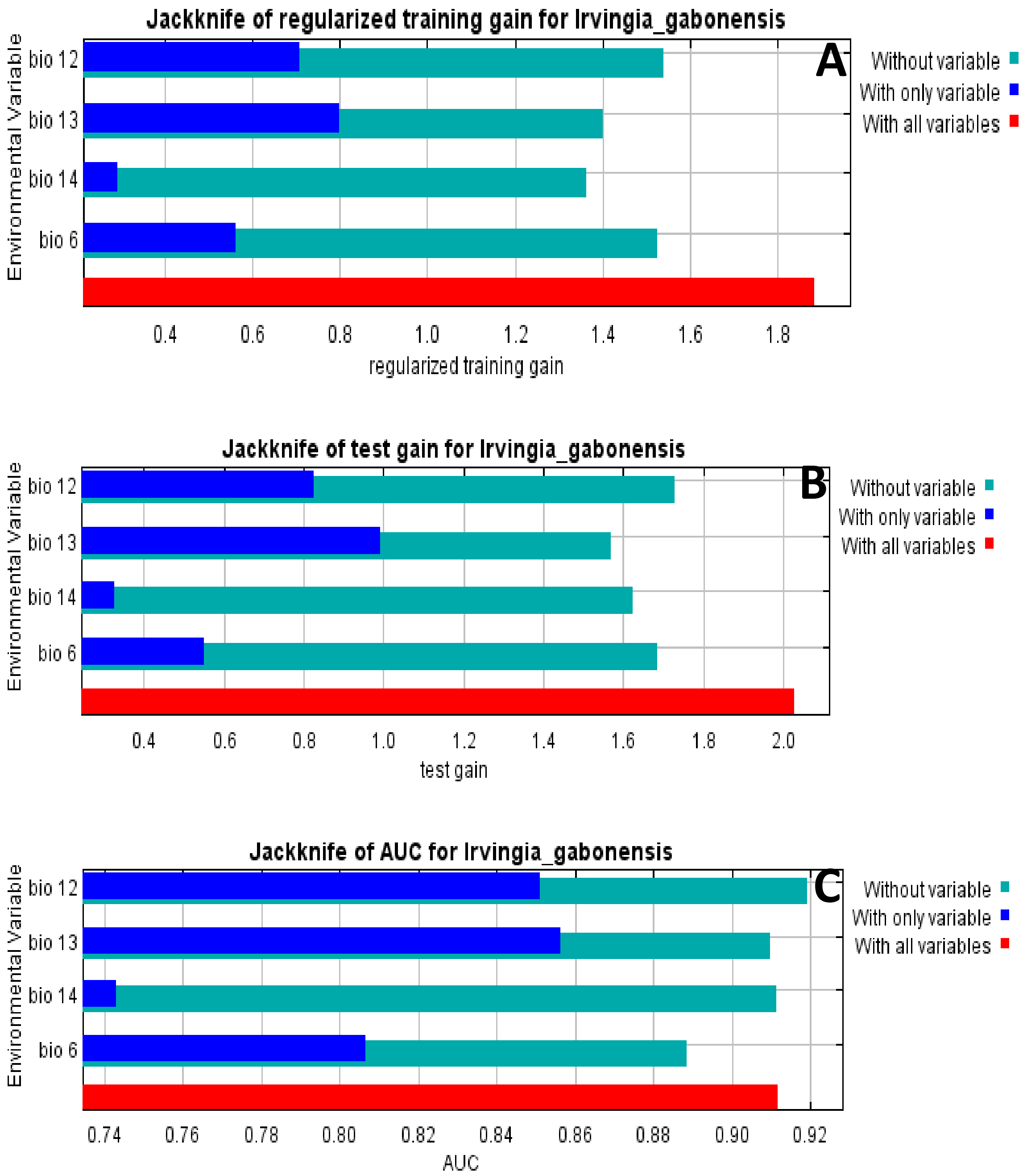

Figure 4: Jackknife tests of variable importance. A) with regularized training gain; B) with test gain; C) with AUC for *Irvingia gabonensis*

Table 2: Percentage contribution and permutation importance of the variables for *Irvingia gabonensis*

Variable	Percent contribution	Permutation importance
bio 13	32.4	22.5
bio 14	24.9	42.1
bio 12	24.4	3.1
bio 6	18.3	32.3

Note: bio 6 (Minimum temperature of coldest month), bio 12 (Annual precipitation), bio 13 (Precipitation of wettest month), bio 14 (precipitation of driest month)

The response curves of these variables to the suitability prediction of the species are presented in Figure 5A, B, C and D for *I. gabonensis*. Bio 6 (Figure 5A) clearly shows the responsiveness of the species to minimum temperature of coldest month variability relative to that of the year. Consistent with the ecology of the species; the logistic prediction shows slight increase in response output from a minimum temperature of 0˚C to 12˚C and rising sharply thereafter and optimizing at 25˚C. The curve for bio 6 therefore, suggests that the limit of low temperature tolerance for the species during the coldest months is between 12 - 25˚C. The response curve of the species to bio 12 (Figure 5B) (annual precipitation) is also consistent with its ecology as indicated in values of precipitation of 1000 mm and above as optimal values for the species high suitability prediction. However, response output drops remarkably in extremely wet weather (annual precipitation greater than 3000mm) (Figure 5B). The response of the species to Bio 13 (Figure 5C) (precipitation of wettest month) shows a good output response with increase of precipitation from 0 to 600 mm and then a sharp decline after the suitability threshold of about 600 mm. The response curve of the species to bio 14 (Figure 5D) (precipitation of driest month) shows good output response from 0 to 60 mm and then a sharp decline after the suitability threshold of 60 mm. The result of the response curves of *I. gabonenesis* further shows that the species is exposed to dry and rainy seasons in its natural habitat.

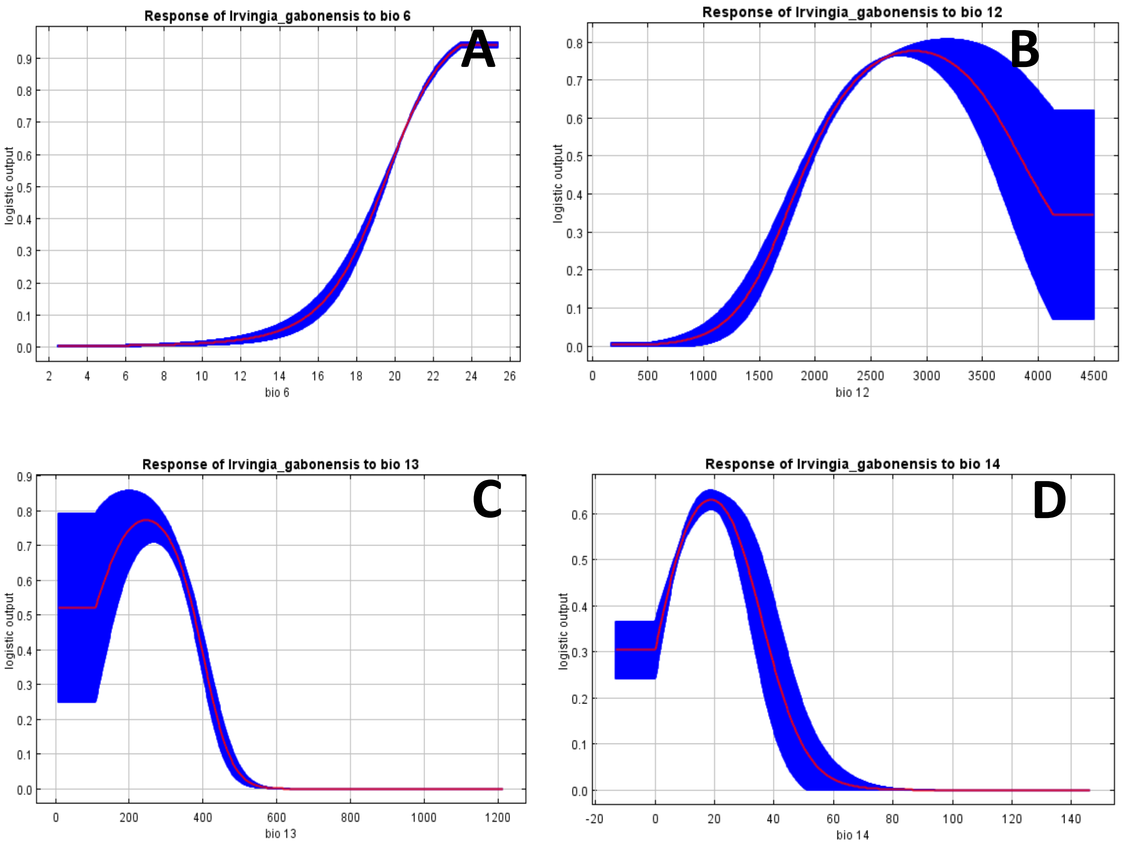

Figure 5: Response curves of most contributing variable to the growth of *I. gabonensis* A) bio 6 (Minimum temperature of coldest month); B) bio 12 (Annual precipitation); C) bio 13 (Precipitation of wettest month); D) bio 14 (precipitation of driest month)

Spatial distribution of *Irvingia gabonensis* at present and future across Cross River State

The analysis of impact of climate on spatial distribution of the species reveals that 19, 116 km^2 corresponding to 94.84% of the study area (20, 156 km2) are presently suitable habitats for the distribution of *I. gabonensis* (Table 3). Presently, the tree species is spatially distributed across the guinea savannah and forest zones of Northern, Central and Southern geographical zones of Cross River State. On the basis of data generated from field studies, the current spatial distribution of *I. gabonensis* in Cross River State is as presented in (Figure 6a).

Model projections into the future under AfriClim RCP 8.5 scenarios 2070 show a significant decrease in the area of suitable habitats to 4, 104 km^2 corresponding to 20.36% of the present area of suitable habitats (20, 156 km^2) for *I. gabonensis* in the Northern, Central and Southern zones of Cross River State (Table 3). The suitable areas fall under a few protected areas (Afi Mountain Wildlife Sanctuary and Cross River National Park, Okwangwo and Oban Divisions) and are the only areas that will remain suitable habitats for the species. The projected spatial distributions of *I. gabonemsis* for AfriClim RCP 8.5 2070 scenario in Cross River State is presented in (Figure 6b).

Table 3: Impact of climate change on the spatial distribution of *Irvingia gabonensis* at present and in the future across Cross River State

Suitability	Present		AfriClim RCP 8.5	
	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)
Suitable	19, 116	94.84	4, 104	20.36
Unsuitable	1, 040	5.16	16, 052	79.64
Total	20, 156		20, 156	

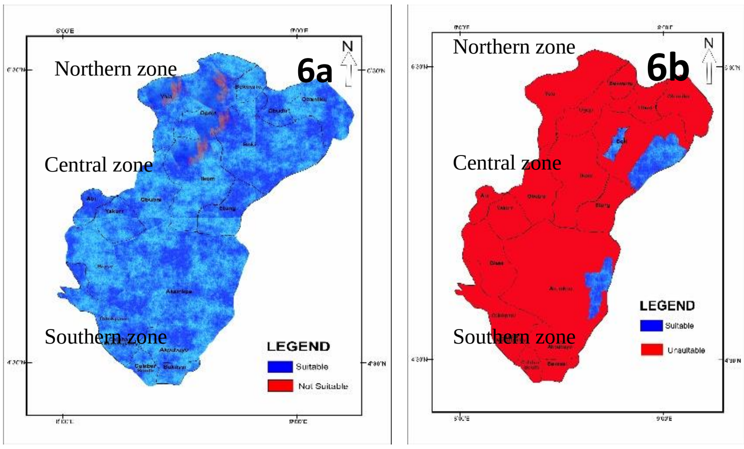

Figure 6a and 6b: Spatial distribution of *Irvingia gabonensis* at present and future under Africlim RCP 8.5 2070 scenario across Cross River State

DISCUSSION

Occurrence

In this study, the 190 occurrence datasets of *Irvingia gabonensis* (O'Rorke) Baill. recorded in the northern, central and southern zone of Cross River State showed that the species had a wide distribution across the study area. This observation is in agreement with other reports of tropical forest ecosystems in Nigeria (Edet *et al.,* 2012; Adekunle *et al.,* 2013; Adeyemi *et.,* 2013; Aigbe *et al.,* 2014; Adeyemi *et al.,* 2015; Ikyaagba *et al.,* 2015; Ogunjemite, 2015; Sanwo *et al.*, 2015; Aigbe and Omokhua, 2015; Akwaji and Edu, 2017). The wide distribution of this species in the study area is not surprising because the tree play a significant role in the cultural and socio-economic life of the people. The trees are valued by the local inhabitants because of their role in soil improvement and conservation, feeds for animals, medicinal and economic value (Akwaji and Edu, 2017) and as a result, they are generally spared from felling. Attua and Pabi (2013) and Wakawa *et al.,* (2017) made a similar report when they carried out tree assessment in forest and guinea savannah ecosystems, respectively. The wide distribution of this species in the study area may also be as a result of adaptation of the species to the area, the favorable microclimate within the forests, the availability of viable seeds of the trees to sustain regeneration. Olajide (2004) and

Christie and Armesto (2003) reported that the abundance or rarity of a timber tree species of economic value in an area of rainforest is a function of intensity or pattern of its exploitation. The wide occurrence of the tree species is to be expected since Cross River State has high number of protected areas and reserves and which are under protection by law.

Model validation

In light of global climate changes, it is essential to identify species with high risk of extinction and to diagnose risk driver factors to reverse the decline of biodiversity (Darrah *et al.*, 2017). Information on changes to species ecological niche is important for assessing species geographic range and their realized niche (Breiner *et al.,* 2017). In this study, the performance of the MaxEnt model was assessed using the Area under the Receiver Operating Characteristic Curve (AUC) (Elith *et al.,* 2006), true skill statistic (TSS) (Allouche *et al.,* 2006; Elith *et al.,* 2006) and Receiver Operating Characteristic (ROC) (Peterson *et al.*, 2008). Model evaluations indicate that the model is robust with an AUC and TSS value of 0.944 and 0.87, respectively. Therefore, the model showed excellent performance and had a good predictive ability. Similar findings of a robust MaxEnt model with high AUC and TSS values for various tree species have been reported; 0.979 and 0.86 respectively for *Milicia excelsa* in Benin, West Afirca (Kakpo *et al.,* 2019), 0.948 and 0.78 for *Juniperus excelsa* in Central and Eastern Alborz Mountains, Iran (Fatemi *et al.*, 2018), 0.819 and 0.867 and 0.72 and 0.78 for *Lonchocarpus sericeus* and *Anogeissus leiocarpa* in Benin, West Africa (Gbetoho *et al.,* 2017), 0.895 and 0.79 for *Dialium guineense* in Benin and other West African countries (Ganglo *et al.,* 2017), 0.899 and 0.79 for endangered medicinal plant (*Homonoia riparia* Lour) in Yunnan, China (Yu-jun *et al.,* 2016), 0.91 and 0.82 for *Syzygium caryophyllum* in Western Ghats, India (Stalin and Swamy, 2015). Also, in the present study variables such as temperature and precipitation were considered. According to Guisan and Zimmermann (2000), direct parameters such as temperature and precipitation are more efficient when the modelling is over large areas. This is contrary to indirect parameters which are not more efficient but are more inclined to introduce errors into the model.

Environmental variables controlling the spatial distribution of *Irvingia gabonensis* across Cross River State

The distribution of a plant species in a geographic space is determined by complex interactions of biotic and abiotic factors. These factors include climate, soil characteristics, inter- and intra-specific competition, anthropic disturbances, and dispersal limitation (Blach-Overgaad *et al.,* 2010). The environmental factors are the main determinants of the living conditions of the species, while dispersal limitations and biotic interactions may further modify the distribution (Soberón and Peterson, 2005). Good knowledge of the environmental requirements of a species is therefore important to assess the broad geographic space where it could survive and its potential response to climate change for conservation and management purposes (Bowe and Haq, 2010). *Irvingia gabonensis* is indigenous to the humid forest zone of the Gulf of Guinea from Western Nigeria to the Central African Republic and South to Angola and westernmost part of DR Congo; it also occurs in Sao Tome and Principe (Orwa *et al.,* 2009a). Its preferred habitat is moist lowland tropical forest below 1000 m altitude and with annual rainfall of 1500 - 3000 mm and mean annual temperature of 25 - 32˚C (Ude *et al.*, 2006). In this study, the Jackknife tests of variable importance (Figure 4) and the table of variable contributions (Table 3) helped to identify four environmental variables as contributing most to the spatial distribution of *I. gabonensis* across Cross River State. These are bio 6 (minimum temperature of coldest month), bio 12 (Annual precipitation), bio 13 (precipitation of wettest month) and bio 14 (precipitation of driest month). The finding of this study is therefore reliable with regards to the ecology of the species. Indeed, the annual precipitation (bio 12) and its variations bio 13 (precipitation of wettest month) and bio 14 (precipitation of driest month) are among the most contributing variables to the prediction model of the spatial distribution of the species. At a large scale, the distribution of a species depends mainly on climate (Vayreda *et al.,* 2013), especially on factors related to water (Svenning and Skov, 2006). Annual precipitation (bio 12) is a measure of the variation in yearly precipitations over the course of the year (O'Donnell and Ignizio, 2012). According to the model, Annual precipitation of 1000 - 2700 mm was found to be suitable for the spatial distribution of *I.*

gabonensis across the study area which is also consistent with the ecology of the species. Water has many functions in the plants and is found to impact the distribution patterns of species at finer scales (Willis and Whittaker, 2002) as compared to global scales. It is a solvent for mineral nutrients and the complex organic matters produced within the plant; it also acts as a temperature regulator during the process of plant transpiration and serves as raw material in the process of photosynthesis which is the basic process underlying all life (Ganglo *et al.,* 2017). Plants can be stressed by lack of moisture as well as an excess of moisture (Ganglo *et al.,* 2017). Because of those important functions, the presence of water in the environment of plants is quite important.

The response of the species to the annual variations of precipitation bio 13 (precipitation of wettest month) and bio 14 (precipitation of driest month) in the study area futher suggest that both species are exposed to dry and rainy seasons in their natural range as the two species are common in primary and secondary forest and guinea savannah (Orwa *et al.,* 2009). Although annual mean temperature (bio 1) was not among the most important contributors to the distribution model of *I. gabonensis*, its variation in terms of minimum temperature of coldest month (bio 6) proved to significantly control the spatial distribution of the species. It is important to emphasize here that the rate of plant growth and development is controlled by its surrounding temperature and each plant has a specific temperature range characterized by a minimum, maximum and optimum (Hatfield and Prueger, 2015). Minimum temperature of the coldest month (bio 6) quantifies the coldest month with the lowest average low temperature with temperature of 21.7˚C (O'Donnell and Ignizio, 2012). The logistic prediction of the response curve shows increase in minimum temperature from 0˚C which rises through 12˚C and stabilizes at 25˚C for *I. gabonensis*. The response curve for bio 6 therefore, confirms that the minimum temperature of coldest month suitable for the spatial distribution of the species is 25˚C which again is consistent with the ecology of the species. According to Hatfield and Prueger (2015), vegetative development increases as temperature rises to the species optimum level and for most plant species vegetative development usually has a higher optimum rate than for the reproductive development. In light of their findings it can be understood that large variations of temperature (high value of bio 6) can affect the optimum temperature of *I. gabonensis* and then impact on the distribution and development both at vegetative and reproductive phases. It can therefore be deduced that the maximum value of bio 6 beyond which the distribution of *I. gabonensis* and *P. macrophylla* can be negatively impacted is 25 ˚C. The generalization of a model depends on the choice of the variables used to run it (Elith *et al.,* 2011). In this study, the variable bio 6 measured availability and variability of light and heat to the species while bio 12, 13 and bio 14, respectively measured the availability and variability of water for *I. gabonensis*. As those variables controlling the spatial distribution of the species are fundamental primary conditions, the models can be generalized to regions outside the study area and serve the purpose of species management in such regions (Elith *et al.,* 2011).

Spatial distribution of *Irvingia gabonensis* at present and future across Cross River State

Predicted changes in species distributions due to global changes, using climatic models with specific algorithms as MaxEnt, have been widely demonstrated (Svenning and Skov, 2006). When climate and habitat variables are used, then the fundamental niche is modelled and the result projected in a geographical space corresponds to the potential distribution (Pearson *et al.*, 2007). The fundamental niche is defined by Hutchison (1957) as the full range of environmental conditions where the species can survive and reproduce without migration. When the biotic interactions and spatial constraints were added to the variables, then the occupied niche was modelled, and this corresponds to the actual distribution in a geographical space (Pearson and Dawson, 2003). Fundamental niche and potential distributions are convenient when the purpose of the modelling is introduced, as it represents the global cultivation potential (Cuni-Sanchez *et al.*, 2010). Therefore, assessing the potential distribution of the species in this study is relevant to support ecological restoration. The AUC and TSS values showed that the models had good predictive power and could be used to predict the distributions of the species under present and future scenarios. Moreover, the response curves are relatively smooth and the model could therefore be well projected in the future. In this study, 19,116 km^2 corresponding to 94.84% of the study area (20,156 km^2) are presently suitable habitats to *I. gabonensis*.

The tree species is currently distributed across the guinea savannah and forest zones of Northern, Central and Southern zones of the study area (Figure 6a). In each zone of the study area, at least one protected area is located in a suitable habitat of the tree species. In the Northern zone, there is the Becheve Forest Reserve. In the Central zone, they are the Afi Mountain and Wildlife Sanctuary and Cross River National Park, Okwangwo Division. In the Southern zone, they are the Cross River National Park, Oban Division and Oban Forest Reserve. Therefore, the protected area network of Cross River State conserves the tree species. In a similar study using MaxEnt model to predict current scenario: Kakpo *et al.,* (2019) reported that about 54, 000 km^2 corresponding to 47.1% of Benin's surface area (114, 763 km^2) was found to be currently suitable to *Milicia excelsa* in the Guinean climatic zone and part of the Sudanian-Guinea and Sudanian climatic zones with each zone comprising of at least one protected area; 83 and 98.9% of Benin is currently suitable to *Lonchocarpus sericeus* and *Anogeissus leiocarpa* (Gbetoho *et al.,* 2017). The current distribution of the tree species as observed in this study may be as a result of less or no fluctuations in climatic variables such as precipitation and temperature (Anderson *et al;* 2006) which are key environmental variables contributing to suitable habitats and geographical distribution of the species (Darrah *et al.,* 2017). Knowledge of the spatial and current distribution of a species is of crucial importance to evaluating extinction risks and forecasting possible future threats from factors such as climate change (Pacifici *et al.,* 2015; Ganglo and Kakpo, 2016).

In contrast to the present species spatial distribution, future projections (Figure 6b) showed a significant decrease in suitable habitats for the species in Cross River State under RCP 8.5 2070 scenario. Model projections showed a significant decrease; 16, 052 km^2 corresponding to79.64% of the present suitable habitats for *I. gabonensis* in the Northern, Central and Southern geographical zones of Cross River State (20, 156 km^2). Only a few protected areas (Cross River National Park (Okwangwo and Oban Divisions and the Afi Mountain Wildlife Sanctuary); 4,104 km^2 corresponding to 20.36% will remain suitable habitats for the species. Similar reports have been made for other forest species by Kakpo *et al.,* (2019) on *Milicia excelsa*, Gbetoho *et al.,* (2017) on *Lonchocarpus sericeus* and *Anogeissus leiocarpa* and Sarangzai *et al.,* (2012) on *Juniperus excelsa* across Benin and Balochistan forest, Pakistan, respectively The differences between the current predictions and future projections could be explained by changes in values of climatic parameters. Climate is projected to become hotter and drier in West Africa under the Representative Concentration Pathways (RCP) of AfriClim (Platts *et al.,* 2015) and will lead to shifts in the potential distributions of the two species at the mid-21st century. Also the decrease in suitable habitats may be due to the significant changes projected for bioclimatic variables, mainly precipitation and temperature. *I. gabonensis* is adapted to temperatures ranging between 25 and 30˚C and precipitation between 1500 and 2700 mm per year (Orwa *et al.*, 2009). According to Busby *et al.*, (2010), fluctuations in climate variables such as precipitation and temperature will have an impact on biological diversity and on the geographical distribution of suitable habitats. Doxa *et al.*, (2017) suggest that protected areas are a principal tool of *in situ* conservation of biodiversity. Based on future projections, this study shows that a few protected areas will play a key role in the conservation of *I. gabonensis* in Cross River State.

CONCLUSION

In this study, we investigated the occurrence and spatial distribution of *I gabonensis* across Cross River State, Nigeria so as to ascertain the conservation areas of the species under climate change scenario using MaxEnt model. Our study revealed that four environmental variables are controlling the spatial distribution of *I. gabonensis* in Cross River State; these are bio 6 (minimum temperature of coldest month), bio 12 (Annual precipitation), bio 13 (precipitation of wettest month) and bio 14 (precipitation of driest month). At present, *I. gabonensis* is suitable and spatially distributed in the northern, central and southern zones of the study area. Under future projections, the suitability prediction will decrease in the northern, central and southern zones of Cross River State under Africlim representative concentration pathway scenario 2070. The area of suitable habitat decreases significantly in all the zones. Only a few protected areas (Afi Mountain and Wildlife Sanctuary (Central zone), Cross River National Park, Okwangwo

(Central zone) and Oban Division (Southern zone) will play a key role in the conservation of *I. gabonensis* in Cross River State. Therefore, it is necessary to take action to conserve effectively the tree species in the protected areas. For species sustainable management, forest managers should strengthen the protection of these protected areas, especially by organizing frequent night patrols. In addition, the species can be used in agroforestry systems during re-forestation campaigns in Cross River State, Nigeria.

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REFERENCES

Adekunle, V.A.J., Olagoke, A.O. and Akindele, S.O. (2013). Tree species diversity and structure of a Nigerian Strict Nature Reserve. *Tropical Ecology*. 54 (3): 275-289.

Adeyemi, A.A., Ibe, A.E. and Okedimma, F.C. (2015). Tree structural and species diversities in Okwangwo Forest, Cross River State, Nigeria. *Journal of Research in Forestry, Wildlife and Environment*. 7: 36-53.

Adeyemi, A.A., Jimoh, S.O. and Adesoye, P.O. (2013). Assessment of tree diversities in Oban Division of the Cross River National Park (CRNP), Nigeria. *Journal of Agriculture, Forestry and the Social Sciences*. 11(1): 216-230.

Aigbe, H.I. and Omokhua, G.E. (2015). Tree species composition and diversity in Oban Forest Reserve, Nigeria. *Journal of Agricultural Studies*. 3(1): 10-24.

Aigbe, H.I. Akindele, S.O. and Onyekwelu, J.C. (2014). Tree species diversity and density pattern in Afi River Forest Reserve, Nigeria. *International Journal of Scientific and Technology Research*. 3(10): 178-185.

Aju, P.C. and Ezeibekwe, I.O. (2010). Understanding and appreciating the need for biodiversity conservation in Nigeria. *Journal of Medicinal Plants Research*. 42: 2605-2608.

Akwaji, P.I. and Edu, E.A. (2017). Population frequency, density, abundance and diversity of tree species in ten communal forests of Northern Cross River State, Nigeria. *International Journal of Current Research*. 9(10): 59581- 59596.

Allouche, O., Tsoar, A. and Kadmon, R. (2006). Assessing the accuracy of species distribution models: prevalence, kappa and true skill statistic (TSS). *Journal of Applied Ecology*. 43: 1223-1232.

Anderson, R.P., Dudík, M., Ferrier, S., Guisan, A., Hijmans, R.J., Huettmann, F., Leathwick, J.R., Lehmann, A., Li, J. and Lohmann, L.G. (2006). Novel methods improve prediction of species distributions from occurrence data. *Ecography*. 29: 129-151.

Araujo, M.B., Alagador, D., Cabeza, M., Nogués-Bravo, D. and Thuiller, W. (2011). Climate change threatens European conservation areas. *Ecology Letters*. 14(5): 484-492.

Attua, E.M. and Pabi, O. (2013). Tree species composition, richness and diversity in the northern forest-savanna ecotone of Ghana. *Journal of Applied Biosciences*. 69: 5437-5448.

Blach-Overgaard, A., Svenning, J.C., Dransfield, J., Greve, M. and Balslev, H. (2010). Determinants of palm species distributions across Africa: the relative roles of climate, non-climatic environmental factors, and spatial constraints. *Ecography*. 33: 380-391.

Bowe, C. and Haq, N. (2010). Quantifying the global environmental niche of an underutilised tropical fruit tree (*Tamarindus indica*) using herbarium records. Agriculture, *Ecosystems and Environment*. 139: 51-58.

Breiner, F.T., Guisan, A., Nobis, M.P. and Bergamini, A. (2017). Including environmental niche information to improve IUCN red list assessments. *Diversity and Distribution*. 23: 484-495.

Busby, J.W., Smith, T.G., White, K.L. and Strange, S.M. (2010). Locating climate insecurity: where are the most vulnerable places in Africa? Austin, TX, USA: University of Texas, The Robert Strauss Centre for International Security and Law, Climate Change and African Political Stability (CCAPS) Programme.

Carvalho, M.C., Gomide, L.R., Dos Santos, R.M., Scolforo, J.S., Tavares de Carvalho, L.M. and Marcio, de Mello, J. (2017). Modelling ecological niche of tree species in Brazillian tropical area. *Cerne*. 23(2): 229-240.

Christie, D.A. and Armesto, J.J. (2003). Regeneration at micro site and tree species co-existence in temperate rainforest of Chilue Island, Chile. *Journal of Ecology*. 91: 776-784.

Cuni-Sanchez, A., Osborne, P.E. and Haq, N. (2010). Identifying the global potential for baobab tree cultivation using ecological niche modelling. *Agroforestry Systems*. 80: 191-201.

Darrah, S.E., Bland, L.M., Bachman, S.P., Clubbe, C.P. and Trias-Blasi, A. (2017). Using coarse-scale species distribution data to predict extinction risk in plants. *Diversity and Distribution*. 23: 435-447.

Doxa, A., Albert, C. H., Leriche, A. and Saatkamp, A. (2017). Priotizing conservation areas for coastal plant diversity under increasing urbanization. *Journal of Environment and Management*. 201: 425-434.

Edet, D.I., Ijeoma, H.M. and Ogogo, A.U. (2012). Preliminary assessment of tree species diversity in Afi Mountain Wildlife Sanctuary, Southern Nigeria. *Agriculture and Biology Journal of North America*. 3(12): 486-492.

Elith, J. and Leathwick, J.R. (2009). Species distribution models: ecological explanation and prediction across space and time. *Annual Review of Ecology, Evolution and Systematics*. 40(1): 677-697.

Elith, J., Graham, C.H., Anderson, R.P., Dudik, M., Ferrier, S., Guisan, A., Hijmans, R.J., Huettmann, F., Leathwick, J.R., Lehmann, A., Li, J., Lohmann, L.G., Loiselle, B.A., Manion, G., Moritz, C., Nakamura, M., Nakazawa, Y., Overton, J.M., Peterson, A.T., Phillips, S.J., Richardson, K., ScachettiPereira, R., Schapire, R.E., Soberon, J., Williams, S., Wisz, M.S. and Zimmermann, N.E. (2006). Novel methods improve prediction of species distributions from occurrence data. *Ecography*. 29: 129-151.

Emebiri, L.C., Nwufo, M.I. and Obiefuna, J.C. (2012).*Pentaclethra macrophylla*: Population characteristics, distribution and conservation status in Nigeria. *International Tree Crops Journal*. 8(2-3): 69-82.

Fatemi, S.S., Rahimi, M., Tarkesh, M. and Ravanbakhsh, H. (2018). Predicting the impacts of climate change on the distribution of *Juniperus excelsa* M. Bieb. in the central and eastern Alborz Mountains, Iran. *iForest*. 11: 643-650.

FME (2006). Federal Government of Nigeria Approved National Forest Policy 2006. Federal Ministry of Environment of Nigeria, Abuja.

Ferrarini, A., Rossi, G., Mondoni, A. and Orsenigo, S. (2014). Prediction of climate warming impacts on plant species could be more complex than expected. Evidence from a case study in the Himalaya. *Ecological Complexity*. 20: 307-314.

Franklin, J. (2010). *Mapping species distributions: spatial inference and prediction*. Cambridge, UK, Cambridge University Press, pp.319.

Gbetoho, A.J., Aoudji, A.K.N., Roxburgh, L. and Ganglo, J. C. (2017). Assessing the suitability of pioneer species for secondary forest restoration in Benin in the context of global climate change. *Bois et Forets des Tropiques*. 332(2): 43-55.

Graham, C.H., Elith, J., Hijmans, R.J., Guisan, A., Townsend, P.A. and Loiselle, B.A. (2008). The influence of spatial errors in species occurrence data used in distribution models. *Journal of Applied Ecology*. 45: 239-247.

Guisan, A. and Zimmermann, N.E. (2000). Predictive habitat distribution models in ecology. *Ecological Modelling*. 135: 147-186.

Hatfield, J.L. and Prueger, J.H. (2015). Temperature extremes: Effect on plant growth and development. *Weather and Climate Extermes*. 10: 4-10.

Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G. and Jarvis, A. (2005). Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology*. 25: 1965-1978.

Hutchinson, G.E. (1957). Concluding remarks. *Cold Harbour Symposia on Quantitative Biology*. 22(2): 415-427.

Ikyaagba, T.E, Tee, T.N., Dagba, B.I., Ancha, U.P., Ngibo, K.D. and Tume, C. (2015). Tree composition and distribution in Federal University of Agriculture

Makurdi, Nigeria. *Journal of Research in Forestry, Wildlife and Environment*. 7(2): 147-157.

Jagadish, M.R., Viswanath, S., Shiva Prakash, K.N., Ravikanth, G. and Rathore, T.S. (2015). Ecological niche modelling for priotizing areas for domestication of introduced bamboo species in India. Conference Paper, 10th World Bamboo Congress, Korea.

Javad, E., Ardavan, G., Mohammad, A. and Zare, C. (2018). MaxEnt modelling for predicting impacts of environmental factors on the potential distribution of *Artemisia aucheri* and *Bromustomentellus – Festucaovina* in Iran. *Polish Journal of Environmental Studies*. 27(3): 1041-1047.

Kakpo, S.B., Aoudji, A.K.N., Gnanguenon Guesse, D., Gbetoho, A.J., Koura, K., Djotan, G. K. and Ganglo, J.C. (2019). Spatial distribution and impacts of climate change on *Milicia excelsa* in Benin, West Africa. *Journal of Forestry Research*, https//doi.org/10.1007/s11676-019-01069-7.

Khanum, R., Mumtaz, A.S. and Kumar, S. (2013). Predicting impacts of climate change on medicinal asclepiads of Pakistan using MaxEnt modelling. *Acta Oecologica*. 49: 23-31.

Merow, C., Matthew, J.S. and John, A.S. Jnr. (2013). A practical guide to MaxEnt for modelling species distributions: what it does, and why inputs and settings matter. *Ecogeography*. 36(10): 1058-1069.

Moss, R.H., Edmonds, J.A., Hibbard, K.A., Manning, M.R., Rose, S.K., Van Vuuren, D.P., Carter, T.R., Emori, S., Kainuma, M., Kram, T., Meehl, G.A., Mitchell, J.F.B., Nakicenovic, N., Riahi, K., Smith, S.J., Stouffer, R.J., Thomson, A.M., Weyant, J.P., Wilbanks, T.J. (2010). The next generation of scenarios for climate change research and assessment. *Nature*. 463: 747-756.

Miller, J.A. and Rogan, J. (2007). Using GIS and remote sensing for ecological modelling and monitoring In: *Integration of GIS and remote sensing*. Mesev, V.(eds). UK, John Wiley and Sons Ltd, pp.233-268.

Moutouama, J.K., Fandohan, A.B., Biaou, S.S.H., Amahowe, O.I., Moutouama, F.T., Natta, A.K. (2016). Potential climate change favored expansion of a range limited species, *Haematostaphis barteri* Hook f. *Journal of Agriculture, Environment and International Development*. 110(2): 397-411.

NIMET, (2015). National weather forecasting and climate research. *Nigerian Meteorological Agency Agrometeorological Bulletin*, 36 (3), 21-31.

O'Donnell, M.S. and Ignizio, D.A. (2012). Bioclimatic predictors for supporting ecological applications in the conterminous United States: U. S. Geological Survey Data Series 691.

Ogunjemite, B. G. (2015). Assessment of floristic composition of Ologbo Concession, Edo State, Nigeria, for conservation planning. *Revue Scientifique et Technique Forêt et Environnement du Bassin du Congo*. 4:10-19.

Olajide, O. (2004). *Growth performance of trees in Akure Forest Reserve, Ondo State, Nigeria*. Ph.D Thesis, University of Ibadan, Nigeria.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Anthony, S. (2009). Agroforestry Database: a tree reference and selection guide version 4.0. www. worldforestry.org/sites/treed bs/treedatabases.asp. (*Irvingia gabonensis* Aubry – Lecomte O'Rorke Baill.). Retrieved 29/03/2020.

Peterson, A.T., Papes, M. and Soberon, J. (2008). Rethinking receiver operating characteristic analysis applications in ecological niche modelling. *Ecological Modelling*. 2131: 63-72.

Phillips, S.J. and Dudik, M. (2008). Modelling of species distributions with MaxEnt: new extensions and a comprehensive evaluation. *Ecography*. 31: 161-175.

Phillips, S.J., Anderson, R.P. and Schapire, R.E. (2006). Maximum entropy modelling of species geographic distributions. *Ecological Modelling*. 190: 231-259.

Platts, P.J., Omeny, P.A. and Marchant, R. (2015). AFRICLIM: high-resolution climate projections for ecological applications in Africa. *African Journal of Ecology*. 53: 103-108.

Sanwo, S.K., Ige, P.O., Sosanya, O.S. and Ogunlaye, O.G. (2015). Tree species diversity and forest stand dynamics in a tropical rainforest in Southern Nigeria.

Malaysian Journal of Applied Biology. 44(2): 65-73.

Sarangzai, A.M., Ahmed, M., Ahmed, A., Tareen, L. and Jan, S.U. (2012). The ecology and dynamics of *Juniperus excelsa* forest in Balochistan-Pakistan. *Pakistan Journal of Botany*. 44(5): 1617-1625.

Shivaprakash, K.N., Gudasalamani, R., Barve, N., Ghazoal, J., Narayanagonada, G.K. and Ramanan, U.S. (2013). Do ecological niche model predictions reflect the adaptive landscape of species? A test using *Myristica malabrica* Lam., an endemic tree in the Western Ghats, India. *PLoS ONE*. 8(11): e82066.

Stalin, N. and Swamy, P.S. (2015). Prodiction of suitable habitats for *Syzygium caryophyllatum*, an endangered medicinal tree by using species distribution modelling for conservation planning. *European Journal of Experimental Biology*. 5(11): 12-19.

Svenning, J.C. and Skov, F. (2006). Potential impact of climate change on the northern nemoral forest herb flora of Europe. *Biodiversity and Conservation*. 15: 3341-3356.

Ude, G.N., Dimkpa, C.O., Anegbeh, P.O., Shuaibu, A.A., Tenkouano, A., Pillay, M. and Tchoundjeu, Z. (2006). Analysis of genetic diversity accessions of *Irvingia gabonensis* Aubry – Lecomte O'Rorke Baill. *African Journal of Biotechnology*. 5(3): 219-223.

Ursula, L.V. and Joao, C.N. (2016). Using ecological niche models to predict the impact of global climate change on the geographical distribution and productivity of *Euterpe oleraceae* Mart. (Arecaceae) in the Amazon. *Acta Botanica Brasilica*. 30(2): 290-295.

Van Vuuren, D.P., Carter, T.R. (2014). Climate and socio-economic scenarios for climate change research and assessment: reconciling the new with the old. *Climate Change*. 122: 415-429.

Van Vuuren, P.D., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., Hurtt, G.C., Kram, T., Krey, V., Lamarque, J.F., Masui, T., Meinshausen, M., Nakicenovic, N., Smith, S.J., Rose, S.K. (2011). The representative concentration pathways: an overview. *Climatic Change*. 109: 5-31.

Vayreda, J., Gracia, M., Martinez-Vilalta, J. and Retana, J. (2013). Patterns and drivers of regeneration of tree species in forests of peninsular Spain. *Journal of Biogeography*. 40, 1252-1265.

Wakawa, L., Suleiman, A., Ibrahim, Y. and Adam, L. (2017). Tree species biodiversity of a Sahelian ecosystem in Noertheast Nigeria. *Journal of Bartin Faculty of Forestry*. 19(2): 166-173.

Warren, R., Van Der Wal, J., Price, J., Welbergen, J.A., Atkinson, I., Ramirez-Villegas, J., Osborn, T.J., Jarvis, A., Shoo, L.P., Williams, S.E. and Lowe, J. (2013). Quantifying the benefit of early climate change mitigation in avoiding biodiversity loss. *Nature Climate Change*. 3(7): 678-682.

Willis, K.J. and Whittaker, R.J. (2002). Species diversity – scale matters. *Science*. 295 (5558): 1245-1248.

Yu-Jun, Y., Xi, C., Zhi-Feng, Y. and Shang-Hong, Z. (2016). MaxEnt modelling for predicting the potential distribution of endangered medicinal plant (*H. ripana* Lour.) in Yunnan, China. *Ecological Engineering*. 92: 260-269.

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OCCURRENCE AND IMPACTS OF CLIMATE CHANGE ON THE GEOGRAPHICAL DISTRIBUTION OF *Pentaclethra macrophylla* Benth IN CROSS RIVER STATE, NIGERIA

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ABSTRACT

African oil bean (Pentaclethra macrophylla Benth) is a multipurpose tree species used for fodder, food, medicine and income across Cross River State, Nigeria. Understanding the impacts of climate change on the geographical distribution of this species may give an insight to its decline or expansion and help to proffer relevant conservation measures if necessary. This study surveyed and documented the occurrence of P. macrophylla using Global Positioning System (GPS) software in 36 forested areas comprising northern, central and southern zone of Cross River State, Nigeria. MaxEnt was used to model the geographical distribution of P. macrophylla at present and in the future under RCP 8.5 horizon 2070 using 15 Bioclim variables. This modelling tool uses presence-only data and is one of the best performing algorithms among those using climate modelling approaches, and is relatively robust for small sample sizes. The performance of the model was evaluated by the area under the receiver operating characteristics (ROC) curve and its related area under curve (AUC), the percentage contribution table of variables and the jacknife charts (Regularized training gain, test gain and AUC) and true skill statistics (TSS). MaxEnt results showed that four Bioclim variables; Bio 6 (Minimum temperature of coldest month), Bio 12 (Annual precipitation), Bio 13 (Precipitation of the coldest month) and Bio 14 (Precipitation of the driest month) were retained as the most important variables contributing to the geographical distribution of the species. The projections show a significant decrease of 49.32% in the suitability of habitats for P. macrophylla in the southern zone. Only the northern and central zones (50.68%) will remain suitable habitats for the species. For sustainable conservation of P. macrophylla, it is necessary to strengthen the protection of the species/afforestation programme in the southern geographical zone of the state.

Keywords: *Pentaclethra macrophylla, climate change, environmental variables, MaxEnt model.*

INTRODUCTION

Global climate change has aroused much interest and concern in the mass media and academia. Warming trends in temperature and climate related extremes such as heat waves, droughts, floods, cyclones, and wildfires are being observed at global scale and across regions (IPCC, 2013, 2014). These effects could result in food insecurity, loss of biodiversity and ecosystems goods, functions, and services provided to people (Bentz *et al.,* 2010, IPCC, 2014). Under climate change threat, species might respond in different ways. For example, species might survive in the margins of their actual range, track or colonize new areas where ecological conditions are more suitable or might even go extinct (IPCC, 2014; Abrahms *et al.,* 2017). In order to address the threat of climate change to biodiversity, it is important to advance our knowledge on species geographic distributions and the factors that govern their spatial patterns. Climatic and physical factors could impact the geographic distributions of species at different spatial scales (Soberon and Peterson, 2005). At large spatial scales, climate is considered more relevant than biotic interactions in determining species geographic distributions (Pearson and Dawson, 2003). Based on this, the approach of ecological niche model (ENM) use the relationship between species occurrence points and their related environmental variables to describe the ecological niche (climatic preferences) and the potential spatial distribution of species (Peterson *et al.,* 2011). Such ecological niche and species distribution models are widely used in biogeography, conservation biology and ecology (Elith *et al.,* 2011; Pearson *et al.,* 2007). The importance of predicting species distribution is increasing rapidly with global changes and their influences on native ecosystems. Knowledge of the spatial and temporal distribution of a species is pivotal for evaluating extinction risks and forecasting possible future threats from factors such as climate change (Pacifici *et al.,* 2015; Ganglo and Kakpo, 2016). Ecological niche models (ENMs) are used to understand ecological requirement of species, predict geographic distributions, select areas for conservation and forecast effects of environmental change (Peterson *et al.,* 2011; Ganglo *et al.,* 2017; Altamiranda-Saavedra *et al.,* 2017; Djotan *et al.,* 2018). Among several programs for ecological niche modeling and habitat suitability prediction, MaxEnt is one of the most used with respect to the type of data used in this study, species presence-only data. This modeling tool using presence-only data is one of the best performing algorithms among those using climate modeling approaches (Phillips *et al.,* 2006), and is relatively robust for small sample sizes (Pearson *et al.,* 2007). MaxEnt is a machine learning method that estimates species distribution across a study area by calculating the distribution probability of maximum entropy, subject to the constraint that the expected value of each feature under this estimated distribution should match its empirical average (Phillips *et al.,* 2006).

The African oil bean (*Pentaclethra macrophylla* Benth) is a tree that grows to between 21 – 30 m in height and more than 60 cm in width. It occurs in the tropics and can be found primarily in the guinea savannah and tropical rain forests of Southern/North Central Regions of Nigeria as well as other seashore (coastline) areas of West and Central Africa (Keay, 1989). The species is affiliated to the family Fabaceae and the sub-family Mimosoideae with no recognized differences in terms of variety (Oboh, 2007). The tree species is a major source of food, fodder, wood, fuel (charcoal), income and medicine for rural dwellers of Cross River State, Nigeria. Despite the considerable potential of *P. macrophylla* and its socio-economic attributes, the resources of the species are still obtained from the wild. In fact, *P. macrophylla* has not been included in various agroforestry and conservation programs of Cross River State and Nigeria at large. Presently, the species is threatened due to over-exploitation, deforestation, various anthropogenic activities and climate change. This study provides primary occurrence data and investigates the impact of climate change under current and future scenarios for *P. macrophylla* for sustainable management and conservation in Cross River State.

MATERIALS AND METHODS

Study area

The Study was carried out in Cross River State, a coastal state located in Southern Nigeria and named after the Cross River, which flows through the state. The land mass of the State is approximately 20,156 square kilometres. The Cross River State shares boundaries with Benue State to the north, Enugu and Abia States to the west, Cameroon Republic to the east and Akwa Ibom and the Atlantic Ocean to the south (Fig. 1a). The State lies between, latitude 5° 45′N and 6˚ 10ˈN and on longitude 8° 30′E and 8˚ 39ˈE (Aju and Ezeibekwe, 2010). The study was carried out in thirty-six (36) communities, selected on the basis of their forested areas, located in the Northern, Central and Southern Senatorial Districts of Cross River State, Nigeria (Figure 1b). An eighteen (18) month study to generate field data was undertaken between April 2019 and October 2020. The elevation of the study area ranges between 140 m to 400 m above sea level. The area has a tropical climate with an average annual rainfall of 1250 mm – 2300 mm. The wet or rainy season lasts for approximately seven months. The zone normally experiences a wet climate, and diurnal temperature variations are well marked throughout the year. Two seasons are discernible in the year; the dry season occurring between November and March, and the rainy season which begins in March, reaching its maximum in July and September (FME, 2006). The temperature is high all year round with only small variations. The proximity of the Atlantic Ocean has a moderating effect on temperature with highest average daily maximum of 35 °C and recorded mean actual temperature of 26 °C. The relative humidity is about 80- 90 per cent (NIMET, 2015). The topography is highly undulating and with soils that are generally deep, porous and weakly structured and well drained soils with low to moderate status (NIMET, 2015). The vegetation of the area is a mixture of mangrove, rainforest and savannah. The rainforest is further subdivided into the lowland rainforest and the freshwater swamp forest (Edet *et al.,* 2012).

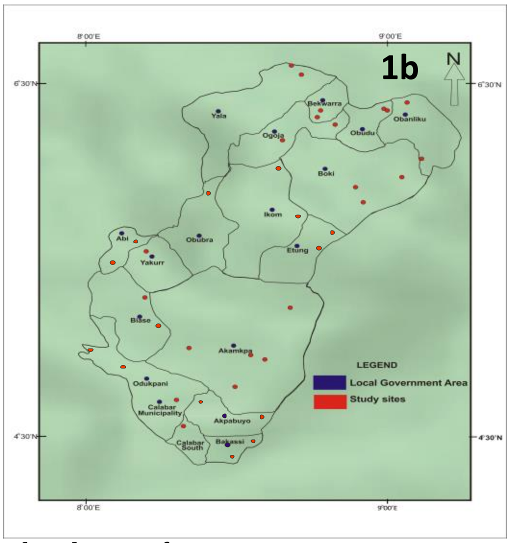


Figure 1a: Location of Cross River State on the geographical map of Nigeria
Figure 1b: Map of Cross River State showing study sites (from data generated during field work)

Occurrence

The coordinates (latitude and longitude) of *Pentaclethra macrophylla* present in the sampled plots in each study site was recorded using Global Positioning System (GPS) software (GARMIN GPS MAP 78 sc). Furthermore, we authenticated each coordinate and converted it to obtain the decimal latitude and decimal longitude using the site www.gps-coordinates.net. The species name, decimal latitude and decimal longitude of *P. macrophylla* was compiled on Microsoft Excel spreadsheet and saved as a .csv (comma separated value) file and used for Ecological Niche Modelling (Philips *et al.*, 2006) as the maxEnt model only recognizes a .csv file. We further cleaned the final dataset of georeferenced records of *P. macrophylla* using Quantum Geographic Information System (QGIS) software ver. QGIS-OSGeo4W-2.18.1 to eliminate occurrences or coordinates that fell outside the training region.

Impact of climate change evaluation

The impact of climate change on the geographical distribution of *P. macrophylla* in the study area at present and in the future was predicted using the Bioclim variables, Quantum Geographic Information System (QGIS) software ver. QGIS-OSGeo4W-2.18.1 and Ecological Niche Modelling software MaxEnt (Maximum entropy modelling of species geographic distributions ver. Jre-8u191-windows).

Environmental variables (BIOCLIM) used for running MaxEnt model

In this study, we used fifteen (15) substantial bioclimatic variables for forest tree habitat in Africa and Nigeria selected from the WorldClim database (http://www.world clim.org/bioclim – Hijmans *et al.*, 2005) to run our model. These variables have been derived from monthly temperature and precipitation parameters over the period of 1950-2000 and are closely associated with growth and development of species, thus they are widely used in the assessment of species distribution (Elith *et al.*, 2006, Graham *et al.*, 2008, Warren *et al.*, 2013). Climate data used for prediction (Future_2070_rcp85_bis) was collected from AfriClim database available from the Coupled Model Inter comparison Project Phase 5 (CMIP5) of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment for the years 2070 (average of 2061-2080 period). These data have been predicted using 15 General Concentration Models (GCM) under four greenhouse gas concentration scenarios known as Representative Concentration Pathways (RCPs). According to van Vuuren *et al.*, (2011) RCPs are third generation scenarios and are preferred to the Special Report on Emissions Scenarios (SRES) because they allow more flexibility and reduced costs in modelling processes. Also, RCPs imply collaboration between impacts, adaptation and vulnerability research, and climate and integrated assessment modelling (van Vuuren and Carter, 2014). RCPs scenarios have been developed to explore different combinations of scenario context (demographic, socioeconomic, land use and technology) (Moss *et al.*, 2010). The 15 bioclim variables we used in this study and their keys are presented in Table 1.

Table 1: Bioclimate variables used for running MaxEnt model

S/N	Code	Environmental variables	Unit
1.	BIO1	Annual Mean Temperature	˚C
2.	BIO2	Mean Diurnal Range (Mean of monthly (max temp – min temp)	˚C
3.	BIO3	Isothermality (BIO2/BIO7) (* 100)	-
4.	BIO4	Temperature Seasonality (standard deviation *100)	CV
5.	BIO5	Max Temperature of Warmest Month	˚C
6.	BIO6	Min Temperature of Coldest Month	˚C
7.	BIO7	Temperature Annual Range (BIO5-BIO6)	˚C
8.	BIO10	Mean Temperature of Warmest Quarter	˚C
9.	BIO11	Mean Temperature of Coldest Quarter	˚C
10.	BIO12	Annual Precipitation	mm
11.	BIO13	Precipitation of Wettest Month	mm
12.	BIO14	Precipitation of Driest Month	mm
13.	BIO15	Precipitation Seasonality (Coefficient of variation)	CV
14.	BIO16	Precipitation of Wettest Quarter	mm
15.	BIO17	Precipitation of Driest Quarter	mm

Source: World Climate database

MaxEnt model calibration

We processed the environmental data for modelling by calibrating environmental layers to Africa and Nigeria using QGIS software (Philips *et al.*, 2006). The environmental layers or Bioclim variables BIO1 - 7 and 10 - 17 (which are Raster files) were loaded on QGIS (Nigeria_disc_shape) one after the other and the occurrence data of *P. macrophylla* (computed on Microsoft Excel spreadsheet and saved as .csv file) was clipped on the environmental layers and saved as Geo. Tif file. The points of occurrence of the tree species was trimmed to create a polygon shape file using the default value 1 as regularization multiplier (beta value) and saved. We further converted the raster layers saved as .tif format to ascii format using QGIS before they were used to run the MaxEnt model.

MaxEnt model evaluation

MaxEnt uses presence data only by generating random test points. For this analysis, we used the suggested default settings which have been shown to yield robust results as reported by Phillips and Dudik (2008). Maximum iteration was set at 1000, number of replications was set at 10 and the model was evaluated by using the area under the receiver operating characteristic (ROC) curve (Peterson *et al.*, 2008) and its related Area Under Curve (AUC) (Elith *et al.*, 2006), the percentage contribution table of variables and the jackknife charts (Regularized training gain, test gain and AUC) were taken into account to judge the most important contributing variables to the model (Phillips and Dudik 2008). The regularized training gain is used as an index of model fit. The Regularized training gain is a measure of the distance between a multivariate distribution of covariates at randomly selected background sites (i.e., a random sample of the entire landscape that a species could potentially inhabit) and a corresponding distribution of covariates at sites of known species occurrences (Elith *et al.*, 2011). Hence, a large regularized training gain (RTG ≥ 1) indicates an affinity for a narrow range of environmental conditions, relative to the broader landscape, while a small training gain (RTG ≤ 1) suggests a lack of specialized habitat requirements (i.e., the distribution of covariates at occurrence sites mirrors the background distribution; Merow *et al.*, 2013). The test gain is in general an indication of how much better-than-random the model fit is. A high gain ≥ 1for a particular variable therefore means that variable has a greater predictive value. The high gain means that these variables are good predicators for where the species can survive and is biologically meaningful (Elith *et al.*, 2006). The AUC is a probability that a randomly chosen presence point of species will be ranked as more suitable than a randomly chosen absence point (Elith *et al.*, 2006). A model is considered as having a good fit when its AUC is close to 1 (AUC ≥ 0.75) (Elith *et al.*, 2006). Furthermore, the performance of the model was assessed using true skill statistic (TSS) (Allouche *et al.*, 2006; Elith *et al.*, 2006). The TSS is the capacity of the model to accurately detect true presences and true absences. A model with TSS ≤ 0 indicates a random prediction; while one with a TSS close to 1(TSS > 0.5) has a good predictive power (Allouche *et al.*, 2006). To generate the final maps and response curves, the model was run using all data points, i.e., including the test data and run 50 times with bootstrapping as the replicated run type. The remaining options were set to default. While generating response curves, the MaxEnt model estimates the relative effect of each predictor (Khanum *et al.*, 2013). Species presence potential was classified using two probability classes; suitable and unsuitable (Kakpo *et al.*, 2019). To post-process the MaxEnt TSS (validate the model) we used the TSS Excel sheet.

Projection of MaxEnt model

To project the MaxEnt model for *P. macrophylla* we generated another niche model which was projected into climate conditions for the year 2070 (Philips *et al.*, 2006) modelled using the Africlimate ensemble model under the Representative Concentration Pathway RCP 8.5 climate scenario (Future_2070_rcp 85).

RESULT

Occurrence

A total number of 105 occurrence points for *P. macrophylla* was recorded from the field and used in this study. The coordinates; decimal latitude (˚N) and longitude (˚E) of *P. macrophylla* were recorded in the Northern, Central and Southern geographical zones of Cross River State.

Model validation

The results of model evaluations for *Pentaclethra macrophylla* indicate its robustness. The average training Area Under Curve (AUC) for the 10 bootstrap replicate runs was AUC = 0.939. The True skill statistics (TSS) value was 0.85 (Figure 3). Therefore, the model showed excellent performance and had a good predictive ability and performed better than random.

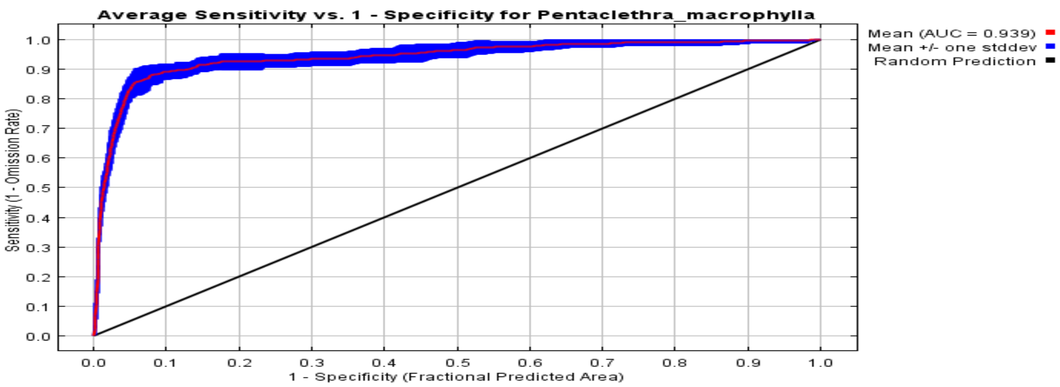


Figure 2: Average Receiver Operating Characteristic (ROC) and related Area Under Curve (AUC) for 10 bootstrap replicates using the MaxEnt model for *Pentaclethra macrophylla*

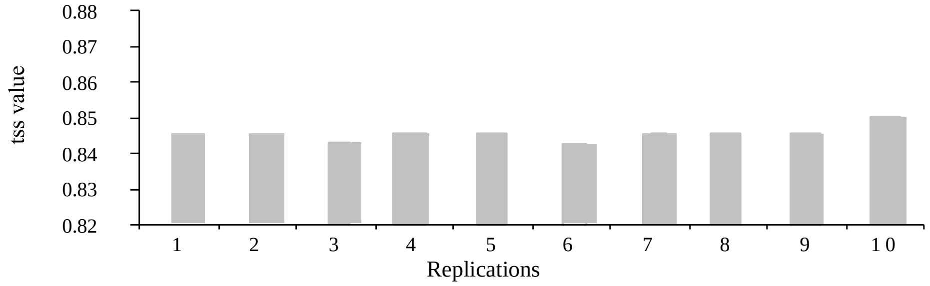
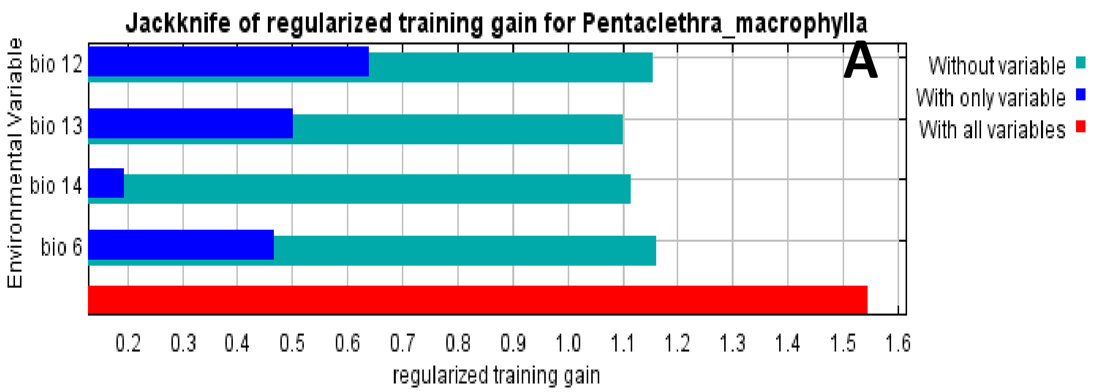
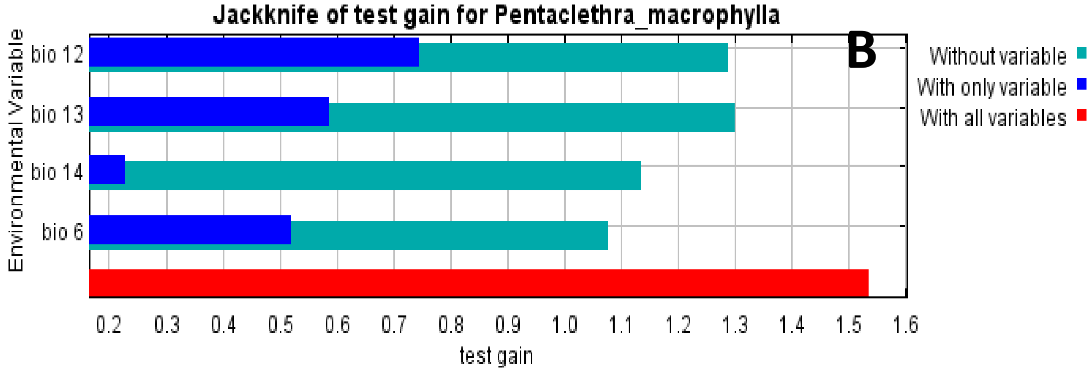


Figure 3: True skill statistics (TSS) value for 10 replicates using the MaxEnt model for *Pentaclethra macrophylla*

Environmental variables controlling the spatial distribution of *Pentaclethra macrophylla* Benth across Cross River State

In this study, the Jackknife tests of variable importance (Figure 4A, B and C) and the table of variable contributions (percentage contribution and permutation importance) Table 2: This measure depends only on the final MaxEnt model, not the path used to obtain it. The contribution for each variable is determined by randomly permuting the values of that variable among the training points (both presence and background) and measuring the resulting decrease in training AUC. A large decrease indicates that the model depends heavily on that variable. Variables are normalized to give percentages. Table 3 helped to identify four environmental variables as contributing most to the spatial distribution of *P. macrophylla* across Cross River State, respectively. These are bio 6 (minimum temperature of coldest month), bio 12 (Annual precipitation), bio 13 (precipitation of wettest month) and bio 14 (precipitation of driest month). The Jackknife test of variable importance showed that leaving out any of these four variables did not allow for optimization of the training gain, AUC and test gain levels relative to using the whole set of variables. Consistent with the Jackknife tests, the table of variable importance for *P. macrophylla* (Table 2) shows that bio 12 (Annual precipitation) was the most important contributing variable among the four variables retained in the model. Bio 14 (Precipitation of the driest month) decreased the gain the most when omitted and appears to be the most informative variable of the model.





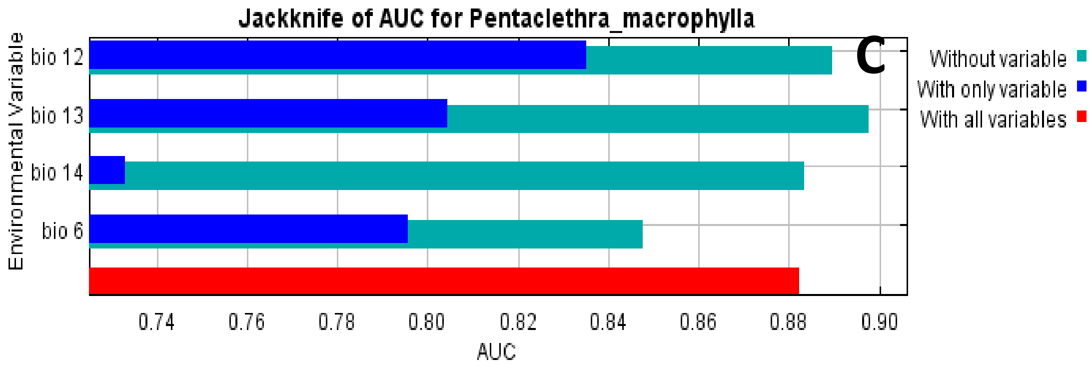


Figure 4: Jackknife tests of variable importance. A) with regularized training gain; B) with test gain; C) with AUC for *Pentaclethra macrophylla*

Table 2: Percentage contribution and permutation importance of the variables for *Pentaclethra macrophylla*

Variable	Percent contribution	Permutation importance
bio 12	33.8	32.5
bio 14	28.2	10.8
bio 13	26.5	43.8
bio 6	11.5	12.8

Note: bio 6 (Minimum temperature of coldest month), bio 12 (Annual precipitation), bio 13 (Precipitation of wettest month), bio 14 (precipitation of driest month)

The response curves of these variables to the suitability prediction of the species are presented in Figure 5A, B, C and D for *P. macrophylla* respectively. Bio 6 (Figure 5A) clearly shows the responsiveness of the species to minimum temperature of coldest month variability relative to that of the year. The logistic prediction shows slight increase in response output from a minimum temperature of 0˚C to 14˚C and rising sharply thereafter and optimizing at 25˚C. The curve for bio 6 therefore, suggests that the limit of low temperature tolerance for the species during the coldest months is between 18 - 25˚C. The response curve of the species to bio 12 (Figure 5B) (annual precipitation) is consistent with its ecology as indicated in values of precipitation of 1000 mm to 2700 mm as optimal values for the species high suitability prediction. The response of the species to Bio 13 (Figure 5C) (precipitation of wettest month) shows good response output with increase of precipitation from 0 to 400 mm and then a sharp decline after the suitability threshold of about 400 mm. The response curve of the species to bio 14 (Figure 5D) (precipitation of driest month) shows good response output from 0 to 20 mm and then a sharp decline after the suitability threshold from after 20 mm. The result of the response curves of *P. macrophylla* further shows that the species is exposed to dry and rainy seasons in its natural habitat.

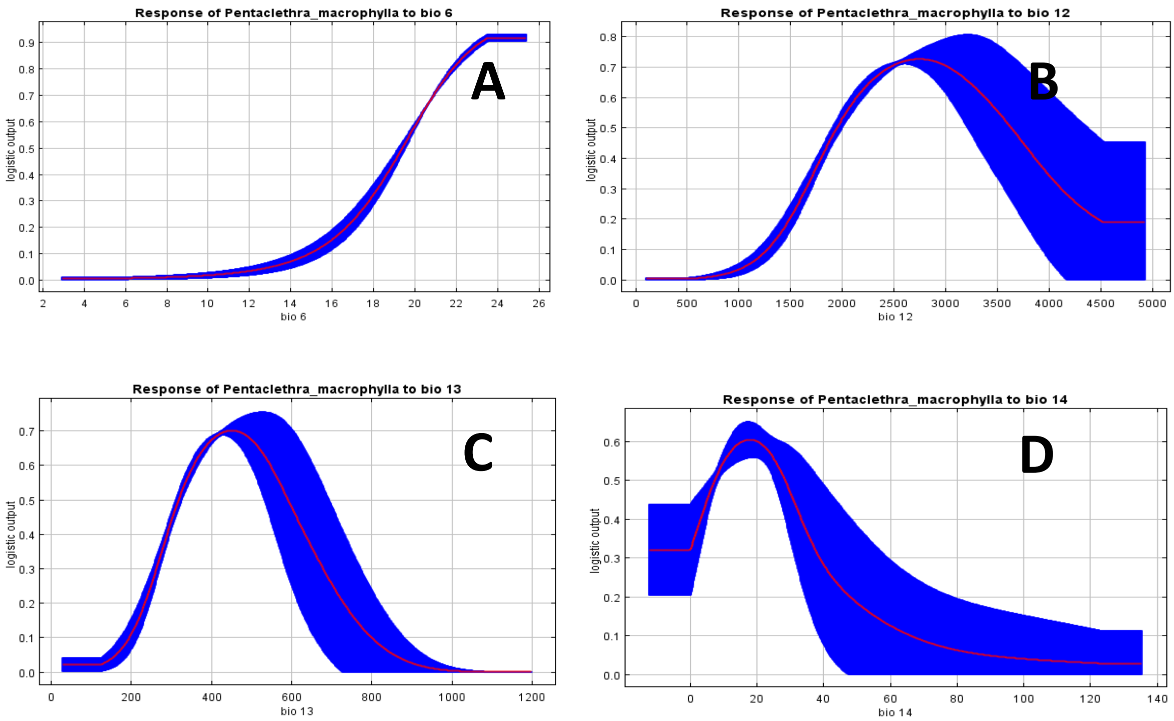


Figure 5: Response curves of most contributing variable to the growth of *P. macrophylla* A) bio 6 (Minimum temperature of coldest month); B) bio 12 (Annual precipitation); C) bio 13 (Precipitation of wettest month); D) bio 14 (precipitation of driest month)

Spatial distribution of *Pentaclethra macrophylla* at present and future across Cross River State

The analysis of impact of climate on spatial distribution of the species reveals that 17, 056 km^{2}corresponding to 84. 62% of the study area (20, 156 km2) are presently suitable habitats for the distribution of *P. macrophylla* (Table 3). Presently, the tree species is spatially distributed across the guinea savannah and forest zones of Northern, Central and Southern geographical zones of Cross River State. On the basis of data generated from field studies, the current spatial distribution of *P. macrophylla* in Cross River State is as presented in (Figure 6a).

Model projection into the future under AfriClim RCP 8.5 scenario 2070 show a significant decrease in the area of suitable habitats of *P. macrophylla* to 9, 940 km^2 corresponding to 49.32% of the present area of suitable habitats (20, 156 km^2) for the species in the southern zone of Cross River State (Table 3). It is mostly the northern and central zones (10, 216 km^2) corresponding to 50.68% that will remain suitable habitats for *P. macrophylla*. The projected spatial distributions of *P. macrophylla* under AfriClim RCP 8.5 2070 scenario in Cross River State is presented in (Figure 6b).

Table 3: Impact of climate change on the spatial distribution of *Pentaclethra macrophylla* at present and in the future across Cross River State

Suitability	**Present**		**AfriClim RCP 8.5**	
	Area (km^2)	**Percentage** (%)	**Area (km^2)**	**Percentage (%)**
Suitable	17, 056	84.62	10, 216	50.68
Unsuitable	3, 100	15.38	9, 940	49.32

Total	20, 156	20, 156

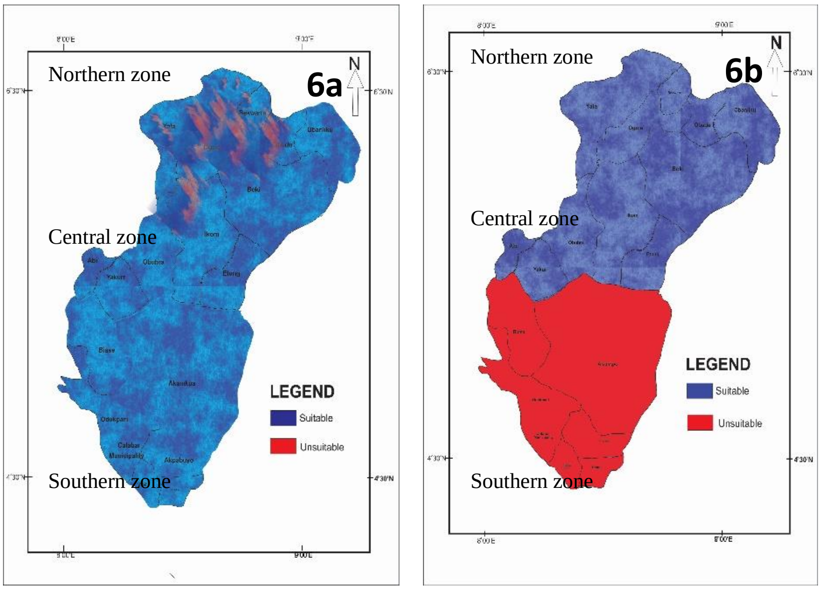


Figure 6a and 6b: Spatial distribution of *Pentaclethra macrophylla* at present and future under AfriClim 8.5 horizon 2070 across Cross River State

DISCUSSION

Occurrence

The 105 occurrence datasets of *P. macrophylla* encountered in northern, central and southern zone of Cross River State showed that the tree species had a wide distribution across the study area. This observation is in agreement with other reports of tropical forest ecosystems in Nigeria (Edet *et al.*, 2012; Adekunle *et al.*, 2013; Adeyemi *et.*, 2013; Aigbe *et al.*, 2014; Adeyemi *et al.*, 2015; Ikyaagba *et al.*, 2015; Ogunjemite, 2015; Sanwo *et al.*, 2015; Aigbe and Omokhua, 2015; Akwaji and Edu, 2017). The wide distribution of this species in the study area is not surprising because the tree play a significant role in the cultural and socio-economic life of the people. The trees are valued by the local inhabitants because of their role in soil improvement and conservation, feeds for animals, medicinal and economic value (Akwaji and Edu, 2017) and as a result, they are generally spared from felling. Attua and Pabi (2013) and Wakawa *et al.*, (2006) made a similar report when they carried out tree assessment in forest and guinea savannah ecosystems, respectively. The wide distribution of this species in the study area may also be as a result of adaptation of the species to the area, the favorable microclimate within the guinea savannah and forests, the availability of viable seeds of the trees to sustain regeneration. Olajide (2004) and Christie and Armesto (2003) reported that the abundance or rarity of a timber tree species of economic value in an area of rainforest is a function of intensity or pattern of its exploitation. The wide distribution of this tree species is to be expected since Cross River State has high number of protected areas and reserves and which are under protection by law.

Model validation

In light of global climate changes, it is essential to identify species with high risk of extinction and to diagnose risk driver factors to reverse the decline of biodiversity (Darrah *et al.*, 2017). Information on changes to species ecological niche is important for assessing species geographic range and their realized niche (Breiner *et al.*, 2017). In this study, the performance of the MaxEnt model was assessed using the Area under the Receiver Operating Characteristic Curve (AUC) (Elith *et al.*, 2006), true skill statistic (TSS) (Allouche *et al.*, 2006; Elith *et al.*, 2006) and Receiver Operating Characteristic (ROC) (Peterson *et al.*, 2008). Model evaluations indicate that the model is robust with an AUC and TSS value of 0.939 and 0.85, respectively. Therefore, the model showed excellent performance and had a good predictive ability. Similar findings of a robust MaxEnt model with high AUC and TSS values for various tree species have been reported; 0.979 and 0.86 respectively for *Milicia excelsa* in Benin, West Afirca (Kakpo *et al.*, 2019), 0.948 and 0.78 for *Juniperus excelsa* in Central and Eastern Alborz Mountains, Iran (Fatemi *et al.*, 2018), 0.819 and 0.867 and 0.72 and 0.78 for *Lonchocarpus sericeus* and *Anogeissus leiocarpa* in Benin, West Africa (Gbetoho *et al.*, 2017), 0.895 and 0.79 for *Dialium guineense* in Benin and other West African countries (Ganglo *et al.*, 2017), 0.899 and 0.79 for endangered medicinal plant (*Homonoia riparia* Lour) in Yunnan, China (Yu-jun *et al.*, 2016), 0.91 and 0.82 for *Syzygium caryophyllum* in Western Ghats, India (Stalin and Swamy, 2015). Also, in the present study variables such as temperature and precipitation were considered. According to Guisan and Zimmermann (2000), direct parameters such as temperature and precipitation are more efficient when the modelling is over large areas. This is contrary to indirect parameters which are not more efficient but are more inclined to introduce errors into the model.

Environmental variables controlling the spatial distribution of *Pentaclethra macrophylla* across Cross River State

The distribution of a plant species in a geographic space is determined by complex interactions of biotic and abiotic factors. These factors include climate, soil characteristics, inter- and intra-specific competition, anthropic disturbances, and dispersal limitation (Blach-Overgaad *et al.*, 2010). The environmental factors are the main determinants of the living conditions of the species, while dispersal limitations and biotic interactions may further modify the distribution (Soberón and Peterson, 2005). Good knowledge of the environmental requirements of a species is therefore important to assess the broad geographic space where it could survive and its potential response to climate change for conservation and management purposes (Bowe and Haq, 2010). *P. macrophylla* occurs in the forest zone of West and Central Africa; from Senegal to South-eastern Sudan and to Angola and on the islands of Sao Tome and Principe (Oboh, 2007). The species is common in primary and secondary forest and coastal savannah, often in the vicinity of creeks and rivers (Orwa *et al.*, 2009). It is most common at altitudes up to 500 m, although growth can be found at higher elevations where rainfall is adequate and temperatures are never cooler than 18˚C. It requires a mean annual rainfall of 1000 – 1500 mm and 2000 - 2700 mm and a mean annual temperature of about 25˚C (Emebiri *et al.*, 2012). In this study, the Jackknife test of variable importance (Figure 4) and the table of variable contributions (Table 3) helped to identify four environmental variables as contributing most to the spatial distribution of *P. macrophylla*, across Cross River State. These are bio 6 (minimum temperature of coldest month), bio 12 (Annual precipitation), bio 13 (precipitation of wettest month) and bio 14 (precipitation of driest month). The finding of this study is therefore reliable with regards to the ecology of the species. Indeed, the annual precipitation (bio 12) and its variations bio 13 (precipitation of wettest month) and bio 14 (precipitation of driest month) are among the most contributing variables to the prediction model of the spatial distribution of the species. At a large scale, the distribution of a species depends mainly on climate (Vayreda *et al.*, 2013), especially on factors related to water (Svenning and Skov, 2006). Annual precipitation (bio 12) is a measure of the variation in yearly precipitations over the course of the year (O'Donnell and Ignizio, 2012). According to the model, Annual precipitation of 1000 - 2700 mm was found to be suitable for the spatial distribution of *P. macrophylla* across the study area which is also consistent with the ecology of the species. Water has many functions in the plants and is found to impact the distribution patterns of species at finer scales (Willis and Whittaker, 2002) as compared to global scales. It is a solvent for mineral nutrients and the complex organic matters produced within the plant; it also acts as a temperature regulator during the process of plant transpiration and serves as raw material in the process of photosynthesis which is the basic process underlying all life (Ganglo *et al.*, 2017). Plants can be stressed by lack of moisture as well as an excess of moisture (Ganglo *et al.*, 2017). Because of those important functions, the presence of water in the environment of plants is quite important. The response of the species to the annual variations of precipitation bio 13 (precipitation of wettest month) and bio 14 (precipitation of driest month) in the study area further suggest that the species is exposed to dry and rainy seasons in its natural range as the species is common in primary and secondary forest and guinea savannah (Orwa *et al.*, 2009). Although annual mean temperature (bio 1) was not among the most important contributors to the distribution model of *P. macrophylla*, its variation in terms of minimum temperature of coldest month (bio 6) proved to significantly control the spatial distribution of the species. It is important to emphasize here that the rate of plant growth and development is controlled by its surrounding temperature and each plant has a specific temperature range characterized by a minimum, maximum and optimum (Hatfield and Prueger, 2015). Minimum temperature of the coldest month (bio 6) quantifies the coldest month with the lowest average low temperature with temperature of 21.7˚C (O'Donnell and Ignizio, 2012). The logistic prediction of the response curve shows increase in minimum temperature from 0˚C to 18 - 25˚C for *P. macrophylla*. The response curve for bio 6 therefore, confirms that the minimum temperature of coldest month suitable for the spatial distribution of the species is 25˚C which again is consistent with the ecology of the species. According to Hatfield and Prueger (2015), vegetative development increases as temperature rises to the species optimum level and for most plant species vegetative development usually has a higher optimum rate than for the reproductive development. In light of their findings it can be understood that large variations of temperature (high value of bio 6) can affect the optimum temperature of *P. macrophylla* and then impact on its distribution and development both at vegetative and reproductive phases. It can therefore be deduced that the maximum value of bio 6 beyond which the distribution of *P. macrophylla* can be negatively impacted is 25 ˚C. The generalization of a model depends on the choice of the variables used to run it (Elith *et al.*, 2011). In this study, the variable bio 6 measured availability and variability of light and heat to the species while bio 12, 13 and bio 14, respectively measured the availability and variability of water for *P. macrophylla*. As those variables controlling the spatial distribution of the species are fundamental primary conditions, the models can be generalized to regions outside the study area and serve the purpose of species management in such geographical areas (Elith *et al.*, 2011).

Spatial distribution of *Pentaclethra macrophylla* at present and future across Cross River State

Predicted changes in species distributions due to global changes, using climatic models with specific algorithms as MaxEnt, have been widely demonstrated (Svenning and Skov, 2006). When climate and habitat variables are used, then the fundamental niche is modelled and the result projected in a geographical space corresponds to the potential distribution (Pearson *et al.*, 2007). The fundamental niche is defined by Hutchison (1957) as the full range of environmental conditions where the species can survive and reproduce without migration. When the biotic interactions and spatial constraints were added to the variables, then the occupied niche was modelled, and this corresponds to the actual distribution in a geographical space (Pearson and Dawson, 2003). Fundamental niche and potential distributions are convenient when the purpose of the modelling is introduced, as it represents the global cultivation potential (Cuni-Sanchez *et al.*, 2010). Therefore, assessing the potential distribution of the species in this study is relevant to support ecological restoration. The AUC and TSS values showed that the model had good predictive power and could be used to predict the distributions of the species under present and future scenarios. Moreover, the response curves are relatively smooth and the model could therefore be well projected in the future. In this study, 17, 056 km^2 corresponding to 84.62% of the study area (20,156 km^2) are presently suitable habitats to *P. macrophylla* (Figure 6a). The tree species is currently distributed across the guinea savannah and forest zones of Northern, Central and Southern zones of Cross River State. In each zone of the study area, at least one protected area is located in a suitable habitat of the tree species. In the Northern zone, it is the Becheve Forest Reserve. In the Central zone, they are the Afi Mountain and Wildlife Sanctuary and Cross River National Park, Okwangwo Division. In the Southern zone, they are the Cross River National Park, Oban Division and Oban Forest Reserve. Therefore, the protected area network of Cross River State conserves the tree species. In a similar study using MaxEnt model to predict current scenario: Kakpo *et al.*, (2019) reported that about 54, 000 km^2 corresponding to 47.1% of Benin's surface area (114, 763 km^2) was found to be currently suitable to *Milicia excelsa* in the Guinean climatic zone and part of the Sudanian-Guinea and Sudanian climatic zones with each zone comprising of at least one protected area; 83 and 98.9% of Benin is currently suitable to *Lonchocarpus sericeus* and *Anogeissus leiocarpa* (Gbetoho *et al.*, 2017). The current distribution of the tree species as observed in this study may be as a result of less or no fluctuations in climatic variables such as precipitation and temperature (Anderson *et al;* 2006) which are key environmental variables contributing to suitable habitats and geographical distribution of the species (Darrah *et al.,* 2017). Knowledge of the spatial and current distribution of a species is of crucial importance to evaluating extinction risks and forecasting possible future threats from factors such as climate change (Pacifici *et al.*, 2015; Ganglo and Kakpo, 2016).

In contrast to the present species spatial distribution, future projections (Figure 6b) showed a significant decrease in suitable habitats for the species in southern Cross River State under RCP 8.5 2070 scenario. Model projection showed a significant decrease; 9, 940 km^2 corresponding to 49.32% in suitable habitats for the species in the southern geographical zone of Cross River State. Only the northern and central zones; 10, 216 km^2 corresponding to 50.68% of the study area (20, 156 km^2) will remain suitable habitats for the species. Similar reports have been made for other forest species by Kakpo *et al.,* (2019) on *Milicia excelsa*, Gbetoho *et al.,* (2017) on *Lonchocarpus sericeus* and *Anogeissus leiocarpa* and Sarangzai *et al.*, (2012) on *Juniperus excelsa* across Benin and Balochistan forest, Pakistan, respectively. The differences between the current predictions and future projections could be explained by changes in values of climatic parameters. Climate is projected to become hotter and drier in West Africa under the Representative Concentration Pathways (RCP) of AfriClim (Platts *et al.,* 2015) and will lead to shifts in the potential distributions of the tree species at the mid-21st century. Also the decrease in suitable habitats may be due to the significant changes projected for bioclimatic variables, mainly precipitation and temperature. *P. macrophylla* is adapted to temperatures ranging between 25 and 30˚C and precipitation between 1500 and 2700 mm per year (Orwa *et al.,* 2009). According to Busby *et al.,* (2010), fluctuations in climate variables such as precipitation and temperature will have an impact on biological diversity and on the geographical distribution of suitable habitats. Based on future projections, this study shows that the northern and central zones will play a key role in the conservation of *P. macrophylla* in Cross River State. Therefore, it is necessary to take action to conserve effectively this tree species in the projected areas.

CONCLUSION

In this study, we investigated the occurrence and impacts of climate change on the present and future geographical distribution of *P. macrophylla* across Cross River State, Nigeria so as to ascertain the conservation areas of the species. Our study revealed that four environmental variables are controlling the spatial distribution of *I. gabonensis* in Cross River State; these are bio 6 (minimum temperature of coldest month), bio 12 (Annual precipitation), bio 13 (precipitation of wettest month) and bio 14 (precipitation of driest month). At present, *P. macrophylla* is spatially distributed in the northern, central and southern geographical zones of the study area. Under future projections, the suitability prediction will decrease in southern Cross River State zone under Africlim representative concentration pathway scenario 2070. Only the northern and central zones will remain suitable habitats for the species. The results obtained provide scientific rationale for effective planning and implementing the conservation of *P. macrophylla* in Cross River State especially the southern zone to avoid extinction.

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REFERENCES

Abrahms, B., Dipietro, D., Graffis, A. and Hollander, A. (2017). Managing biodiversity under climate change: challenges, frameworks, and tools for adaptation. Biodiversity Conservation. 20: 1-17.

Adekunle, V.A.J., Olagoke, A.O. and Akindele, S.O. (2013). Tree species diversity and structure of a Nigerian Strict Nature

Reserve. Tropical Ecology. 54(3): 275-289.

Adeyemi, A.A., Ibe, A.E. and Okedimma, F.C. (2015). Tree structural and species diversities in Okwangwo Forest, Cross River State, Nigeria. Journal of Research in Forestry, Wildlife and Environment. 7: 36-53.

Adeyemi, A.A., Jimoh, S.O. and Adesoye, P.O. (2013). Assessment of tree diversities in Oban Division of the Cross River National Park (CRNP), Nigeria. Journal of Agriculture, Forestry and the Social Sciences. 11(1): 216-230.

Aigbe, H.I. and Omokhua, G.E. (2015). Tree species composition and diversity in Oban Forest Reserve, Nigeria. Journal of Agricultural Studies. 3(1): 10-24.

Aigbe, H. I. Akindele, S. O. & Onyekwelu, J. C. (2014). Tree species diversity and density pattern in Afi River Forest Reserve, Nigeria. International Journal of Scientific and Technology Research, 3 (10), 178-185.

Aju, P.C. and Ezeibekwe, I.O. (2010). Understanding and appreciating the need for biodiversity conservation in Nigeria. Journal of Medicinal Plants Research. 42: 2605-2608.

Akwaji, P.I. and Edu, E.A. (2017). Population frequency, density, abundance and diversity of tree species in ten communal forests of Nortehrn Cross River State, Nigeria. International Journal of Current Research. 9(10): 59581- 59596.

Allouche, O., Tsoar, A. and Kadmon, R. (2006). Assessing the accuracy of species distribution models: prevalence, kappa and true skill statistic (TSS). Journal of Applied Ecology. 43: 1223-1232.

Altamiranda-Saavedra, M., Arboleda, S., Parra, J.L., Peterson, A.T. and Correa, M.M. (2017). Potential distribution of mosquito vector species in a primary malaria endemic region of Colombia. PLoS ONE. 12(6), e0179093.

Anderson, R.P., Dudík, M., Ferrier, S., Guisan, A., Hijmans, R.J., Huettmann, F., Leathwick, J.R., Lehmann, A., Li, J. and Lohmann, L.G. (2006). Novel methods improve prediction of species distributions from occurrence data. Ecography. 29: 129-151.

Attua, E.M. and Pabi, O. (2013). Tree species composition, richness and diversity in the northern forest-savanna ecotone of Ghana. Journal of Applied Biosciences. 69: 5437-5448.

Bentz, B.J., Regniere, J., Fettig, C.J., Hansen, E.M., Hayes, J.L., Hicke, J.A., Kelsey, R.G., Negron, J.F. and Seybold, S.J. (2010). Climate change and bark beetles of the Western United States and Canada: direct and indirect effects. Bioscience. 60: 602-613.

Blach-Overgaard, A., Svenning, J.C., Dransfield, J., Greve, M. and Balslev, H. (2010). Determinants of palm species distributions across Africa: the relative roles of climate, non-climatic environmental factors, and spatial constraints. Ecography. 33: 380-391.

Bowe, C. and Haq, N. (2010). Quantifying the global environmental niche of an underutilised tropical fruit tree (Tamarindus indica) using herbarium records. Agriculture, Ecosystems and Environment. 139: 51-58.

Breiner, F.T., Guisan, A., Nobis, M.P. and Bergamini, A. (2017). Including environmental niche information to improve IUCN red list assessments. Diversity and Distribution. 23: 484-495.

Busby, J.W., Smith, T.G., White, K.L. and Strange, S.M. (2010). Locating climate insecurity: where are the most vulnerable places in Africa? Austin, TX, USA: University of Texas, The Robert Strauss Centre for International Security and Law, Climate Change and African Political Stability (CCAPS) Programme.

Christie, D.A. and Armesto, J.J. (2003). Regeneration at micro site and tree species co-existence in temperate rainforest of Chilue Island, Chile. Journal of Ecology. 91: 776-784.

Cuni-Sanchez, A., Osborne, P.E. and Haq, N. (2010). Identifying the global potential for baobab tree cultivation using ecological niche modelling. Agroforestry Systems, 80: 191-201.

Darrah, S.E., Bland, L.M., Bachman, S.P., Clubbe, C.P. and Trias-Blasi, A. (2017). Using coarse-scale species distribution data to predict extinction risk in plants. Diversity and Distribution. 23: 435-447.

Djotan, A.K.G., Aoudji, A.K.N., YehouenouTessi, D.R., Kakpo, S.B., Gbetoho, J.A., Koura, K. and Ganglo, J.C. (2018). Vulnerability of Khaya senegalensis Desr. and Juss. to climate change and to the invasion of Hypsipy larobusta Moore in Benin (west Africa). International Journal of Biology and Chemical Science. 12(1): 24-42.

Edet, D.I., Ijeoma, H.M. and Ogogo, A.U. (2012). Preliminary assessment of tree species diversity in Afi Mountain Wildlife Sanctuary, Southern Nigeria. Agriculture and Biology Journal of North America. 3(12): 486-492.

Elith, J., Graham, C.H., Anderson, R.P., Dudik, M., Ferrier, S., Guisan, A., Hijmans, R.J., Huettmann, F., Leathwick, J.R., Lehmann, A., Li, J., Lohmann, L.G., Loiselle, B.A., Manion, G., Moritz, C., Nakamura, M., Nakazawa, Y., Overton, J.M., Peterson, A.T., Phillips, S.J., Richardson, K., ScachettiPereira, R., Schapire, R.E., Soberon, J., Williams, S., Wisz, M.S. and Zimmermann, N.E. (2006). Novel methods improve prediction of species distributions from occurrence data. Ecography. 29: 129-151.

Elith, J., Philips, S.J., Hastie, T., Dudik, M., En Chee, Y. and Yates, C.J. (2011). A statistical explanation of MaxEnt for ecologists. Diversity and Distribution. 17: 43-57.

Emebiri, L.C., Nwufo, M.I. and Obiefuna, J.C. (2012).Pentaclethra macrophylla: Population characteristics, distribution and conservation status in Nigeria. International Tree Crops Journal. 8(2-3): 69-82.

Fatemi, S. S., Rahimi, M., Tarkesh, M. & Ravanbakhsh, H. (2018). Predicting the impacts of climate change on the distribution of Juniperus excelsa M. Bieb. in the central and eastern Alborz Mountains, Iran. iForest, 11, 643-650.

FME (2006). Federal Government of Nigeria Approved National Forest Policy 2006. Federal Ministry of Environment of Nigeria, Abuja.

Ganglo, J.C. and Kakpo, S.B. (2016). Completeness of digital accessible knowledge of the plants of Benin and priorities for future inventory and data discovery. Biodiversity Information. 11: 23-39.

Ganglo, J.C., Djotan, G.K., Gbetoho, J.A., Kakpo, S.B., Aoudji, A.K.N., Koura, K. and YehouenouTessi, D.R. (2017). Ecological niche modelling and strategies for the conservation of Dialium guineense Willd. (Black velvet) in West Africa. International Journal of Biodiversity Conservation. 9(12): 373-388.

Gbetoho, A.J., Aoudji, A.K.N., Roxburgh, L. and Ganglo, J.C. (2017). Assessing the suitability of pioneer species for secondary forest restoration in Benin in the context of global climate change. Bois et Forets des Tropiques. 332(2): 43-55.

Graham, C.H., Elith, J., Hijmans, R.J., Guisan, A., Townsend, P, A., Loiselle, B.A. (2008). The influence of spatial errors in species occurrence data used in distribution models. Journal of Applied Ecology. 45: 239-247.

Guisan, A. and Zimmermann, N.E. (2000). Predictive habitat distribution models in ecology. Ecological Modelling. 135: 147-186.

Hatfield, J.L. and Prueger, J.H. (2015). Temperature extremes: Effect on plant growth and development. Weather and Climate Extermes. 10: 4-10.

Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G. and Jarvis, A. (2005). Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology. 25: 1965-1978.

Hutchinson, G.E. (1957). Concluding remarks. Cold Harbour Symposia on Quantitative Biology. 22(2): 415-427.

Ikyaagba, T.E, Tee, T.N., Dagba, B.I., Ancha, U.P., Ngibo, K.D. and Tume, C. (2015). Tree composition and distribution in Federal University of Agriculture Makurdi, Nigeria. Journal of Research in Forestry, Wildlife and Environment. 7(2): 147-157.

IPCC (2013). Climate Change 2013: The Physical Science Basis. Contribution of Working Group 1 to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Stocker, T. F., Qin, D., Plattner, G. K., Tignor, M., Allen, S. K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P. M. (eds.) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC (2014). Climate Change 2014: Impacts, Adaptation and Vulnerability. Summaries, Frequently Asked Questions and Cross Chapter Boxes. A contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Field, C. B., Barros, V. R., Dokken, D. J., Mach, K. J., Mastrandrea, M. D., Bilir, T. E., Chatterjee, M., Ebi, K. L., Estrada, Y. O., Genova, R. C., Girma, B., Kissel, E. S., Levy, A. N., MacCracken, S., Mastrandrea, P. R., White, L. L. (eds.) World Meteorological Organization, Geneva, Switzerland.

Kakpo, S.B., Aoudji, A.K.N., Gnanguenon Guesse, D., Gbetoho, A.J., Koura, K., Djotan, G.K. and Ganglo, J.C. (2019). Spatial distribution and impacts of climate change on Milicia excelsa in Benin, West Africa. Journal of Forestry Research. https//doi.org/10.1007/s11676-019-01069-7.

Keay, R.W.J. (1989). Trees of Nigeria. New York, Oxford University Press, pp.476.

Khanum, R., Mumtaz, A.S. and Kumar, S. (2013). Predicting impacts of climate change on medicinal asclepiads of Pakistan using MaxEnt modelling. Acta Oecologica. 49: 23-31.

Merow, C., Matthew, J.S. & John, A.S. Jnr. (2013). A practical guide to MaxEnt for modelling species distributions: what it does, and why inputs and settings matter. Ecogeography. 36(10): 1058-1069.

Moss, R.H., Edmonds, J.A., Hibbard, K.A., Manning, M.R., Rose, S.K., Van Vuuren, D.P.,

Carter, T.R., Emori, S., Kainuma, M., Kram, T., Meehl, G.A., Mitchell, J.F.B., Nakicenovic, N., Riahi, K., Smith, S.J., Stouffer, R.J., Thomson, A.M., Weyant, J.P., Wilbanks, T.J. (2010). The next generation of scenarios for climate change research and assessment. Nature. 463: 747-756.

NIMET (2015). National weather forecasting and climate research. Nigerian Meteorological Agency Agrometeorological Bulletin. 36(3): 21-31.

O'Donnell, M.S. and Ignizio, D.A. (2012). Bioclimatic predictors for supporting ecological applications in the conterminous United States: U. S. Geological Survey Data Series 691.

Oboh, G. (2007). Pentaclethra macrophylla: Record from PROTA 4U. Van der Vossen, H.A.M. & Mkamilo, G. S. (Editors).PROTA (Plant Resources of Tropical Africa /Ressources végétales de l'Afriquetropicale), Wageningen, Netherlands.

Ogunjemite, B.G. (2015). Assessment of floristic composition of Ologbo Concession, Edo State, Nigeria, for conservation planning. Revue Scientifique et Technique Forêt et Environnement du Bassin du Congo. 4: 10-19.

Olajide, O. (2004). Growth performance of trees in Akure Forest Reserve, Ondo State, Nigeria. Ph.D Thesis, University of Ibadan, Nigeria.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Anthony, S. (2009). Agroforestry Database: a tree reference and selection guide version 4.0. www.worldforestry.org/sites/treed bs/treedatabases.asp. (Pentaclethra macrophylla Benth.). Retrieved 29/03/2020.

Pacifici, M., Foden, W.B., Visconti, P., Watson, J.E.M., Butchart, S.H.M., Kovacs, K.M., Scheffers, B.R., Hole, D.G., Martin, T.G., Akcakaya, H.R., Corlett, R.T., Huntley, B., Bickford, D., Carr, J.A., Hoffmann, A.A., Midgley, G.F., Pearce-Kelly, P., Pearson, R.G., Williams, S.E., Willis, S.G., Young, B. and Rondinini, C. (2015). Assessing species vulnerability to climate change. Nature Climate Change. 5: 215-225.

Pearson, G.R., Raxworthy, J.C., Nakamura, M. and Peterson, A.T. (2007). Predicting species distribution from small numbers of occurrence records: a test case using cryptic geckos in Madagascar. Journal of Biogeography. 34: 102-117.

Pearson, R.G. and Dawson, T.P. (2003). Predicting the impacts of climate change on the distribution of species: are bioclimatic envelop models useful? Global Ecology and Biogeography. 12: 361-371.

Peterson, A.T., Papes, M. and Soberon, J. (2008). Rethinking receiver operating characteristic analysis applications in ecological niche modelling. Ecological Modelling. 2131: 63-72.

Peterson, A.T., Soberon, J., Pearson, R.G., Anderson, R.P., Nolcamua, M., Martinez-Meyer, E. and Arajuo, M.B. (2011). Ecological niches and geographical distributions. Princeton University Press, Princeton, New Jersey, USA.

Phillips, S.J. and Dudik, M. (2008). Modelling of species distributions with MaxEnt: new extensions and a comprehensive evaluation. Ecography. 31: 161-175.

Phillips, S.J., Anderson, R.P. and Schapire, R.E. (2006). Maximum entropy modelling of species geographic distributions. Ecological Modelling. 190: 231-259.

Platts, P.J., Omeny, P.A. and Marchant, R. (2015). AFRICLIM: high-resolution climate projections for ecological applications in Africa. African Journal of Ecology. 53: 103-108.

Sanwo, S.K., Ige, P.O., Sosanya, O.S. and Ogunlaye, O.G. (2015). Tree species diversity and forest stand dynamics in a tropical rainforest in Southern Nigeria. Malaysian Journal of Applied Biology. 44(2): 65-73.

Sarangzai, A.M., Ahmed, M., Ahmed, A., Tareen, L. and Jan, S.U. (2012). The ecology and dynamics of Juniperus excelsa forest in Balochistan-Pakistan. Pakistan Journal of Botany. 44(5): 1617-1625.

Soberon, J. and Peterson, A.T. (2005). Interpretation of models of fundamental ecological niches and species distributional areas. Biodiversity Informatics. 2: 1-10.

Stalin, N. and Swamy, P.S. (2015). Prodiction of suitable habitats for Syzygium caryophyllatum, an endangered medicinal tree by using species distribution modelling for conservation planning. European Journal of Experimental Biology. 5(11): 12-19.

Svenning, J.C. and Skov, F. (2006). Potential impact of climate change on the northern nemoral forest herb flora of Europe. Biodiversity and Conservation. 15: 3341-3356.

Van Vuuren, D.P., Carter, T.R. (2014). Climate and socio-economic scenarios for climate change research and assessment: reconciling the new with the old. Climate Change. 122: 415-429.

Van Vuuren, P.D., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., Hurtt, G.C., Kram, T., Krey, V., Lamarque, J.F., Masui, T., Meinshausen, M., Nakicenovic, N., Smith, S.J., Rose, S.K. (2011). The representative concentration pathways: an overview. Climatic Change. 109: 5-31.

Vayreda, J., Gracia, M., Martinez-Vilalta, J. and Retana, J. (2013). Patterns and drivers of regeneration of tree species in forests of peninsular Spain. Journal of Biogeography. 40: 1252-1265.

Wakawa, L., Suleiman, A., Ibrahim, Y. and Adam, L. (2017). Tree species biodiversity of a Sahelian ecosystem in Noertheast Nigeria. Journal of Bartin Faculty of Forestry. 19(2): 166-173.

Warren, R., Van Der Wal, J., Price, J., Welbergen, J.A., Atkinson, I., Ramirez-Villegas, J., Osborn, T.J., Jarvis, A., Shoo, L.P., Williams, S.E. and Lowe, J. (2013). Quantifying the benefit of early climate change mitigation in avoiding biodiversity loss. Nature Climate Change. 3(7): 678-682.

Willis, K.J. and Whittaker, R.J. (2002). Species diversity – scale matters. Science, 295(5558): 1245-1248.

Yu-Jun, Y., Xi, C., Zhi-Feng, Y. and Shang-Hong, Z. (2016). MaxEnt modelling for predicting the potential distribution of endangered medicinal plant (H. ripana Lour.) in Yunnan, China. Ecological Engineering. 92: 260-269.

DIVERSITY AND ETHNOBOTANICAL POTENTIAL OF WOODY PLANT SPECIES IN FEDERAL UNIVERSITY DUTSE, JIGAWA STATE.

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ABSTRACT

Woody plant species diversity with their ethno-botanical potentials serve as medicinal, food, protection and economical needs. Four land use type were sampled to determine the diversity and composition of woody plant species in the study area. Four 50 × 50m sample plots were randomly located in each of: Residential area, Crop farm, Reserve area and Orchard. Complete enumeration of woody plants species with Diameter at Breast Height (DBH) ≥ 5cm was carried out within 50 × 50m sample plots. Woody species with DBH ≥ 2cm but ≤ 5cm were enumerated within 5×5m subplots and plant species ≤ 2cm were enumerated within 1×1m mini plots. Data collected were analysed using Shannon wiener Diversity index. Two hundred and thirty-eight (238) woody plant species were identified. A total of 30 questionnaires was administered to sample the perceived ethno-botanical potentials of woody plants within the campus. The common and preferred species with the highest percentage was Azadirachta indica, and Acasia sieberiana, Anacarduim occidentales, Citrus sinensis and Diospyrous mespiliformis. The tree species diversity as measured according to different land use types. Reserve area had the highest diversity followed by Residential area, Crop farm and Orchard which have the least number of plants species. The low number of tree species revealed poor management and planning which significantly affected species diversity in the orchard. Participatory ethnobotany and interview were used for the ethnobotanical survey. Eighty percent of plant species had more than one use; categories with medicinal use topping the list (80%). Other uses include: food (12%) and protection (8%). It also shows that different types of plant species can be used to cure different illnesses such as Malaria typhoid and Diarrhea.

Key words: Diversity, land use, ethnobotany, composition and woody plants

INTRODUCTION

Nigeria's woody plant species coverage provides a range of products and services that play an important role in the economy and overall wellbeing of the country (Kreft and Jetz, 2007). Small farmers around the world deliberately keep trees and shrubs on land to serve a range of purposes such as farming or grazing (Bhattarai and Vetaas, 2003). The broad range of roles woody plants play in traditional farming systems have been described by authors (Lisa *et al.,* 2019 and Tabuti 2012). Farmers protect plant, and promote woody species within and around their home gardens, fields, and communal pasturelands to derive a range of benefits, including provisions of food, fodder, construction materials, farm equipment, fuel wood, and medicines. Thousands of woody plant species are grown locally for food or used in traditional agriculture, some of them scarcely or only partially domesticated (Heywood, 1995). Woody plants have been used as sources of medicine for millennia, and these traditional medicine systems continue to be extremely important today.

Ethnobotany is the study of the relationship between plants and people (Balick and Cox, 1996). It includes study of the uses of plants by humans and the relationship between humans and vegetation. The definition of ethnobotany can be sum up in four words that is people, plants, interactions and uses. Ethnobotanical knowledge has been shown to be a relatively accessible and reliable source of information on vegetation dynamics. It has also provided valuable information about single species, which can be directly applied to local resource management (Wezel and Lykke 2006). The perceptions of plant species by local people complement data from vegetation studies, which are less able to provide insights into long-term vegetation change and the distribution of rare species (Lykke *et al*., 1999). Moreover, many native woody species have important potential for agroforestry and the restoration of degraded lands. Thus, knowing the preferences of local people helps to implement management solutions for natural resources that are locally accepted and better match their needs (Belem *et al.* 2007). Exploring this aspect could greatly advance the understanding of species' niches, present and past distributions, extent of use and types of threats.

It is unfortunate to say that woody plant species are threatened by overexploitation, lack of natural regeneration, poor management, low availability of saplings for regeneration, climate change among others. Even the introduced species like *Eucalyptus globulus* in the savannas are faced with the above-mentioned factors. Thereby contributing differently to the decline in abundance. The major causes of woody plant species loss are linked to rapid human population growth rates and poverty. Northwest Nigeria is nothing different from the generality of the country's careless attitude towards conservation because of poverty and high level of illiteracy. These drivers force people to harvest woody plant species using poor methods and at unsustainably high intensities.

Materials and Methods

The study was conducted in Federal University Dutse campus located within between latitudes 11^0 39''N to $11^0$69''N and longitude 9^o15''E to 9^0 36''E (figure1). Dutse is a city located in northern Nigeria. It covered about 1147246km and a population of 125773 male and 125362 female. The state was created in 1991 during the military regime of General Ibrahim Badamosi Babangida. Dutse (Dutsi, in earlier notes) got its name from the rocky topography peculiar to the area. Different forms of rocks can be seen widely spread across the town. Federal University Dutse was established in November 2011. The amount of rainfall received annually is usually around 743mm. The average annual temperature is 34.5^0C. The topography is characterized by high land area which is almost 750 meters. Soil tends to be fertile ranging from sandy-loam (Salami and Lawal, 2018).

The study area was stratified into four, based on land use types as describe by Gauch (1982). These include: Crop farm, Residential areas, Orchard and reserve area which are all located within Federal University Dutse. On ethnobotanical potentials of the trees, questionnaires were employed as primary source of data. A total of 30 questionnaires were distributed in the study area. Of the thirty, 10 questionnaires were administered to the staff and students, 10 to the neighboring communities, and 10 to the local medical practitioners around the university community.

Four 50 × 50 m sample plots were randomly established in each of: Crop farm, Residential area, Reserve area and Orchard, with a minimum distance of 50 m between any two plots in order to give room for variation in microsite factors. Measurement and identification were limited to all woody plants species within the 50 × 50 m sample plots such that woody plants species with DBH ≥ 5 cm in the various land use types were counted within the sample plots. The diameter at breast height (DBH) was measured at 1.3 m above the ground. The scientific names of all the tree species encounter in each sample plot were recorded. In each of the sample plots, five 5×5 m subplots were established such that four quadrats were at the corners and one at the center. Shrubs and saplings with DBH ≥ 2 cm but ≤ 5 cm were enumerated within the subplot. At the center of each 5 × 5 m subplot, one 1 × 1 m subplot was established within which seedlings and wildlings were enumerated.

Data analysis

The following indices were employed following Somorin (2010):

(i) Shannon-Wiener diversity index:

Shannon Diversity Index

$$Hi = \sum_{i=1}^{s} (p_i Lnp_i) \ldots \ldots (\text{eqn1})$$

Where, H' is the Shannon-Wiener diversity index; S= is the total number of species in the community; *pi* is the proportion of S made up of the i^{th} species; *Ln* = natural logarithm.

Plant species diversity were calculated using Shannon wiener index of diversity and a measure of equitability was derived.

Density

$$D = {}^{n_i}/_{N} \ldots\ldots \text{(eqn2)}$$

Relative Density

$$RD = [{}^{n_i}/_{N}]X100\% \ldots\ldots\ldots \text{(eqn3)}$$

Where RD = Relative density, *ni* = Density of a particular species i and N = Total density of all species.

Descriptive statistical method was used for assessing the ethno-botanical potentials of woody plants species using table frequency and percentage. The formula is as shown below;

$X = \frac{F}{n}\ x\ 100 \ldots\ldots$ (*eqn 4*)

Where;

F = frequency

n = number of respondents

RESULT

A total of 238 plant species were recorded across the different land uses. The most abundance species were *Azadirachta indica* and *Acasia sieberiana* as observed in the residential and Reserve areas. They (*Azadirachta indica* and *Acasis sieberiana*) equally had the highest species density of 0.0018/ha and 0.0017/ha respectively. Orchard had the highest species richness (Table 1). *Ficus ingens* and *Terminalia mantaly* were observed to have the lowest densities across the land use types as presented in table 1. *Azadirachta indica* had a frequency of 23.00/ha in both residential areas and protected areas but zero frequency in the Orchard.

A total of 32 plant species were recorded in the subplots. Residential area had the highest woody plant species density of 0.0043 while protected areas had the lowest density of 0.0001. *Pilostigma histata* had the highest relative density in the residential area (86.00) but accounted for the lowest relative density in the protected area (14.0). The species area has high relative distribution across the land use types except for *Diospyros mespiliformis* that accounted for 11.75 under the protected area.

The species composition for the ground flora as presented in table 3 below shows that almost all the species belong to the family Poaceae except for *Hyptis spicigera* that belongs to the family Lamiaceae.

Ethno-botanical survey involved the community people aged between 18-25, 26-35, 36-40 and 41 as shown in (Table 4). The result of this study shows that people between the age of 36-40 has the higher percentage of respondents followed by 26-35. Seventy-six (76.7%) of the respondents were male, while (23.3%) were female. It also shows that seventy-three (73%) of the respondents were married, (23%) were single.

Fifteen useful plants were identified base on their Genus, Species, Hausa name, and Part used in table (5). The use of plant by the people was grouped into three major categories Viz: Medicinal uses, food and wood/construction. Ninety percent of the species have more than one uses.

Table 1: Distribution of Woody plant species (DSH ≥ 5 cm) diversity and composition in the various land used types

Tree specie	Density	Frequency	Abundance	R/density	R/frequency	R/Abundance
	Residential Areas					
Acasia seberiana	0.0004	10.50	14.33	8.51	21.99	9.46
Azadirachta indica	0.0018	23.00	11.75	38.29	48.17	7.76
Acasia sayel	0.0008	5.00	14.33	17.02	10.47	9.46

Delonix regia	0.0004	5.25	10.75	17.02	2.09	7.09
Eucalyptus camaldulensis	0.0004	1.00	43.00	10.64	2.09	28.38
Olea europea	0.0005	2.00	43.00	17.02	4.19	28.38
Terminalia mantaly	0.0001	1.00	14.33	2.13	2.09	9.46
	RESERVED AREAS					
Adansonia digitata	0.0001	4.25	23.50	2.00	6.72	22.22
Acasia semia	0.0005	7.00	15.67	10.00	11.07	14.82
Acasia nilotica	0.0001	5.00	15.67	2.00	7.91	14.82
Azadirachta indica	0.0009	23.00	11.75	18.00	36.36	11.11
Acasia seberiana	0.0017	8.00	15.67	34.00	12.65	14.82
Diospyros mespiliformis	0.0008	10.00	15.67	16.00	15.81	14.82
Termarindus indica	0.0009	3.00	23.5	18.00	4.74	22.22
	CROP FARM					
Acasia nilotica	0.0002	5.00	12.00	7.69	11.05	8.00
Azadirachta indica	0.0004	23.00	9.00	15.39	50.83	6.00
Adansonia digitata	0.0004	4.25	18.00	15.39	9.39	12.00
Borassus aethiopum	0.0005	3.00	36.00	19.23	6.63	24.00
Diospyros mespiliformis	0.0005	3.00	12.00	19.23	6.63	8.00
Delonix regia	0.0002	5.25	9.00	4.75	11.60	6.00
Phoenix dactylifera	0.0003	4.25	18.00	11.54	9.39	12.00
Terminalia superba	0.00022	0.5	36.00	7.69	1.10	24.00
Ficus ingens	0.0001	0.25	36.00	3.85	0.75	4.00
	ORCHARD					
Anacarduim occidentale	0.0037	9.25	37.00	50.69	35.24	58.73
Citrus sinensis	0.0026	7.00	26.00	35.62	26.67	41.27
Acasia sieberiana	0.001	10.00	0.001	13.69	38.09	0.01

Source: Field Work Survey, 2021.

Table 2: Woody plant species composition (≥ 2 cm but ≤ 5 cm) across land use types

Tree species	Density	Frequency	Abundance	R/density	R/frequency	R/abundance
	RESIDENCIAL AREA					
Acasia seberiana	0.0027	0.75	2.33	4.00	37.50	15.98
Azadirachta indica	0.0004	0.5	1.75	8.00	25.00	12.00
Acasia seyal	0.0001	0.25	7.00	2.00	12.50	48.01
Pilostigma histata	0.0043	0.5	3.50	86.00	25.00	221.52
	RESERVE AREA					
Acasia sieberiana	0.0004	0.5	3.50	57.14	28.57	17.65
Diospyros mespiliformis	0.0001	0.75	2.33	14.29	42.86	11.75
Pilostigma reticulum	0.0001	0.25	7.00	14.29	14.29	35.30
Leptadenia hastate	0.0001	0.25	7.00	14.29	14.29	35.30
	CROP FARM					
Azadiracta indica	0.0005	0.50	1.67	55.56	50.00	25.04
Acasia sieberiana	0.0004	0.50	5.00	44.46	74.96	74.96

	ORCHARD					
Acasia sieberiana	0.0012	0.5	3.00	75.00	66.67	33.33
Citrus sinensis	0.0004	0.25	6.00	25.00	33.33	66.66

Source: Field Survey 2021

Table 3: Vascular plant species (≤ 2cm)

Scientific name	**Family name**
Residential Area	
Andropogan gayanus	Poaceae
Pennisetum purpurium	Poaceae
Cynodon dactylin	Poaceae
Reserve Area	
Pennisetum purpurium	Poaceae
Eremochloa ophiuroides	Poaceae
Hyptis spicigera	Lamiaceae
Crop Farm	
Andropogan gayanus	Poaceae
Orchard	
Andropogan gayanus	Poaceae
Pennisetum purpureum	Poaceae

Source: Field Survey 2021

Table four: Demographic characteristics of respondent

AGE	**FREQUENCY**	**PERCENT**
18-25	5	16.7
26-35	10	33.3
36-40	11	36.7
41 and Above	4	13.3
Total	30	100.0
GENDER		
Male	23	76.7
Female	7	23.3
Total	30	100.0
MARITAL STATUS		
Married	22	73.3
Single	7	23.3
Divorced	1	3.3
Total	30	100.0
QUALIFICATION		
Primary	7	23.3
Secondary	1	3.3
Tertiary	11	36.7
Others	11	36.7
Total	30	100.0
OCCUPATIONAL STATUS		
Lecturing	6	20.0
Students	7	23.3
Medical traditionalist	8	26.7
Farmers	9	30.0
Total	30	100.0
ACCESS TO HERBAL MEDICATION		
Yes	26	86.7
No	4	13.3
Total	30	100.0

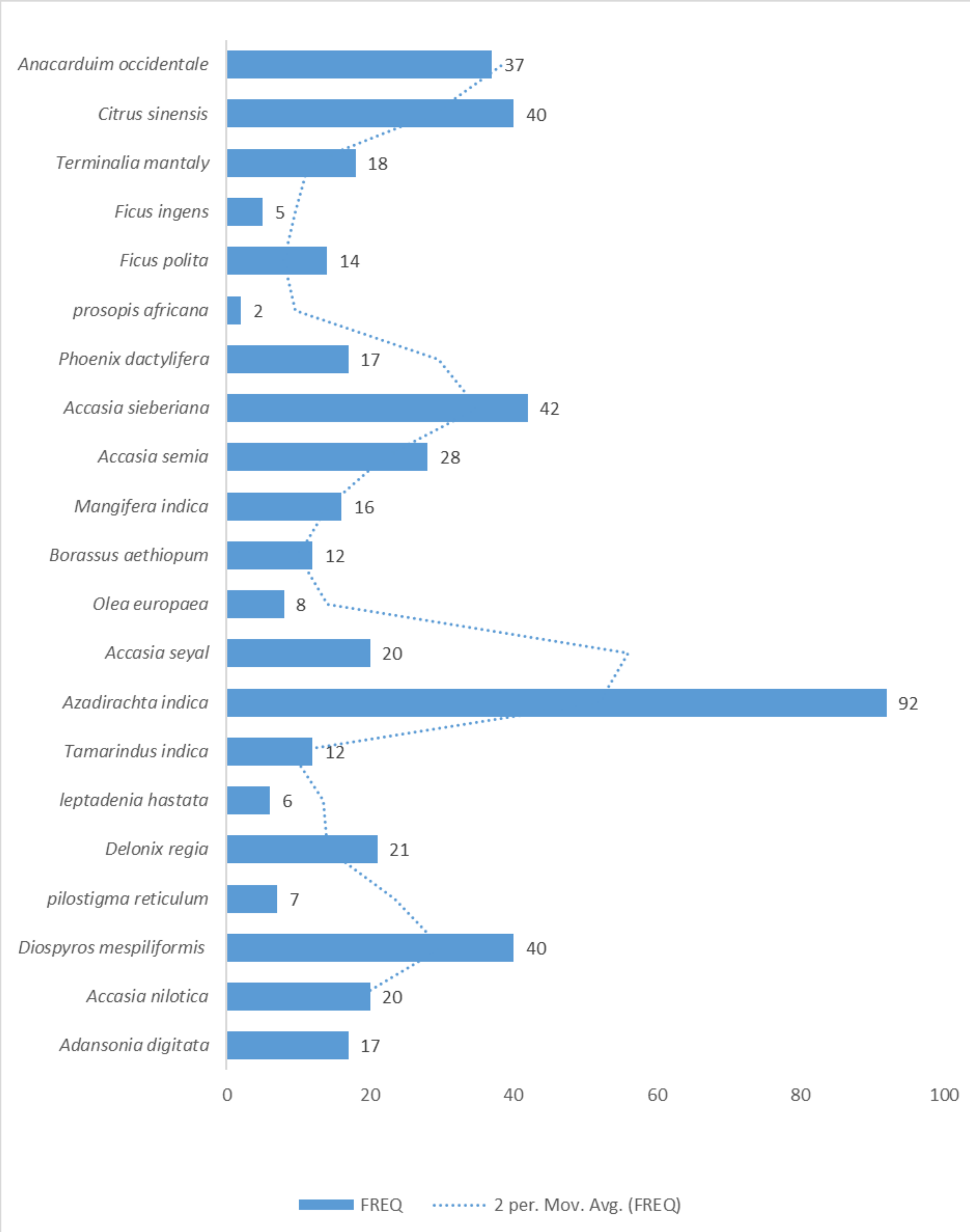
COMMON ILLNESSES		
Malaria typhoid	22	73.3
Sickle cell mizzles	8	26.7
Total	30	1O0.0
COMMON ILLNESSES CURED		
Yes	28	93.3
No	2	6.7
Total	30	100.0
NAMES OF HERBS USED TO CURE ILLNESSES		
Azadirachta indica	8	26.7
Eucalyptus camaldulensis	16	53.3
Moringa olifera	6	20.0
Total	30	100.0
SOURCE OF HERBAL COLLECTION		
F.u.d	20	66.7
Neighboring community	7	23.3
Market	3	10.0
Total	30	100.0
CAUSES OF CHANGES		
Urbanization/infrastructural D	5	16.7
Farming	23	76.7
Grazing	1	3.3
Lack of proper fencing of campus	1	3.3
Total	30	100.0
ECONOMIC USES		
Yes	30	100

Source: Field Survey 2021

Table 5: Some selected plant species in the study area and there uses

S/N	Genus	Species	Hausa name	Treatments	Part used
1.	*Azadirachta*	*Indica*	Maina	1. It reduce blood sugar level 2. use as herbicides and shade	Bark and leaves
2.	*Eucalyptus*	*camaldulensis*	Dogon yaro	1. It treats malaria and fever 2. It is treat bladder disease	Leaves and root
3.	*Adansonia*	*Digitata*	Kuka	1. It is use as shade 2. use as food	Leaves and root
4.	*Acasia*	*Seberiana*	Farar kaya	1. It reduces body fat 2. It promote oral health	Bark and leaves
5.	*Prosopis*	*Africana*	Kirya	1. Used to treat typhoid fever 2. It treat abdominal pain	Bark and root
6.	*Delonix*	*Regia*	Filawa	1. It treat pneumonia 2. It treat rheunmatoid arthritis	Bark and leaves
7.	*Mamgifera*	*Indica*	Mangwaro	1. It treat hypertension 2. It is use as food	Bark,leaves and fruits
8.	*Phoenix*	*dactylifera*	Dabino	1. It treat asthma 2. It is use as food	Bark and fruits
9.	*Ficus*	*Ingens*	Shirinya	1. It treat Eczema 2. It lower blood sugar level	Leaves and bark
10.	*Olea*	*europaea*	Zaitun	1. It treat urinary tract 2. It is use as food	leaves and friuits
11.	*Acasia*	*Semia*		1. It treat malaria 2. It treat typhoid fever	Bark and leaves
12.	*Diospyros*	*mespiliformis*	Kanya	1. It treat headaches 2. It is use as food	Leaves and fruits
13.	*Citrus*	*Aurantium*	Lemon tsami	1. It treat nausea 2. It is use as food	Leaves and fruits
14.	*Anacarduim*	*Occidentale*	Kashu	1. It. treat eczema 2. It is use as food	Leaves and fruit
15.	*Borassus aethiopum*	*Aethiopum*	Giginya	1. It is treat diarrhea 2. It is use as food	Leaves, fruits and bark

Source: Field Survey, 2021


Anacarduim occidentale
Citrus sinensis
Terminalia mantaly
Ficus ingens
Ficus polita
prosopis africana
Phoenix dactylifera
Accasia sieberiana
Accasia semia
Mangifera indica
Borassus aethiopum
Olea europaea
Accasia seyal
Azadirachta indica
Tamarindus indica
leptadenia hastata
Delonix regia
pilostigma reticulum
Diospyros mespiliformis
Accasia nilotica
Adansonia digitata
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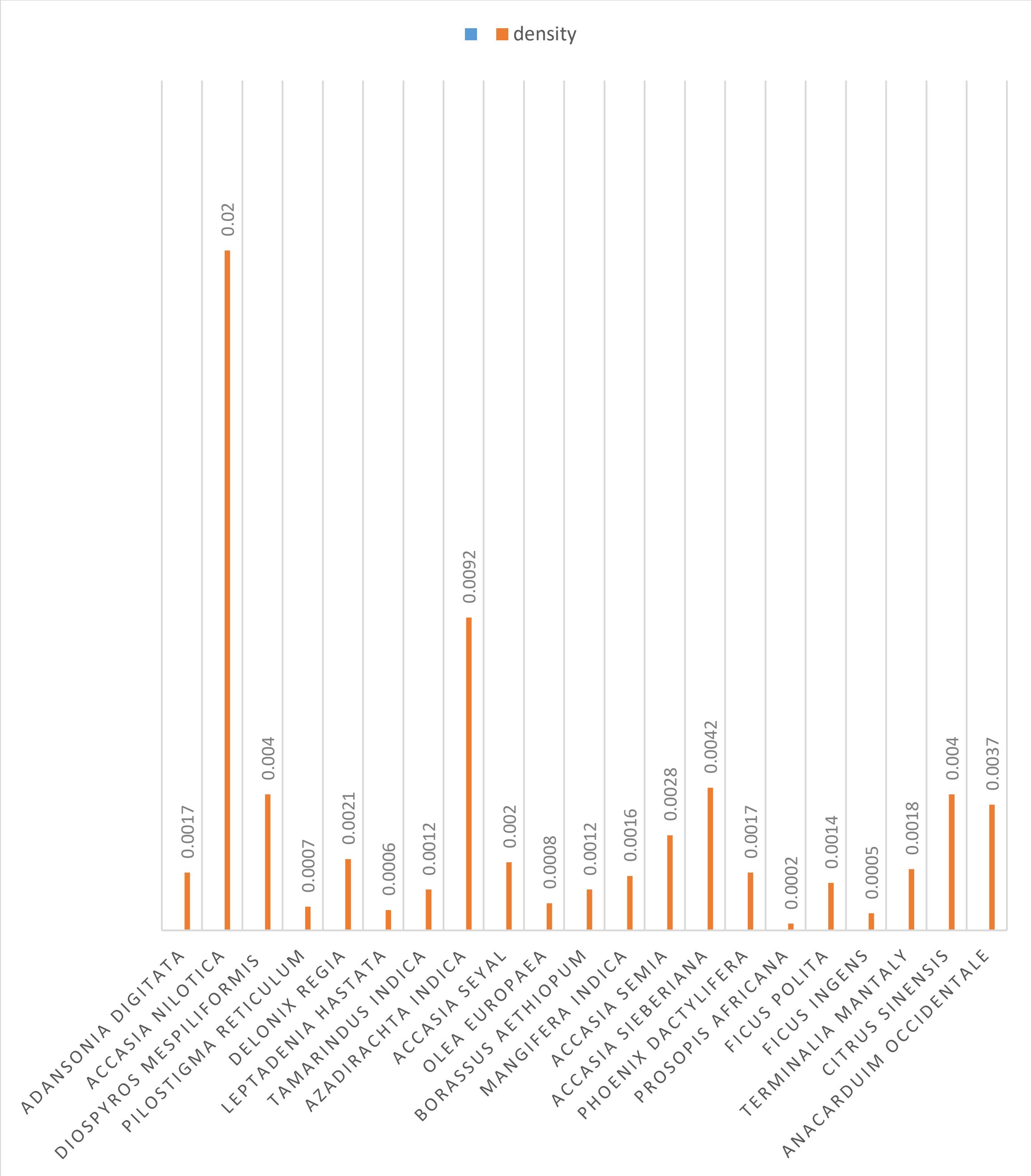

DISCUSSION

It was observed that *Azadirachta indica* (Meliaceae) was the dominant species in the three sample plots because the species is more suitable for the geographical area in terms of survival rate and reproduced more frequency by natural means (through the dispersal of seedlings by wind, birds and rodents and by natural agents) which make it to be more abundance than other tree species. Salami (2017) reported that the dominance of Fabaceae and Maliacea in Omo Forest Reserve was aided by wind dispersal which enhanced their spread in the study location.

This atudy shows that ethno-botanical potentials of woody plant species is predominantly male occupation, meanng that they have a key role to play in the diets of millions of people. This is similar to the findings of Jimoh and Haruna (2007). Most of the respondent are farmers as they form 30% follow by Medical traditionalist. As shown in the table most of the people have access to herbal medication and could be able to cure some common illnesses such as Malaria typhoid and Sickle cell mizzles. Eucalyptus has the highest number of species used to cure Malaria typhoid, and also shows that most of the people source their plant species for medication within the University.

Most of the people rely on plant to meet their health needs. This is true of the people in these areas as they use almost all plants recorded for medicinal purpose. This is similar to the finding of Duguma (2015) which says that the high value obtained for medicinal uses is an indication that the use of plant for medicinal purpose is of great value to the people of the area and it plays a significant role in their health care system. Most of the plant species found in the areas were used as herbs with large numbers of tall and large diameters trees.

CONCLUSION

Federal University Dutse houses significant diverse tree species that has numerous medicinal and none medicinal benefits. Most of the tree are explore by the people within and outside the university. This exploration is done with little or no management strategies which post a threat to the survival of these tree species. Except adequate management actions are taken towards their conservation, these beneficial trees species may be explored beyond their resilience in the near future. It is hereby recommended to have continues sensitization on the need for conservation within and outside the campus. Also there should be a timely reassessment of the tree species in the campus while regeneration strategies are being put in place

REFERENCES

Balick, A. G. and Cox, T. D. (1996). Energy supply and patterns of species richness on local and regional scales. In: Species Diversity in Ecological Communities (Ricklefs RE, Schluter D, eds), pp. 6674. University of Chicago Press, Chicago

Belem, B., Nacoulma, B. M., Gbangou, R., Kambou, S., Hansen, H. H. and Gausset, Q. (2007). Use of Non G D Wood Forest Products by local people bordering the ‘‘Parc National Kabore Tambi’. *Burkina Faso. Journal of Transdisciplinary Environmental Studies*. 5(6):1-21.

Bhattarai, K. R., and Vetaas, O. R. (2003). Variation in plant species richness of different life forms along a subtropical elevation gradient in the Himalayas, east Nepal. *Global Ecology and Biogeography.* (12) 327–340.

Duguma, L.A. and Minang, P.A. (2015). Leveraging landscapes: A systems approach to drivers of change. In *Climate-Smart Landscapes: Multifunctionality in Practice*; Minang, P.A., van Noordwijk, M., Freeman, O.E., Mbow, C., de Leeuw, J., Catacutan, D., Eds.; ASB Partnership for The Tropical Forest margins, World Agroforestry Centre: Nairobi, Kenya. pp. 135–149.

Gauch, H. G., (1982). Multivariate Analysis in Community Ecology. Cambridge University.

Heywood, V. H. (1995). Global biodiversity assessment. New York NY: Cambridge University Pr. 1140 p.

Jimoh, S. O. and Haruna, E. A. (2007). Contribution of non-timber forest products to house food security and income around Onigambari Forest Reserve, Oyo State, Nigeria. *Journal of Environmental* Extension, (6) 28-33.

Kreft, H and, Jetz, O. (2007) Global patterns and determinants of vascular plant diversity. Proceedings of the National Academy of Sciences USA. 9 (104): 5925–5930.

Lalisa, A.D., Joanes, A., Peter, A.M., Alemayehu, N., Ayana, B.G., Judith, M.N. and Florence, B. (2019). Deforestation and Forest Degradation as an Environmental Behavior: Unpacking Realities Shaping Community Actions. *Land.* (*8*) 26.

Lykke, A. M, Fog, B. and Madsen, J. E. (1999). Woody vegetation changes in the Sahel of Burkina Faso assessed by means of Local knowledge aerial photos and botanical investigations. *Danish Journal of Geography.* 4 (2): 57-68.

Salami, K. D. (2017). Trees species Diversity and Soil status of Omo Biosphere and Gambari Forest reserves in Southwestern Nigeria. Ph.D Thesis, Department of Forest Resources Management, University of Ibadan, Nigeria.

Salami, K. D. and Lawal, A. A. (2018). Tree species diversity and composition in the Orchard of Federal University Dutse, Jigawa State. *Journal Forestry Res. and Management.* 15(2): 112-122, www.jfrm.org.ng

Somorin, A.O (2010). Climate impacts, forest-dependent rural livelihoods and adaptation strategies in Africa: A review. African Journal of Environmental Science and Technology Vol. 4(13), pp. 903-912.

Tabuti, J.R.S., Kukunda, C.B., Kaweesi, D. and Kasilo, O.M.J. (2021). Herbal Medicine use in the Districts of Nakapiripirit, Pallisa, Kanugu, and Mukono in Uganda. *Journal of Ethnobiology and Ethnomedicine.* (8)35. http://dio.org/10.1186/1746-4269-8-35

Wezel, A. J. and Lykke, A.M. (2006). Woody vegetation change in Sahelian West Africa: evidence from local knowledge. *Journal of Environment, Development and Sustainability*. 9(8): 553-567.

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LOSS OF BIODIVERSITY THROUGH DIFFERENT SOURCES OF POLLUTION

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ABSTRACT

A major source of loss of plant biodiversity has been traced to anthropogenic factors, in which pollution is an important aspect. This necessitates establishment of facts on different polluted sites in Oyo, and Osun States in order to prevent the occurrence that further leads to loss of biodiversity of the affected ecosystems.

Descriptive research was carried out to assess the level of distortion done to the former stabilized environments. This was aimed to assessing the floral composition of two different spent oil and fertilizer polluted ecosystems using quadrat method of sampling. Relative densities, frequencies and Importance value of each plant in the study sites were carefully calculated.

The results informed that: the floral composition of the oil spent polluted sites when compared with their respective control sites and the other (2) fertilizer polluted sites, recorded less diverse plant species. There was increased in the density of monocotyledonous plant species such as: Maximum panicum, Pennisetum pedicellatum, Eragrostis spp and others. However, the fertiliser polluted sites are less reduced in plant species diversity when compared with their respective control sites. Passiflora foetida is the only plant species growing on the two (2) polluted sites but not in all control sites except that of fertilizer polluted control site. Oil spent polluted site, being the most vulnerable site to loss of plant species needs to be checked from continuity in order to guide against the worst occurrence that leads to climate change.

Keywords: *Biodiversity loss, Pollution, spent oil, fertilizer, polluted sites and plant*

INTRODUCTION

Human activities (anthropogenic factor) could be well responsible for shift in species distribution and abundance. However, if no check is done to its excesses, it stands as climate change driver which usually advanced to a dreadful issue to the global world (Chen *et al*. 2011, Poloczanska *et al.,* 2013, Pecl *et al*., 2017). It then becomes a major concern of the whole world from region to region no matter the level of the species enrichens the country is so as to be conscious of the global warming. Nigeria as a country is endowed with lots of natural resources in which petroleum is a principal one among others which includes arable land (The United Nations Agenda 21, 2012). However, the increasing effect of anthropogenic disorder has destabilized enriched species ecosystems (Burma, 2015). Although, oil upon dispersion continues to undergo further compositional deviations due to weathering that makes it reduced toxic, more viscous, and more likely to coagulate (Mendelssohn *et al*., 2012). Small quantity of refined or spent oil if spilt on terrestrial ecosystem has recorded very large negative effects on both flora and fauna components of the fragile ecosystems (Houghton, 2012). So also, there has been much pressure on farm land due to vast increase in human population. In an attempt to meet up with food demand of the large population, there is abuse use of fertilisers above the permissible level. The impact is well felt on the biotic components and was physically and observed firstly on the plant biodiversity.

This study is set to assess the contribution of human in the aspect of pollution to loss of plant biodiversity. So also, it was set to evaluate the degree of contribution by different pollution sources which its continuity may finally dragged the entire world to global warming.

MATERIALS AND METHODS

The study was carried out from two States (Osun and Oyo), Nigeria. Each of the fertiliser polluted sites was chosen for the research study due to the information gathered about them from the users of the plots. The two-mechanic workshops chosen for the study were chosen based on the confirmation of the length of period over ten (10) years. Three (3) soil samples were taken from each site including control, mixed together and sent for analysis. The result is garnished in table 1.

Vegetation survey was carried out on both spent oil contaminated sites for this study at: (Mechanic Workshop, LAUTECH Ogbomoso-Ilorin Road and INEC office, Ogbomoso, Oyo State and on both fertiliser polluted sites at: Ojo Aro, Ara-Ede road, Osun State and at: Vice Chancellors (VC) lodge, LAUTECH, Oyo State. Quadrat sampling was adopted by laying transect lines at both middle and diagonal sides of the measured plots of each studied site (10 m X 10 m). Quadrats were placed on the laid transects, plant species rooted in the quadrats were identified, counted and recorded. The Relative Importance Value (RIV) were calculated from the values of Relative Density and Relative frequency of each plant species as follows: RIV = (RD + RF) ÷ 2.

RD = The population density of each plant species in relation to the total population of all plant species recorded in the study site.

RF = The number of quadrats in which each plant species occurred in relation to the total number of quadrats laid in the study site.

RESULTS

Table 1: Heavy metal contents of spent oil, fertiliser polluted soils and their corresponding control soil samples and the recommended safe levels of WHO, 2007; FAO, 2016 in soil

Soil Samples	Cu (mg/kg)	Zn (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Pb (mg/kg)
	Spent oil polluted soil and the corresponding control				
O-I Road	7.75^{a}±	25.25^{a}±0.42	25.75^{a}±0.38	13.56^{a}±0.24	10.9 ^{a}±0.11
Control	2.80^{c}±0.16	9.36 ^{b}±0.42	6.22 ^{e}±0.38	6±0.24	0.03±0.11
INEC Area	7.57 ^{a} ±0.16	24.3 ^{a}±0.42	23.9^{b}±0.38	11.8 ^{b}±0.24	8.5^{c}±0.11
Control	3.30 ^{b}±0.16	7.42^{c}±0.42	6.8 ^{d}±0.38	5.2^{d}±0.24	0.08^{d}±0.11
WHO & FAO	4.4±0.16	12±0.42	8.4±0.38	6.4±0.24	4.5±0.11
Fertiliser polluted soil and their corresponding control					
FP Ojo aro	1.79 ^{d}±0.16	9.11^{b}±0.42	16.0 ^{c}±0.38	5.8^{c}±0.24	10.5^{b}±0.11
Control	0.09^{e}±0.16	4.8 ^{d}±0.42	7.3 ^{d}4±0.38	5 ^{d}±0.24	0.04^{d}±0.11
FP VC lodge	1.80^{d}±0.16	9.10^{b}±0.42	15.8 ^{d}±0.38	4.8^{e}±0.24	10.7 ^{a}±0.11
Control	0.05±0.16	4.2 ^{d}±0.42	5.11^{f}±0.38	4.9^{e}±0.24	0,01^{d}±0.11
WHO & FAO	4.4 ^{e}±0.16	12±0.42	8.4±0.38	6.4±0.24	4.5±0.11

Plant species composition on Ilorin-Ogbomoso Road (I-O) spent oil polluted site recorded fifteen (15) reduced plant species, while their corresponding control sites recorded nineteen (19) table 2. So also, the plant density and frequency on the polluted soil (109 and 63) respectfully. The data explained the reduced plant population and poor plant species distribution on spent oil polluted site when compared with the floral composition on control site with plant density (295) and frequency (179). Some plant species like: *Tridax procumbens*, *Gomphrena celosioides*, *Acanthospermum hispidium*, *Flueya aestuans* failed to grow on the polluted site but thrive well on the control site. *Sida corymbosa* recorded the highest density (22) and frequency (9) table 2.

Table 2: Floral Composition of Spent Oil Polluted and control Sites at (Mechanic Workshop: Ilorin Ogbomoso Road, LAUTECH, Ogbomoso, Oyo State)

Plant Spp.	Density		Frequency		Relative Density (RD)		Relative Frequency (RF)		RIV=RD+RF/2	
	Polluted	Control	Polluted	Control	Polluted	Control	Polluted	Control	Polluted	Control
Sida acuta	23	41	8	26	21.	13.89	12.69	14.52	16.85	64.21
Amaranthus hybridus	12	35	8	18	21	11.86	11.11	10.05	16.06	10.96
Tridax procumbens	-	5	-	4	-	1.69	-	2.23	-	1.96
Nicotiana tabacum	1	4	1	4	0.9	1.36	1.59	2.23	1.25	1.80
Chromolaena odorata	15	24	7	15	13.76	8.14	11.11	8.38	19.32	8.26
Syndrella nudiflora	6	20	2	16	5.50	6.78	3.17	8.93	4.34	7.86
Passiflora foetida	4	-	4	-	3.67	-	6.35	-	5.01	-
Gomphrena celosioides	-	8	-	5	-	2.71	-	2.79	-	4.11
Peuraria montana	8	15	5	12	0.9	5.85	7.94	6.70	4.42	6.28
Sida corymbosa	22	43	9	15	20.18	14.58	14.29	8.38	17.24	11.48
Ageratum conyzoides	2	38	2	21	1.83	12.88	3.17	11.73	2.5	12.31
Sienna obtusifolia	3	19	3	12	2.75	6.44	4.76	6.70	3.76	6.57
Acanthospermum hispidium	-	6	-	4	-	2.03	-	2.23	-	2.13
Fluerya aestuans	-	2	-	2	-	0.67	-	1.12	-	0.90
L. coromandelianum	3	13	3	11	2.75	4.41	4.76	6.14	3.76	5.28
Panicum maximum	1	8	1	5	0.9	2.71	1.58	2.79	1.24	2.75
Paniculate	7	10	5	7	6.42	3.39	7.94	3.92	7.18	3.66
Kyllinga squamulata	5	9	5	7	6.42	3.05	7.94	1.68	7.18	2.37
Total Summation	109	295	63	179	107.98	102.44	90.27	73.71	110.11	152.89

Table 3: Floral Composition of Spent Oil Polluted and control Sites at (Mechanic Workshop -INEC Environment Ogbomoso, Oyo State)

Plant Spp.	Density		Frequency		Relative Density (RD)		Relative Frequency (RF)		RIV=RD+RF/2	
	Polluted	Control	Polluted	Control	Polluted	Control	Polluted	Control	Polluted	Control
Sida acuta	21	43	8	26	13.29	10.02	7.07	9.35	10.18	9.69
Cynodon dactylon	13	34	10	27	8.23	7.92	8.85	9.71	8.54	8.82
Mitracarpus villosus	4	24	9	4	2.53	5.59	7.96	1.43	5.25	3.51
Crotalaria retusa	1	4	1	4	0.63	0.93	0.88	1.43	0.69	1.18
Cyperus rotundus	8	23	7	21	5.06	0.05	6.19	7.55	5.63	3.8
Panicum maximum	15	24	7	15	9.49	5.59	6.19	5.40	7.84	5.50
Ficus exasperata	1	6	1	5	0.63	1.39	0.88	1.80	0.76	1.60
Kyllinga squamulata	4	12	4	10	2.53	2.79	3.54	3.60	3.04	3.20
Hyptis suavelens	2	8	2	5	1.26	1.86	1.77	1.80	1.52	1.83
Urena lobata	8	15	5	12	5.06	3.49	4.42	4.32	4.74	3.91
Passiflora foetida	5	8	4	6	3.16	1.86	3.54	2.16	3.35	2.01
Sida corymbose	22	43	9	15	13.92	10.02	7.96	5.40	21.88	7.71
Ageratum conyzoides	2	38	2	21	1.27	8.86	1.77	7.55	1.52	8.21
Solanum nigrum	3	19	3	12	1.20	4.42	2.65	1.08	1.93	2.75
Sida cordifolia	16	28	12	20	10.13	6.52	10.61	4.32	10.37	5.42
Tridax procubens	16	35	12	33	10.13	8.15	10.61	11.87	10.37	10.01
Nicotiana tabacum	3	25	3	12	1.20	5.83	2.65	4.32	1.93	5.08
Chromolaena odorata	3	13	3	11	1.20	3.03	2.65	3.96	1.93	3.50
Syndrella nudiflora	1	8	1	5	0.63	1.86	0.88	1.80	0.76	1.83
Fleurya aestuans	7	10	5	7	4.43	2.33	4.42	2.52	4.43	2.43
Gomphrena celosioides	5	9	5	7	3.16	2.20	4.42	2.52	3.79	2.36
Total Summation	158	429	113	278	99.14	94.71	99.91	93.89	110.45	94.35

Table 4: Floral Composition of Fertiliser Polluted and control Sites at (Ojo aro, Ara- Ede Road, Osun State)

Plant Spp.	Density		Frequency		Relative Density (RD)		Relative Frequency (RF)		RIV=RD+RF/2	
	Polluted	Control	Polluted	Control	Polluted	Control	Polluted	Control	Polluted	Control
Celosia argentea	6	27	6	25	3.14	5.01	4.05	5.92	43.54	5.47
Manihot esculentum	11	55	9	32	5.76	10.22	6.08	7.58	5.92	8.90
Sienna obtusifolia	21	34	11	30	11.00	6.31	7.43	7.11	9.22	6.71
Tithonia diversifolia	24	42	14	23	12.57	5.45	9.50	3.32	11.04	4.39
Fluerya aestuans	2	15	2	13	1.05	7.80	1.35	3.08	1.20	5.44
Aspilia africana	1	14	1	14	0.52	2.60	0.68	3.32	0.60	2.96
Centrosema pubescence	12	24	8	20	6.28	4.46	5.41	4.74	6.52	4.60
Sida cordifolia	13	26	10	22	6.28	4.83	6.76	5.21	6.52	5.02
Tridax procumbens	2	22	2	20	1.05	4.09	1.35	4.74	1.20	4.42
Sida corymbose	4	12	4	11	2.09	2.23	2.70	2.61	2.40	2.42
Pueraria spp.	3	14	2	14	1.57	2.60	1.35	3.32	1.46	2.96
Physalis angulata	1	12	1	11	0.52	2.23	0.68	2.61	0.6	2.42
Pennisetum pedicellatum	8	17	6	13	4.19	3.16	4.05	3.08	4.12	3.12
Passifora foetida	8	6	5	6	4.19	1.12	3.38	1.42	3.64	1.27
Phyllanthus amarus	16	43	9	15	8.38	7.99	6.08	3.55	7.23	5.77
Malvastrum coromandelianum	2	8	2	6	1.05	1.49	1.35	1.42	1.20	1.46
Hisbiscus sabdarifa	12	21	8	19	6.28	3.90	5.41	4.50	5.85	4.20
Sida acuta	3	11	12	8	1.57	2.04	8.11	1.90	4.84	1.97
Spigelia anthelmia	8	43	6	27	4.19	7.99	4.03	6.40	4.11	7.20
Hypogtis eagypsium	3	13	3	10	1.57	2.42	2.03	2.37	1.80	2.40
Passiflora foetida	4	1	4	1	2.09	0.19	2.70	0.24	2.40	0.22
Peperomia pellucida	2	8	2	7	1.05	1.49	1.35	1.66	1.20	1.58
Ocimum gratissimum	3	8	2	8	1.57	1.49	1.35	1.90	1.46	1.70
Cochorus olitorius	3	18	2	16	1.57	3.35	1.35	3.80	1.46	3.58
Marcharanchia spp.	1	11	1	16	0.52	2.04	0.68	3.80	0.60	2.92
Miralbilis jalapa	3	8	2	6	1.57	1.49	1.35	1.42	1.46	1.46
Carica papaya	2	5	2	4	1.05	0.93	1.35	0.95	1.20	0.94
Andrographis paniculate	11	20	10	18	5.80	3.71	6.76	4.27	6.28	3.99
Heliotropism spp.	2	8	2	7	1.05	1.49	1.35	1.66	1.20	1.60
Total sumation	191	538	148	422	93.24	96.14	95.97	86.54	140.27	101.09

Table 5: Floral Composition of Fertiliser Polluted and control Sites at (VC's Lodge, LAUTECH, Ogbomoso, Oyo State)

Plant Spp.	Density		Frequency		Relative Density (RD)		Relative Frequency (RF)		RIV=RD+RF/2	
	Polluted	Control	Polluted	Control	Polluted	Control	Polluted	Control	Polluted	Control
Pueraria spp.	19	41	8	25	13.1	14.49	8.60	11.06	10.85	12.78
Tithonia diversifolia	12	35	9	20	8.28	12.37	9.68	8.85	8.57	10.60
Tridax procumbens	8	15	6	13	5.52	5.30	6.45	5.75	5.99	5.53
Aspilia Africana	1	14	1	14	0.69	4.95	1.08	6.19	3.44	5.57
Centrosema pubescence	15	24	7	20	10.34	8.48	7.53	8.85	8.94	8.67
Sida cordifolia	13	20	2	17	8.97	7.07	2.15	7.52	5.56	7.30
Sida corymbose	4	12	4	11	2.76	4.24	4.30	4.87	3.53	4.56
Pennisetum pedicellatum	8	17	6	13	5.52	6.01	6.45	5.75	5.99	5.88
Passifora foetida	8	1	5	1	5.52	0.35	5.38	0.44	5.45	0.40
Phyllanthus amarus	22	43	9	15	15.17	15.19	9.68	6.64	12.43	11.32
Malvastrum coromandelianum	2	8	2	6	1.38	2.83	2.15	2.65	1.77	2.74
Hisbiscus sabdarifa	12	21	3	9	8.28	7.42	3.23	3.98	5.76	6.59
Sida acuta	-	6	-	4	-	2.12	-	1.77	-	1.95
Spigelia anthelmia	-	2	2	2	-	0.71	2.15	0.88	2.65	0.80
Manihot esculentum	3	13	3	10	2.07	4.59	3.23	4.42	2.65	4.51
Passiflora foetida	4	1	4	1	2.76	0.35	4.30	0.44	3.53	0.40
Peperomia pellucida	2	8	2	7	1.40	2.83	2.15	3.10	1.77	3.90
Cochoius olitorius	3	18	2	16	2.07	6.36	2.15	7.08	2.11	6.72
Celosia argentea	-	11	-	16	-	3.89	-	7.08	-	5.49
Miralbilis jalapa	5	4	5	3	3.45	1.41	5.38	1.33	4.42	1.37
Carica papaya	2	5	2	4	1.38	1.77	2.15	1.77	1.77	1.77
Andrographis paniculate	11	15	11	15	7.59	5.30	11.83	6.64	9.71	5.97
Total sumation	145	283	93	226	112.48	118.03	96.79	107.06	106.89	114.82

DISCUSSIONS

Failure of many plant species to grow on spent oil polluted site could be due to the presence of the Polycyclic Aromatic Hydrocarbons (PAHs) in spent oil and which has been shown to have had indirect secondary effects like disruption of plant water-air relationship (Renault *et al*., 2000).The study also observed that species diversities and densities of plants grown on the two (2) corresponding control sites (i.e adjacent sites to each of the used polluted sites in this study), outweighed those that grown on the two (spent oil and fertilizer polluted) sites. The reason for this may be due to the report given that spent oil affects biological, physical, chemical and microbiological components of the soil in various ways (Agbogidi and Ejemeta, 2005; Agbogidi, 2010) and thereby, affecting the growth, development, productivity and yield of plants (Osubo and Anoiefo, 2003; Agbogidi, 2011). The severe loss of plant biodiversity associated with the spent oil polluted site is corroborated by Bautista and Rahman (2016), as they concluded in their study that the death of several globally important wildlife species has been reported and another vast number of species severely affected by oil coating are the plant leaves and stem which are been covered by oil. *Passiflora foetida* species was observed present on all the studied polluted sites but found with less density on only one of the studied control sites.

CONCLUSION

This study concluded that both pollution from spent oil and excess use of fertilizer contribute to loss of plant biodiversity. However, the severe loss was recorded from spent oil polluted site. *Passiflora foetida* species may possibly be a specific plant any polluted sites.

Recommendation

Intermittent inspection must be carried out by the health practitioners to curb and guide them from: encroachment of extended vegetation plots by the mechanical Engineers and indiscriminate discharge of spent oil around. They must be lectured on the severe effect posed on different ecosystems. Regular action must be taken by the Extension agents in collaboration with the health practitioners to check, create awareness and campaign on the judicious use of fertilizer on food crop production. They must organize public lecture on the negative impact of this and the overall trembling results.

REFERENCES

Agbogidi, OM. and Ejemeta, O.R. (2005). An assessment of the effect of crude oil pollution on soil properties, germination and growth of *Gambaya albida* (L). *Journal of Agricultural Science and Technology*. 8(2): 148- 155.

Agbogidi, OM. (2010). Screening six cultivars of cowpea (Vigna unguiculata (L) lp) for adaptation to soil contaminated with spent engine oil. *Academic Arena*. 2(4): 33-40

Agbogidi, MO. (2011). Susceptibility of five cultivars of Soya bean (*Glycine max*) (L) Merr. seeds to spent engine oil. *International Journal of Science Nature*. 2(3): 447-451.

Bautista, H1 and Rahman, KMM. (2016). Effects of crude oil pollution in the tropical rainforest biodiversity of Ecuadorian Amazon Region. *Journal of Biodiversity and Environmental Sciences* (JBES) 8: (2). 249-254 http://www.innspub.net

Buma, B. (2015). Disturbance interactions: characterization, prediction, and the potential for cascading effects. *Ecosphere* 6:70.

Houghton, JP and Gilmour RH. (2012). Prince William Sound intertidal biota, several years later: Has it recovered? In: Proceedings of the International Oil Spill Conference. Washington, DC: *American Petroleum Institute*. 679-685.

Osubor CC and Anoliefo GO. (2003). Inhibitory effects of spent lubricating oil on the growth and respiratory functions of *Arachis hypogea* L. *Benin Science Digital*. 1: 73- 79.

Renault, S., Zwlazek JJ, Fung M and Tuttle S. (2000). Germination, growth and gas exchange of selected boreal forest seedlings in soil containing oil sands tailing. *Environment*. 107: 357-365.

The United Nations Agenda 21—Nigeria (2012). https://sustainabledevelopment.un.org/content/documents/1023nigerianational report. Pdf.

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DISTRIBUTION AND DYNAMICS OF CARBON IN THE SOILS OF TEACHING AND RESEARCH FARM, UNIVERSITY OF IBADAN

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ABSTRACT

A study was carried out at the Teaching and Research farm, University of Ibadan. Soil samples were collected at different land use types (Arable, fallow, organic farm and oil palm). The samples were subjected to analysis in the laboratory for total, organic and inorganic carbon as well as other physical and chemical parameters using standard procedures. The soils were generally sandy with texture ranging from sand to sandy loam at different depths. Total, organic and inorganic carbon was highest at 297, 29.2 and 267 g/kg, respectively in the arable land use. However, total and inorganic C was lowest in the oil palm at 100 and 76 g/kg respectively while organic carbon was lowest (11.2 g/kg) in the fallow. Organic carbon correlates significantly with Zn, Mn, Fe, Mg and available P across the land use types. Land use types influenced the dynamics of organic and inorganic carbon due to the balance of carbon inputs against output therefore, the landuse types that improve the organic carbon content of soils are advocated for sustainable soil health and productive crop yields.

***Keywords**: soil characteristics, Carbon sequestration, Soil health, Land use*

INTRODUCTION

Soil is the largest pool of terrestrial carbon in the biosphere, storing more carbon than is contained in plants and the atmosphere combined (Schlesinger 1997; Stavi and Lal, 2013). The abundance of carbon in the soil affects and is affected by plant production, and its role as a key control of soil fertility and agricultural production has been recognized for more than a century (Wang *et al*., 2002; Wang *et al*., 2013). Soil carbon is part of the much larger global carbon cycle that involves the cycling of carbon through the soil, vegetation, ocean and the atmosphere. **Soils host the largest terrestrial carbon pool** *(*Scharlemann *et al.,* 2014) **and play a crucial role in the global carbon balance by regulating dynamic bio-geochemical processes and the exchange of greenhouse gases with the atmosphere** *(Stavi and* Lal, 2013). Soil organic carbon is the main component of soil organic matter, the amount of organic carbon that exists in any given soil is determined by the balance between the rates of organic carbon input (vegetation, roots) and output (Carbon dioxide from microbial decomposition). However, soil type, climate, management, mineral composition, topography, soil biota (soil forming factors) and the interactions between each of these are modifying factors that will affect the total amount of soil organic carbon in a profile as well as the distribution with depth, any changes made to the natural status of the soil systems e.g. conversion to agriculture, deforestation, plantation, will result in different conditions under which organic carbon enters or exit the system. Both land use types and production systems have been known to affect soil carbon levels. Higher soil organic matter levels have been reported in the organic systems than in conventional systems, and the higher soil carbon levels also tend to hold soil particles together thereby reduce or prevent soil erosion (Franzluebbers, *et al*., 1995; Pimentel *et al*., 2005). Our capacity to predict and ameliorate the consequences of climate and land cover changes depends, partly on a clear description of carbon distributions and the controls of SOC inputs and outputs. **Levels of soil organic carbon storage are therefore mainly controlled by managing the amount and type of organic residues that enter the soil (i.e. the input of carbon to the soil system) and minimizing the soil carbon losses (Fang *et al*., 2010).** The magnitude of the soil organic carbon storage is spatially and temporally variable and determined by different abiotic and biotic factors (Weissert *et al*., 2016).

Mapping the spatial distribution of soil carbon has been of great interest as exemplified by the increasing number of publications in mapping soil carbon stock globally and nationally. Soil mapping (both conventional and digital) has been the basis of soil carbon estimates and are still being used for mapping areas that have a limited number of soil observations (Batjes, 1996). However, digital soil mapping technology has progressed rapidly in the past decade, making it operational for routine mapping over large areas (Grunwald *et al*., 2012). The knowledge of the distribution and dynamics of soil carbon will assist farmers to make the right choice of crops and develop soil management strategies that would promote maximum productivity. There is little or no information on soil carbon dynamics in the study area hence this study was carried out to determine the distribution pattern of soil carbon, the relationship between soil carbon and other soil properties and the influence of soil types and land use on soil carbon in the soils of the Teaching and Research farm, University of Ibadan.

MATERIALS AND METHODS

Location

The study was carried out at the Teaching and Research Farm, University of Ibadan, Oyo State Nigeria. The area lies between the latitude 07.45557°N – 07.855207°N and Longitude 03.61202°E – 03.89372°E with an average altitude of 185m above sea level. The size of the study area is about 15.7ha with River Ona making the northern boundary of the study site. The mean annual rainfall is about 1278.5mm (NIMET, 2018). The area falls within the rainforest zone with a mean annual humidity of 62.8% and the mean monthly temperature ranging between 24°C and 28°C. The dominant land use type of the study area includes Arable farming where crops like cassava, vegetable, yam, and cowpea are grown. Farming system consists of oil palm plantation and Organic farming whereby organic system is used to grow crops like pepper, vegetables and cucumber.

Field work

A detailed soil survey using the rigid grid method of survey was carried out and transects were laid 80m apart while observation points were taken with the aid of the GPS at 80m intervals along the transects. Identified mapping units were further examined in detail using standard soil profile pits of dimension 2m × 1.5m ×2m which were described according to standard FAO (1990) guidelines. Soil samples were collected from genetic horizons while undisturbed samples were collected using cylindrical metal cores of known volume. Soil samples were also collected at 0-15 cm and 15-30 cm from identified land use types.

Laboratory analysis

The soil samples were air-dried and processed to analyze for both physical and chemical properties using standard procedures. Particle size analysis of < 2 mm fine earth fractions was carried out to determine the soil texture by the hydrometer method as described by Gee and Bauder (1986). Bulk density was determined after oven-drying undisturbed core samples to constant weight as described by Mckenzie *et al*. (2002). Soil pH was determined in water with a ratio of 1:1 using a glass electrode pH meter**.** Total carbon was determined using the Loss on ignition method (Udoh and Ogunwale, 1986). Organic carbon was determined using the wet chromate oxidation method (Walkley and Black, 1934) while Inorganic carbon was determined by subtraction of the organic carbon from total carbon since the total carbon measures both organic and inorganic carbon. Total nitrogen was determined using the micro-Kjehdahl method (Jackson, 1962). Available phosphorus was extracted with Bray P1 and the concentration assayed in the ascorbic acid (blue colour) on a spectrophotometer. Exchangeable acidity was determined using the method of Mclean (1965). Exchangeable cations (K, Na, Ca and Mg) were leached with neutral normal acetic acid while extractable micronutrients (Cu, Zn, Fe and Mn) were extracted with dilute HCl solution. The concentrations of K and Na were determined with Flame photometer while the other cations and micronutrients were done using Atomic Absorption Spectrometer (AAS). The Effective Cation Exchange Capacity (ECEC) was calculated as the sum of exchangeable cations and the exchangeable acidity (Rhoades, 1982) and Base saturation were computed.

Statistical Analysis

The data was subjected to descriptive analysis and one-way Analysis of variance (ANOVA). Significant means were separated using Least Significant Differences (LSD) at five (5) % level of significance.

RESULTS AND DISCUSSION

Land use types and forms of carbon

Selected soil properties and the various forms of carbon in the land use types studied are presented in Table 1. Soil pH is an indicator of the acidity alkalinity of soil, and is a reflection of important physical and chemical properties determining soil quality (Nagy and Konya, 2007). Soil pH is a major factor affecting soil nutrient availability and chemical substances in soil. Soil pH also has a profound impact on a number of other soil properties. Extremes in acidity or alkalinity will change the nutrients available resulting in the unbalance absorption of elements in plants (Schimel *et al.*, 2011). Soil pH generally ranges from 1-14, the optimum range for most agricultural crops is between 5.5 and 7.5. In Table 1, at 5% level of significance, there is no significant difference between the pH of the different land use in the study area. The arable land was the most acidic of all the land use types, which is in line with the findings of Ololade *et al*. (2010) who reported increased leaching of cations in favour of reserved acidity.

Total carbon was observed to be high in Arable land (297g/kg) which was significantly different from fallow and oil palm land use but not significantly different from Organic farm, these may be due to the presence of high organic matter available in the soils of the arable and organic farm land use. This corroborates the observations of Bastida *et al*. (2007) which states that organic matter content in agricultural and forest soils is a function of the management practices. The organic carbon in the arable farm is significantly different from that of the fallow system while the organic carbon in the organic farm is also significantly from the fallow land use. Considering the inorganic carbon, only the inorganic carbon of arable land use is significantly different from the oil palm, while among other land use, inorganic carbon is not significantly different.

Table 1: Effects of land use on selected soil properties and forms of carbon

Land use	N	P	K	ECEC	pH	Total C	Organic C	Inorganic C
	g/kg	mg/kg	cmol/kg				g/kg	
Fallow	0.56	9.63	0.92	12.92	6.89	107	11.2	95
Oil Palm	2.24	21.7	0.49	4.45	6.33	100	23.6	76
Organic farm	2.24	14.3	2.56	12.08	7.62	235	25.0	210
Arable	2.24	4.69	0.84	7.48	7.14	297	29.2	267
LSD					NS	164.7	12.6	170.7

Correlation analysis of the total organic carbon and other chemical properties

It was observed in Table 2 that the total organic carbon and micronutrients are highly positively correlated except the Cu which was negatively correlated with the value -0.36. This agrees with the findings of Orimoloye *et al*. 2018 who observed an increased availability of micronutrients with increasing organic carbon. Considering the Macronutrients, the total organic carbon was positively correlated with Ca and significantly with Mg ($P \leq 0.05$) which is in line with the result obtained by Cholbe *et al* (2020) while potassium and sodium were observed to be negatively correlated similar to the result obtained by Megistu *et al*. (2017). Also, the available phosphorus had a significantly positive correlation ($r = 0.92$) with organic C as corroborated by the results of Cholbe *et al* (2020). Though, it has been observed that large proportions of the Phosphorus can be tied up with micronutrients at low pH or bound by Ca at high pH (Esekhade *et al*., 2003), the pH levels of this study sites and the land uses are near neutral which possibly enhanced mineralization of organic phosphorus thus increasing the content of P with increased organic carbon in the soil. Exchangeable sodium percentage (ESP) was observed to be negatively correlated ($r = -0.68$) with organic C, similar to what was also reported by Cholbe (2020), which could be explained by the sodium salt dispersion and dissolution causing chemical hydrolysis of organic material, leading to the storage of a very low amount of organic C in the soil.

Table 6: Correlation analysis of the chemical elements across mapping units and land use types

Parameter	Zn	Cu	Fe	Mn	ESP	BS	ECEC	K	Na	Mg	Ca	H+	Avail P	Total N	Org C
	(mg/kg)				(%)		(cmol/kg)						(mg/kg)	(g/kg)	
pH	0.66	-0.08	0.56	0.66	-0.71	-0.26	0.36	-0.27	-0.3	0.76	0.27	0.6	0.78	-0.64	-0.94*
Org C (g/kg)	0.99**	-0.36	0.99**	0.99**	-0.68	0.46	0.58	-0.15	-0.2	0.95*	0.58	-0.21	0.92*	0.93*	
Total N (g/kg)	-0.93*	0.37	-0.94*	-0.94*	0.83	-0.49	-0.64	0.1	0.25	-0.95*	-0.66	0.2	-0.86		
Avail P (mg/kg)	0.96*	-0.36	0.90*	0.96*	-0.71	0.08	0.39	-0.38	-0.37	0.56	0.34	0.13			
H+	-0.07	0.33	-0.2	-0.08	0.05	-0.8	-0.1	-0.12	0.04	0.02	-0.25				
Ca (cmol/kg)	0.54	0.2	0.66	0.55	-0.34	0.78	0.98**	0.68	0.51	0.65					
Mg (cmol/kg)	0.97*	-0.23	0.96*	0.98**	-0.73	0.35	0.69	-0.06	-0.13						
Na (cmol/kg)	-0.22	0.6	-0.1	-0.2	0.6	0.35	0.56	0.94*							
K (cmol/kg)	-0.18	0.54	-0.04	-0.17	0.39	0.54	0.68								
ECEC (cmol/kg)	0.57	0.24	0.67	0.58	-0.3	0.67									
BS (%)	0.35	-0.03	0.51	0.36	-0.19										
ESP (%)	-0.68	0.3	-0.65	-0.68											
Mn (cmol/kg)	1.00***	-0.36	0.98**												
Fe (cmol/kg)	0.98	-0.28													
Cu (cmol/kg)	-0.37														

However, the result of the study indicated that in the context of major plant nutrients, total nitrogen and available phosphorus in particular, (although they had a positive correlation with organic carbon) the impact of these two nutrients on the accumulation of organic C in the soil was small because their amounts were mainly in the range of low to very low. A non-significantly negative correlation was obtained with K and Na in this study similar to what was obtained by Ingle *et al*. (2018) who also in contrast, observed a negative correlation between organic C and calcium and magnesium. This suggested that the increase in organic matter will result in progressive decrease in K and Na. The major contribution of K and Na on ECEC might be the cause of insignificant relationship between soil organic carbon and ECEC. This observation was similar to what was obtained by Abad *et al* (2014). Organic C and pH have been found to maintain a generally negative correlation under natural conditions at various scales, a feature attributed to their innate internal relationship (Zhou *et al*., 2019). Organic matter on decomposition releases organic acids, leading to lower soil pH values. In addition, relatively high pH values accelerate the decomposition of soil organic carbon, resulting in a decrease in organic matter storage capacity (Schimel *et al*., 1994; Zhou *et al*., 2019).

The total nitrogen was positively correlated with total organic carbon. This observation is in line with result obtained by Zhou *et al*, (2019). Nitrogen has a very mobile character in the soil; therefore, it is necessary to minimize its loss in the soil. This is in line with the positive correlation reported in a limited number of two papers (Wang *et al*, 2010; Luo *et al*., 2017). The positive correlation is due to the combination of complex influence factors, which deserves further investigation. Meanwhile, the relationships can be different at different locations of sub-regions (Mfaume *et al*., 2019) or different soil layers (Xue and An, 2018). It could also be due to a combination of soil properties and climatic factors (Luo *et al*., 2017).

CONCLUSION

Soil organic carbon was higher in arable land use and organic farm. Though these findings may be influenced by the land management adopted especially in the arable crop fields, the land use and land management influenced the amount of organic matter in the soil due to the balance of carbon inputs against outputs. Soil carbon is central to nutrient cycling and nutrient supply in agricultural soils and significantly affected the soil content of primary nutrients. Land use that generates more organic matter and retain it on-site tends to have higher soil organic carbon levels and is advocated for sustainable cropping and soil fertility maintenance.

REFERENCES

Abad, J. R. S., Hassan,K. and Alamdarlou, E. H. 2014. Assessment the effects of land use changes on soil physicochemical properties in Jafarabad of Golestan province, Iran. *Bulletin of Environment, Pharmacology and Life Sciences*. 3: 296–300.

Bastida F, Moreno JL, Hernandez T, Garcia C (2007) The long-term effects of the management of a forest soil on its carbon content, microbial biomass and activity under a semi-arid climate. *Applied Soil Ecology* 37: 53–62.

Batjes, N.H., 1996. The total C and N in soils of the world. *European Journal of Soil Science* 47, 151–163.

Cholbe, M. K., Yeme, F. K. and Woldeyohannes, W. H. 2020. Fertility Status of Acid Soils under Different Land Use Types in Wolaita Zone, Southern Ethiopia. *Applied and Environmental Soil Science*, 2020: 1-9 https://doi.org/10.1155/2020/3713967

Esekhade, T. U., Ugwa, I. K. and Orimoloye, J. R. (2003). Uptake of Ca and Mg in four rubber-based cropping systems. *Journal of Agriculture*, *Forestry and Fisheries* 3:52-56.

Fang, J. Y., Yang, Y. H., Ma, W. H., Mohammat, A. and Shen, H. H. 2010. Ecosystem carbon stocks and their changes in China’s grasslands. *Science China Life sciences* 53:757–765.

FAO 1990. Guidelines for soil profile description. Soil resources management and conservation service, Food and Agriculture Organisation, (FAO), Rome.

Franzluebbers, A. J., Hons, F.M., Zuberer, D. A. 1995. Tillage and crop effects on seasonal soil carbon and nitrogen dynamics. *Soil Science Society of American Journal* 59: 1618–1624.

Ingle, Sagar N, MSS Nagaraju, Nisha Sahu, Nirmal Kumar, Pramod Tiwary, Rajeev Srivastava, TK Sen and RA Nasre 2018. Soil fertility status of macro-nutrients and micronutrients in Bareli watershed of Seoni district, Madhya Pradesh, India. *International Journal of Chemical Studies*. 6(4): 1950-1953

Gee, G.W., Bauder, J.W., 1986. Particle size analysis. In: Klute, A.(Ed.), Methods of Soil Analyses, Part 1, ASA Monograph 9, 2nd Edition. ASA, Madison, WI, pp. 383–411.

Grunwald, S., Thompson J.A., Minasny, B. and Boettinger, J. L. 2012. Digital Soil Assessments and Beyond In: Minasny, Malone & McBratney (eds) Proceedings of the fifth global workshop on digital soil mapping, Sydney, Australia, 10–13 April 2012 pp 1-8

Jackson, M. L. 1962. Soil chemical analysis. International Institute for Tropical Agriculture (IITA). Manual Series No. 1, 70- 81

Lal, R. 2004. Soil carbon sequestration impacts on global climate change and food security. *Science* 304: 1623–1627.

Luo, Y., Shi, Z., Lu, X., Xia, J., Liang, J., Jiang, J., Wang, Y., Smith, M. J., Jiang, L., Ahlstrom, A., Chen, B., Hararuk, O., Hastings, A., Hoffman, F., Medlyn, B., Niu, S., Rasmussen, M., Todd-Brown, K., and Wang, Y. P. 2017. Transient dynamics of terrestrial carbon storage: mathematical foundation and its applications. *Biogeosciences* 14: 145–161

Mckenzie, N., Coughlan, K. and Cresswell, H. 2002. Soil physical measurement and interpretation for land evaluation. CSIRO Publishing, Collingwood, Victoria

Mclean, E. O. 1965. Aluminium in Methods of Soil Analysis. America Science Agronomy, Madison, Wisconsin, 978-998

Mengistu, C., Kibebew, K. and Tarekegn, F. 2017. Influence of different land use types and soil depths on selected soil properties related to soil fertility in Warandhab area, horo guduru wallaga zone, Oromiya, Ethiopia. *International Journal of Environmental Sciences & Natural Resources*, 4 (2): p 555634.

Mfaume, D. P., Msanya, B. M. and Msaky, J. J. 2019. Pedological Characterization and Fertility Assessment of Mbimba Substation Soils Under Coffee Production in Mbozi District, Tanzania. *International Journal of Advances in Scientific Research and Engineering* 5 (10): 221-235

Nagy, N. M. and Konya, J. 2007. Study of pH-dependent charges of soils by surface acid-base properties. *Journal of Colloid and Interface Science*, 305, (1): 94-100

Nelson, D. W. and Sommers, L. E. 1982. Total carbon, organic carbon, and organic matter. In: Methods of soil analysis Part 2 *Chemical and microbiological properties*: 539–579.

Ololade I. A, Ajayi, I. R., Gbadamosi, A. E., Mohammed O. Z. and Sunday, A. G. 2010. Study on effects of soil physico-chemical properties on cocoa production in Ondo State. *Modern Applied Science* 4 (5): 35 – 43.

Orimoloye, J. R., Awe, V. O. and Adamu, I. 2018. Status of micronutrients in some soils on basement complex parent rock along a toposequence in Ibadan, southwestern Nigeria**.** *Nigerian Journal of Ecology* 17(1): 1-13.

Pimentel, D., Hepperly, P., Hanson, J., Douds, D. and Seidel, R. 2005. Environmental, Energetic, and Economic Comparisons of Organic and Conventional Farming Systems. *BioScience*, 55 (7): 573–582

Rhoades, J. D., 1982. Cation exchange capacity. In: Methods of soil analysis. Part 2. Chemical and Microbiological Properties (A.L. Page, R.H. Miller and D.R. Keeney), (Eds.) American Society of Agronomy, Inc. *Soil Science Society of America*. Inc. Madison, Wisconsin, pp: 149-157.

Scharlemann, J. P. W., Tanner, E. V. J., Hiederer, R. and Kapos, V. 2014. Global soil carbon: understanding and managing the largest terrestrial carbon pool, *Carbon Management*, 5 (1): 81-91, DOI: 10.4155/cmt.13.77

Schimel, D. S., Braswell, B. H., Holland, E. A., McKeown, R. and Ojima, D. S. 1994. Climatic, edaphic, and biotic controls over storage and turnover of carbon in soils. *Global biogeochemical cycles* 8: 279–293.

Schlesinger WH, Andrews JA (2000) Soil respiration and the global carbon cycle. *Biogeochemistry* 48: 7–20.

Stavi, I. and Lal, R. (2013) Agriculture and Greenhouse Gases, a Common Tragedy. A Review. Agronomy for Sustainable Development, 33, 15. https://doi.org/10.1007/s13593-012-0110-0

Udoh E.J. and Ogunwale, J.A. (1986). Laboratory Manual for Analysis of Soils, Plants and Water Samples. Department of Agronomy, University of Ibadan. 86pp

Walkley, A. J. and Black, I.. A. 1934. Estimation of soil organic carbon by the chromic acid titration method. *Soil Science*. 37, 29-38.

Wang G. X., Qian, J., Cheng, G. D. and Lai, Y. M. 2002. Soil organic carbon pool of grassland soils on the Qinghai-Tibetan Plateau and its global implication. *Science of the Total Environment* 291: 207–217.

Wang, M., Su, YZ, Yang R, Yang X (2013) Allocation patterns of above- and below-ground biomass in desert grassland in the middle reaches of Heihe River,Gansu Province, China. *Chinese Journal of Plant Ecology* 37: 209–219.

Wang, X. F., Su, Y. Z., Yang, R. and Lee, J. 2010. Effects of sandy desertified land rehabilitation on soil carbon sequestration and aggregation in an arid region in China. *Journal of Environmental Management* 91: 2109–2116.

Weissert, L. F., Salmond, J. A. and Schwendenmann, L. 2016. Variability of soil organic carbon stocks and soil CO2 efflux across urban land use and soil cover types. *Geoderma* 271:80-90. DOI: 10.1016/j.geoderma.2016.02.014

Xue, Z. and An, S. 2018. Changes in Soil Organic Carbon and Total Nitrogen at a Small Watershed Scale as the Result of Land Use Conversion on the Loess Plateau. *Sustainability* 10, 4757; doi:10.3390/su10124757

Zhou, W., Han, G., Liu, M. and Li, X. 2019. Effects of soil pH and texture on soil carbon and nitrogen in soil profiles under different land uses in Mun River Basin, Northeast Thailand. *PeerJ* 7:e7880 https://doi.org/10.7717/peerj.7880

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EFFECT OF AQUEOUS LEAF EXTRACT OF *Pentaclethra macropgylla* (Fabaceae) ON GROWTH AND YIELD OF POTATO *(Ipomea batatas* L.)

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ABSTRACT

African oil bean (Pentaclethra macrophylla [PM]) is a promising multipurpose agroforestry tree of the mimosoid sub-family (Fabaceae) in Nigeria. This study on the effect of different concentrations of P. macrophylla Aqueous Leaf Extracts (ALE) on the growth and yield of sweet potatoes (Ipomea batatas) was conducted at the greenhouse facility of Federal College of Agriculture, Ishiagu Southeast Nigeria. Fresh stem cuttings of sweet potato (orange flesh var.) were planted in polybags filled with 35 kg topsoils and were monitored for 16 weeks after planting (WAP). The treatments comprised five levels of ALE of P. macrophylla (0%-T1 control, 10%-T2, 20%-T3, 40%-T4 and 80%-T5), replicated eight times in completely randomised design. Data were collected on vine length-VL (cm), stem thickness-ST (mm), Number of Leaves (NL), Number of Branches (NB), Fresh Tuber Weight–FTW (g) and Fresh Weight of Shoot-FWS (g) at harvest. Data collected were analysed using descriptive statistics and ANOVA at 5% level of probability. Results showed that VL, ST, NL, NB, FTW and FWS of I. batatas at 16 WAP ranged from 324.1(T2) to 181.9 (T1), 6.0 (T2) to 3.7 (T5), 216.1 (T4) to 116.6 (T1), 17.1(T4) to 11.4(T1 control), 568.8(T5) to 281.3(T1 control) and 130.9(T3) to 102.1(T1 control), respectively. The results indicated that 40% ALE significantly enhanced NL and NB. The FTW (568.5 g and 456.3 g) was higher at 80% and 40% ALE, respectively, than in the control (281.3 g) which gave the lowest. Thus, aqueous leaf extract of Pentaclethra macrophylla at 40% encouraged number of leaves, number of branches and fresh tuber weight in Ipomea batatas. In conclusion, stimulatory allelopathic potential of the tree leaf extracts on the arable crop was established from the findings.

Keywords: *Agroforestry, allelopathy, allelochemicals, aqueous leaf extracts, growth factor, Ipomea batatas*

INTRODUCTION

Allelopathy is a natural ecological phenomenon in which different organisms affect the functioning of other organisms in their vicinity, negatively or positively (Rice, 1984) by releasing secondary metabolites (Farooq, 2011a). Chemicals thus released, the allelochemicals, are mostly secondary metabolites, which are produced as byproducts during different physiological process in plants (Farooq, 2011a; Bhadoria, 2011). Important secondary metabolites identified as allelochemicals are phenolics, alkaloids, flavonoids, terpenoids, momilactone, hydroxamic acids, brassinosteroids, jasmonates, salicylates, glucosinolates, carbohydrates and amino acids (Kruse 2000; and Farooq *et al.*, 2011a).

Actions of these are compounds are concentration dependent (Einhellig, 1986), as these inhibit the plant growth at high concentrations and stimulate it at low concentrations (Narwal, 1994). These allelochemicals may thus be used as natural pesticides at high concentration (Farooq *et al.*, 2009). Inhibitory role of allelochemicals is well explored and previously was the only known dimension of allelopathy. This role has been directly and indirectly used for weed management. A lot of research work has been done to explore the inhibitory potential of different allelopathic crops and trees for weed management (Cheema 2004; *et al.*, Iqbal *et al.*, 2007; Jamil *et al.*, 2009, Farooq *et al.*, 2011b). It is a pragmatic substitute for synthetic herbicides as allelochemicals do not have residual or toxic effects (Bhadoria, 2011). This inhibitory feature is attributed to the blockage or cessation of important physiological and metabolic processes of plant. On the other hand, allelochemicals stimulate growth and impart resistance against several abiotic stresses (Farooq, 2009) at low concentrations. Only few studies have been carried out to investigate the growth stimulatory potentials by the allelochemicals. Allelopathic water extracts application at lower concentrations stimulated germination and growth of different crops (Anwar 2003; Cheema 2012). Application of allelochemicals at low concentrations to crops can be a cost-effective and efficient way to benefit growth and to enhance crop productivity (Oudhia *et al.*, 1998). Allelopathy, thus, can be adopted as a natural alternate of chemical and mechanical options of pest management, crop growth and productivity enhancement.

Pentaclethra macrophylla (African oil bean) is an indigenous multipurpose agroforestry tree of sub-Saharan distribution belonging to the family Fabaceae (leguminosae). Its seed has been used as spices as well as yields edible vegetable oil. The tree has been used as mulch materials (from leaf litters), nurse and shade trees in traditional home garden farming system in southeast Nigeria agroecosystem where it grows alongside common arable crops. African oil bean tree root nodulation potentials and ability to fix soil nitrogen has been reported (Ladipo *et al.,* 1993: Sprent, 2005; Diabate *et al.,* 2005; Ogbu, 2019). The sweet potato (*Ipomea batatas* L.) is one of the common arable and staple food crops of Nigeria, and is well adapted and cultivated in southeast region of the country.

The present study therefore, is a strategy to determine the allelopathic status of African oil bean tree (whether beneficial or detrimental) in relation to arable crop production in home gardening/mixed crops farming system prevalent in southeastern region of Nigeria. Specific objectives of the research were: to evaluate the allelopathic effect of *Pentaclethra macrophylla* aqueous leaf extract different concentrations on the growth of sweet potato (*I. batatas*) 'Orange flesh (OFSP) variety' in Ishiagu derived savanna agroecological zone of Ebonyi state Nigeria; and to determine the allelopathic effect of aqueous leaf extracts various concentrations on the yield of sweet potato in the study area.

MATERIALS AND METHOD

Location of study and experimental design

The research was conducted at the Greenhouse facility of Federal College of Agriculture, Ishiagu, Ebonyi State Nigeria. Ishiagu lies within the southeast derived savanna ecological zone of the country. It is located on latitude 05^{o} 52'N, longitude 07^{o} 35'E and altitude 57 m above sea level. Rainfall distribution is bimodal with peaks in the months of July and September or October. The dry season spans November to March or April with a characteristic cold dry dust laden interval known as harmattan, during the months of December through to February.

The experimental design used was Complete Randomized Design (CRD). There were five treatments (the different concentrations of *P. macrophylla* aqueous leaf extracts) including control replicated eight (8) times. The treatments were as follows: T_1 - 0% control (water), T_2 - 10%, T_3 - 20%, T_4 - 40%, and T_5 - 80% concentrations of the aqueous leaf extract. A total of 40 bags was filled with 35 kg forest topsoil each to serve as growth medium for the test crop. The soil physico-chemical property before the experiment was carried out using standard procedures.

Freshly harvested, shade dried leaves of *P macrophylla* were soaked in water to prepare the various concentrations of the aqueous leaf extracts (Owoseni and Awodoyin, 2013; Ogbu, 2019) as follows: 100 g of leaves were soaked in one (1) litre of water for 10 % concentration; 200 g of leaves in one litre for 20 % concentration; 400 g of leaves in one litre for 40% concentration; 800 g of leaves in one litre for 80% concentration; while none leaf extract water (0%) served as control. The leaves were allowed to remain soaked for 24 hours before filtration to obtain the various concentrations extracts (i.e. 10%, 20%, 40% and 80%). The aqueous leaf extracts including the water alone (0%) concentrations (i.e. control) were thereafter ready for use; and were readily prepared in advance when needed.

Agronomic Practices and treatments applications

The sweet potato (OFSP variety) cuttings were sourced from National Root Crops Research Institute (NRCRI) Umudike Abia State Nigeria; and planted following standard practices. Two cuttings of the test crop were planted per bag/plot, but was thinned later to one stand per bag after sprouting at about 3 weeks after planting. The bags were perforated under to aid aeration and drainage. Each bag was given 200 mL of the aqueous leaf extracts according to the concentrations with a cup calibrated in 200 mL. The extracts application was done in the evening at 2 days interval for the period of the crop growth. The planted cuttings were observed for 16 Weeks After Planting (WAP) to assess growth performance and yield among the various treatments. Weeds were control mechanically by hand pulling as the need arose.

Data collection and analysis

Data were collected on the following parameters: soil physico-chemical properties, phytochemical contents of the *P. macrophylla* leaves; while vine length (cm), number of leaves, number of branches; stem thickness (mm), fresh tuber weight (g) and fresh shoot weight (g) were also determined periodical until harvest (16 WAP). The soil physico-chemical properties and phytochemical contents of the *P. macrophylla* leaves were determined at the Soil laboratory of National Root Crops Research Institute (NRCRI) Umudike Abia State and National Horticultural Research Institute, Ibadan Oyo State Nigeria, respectively, following standard laboratory procedures. The sweet potato vine length was measured using metre tape; both number of leaves and number of branches were determined by physical count; stem thickness was measured by use of digital veneer caliper; while fresh tuber weight and fresh shoot weight were measured using electronic weighing balance. Data collected were analyzed using one way Analysis of Variance (ANOVA) according to the procedure for the complete randomized design (CRD). Treatment means were separated and compared using Fisher's least Significance Difference (LSD) at 5% probability level. Descriptive statistics was also used where appropriate.

RESULTS

Physicochemical properties of soil sample used

The results of the physical and chemical properties of the soil sample are as indicated in Table 1.The soil sample used generally indicated that the soil was sandy loam

.**Table 1:** Initial Physicochemical properties of Soil sample used as growth medium

Soil properties	Values
Clay (%)	15
Silt (%)	12
Texture class	Sandy loam
Total sand (%)	70
pH (H_{20})	5.0
Organic carbon (gkg^{-1})	7.5
Total nitrogen (gkg^{-1})	0.5
Exchangeable bases (Cmol/kg^{-1})	
Sodium (Na^+)	0.13
Potassium (K^+)	0.10
Calcium (Ca^{2-})	2.40
Magnesium (Mg^{2+})	0.10
Cation exchange capacity (CEC) Cmol/kg^{-1}	8.15
Base Saturation (%)	33.5
Exchange Acidity (Cmol/kg^{-1})	
Aluminum ($A/^{3-}$)	0.65
Hydrogen (H^+)	0.80
Available phosphorus	10.1

Phytochemical contents of P. macrophylla Aqueous leaf extract

The result in Table 2 showed the phytochemical analysis results of *P. macrophylla* aqueous leaf extract.

Effect of different concentrations of P. macrophylla aqueous leaf extract on growth parameters of sweet potato (OFSP variety): vine length, number of leaves, number of branches and stem thickness

The effect of different concentrations of *P. macrophylla* Aqueous Leaf Extract (ALE) on vine length, number of leaves, number of branches and stem thickness at 16 WAP was presented in Table 3. The results showed that for vine length at 16 WAP, there was a significant difference (P>0.05) between the various ALE concentrations applied. The T_2 (10% ALE) gave the highest mean vine length (324.1 cm), followed by T_5 (80% ALE) which had 316.1, while T_1 (0% control) gave the least mean vine length (181.9 cm).

Considering number of leaves at 16 WAP, there was significant difference (P>0.05) among the ALE concentrations applied. However, it was recorded that T_4 (40% ALE) gave the highest mean number of leaves (216.1), seconded by T_5 (80%) that had 196.6, while T_1 (0% ALE) gave the least mean number of leaves (116.6).

Table 2: Phytochemical contents of *Pentaclethra macrophylla* aqueous leaf extract

Parameter (unit)	Quantitative	Qualitative
Moisture content (%)	13.7	
Ash content (%)	3.3	
Fat content (%)	15.1	
Crude fibre content (%)	8.2	
Protein content (%)	21.6	
Carbohydrate (%)	38.5	
Phenols (mg/100g)	916.3	+ + +
Phenolic acid (mg/100g)	94.4	+ +
Flavonoids (mg/100g)	667.1	+ + +
Mimosine (mg/100g)	7.5	-
Cinnamic acid (mg/100g)	8.4	_
Quinine (mg/100g)	8.9	_
Tannins (mg/100g)	24.1	+
Terpenoids (mg/100g)	10.1	_
Coumarins (mg/100g)	7.4	+

Table 3: Effect of different concentrations of *P. macrophylla* ALE on growth parameters of sweet potato (OFSP variety) at 16 WAP

Treatments	VL (cm)	NL	NB	ST (mm)
T_1 0% control	181.9±45.3	116.6±10.3	11.4±7.1	5.4±1.6
T_2 10% conc.	324.1±119.9	181.6±60.7	14.4±5.3	6.0±0.8
T_3 20% conc.	34.7±63.9	172.1±70.0	14.6±5.5	5.4±1.4
T_4 40% conc.	296.7±45.79	172.1±70.4	17.1±9.9	5.4±1.2
T_5 80% conc.	316.1±65.6	196.6±22.7	15.0±2.5	3.7±1.3
F-LSD 0.05	97.84	60.98	2.06	1.41

ALE= Aqueous leaf extract; SD= Standard deviation; WAP= Week after planting; vine length (VL), number of leaves (NL), number of branches (NB) and stem thickness (ST). Values are mean ± SD (n=8)

In addition, Table 3 showed that there was significant effect (P<0.05) on number of branches of sweet potato crop stands that were administered the various ALE concentration. However, it was recorded that T_4 (40% ALE) gave the highest mean number of branches (17.1), which was followed by T_5 (80% ALE) that had mean 15.0 number of branches, while T_1 (0% control) gave the least mean number of branches (11.4).

Result in Table 3 also showed that the different ALE concentration applied had significant effects (P<0.05) on stem thickness of sweet potato vine at 16 WAP. The T_2 (10% ALE) gave the highest mean stem thickness (6.0), followed by T_3 (20% ALE) which had 5.4, while T_4 (40% ALE) recorded the least mean stem thickness (3.7).

Effect of different concentrations of P. macrophylla aqueous leaf extract on fresh tuber and fresh shoot weights (biomass - grams) of sweet potato yield at harvest

The effect of different concentrations of *P. macrophylla* ALE on fresh tuber and fresh shoot weights of sweet potato yield at harvest are presented in Table 4. The result showed that the different ALE concentration applied had significant effects (P<0.05) on the fresh tuber weight (gram). The T_5 (80% ALE) recorded significantly highest fresh tuber yield (568.8g), followed by T_4 (40% ALE) that had 456.3 g mean fresh tuber per crop stand at 16 WAP; while T_1 (0% control) gave the least mean fresh tuber yield of 281.3 g.

The effect of different concentration of *P. macrophylla* ALE on the fresh shoot weight (grams) of sweet potato crop stands at harvest was also presented in Table 4. The result indicated that the different ALE concentration applied had significant effects (P<0.05) on the fresh shoot weight of the test crop at 16 WAP. Specifically, the T_3 (20% ALE) gave the highest mean fresh shoot weight (130.9), which was closely followed by T_2 (10% ALE) that had 130.1 g fresh shoot weight; while T_1 (0% control) gave the least mean fresh shoot weight (102.1).

Table 4: The effect of different concentrations of *P. macrophylla* aqueous leaf extract on fresh tuber (FT) and fresh shoot (FS) weights (biomass) of sweet potato yield at harvest (16 WAP)

Treatments	FT (g)	FS (g)
T_1 0% control	281.3±119.7	102.1±95.9
T_2 10% conc.	400.0±182.0	130.1±61.2
T_3 20% conc.	431.3±74.74	130.1±87.3
T_4 40% conc.	456.8±144.6	125.4±133.1
T_5 80% conc.	427.5±129.1	117.1±36.0
F-LSD 0.05	145.25	19.10

SD= Standard deviation; WAP= Week after planting. Values are mean± (SD (n=8)

DISCUSSION

The laboratory bioassay of *Pentaclethra macrophylla* aqueous leaf extract solution revealed appreciable level of protein contents (21.6%), as well as presence of identified allelochemicals, including phenols, phenolic acid, flavonoids, mimosine, coumarins, tannins and terpenoids among others. Some of these non-protein amino acids (for example mimosine, albizine (mimosoids), pipecolic acid and its derivatives; coumarins) had been reported to be common among the mimosoid sub-family of the Fabaceae (LPWG, 2013; LPWG, 2017). However, the present study obviously uncovered other allelochemicals that may be found in *P. macrophylla*, namely cinnamic acid, flavonoids, phenols, phenolic acid, quinine, tannins and terpenoids.

After 16 weeks of routine application of the *P. macrophylla* ALE on sweet potato (OFSP variety) crop stands, most of the growth parameters assessed responded remarkably positive to the various ALE treatments better than the control. This could be attributed to the stimulatory effects of the allelochemicals contained in leaf extracts at low concentrations which has a promontory influence on growth of test crops. This finding is in line with the findings of Einhelling and Ramussen (1979), Einlelling *et al.,* (1993) and Ogbu *et al.,* (2020) which reported that allelochemicals released by some plants have stimulatory effects at low concentrations; and very interesting fact was that these particular allelochemicals naturally have growth enhancing potential and these are produced in specified concentrations favoring plant growth. Narwal (1994) reported that plants use secondary metabolites as messenger under sub optional conditions to trigger the defense mechanisms and production of phytochemicals, hormones biologically active secondary metabolites and variety of proteins necessary to defend the plant ultra-structures from such hazards. This finding is also in conformity with the report of Chon *et al.* (2003) who opined that growth promotion by the allelochemicals was associated with test species, environmental condition and growth stages at which they are applied. They also reported that root growth of alfafa was significantly increased by water extracts of different plants of Compositae family when applied at low concentrations.

The result also revealed that there was significant ($P<0.05$) effect on fresh tuber and fresh shoot weights (biomass) of sweet potato root yield (gram) at harvest, due to the ALE concentrations application. However, the yield results showed that T_5 (80% ALE) remarkably improve the tuber yield of the test crop followed by T_4 (40% ALE); while T_3 (20% ALE) and T_2 (10% ALE) obtained the highest fresh shoot weight, better than the T_1 (0% control). This could be attributed to the fact that African oil bean leaf extract possess allelochemicals that is responsible to the improvements of sweet potato yield at higher concentrations. This is conformity with the reports of Cheema *et al.,* (2012) who stated that application of allelopathic extracts at high concentrations substantially suppresses the weed density and biomass reduction. Also concentrated sorghum water extract controlled *Chenopodum album*, *Pharlaris minor*, *Fumaria indica* and *Rumex dentatus* in wheat crop. It has also been successfully used against weeds of cotton, sunflower and mung bean, and it increased the yield of these crops by 3-59% depending upon the application. Also Einhelling and Erickson (1984) observed that production of allelochemicals at higher rates induced resistance in plants against stresses and helps them grow vigorously under such concentrations. Allelochemicals may thus be used as natural pesticides at high concentration (Farooq *et al.,* 2009).

In conclusion, some allelochemicals (namely coumarins, flavonoids, mimosine, phenols, phenolic acid, tannins and terpenoids among others) present in *Pentaclethra macrophylla* were identified to be responsible for observed stimulatory effect of the tree plant aqueous leaf extract when applied to sweet potato crop stands at 40% to 80% concentrations. Both growth and yield parameters of test crop indicated remarkable positive responses to the allelochemicals understudied in the present report.

REFERENCES

Anwar, S., W.A Shah, M. Shafi, J. Bakht and M.A. Khan (2003). Efficiency of sorgaab (sorgaab) and herbicide for weed control in wheat (*Triticum sativum*) crop. *Pak. J. Weed Sci. Res.,* 9: 161–170.

Bhadoria, P.B.S. (2011). Allelopathy: a natural way towards weed management. *Amer. J. Exp. Agric.,* 1: 7–20

Chon, S.U. and C.J. Nelson. (2012). Allelopathic dynamics in resource plants. In: Cheema Z.A., M. Farooq and A. Wahid (eds.). Allelopathy: Current Trends and Future Applications. Springer: Verlag Berlin Heidelberg, Germany. pp: 81-110.

Cheema, Z.A., A. Khaliq and S. Saeed, (2004). Weed control in maize (*Zea mays* L.) through sorghum allelopathy. *J. Sustain. Agric.*, 23: 73–86

Chon, S.U., Y.M. Kim and J.C. Lee, (2003). Herbicidal potential and quantification of causative allelochemicals from several compositae weeds. *Weed Res*., 43: 444 – 450

Diabate, M., Munive A., de Faria S.M., Ba A., Dreyfus, B. and Galiana, A. (2005). Occurrence of nodulation in unexplored leguminous trees native to the West African tropical rainforest and inoculation response of native species useful in reforestation. *New Phytologist* 166:231 – 239.

Einheling, F.A. (1995). Characterization of the mechanisms of allelopathy modeling and experimental approaches, In: Cheng, H and K.M.M indergif Dakshini (eds). Allelopathy organisms, processes and applications. American Chemical Society.

Einhellig, F.A. and P.C. Erickson, (1984). Interactions of temperature and ferulic acid stress on grain sorghum and soybeans. *J. Chem. Ecol.*, 10: 161–170

Einhellig, F.A. and J.A. Rasmussen, (1979). Effects of three phenolic acids on chlorophyll content and growth of soybean and grain sorghum seedlings .*J. Chem. Eco.*, 5:815–824

Einhellig, F.A., J.A. Rasmussen, A.M. Hejl and I.F. Souza, (1993). Effects of root exudate sorgoleone on photosynthesis. *J. Chem. Ecol*., 19: 369 375

Farooq, M., K. Jabran, Z.A. Cheema, A. Wahid and K.H.M. Siddique, (2011a). The role of allelopathy in agricultural pest management. *Pest Manage. Sci.*, 67: 493–506

Farooq, M., M. Habib, A. Rehman, A. Wahid and R. Munir, (2011b). Employing aqueous allelopathic extracts of sunflower in improving salinity tolerance in rice. *J. Agric. Soc. Sci.*, 7: 75–80

Farooq, M., A. Wahid, N. Kobayashi, D. Fujita and S.M.A. Basra, (2009). Plant drought stress: Effects, mechanisms and management. *Agron. Sustain. Dev.*, 28: 185–212

Iqbal, M.A., (2011). Response of canola (*Brassica napus L.*) to foliar application of moringa(*Moringa olifera L.*) and brassica (Brassica napus L.) water extracts. MSc Thesis, Department of Agronom University of Agriculture, Faisalabad, Pakistan

Iqbal, J. and Z.A. Cheema and M. An, (2007). Intercropping of field crops in cotton for the management of purple nutsedge (*Cyperus rotundu L*.). *Plant Soil*, 300: 163–171

Jamil, M, Z.A. Cheema, M.N Mushtaq, M. Farooq and M.A. Cheema, (2009). Alternative control of wild and canary grass in wheat fields by allelopathic plant water extracts. *Agron. Sustain. Dev.* 29:475-482.

Kruse, M.M. strandberg and B. Strandberg (2000). Ecological effects of Allepathic plants a Review, P: 66 National Environmental Research Institute. NERI, Technical Report No. 315, Silkeborg, Available online at http://www2.dm.dic11-viden/2 publikationer13...irapporter/fr315.pdf (accessed:15 February 2019). .

Ladipo, D.O., Kang, B.T. & Swift, M.J. (1993). Nodulation in *Pentaclethra macrophylla Benth*.; a multipurpose tree with potential for agroforestry in the humid lowlands of West Africa. *Nitrogen Fixing Tree Research Reports* 11: 104–115.

Legume Phylogeny Working Group (LPWG). (2013). Legume phylogeny and classification in the 21st century: Progress, prospects and lessons for other species-rich clades. *Taxon* 62 (2): 217–248.

Legume Phylogeny Working Group (LPWG). (2017). A new subfamily classification of the Leguminosae based on a taxonomically comprehensive phylogeny. *Taxon* 66 (1): 44–77. https://doi.org/10.12705/661.3

Narwal, S.S. (1994). Allelopathy in crop production. Scientific Publishers, Jodhpur, India.

Ogbu, J.U. (2019). Distribution, propagation and seedling growth of *Pentaclethra macrophylla* Benth., and its allelopathic effects on maize and okra in southeastern Nigeria. PhD thesis. University of Ibadan, Nigeria.

Ogbu, JU, Awodoyin, RO and Olubode, OS. (2020). Allelopathic effect of *Pentaclethra macrophylla* Benth. leaf extracts on germination and seedling growth of Maize and Okra. *Asian Journal of Biological Sciences* Volume 13(3): 285 - 292. DOI: 10.3923/ajbs.2020.285.292 https://scialert.net/abstract/?doi=ajbs.2020.285.292.

Oudhia, P., S.S.S. Kolheand R.S. Tirpathi, (1998). Allelopathic effect of Blumealacera L. on rice and common Kharif weeds. *Oryza*, 35: 175–177

Owoseni, O. and Awodoyin R.O. (2013). Allelopathic effect of aqueous shoot and root extracts of *Alternanthera brasiliana* (L) O. Kuntze on the germination and seedling growth of *Amaranthus cruentus L*. and Zea mays L. *Ibadan Journal of Agriculture Research* 9: 257 -264.

Rice, E.L., (1984). Allelopathy, 2nd edition. Academic Press, New York, USA

Sprent J.I. (2005). West African legumes: the role of nodulation and nitrogen fixation. *New Phytologist* 167: 326–330.

ILLEGAL CRUDE OIL REFINING AND ITS IMPLICATIONS ON THE NIGER DELTA'S ECOSYSTEM

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ABSTRACT

Crude oil is the major source of revenue in Nigeria with the vast majority of exploration from the Niger Delta. Illegal refining of stolen oil is a major cause of oil spills and comes with steep environmental, economic, and social costs in the region. Oil theft, artisanal refineries, and ecosystem pollution are simultaneously linked. Therefore, the review paper seeks to highlight the effect of illegal refineries on the region's ecosystems currently exacerbated by black soot pollution, the causes of increasing artisanal refineries, the implication of illegal oil destruction, and possible solutions. The review revealed that illegal crude oil refining has a denudating impact on flora and fauna, air, soil, aquatic ecosystems, and the mangroves. Causes of illegal refineries include poverty and low standard of living, the pragmatic collaboration between security authorities and other actors, the relatively low set-up cost, and the lackadaisical attitude of oil companies towards the replacement damaged oil facilities. The common practice of burning recovered stolen crude further damages the ecosystem. The need for government agencies, laws, and policies for environmental protection to be active while creating synergy with security outfits to curb the menace and engaging in regular cleanups through phytoremediation are possible solutions. We recommend the following; shutdown of all illegal refineries, stakeholders' synergies to guard against oil pollution and biodiversity loss, environmental education, and youth empowerment through vocational training and cleaning, afforestation, and reforestation of degraded sites.

Keyword: Artisanal Refining, *Kpo-Fire*, Oil Spillage, Pollution, Niger Delta

INTRODUCTION

Crude oil exploration and exploitation is very lucrative and the major source of revenue in Nigeria (Anejionu *et al.*, 2015; Romsom, 2022). Approximately 250,000 barrels of crude oil are stolen daily in Nigeria with the majority sold internationally while about 25% stay in the Niger Delta for Illegal oil refining and consumption (SDN, 2015; Romsom, 2022; Ufuoma, 2022). Illegal crude oil refining or artisanal refining or oil bunkering refers to activities or processes that involve crude oil theft and locally refining them through the use of local resources, using traditional knowledge and skills with little or no application of modern technology (Douglas, 2018). It's a local oil fractional distillation method that involves heating crude oil over a specific range of boiling points in a fabricated oven to extract petroleum products, with the residue being discharged into the environment without consideration of the impact and consequences to the ecosystem (Barenboim *et al.*, 2015; Douglas, 2018).

The rudimentary materials for this illegal refining involve drums and metal pipes welded together, in which crude oil is heated and the resultant distillate crude products (kerosene, fuel, and diesel) are collected, cooled, and condensed in tanks for consumption (Barenboim *et al.*, 2015; Douglas, 2018). These products are readily available at cheap prices for the average man, consequently satisfying local energy demand. The artisanal refinery has created jobs for many youths in the region at the detriment of the ecosystem (SDN, 2015). The production and marketing system is highly organised with some producing, while others are marketing and distributing these products to communities within and outside the region (SDN, 2015; Douglas, 2018). "*Kpo-fire*" is a local slang used to describe the artisanal refinery process, which is coined from the explosive sound heard when oil is used as the fuel for the refining purpose, and the term is also used to describe kerosene, fuel, and diesel gotten from artisanal refining (Douglas, 2018).

Illegal refining of stolen oil is one of the major causes of oil spills in the Niger Delta while other causes include sabotage of oil installations, corrosion of pipelines and storage tanks, and accidents in oil production operations (Efenakpo *et al.,* 2018; Bello and Amadi, 2019). The World Bank (1995) observed that oil companies understate the incidents of oil spillage in the Niger Delta. The Department of Petroleum Resources (DPR) estimated that 2.4 million barrels of petroleum were spilled into the Niger Delta between 1976 and 1996 in 4,835 incidents (Vidal, 2010). Illegal oil refining in the region comes with steep environmental, economic, and social costs (Asimiea and Omokhua, 2013; Bello and Amadi, 2019). Refining the crude oil by this method, yields 2% kerosene, 2% fuel, 41% diesel, and 55% waste and after the desired products are collected, large quantities of residue (waste) produced are dumped indiscriminately on land and water body causing environmental pollution while part of the residue is used as fuel for further refining process (SDN, 2015; Douglas, 2018; Bello and Amadi, 2019).

Apart from the economic considerations of crude oil theft in Nigeria, the environmental degradation associated with these illegal oil refineries is immersed (Asimiea and Omokhua, 2013; Bello and Amadi, 2019). Although there are no reliable figures on the number of spills and the extent to which illegal artisanal refineries contribute to the environmental pollution in the region but severe noticeable damage is done to our environment as a result of this local fractional distillation method. This crude technology of oil refining often leads to a significant quantity of oil waste being dumped in creeks, forests, mangroves, rivers, and lands causing enormous damage to both the biotic and abiotic components of the environment (Douglas, 2018). Crude oil refining contributes solid, liquid, and gaseous wastes in the environment that can resist degradation and, remain persistent in sediments and when in organisms, could accumulate in adipose tissues and further transferred up the trophic chain and food web (Decker, 1997; Ndidi *et al.,* 2020).

The Niger Delta where most of these illegal refining are carried out is the third-largest wetland ecosystem in the world covering approximately 75,000 km^2 (Efenakpo *et al.,* 2018). The region consists of nine states and is endowed with crude oil deposits and a lot of biodiversities that have been immensely exploited, as well as abundant natural resources (Figure 1) (Efenakpo *et al.,* 2018). It has the richest wildlife resources (flora and fauna) found in the country's rainforest ecosystem and harbours many locally and globally endangered species and approximately 60-80% of all plant and animal species found in Nigeria (Efenakpo *et al.,* 2018). Five distinct ecological zones namely; mangrove forest and coastal vegetation, freshwater swamp forest, lowland rain forest, derived savannah, and montane zone can be observed in the region (Efenakpo *et al.,* 2018).

The region's wetlands and its rich biodiversity repository are changing rapidly due to several anthropogenic activities namely; oil spillage and gas pollution, urbanization and deforestation, invasive alien species, annual bush burning practice, and land clearing for agricultural purposes (Adekola and Mitchell, 2011; Efenakpo *et al.,* 2018). Consequently, raising concerns for the wetlands' health and biodiversity and communities relying upon its ecosystem services. Bello and Amadi (2019) posited that the region, which is the main seat of oil and gas production in Nigeria, is suffering from the destructive effects of oil and gas exploration and production in terms of enormous oil pollution, biological diversity degradation, and extinction.

Oil pollution from Illegal crude oil distorts aquatic life which not only destroys the source of livelihood of fishes but also causes a shortage of supply of seafood (Albert *et al,* 2018). It destroys the fertile soil as well as crop yields (Nwankwoala *et al.,* 2017; Ogbuagu *et al.,* 2011; Douglas, 2018), which makes it difficult for the farmer to farm as a means of livelihood. It also causes air pollution through the rapid spread of black soot (Onakpohor *et al.,* 2020; Simi-Wellington and Ideriah, 2020). The impact of illegal refineries on the aquatic environment in the Niger Delta has raised questions of great concern in the minds of the inhabitants in the region who have suffered polluted air, contaminated environment, degraded forests, biodiversity loss, and high atmospheric temperatures (Anejionu *et al.*, 2015).

Although, the economic impact of oil theft associated with these operations of the illegal refineries and on their host communities are widely reported (Oredein, 2013; Bebeteidoh *et al.*, 2020) only a few independent surveys on the impact of the artisanal refineries on the highly sensitive environment of the Niger Delta are reported e.g. impact on vegetation (Hammadina and Anyanwu, 2012; Asimiea and Omokhua, 2013), soil fungi (Douglas, 2018), aquatic ecosystems (Ndidi *et al.*, 2020), mangroves (Onyena and Sam, 2020). This review paper, therefore, seeks to holistically highlight the effect of illegal refineries on the Niger Delta's ecosystems which is recently exacerbated by the increasing air pollution (black soot) in the Niger Delta environment.

Niger Delta Biodiversity Conservation

Biodiversity is the variation among living organisms, which encompasses species diversity (the number of different species), genetic diversity (gene pool variety within species), and ecosystem diversity (the variety of interactions among living things in natural communities) (Okiwelu and Anyawu, 2003) and the key purposes of conservation are to maintain essential ecological processes and life support system, preservation of genetic resources and sustainable utilization of species and ecosystems (IUCN/UNEP/WWF, 1980). However, the activities of artisanal refineries have truncated conservation measures and rapidly promote extinction in the oil-rich region of the Niger Delta. The region is regarded globally as a biodiversity hot spot with the World Wide Fund for Nature (WWF) Global 200 Ecoregion classifying it as a critically endangered ecosystem, while the World Bank (1995) posited that the region is the second most sensitive environment in Africa. Also, the International Union for the Conservation of Nature and Natural Resources (IUCN), posited from the evaluation of coastal regions of eleven West African countries, that Niger Delta is unprotected due to the loss of substantial portions of their area which translates to the loss of biodiversity despite having over 70 Protected Areas (PAs) (Phil-Eze and Okoro, 2009; Bello and Amadi, 2019).

There are over 119 mammal species, 201 bird species, 248 fish species, 30 reptile species, and over 850 vulnerable tree species in the Niger Delta region (Phil-Eze and Okoro, 2009). With a total coastline of 400 km, it accounts for about 50% of the Nigerian coastline and over 80% of the coastal fisheries production. Local modular refining of crude oil in the region causes pollution which is traumatic to the environment and biodiversity. Mankind cannot possibly exist alone without other important components of biodiversity (Bello and Amadi, 2019). All components have a symbiotic relationship and they work together to ensure continued existence (Lang and Benbow, 2013; Gross *et al.*, 2021). Several components of the region's biodiversity are important because they provide food, medicine, and raw materials for the production of other essential goods. The life of a man is indirectly threatened when there is a failure to control activities that destroy biodiversity and promote oil pollution.

Niger Delta region of Nigeria has about 606 oil fields with 355 situated onshore; 251 situated offshore with 5284 drilled oil wells and 7,000 km of oil and gas pipelines (Anifowose, 2008; Onuoha, 2008). Activities of the oil industry are widespread across the length and breadth of the region (Figure 2). There is virtually no part of the Delta that is protected from the influence of oil and gas exploration. This includes some of the most important sites and habitats for biodiversity. This in turn endangers both the aquatic and terrestrial biodiversity of the region. Dublin-Green *et al*. (1999) reported that between 1976 and 1997, there were 5,334 reported cases of oil spillages, releasing around 2.8 million barrels of oil. The official figures of SPDC (2004) show that between 1976 and 2001, 3 million barrels were spilled in 6,187 incidents.

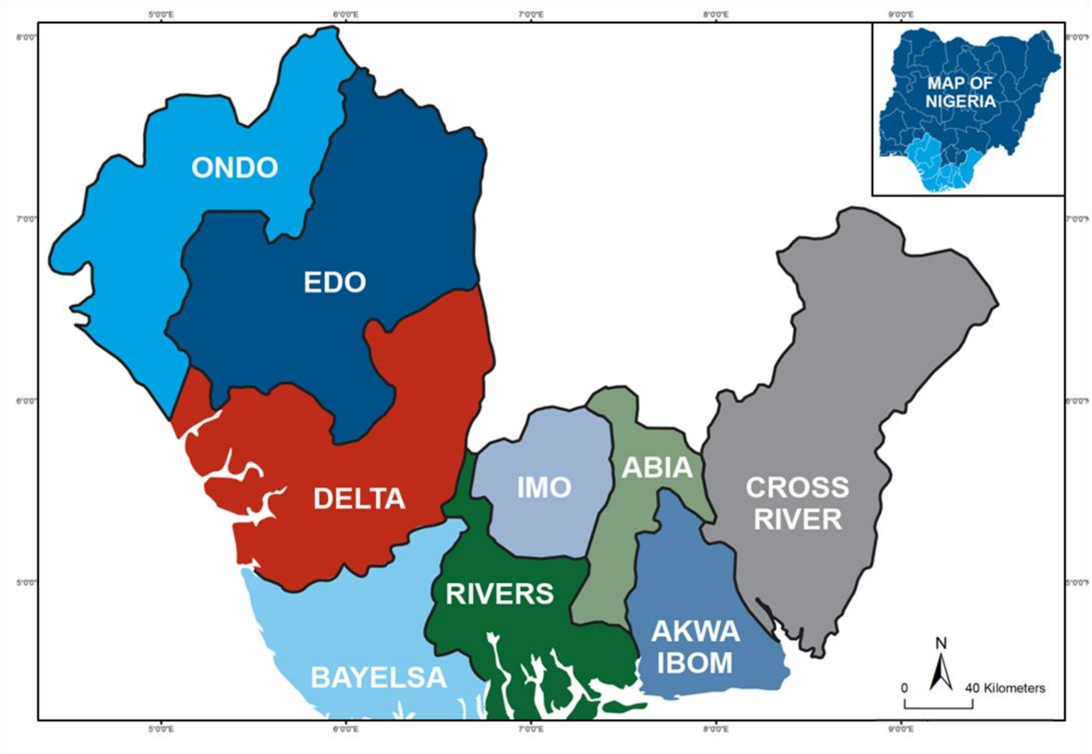

Figure 1: Map of Niger Delta Region Showing the 9 states of the oil-rich region. Inset: Map of Nigeria showing position of Niger Delta Region.

Oil Spillage and Gas Pollution

However, in 2013, National Oil Spillage Detection and Response Agency (NOSDRA) established a National Oil Spills Monitor (https://oilspillmonitor.ng/), a Global Information System (GIS) web application for the official collection of data on oil spills from all operators in the Niger Delta is displayed in an online map for public access. NOSDRA's record of oil spills between 2006 and 2021 is 721,657.61 barrels spilled in 13,613 incidents (Figure 2). These oil spills, directly and indirectly, affect biodiversity in the Niger Delta Region making the region a more fragile ecosystem.

More also, Nigeria flares more natural gas associated with oil extraction than any other country in the world, with estimated flaring wastes of 2.5 billion cubic feet (70,000,000 m^3) of the 3.5 billion cubic feet (100,000,000 m^3) of associated gas (AG) generated yearly and because extracting economically viable associated gas from oil is costly, gas flaring is practiced in Nigeria despite the act being typically frowned upon because it emits harmful components into the atmosphere and contributes to climate change (Wikipedia, 2022). Large volumes of methane are released as a result of gas flaring, which has a strong global warming potential.

Flares also produce hazardous substances such as nitrogen dioxides, sulphur dioxide, volatile organic compounds including benzene, toluene, xylene, and hydrogen sulfide, as well as carcinogens like benzopyrene and dioxins which contribute to acid rain. Exposure to such compounds can cause respiratory issues in humans and wildlife. Asthma, breathing problems, and discomfort, as well as chronic bronchitis, can all be worse by these compounds. Benzene, which is known to be emitted in huge levels from gas flares, is widely established as a cause of leukemia and other blood-related disorders (Wikipedia, 2022)

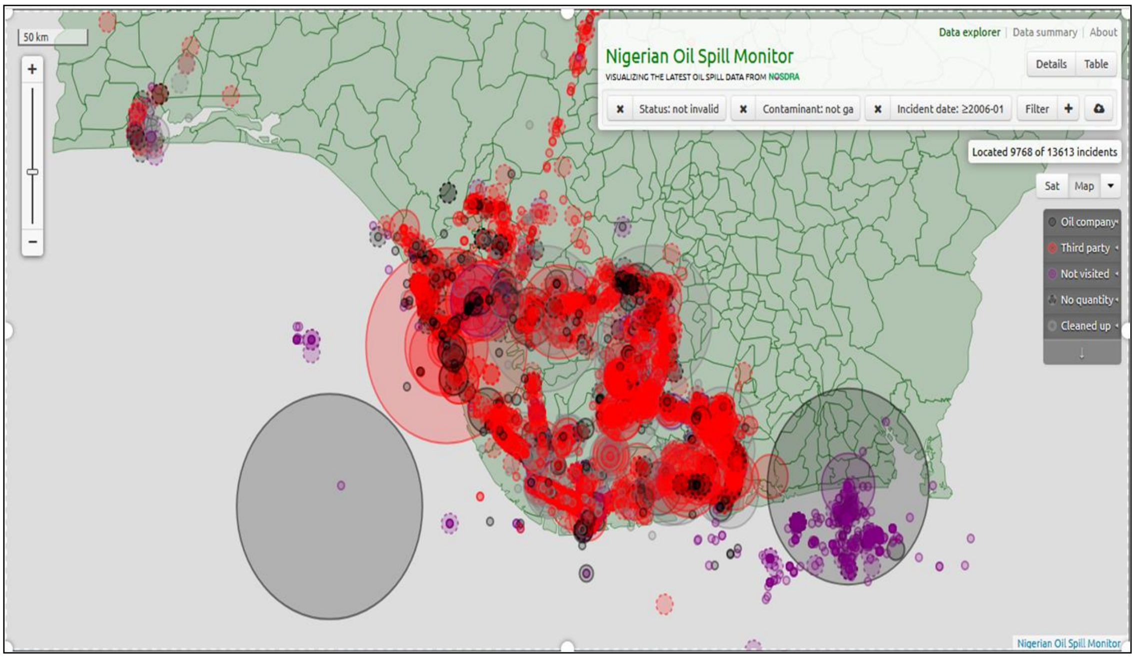

Figure 2: Oil Spillage in the Niger Delta Region, Source: NOSDRA (2021)

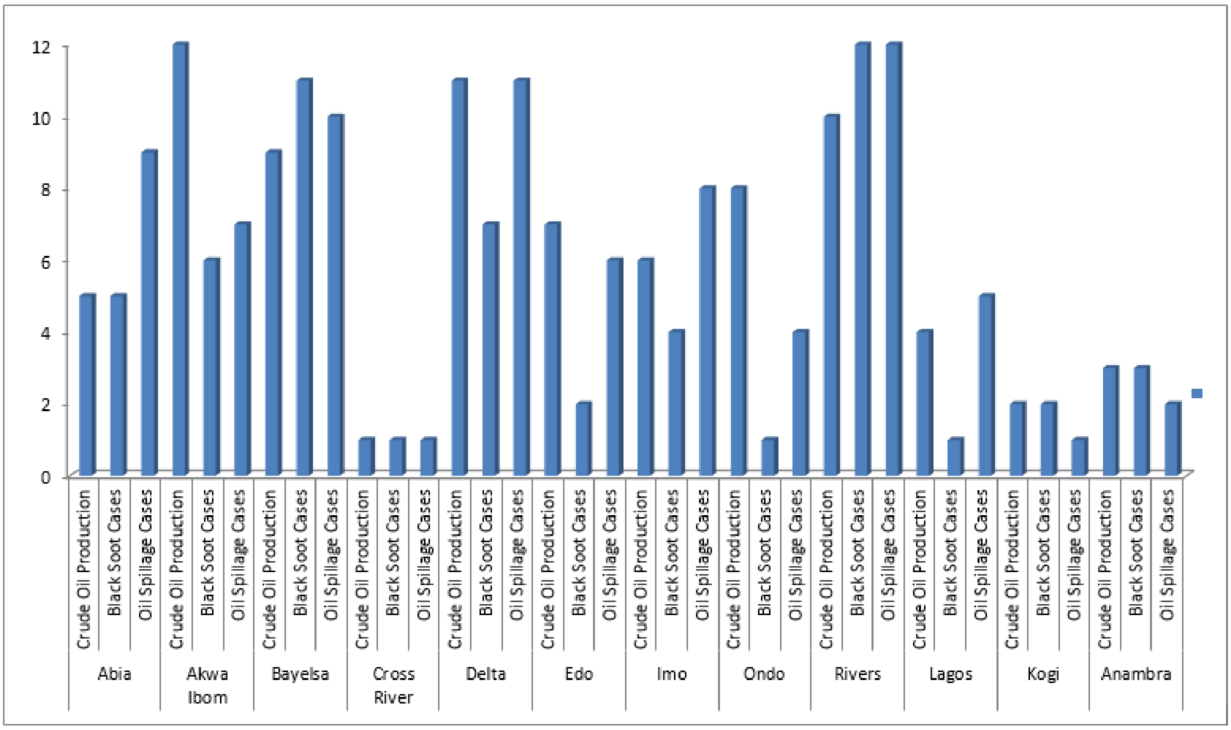

Figure 3: State ranking of Oil production, spillage, and black soot in the Niger Delta Region,

Plate 1: (A) Camp worker attends to the fire, powering the oven to cook the crude (B) Cooking installation at illegal oil refining camp (C) A man carries refined oil in buckets near the river Nun in Bayelsa State; (D) Crude oil drenches the ground soil (E) Environmental degradation surrounding a camp (F) A worker pours crude oil into a locally made burner using a funnel in Bayelsa State, (G) A man collects polluted water at an illegal oil refinery site near river Nun in Bayelsa State; and (H) A man working at an illegal oil refinery site pours oil under a locally made burner to keep the fire going in Bayelsa State. (I) Men work at an illegal oil refinery site near river Nun in Bayelsa State Photo Credit: Plates A, B, D, E by SDN, 2015 and Plate C, F, G, H, I by Akintunde Akinleye Atlantic, 2022.

Artisanal Oil Refining Impact on Niger Delta Region

The impact of artisanal oil refining in the Niger Delta is tremendous and widespread covering biological, social (militancy, migration, and the rise of environmental refugees), and economic (nutritional deficiency and food shortages, destruction of traditional means of livelihood) aspects of both humans and the entire ecosystem. Environmental effects of artisanal refineries include pollution of air, water, soil, contamination of plants, fishes, and animals with attendant health consequences following human consumption. However, the scope of impact was limited to; flora and fauna, air, soil, aquatic ecosystems, and the mangroves.

(i) Flora and Fauna

The widespread artisanal oil refinery contributes to the growing decline of biodiversity such as wild flora and fauna in the Niger Delta. Flora and fauna in the region are severely impacted as these refineries pollute the air, water, soil, and the entire ecosystem. Faunas absorb heavy metals from polluted ecosystems which harm them. For animals such as birds that rely on beautiful plumage colouration for courtship, gaseous pollution (black soot) from artisanal refineries may also indirectly affects their reproduction. Flora absorbs hazardous substances such as the Polynuclear Aromatic Hydrocarbons (PAHs), from the residual waste deposited on the soil, water, and atmosphere. This affects plant growth and results in the reduction of the abundance and diversity of plant species.

Yabrade and Tanee, (2016) compared the Total Hydrocarbon Content (THC) and the Total Organic Carbon (TOC) in affected sites to total hydrocarbon and total organic carbon in the unaffected controlled site and observed that there was a significant increase in THC and TOC in refinery sites compared to the controlled sites. Thus, artisanal oil refineries can be disastrous to the ecosystem. More also, the process of photosynthesis is also impaired as a result of the introduction of phytotoxins into the environment wherever oil spills occur.

Asimea and Omokhua (2013) observed that artisanal oil refinery affects the regeneration of plant species as seeds and saplings on the forest floor are contaminated. The roots of the matured trees can also be destroyed and this can affect the flow of nutrients to other parts of the tree. Continuous increase in the accumulation of toxic waste from the refineries can result in the loss of vegetation which produces food and shelter for fauna species.

The aesthetic scenery of the forest and the presence of fauna species that enhance ecotourism in the region can be affected as a result of the fragmentation of the wildlife habitat. Important ecosystem services such as recycling of water, air purification, and the amelioration of climate change can be disrupted. In addition, the production of crops and fishing activities are also affected. Crops on farmlands will either die or have stunted growth. Oil spills on the river can as well affect the survival of aquatic organisms by blocking the flow of oxygen needed in the water. Shortage in the production of crops and the aquatic organism can result in a shortage in the food supply which can affect society. One very important effect of the discharge of illegal refineries waste is the loss of vegetation which provide food and shelter for both vertebrates and invertebrates, this leads to fragmentation of wildlife habitat, alteration of the local water cycle since trees play important role in water cycling and disruption of air purification role of trees due to reduced carbon sequestration and aggravation of climate change (Umechuruba, 2005).

(ii) Air

The operations of artisanal refineries are carried out in the creeks where the environmentally dangerous hydrocarbons are discharged directly into the atmosphere and waterways thereby constituting severe degradation and pollution to the surrounding environment (Plate 1) (Odubo and Onyige, 2019). Artisanal petroleum refining technology in the Niger Delta is a source of air pollution, hence impacting air quality (Onakpohor *et al.,* 2020). Artisanal refining is also responsible for the inputs of gaseous, solid, and liquid wastes into the environment (Avwiri and Ononugbo, 2012). The air quality of artisanal refining areas and their surrounding communities are poor as pollutants such as nitrogen dioxide (NO_2), volatile organic compounds (VOCs), and *ammonia* (NH_3) which are usually above the recommended limits by the World Health Organization (Simi-Wellington and Ideriah, 2020).

Oil pollution gives rise to the occurrence of certain ailments such s respiratory tract irritation, (cough, catarrh, tearing), allergies, irritation of the eyes, irritation of the skin, exacerbation of asthma, lung cancer, chronic bronchitis, Chronic Obstructive Pulmonary Disease (COPD) and several other chronic lung diseases as some of the health effects in areas that have suffered from oil pollution in Nigeria (Oyadongha, 2021). This is often a result of inhalation of contaminated air, intake of oil-polluted contaminated food, and also as a result of the consumption of contaminated water. Hydrocarbon and black soot air pollution-related illnesses could assume an epidemic proportion and thus overwhelm the health facilities and health manpower resulting in the sudden collapse of the health sector (Oyadongha, 2021).

Consequently, the health, environmental, economic, and social effects of hydrocarbon and black soot-related air pollution are dangerous to humans and the environment and must be given keen attention and speedy solution in stopping this looming epidemic from exploding and getting out of proportion and control. **Approximately 112 illegal refineries were discovered in** a particular community located along the OML 17 trunk lines in **Ikwerre Local Government Area of Rivers State which amount to** 99% of the discoveries on the heels of the recent efforts by the state government to bring to an end the economic sabotage brought as a result of the illegal refineries, as well as the health implications resulting from black soot pollution (Channels, 2022).

(iii) Soil

Loss of biodiversity and destruction of habitats, largely due to topsoil degradation is a major adverse effect of artisanal refineries and oil pollution (Plate 1). Soil pollution by crude oil and its bye products as a result of "*Kpo-fire*" is one of the most common environmental challenges in the Niger Delta. Oil pollution results in the destruction of the region's traditional local economic support systems of farming and fishing lands. Polluted soils by artisanal refining activities don't only deprive the soil of aerations by forming a coat on the topsoil but also kill soil microbes, fungi (micro and macro), and soil organisms that help in soil improvement (Douglas, 2018).

Some of these wastes contain toxic components such as the PAHs, which have been reported to be the real contaminants of oil and the most abundant of the main hydrocarbons found in the crude oil mixture (Ndidi *et al.*, 2020). Nwankwoala *et al.* (2017) analyzed soil samples from artisanal refining sites and recorded high levels of crude content from 1m, with concentration reducing with depth up to 3m. Once introduced in the environment, PAHs could be stable in soils and sediments thus, resist degradation and when absorb by organisms, could accumulate in adipose tissues and further transferred up the trophic chain or web (Martens and Frankenberger, 1995; Ogbuagu *et al.,* 2011).

(iv). Aquatic Ecosystems

The refining processes often lead to two drums of crude oil amounting to one drum of the product once refined, leading to a significant quantity of waste being released into the aquatic environment (Anifowose *et al.,* 2014; Albert *et al.*, 2018). Artisanal refineries like most industrial activities produce environmental hazards that are slow poisons (Asimiea and Omokhua, 2013). Aquatic ecosystems oil spills pollution is the single most important threat to freshwater, coastal, and marine ecosystems of the Niger Delta, and such impacts the drinking water quality, testudines, fisheries, and other aquatic organisms (IUCN Niger Delta Panel, 2018).

Fishes have been driven away from shallow waters into the deep-sea as a result of pollution in the region. Oil attenuates oxygen in the water column and coats the breathing apparatus of aquatic organisms. Specifically, it starves mangroves of oxygen by coating the breathing roots of the mangroves and scotches the tender structures of aquatic macrophytes of tidal freshwater vegetation. Untreated crude oil waste discharged indiscriminately into aquatic systems destroys the medicinal plant. There are growing concerns about the quality of fish and other seafood due to the accumulation of hydrocarbons with a serious health issue in the region.

More also, the fisheries sector is suffering due to the destruction of fish habitat in the mangroves and highly persistent contamination of many of the creeks due to heavy metals transported during artisanal refining, making them unsuitable for fishing (Davies and Ekperusi, 2021). The contents of the effluents have serious toxicological effects on aquatic life, the environment, and humans. When industrial effluent and oil waste is discharged into a water body, it can cause depletion of dissolved oxygen due to transformation of organic components into inorganic compounds, loss of biodiversity through a decrease in amphipod population that is important in the food chain, eutrophication, and short-term toxicity in fish (Decker, 1981). Environmental pollution resulting from artisanal refining activity has altered the natural quality of the aquatic ecosystem thereby posing an adverse effect on the food chain.

(v) Mangrove

Severe damage has been done to the aquatic environment as a result of artisanal refining which has led to the loss of the mangrove plants in the region (Plate 2 B, E, and G). Duke (2016) noted that a review of crude oil impact on mangroves shows that 37% of the global impact had occurred in the Niger Delta. Artisanal refining has caused pollution in many intertidal creeks which have left the mangroves denuded of leaves and stems, leaving roots coated in a bitumen-like substance sometimes 1cm or thicker. Mangroves are a shelter for biological diversity consisting of diverse aquatic and terrestrial flora and fauna which include mammals (monkeys, antelopes, and manatees), mollusks (bivalves, oysters), crustaceans, fish, reptiles, and avian species (Onyena and Sam, 2020).

They are spawning areas for fish and nurseries for juvenile fish and the extensive pollution of these areas is impacting the fish life-cycle (Albert *et al.*, 2018). The magnitude of the damage experienced on mangrove vegetation depends on the sensitivity of its pneumatic roots to petroleum waste (Asimiea, 2011). The mangrove vegetation in the Niger Delta brackish water area includes five species namely *Rhizophora racemose, Rhizophora harrisonii, and Rhizophora mangle* (Red Mangroves), *Avicennia Africana* (White Mangrove), and *Laguncularia racemosa* (Black Mangrove*).* Other species of plants observed are the marine grass *Paspalum vaginatum*, and fern *Acrostichum aureum* which are all affected by waste from artisanal refineries.

Dominic (2016) and Ikezam *et al.* (2021) reported that wastes from artisanal refining sites released into the river spread along the up and downstream river course due to tidal effects consequently leading to the death of mangrove plants, especially those close to the sites showing heavy mortality of merchantable trees as a result of the wastes discharged from illegal refineries. As the mangrove plants die and decay, the soil stabilization properties of the roots are lost, leading to coastal erosion. The loss of vegetation drastically hampered the regeneration of species in the mangrove forest due to contamination of seeds and saplings on the forest floor (Asimiea and Omokhua, 2013).

Causes of Increasing Oil Theft, Artisanal Refineries, and Ecosystem Pollution

Poverty and low standard of living despite the available resources in the Niger Delta is one of the major causes of increasing illegal refineries. The artisanal refinery is a business that is fast growing and has spread in all communities with oil fields in the Niger Delta region (Figure 4) (SDN, 2015; Ikezam *et al.*, 2021). The rapid development of artisanal oil refining camps across the region has resulted in a semi-structured, informal, and highly entrepreneurial economic system that is managed and operated in each local area along a discrete five-stage value chain, which includes; tap installation, tapping point operation, supply of stolen crude for export and local refining, local refining into products stage, and distribution and sale of refined products (SDN, 2015). Oil theft is aided in Nigeria by pragmatic collaboration between security authorities, militia organizations, the local populace, and oil company employees (SDN, 2015; Bello and Amadi, 2019; Romsom, 2022).

Hot-tapping and cold-tapping are two ways used by artisanal refineries to undertake oil bunkering and steal thousands of barrels of oil per day from existing oil pipelines (SDN, 2015). In Nigeria, oil theft is sometimes the sole means of survival for many and can also occur during the transit of the crude oil product. Oil theft, artisanal refineries, and ecosystem pollutions are simultaneously linked as an increase in crude oil theft will consequently increase the numbers of artisanal refineries cases as such ecosystem pollutions (Figure 3).

The lackadaisical and nonchalant attitude of oil companies towards repairs and/or replacement of old and damaged oil facilities in collaboration with the inability of the Nigerian state to provide basic public services and security in the Niger Delta has consequently increased artisanal refineries in the region (SDN, 2015). The Federal Government's failure to intervene and bring sustainable development to the region has also led to the initiation of militancy activities which is also a contributing factor to the growing numbers of these illegal refineries.

The artisanal refinery is a major challenge to the petroleum industries, man, and its environment through its process of sourcing the raw material, mode of production, and after-use effect. These refineries carry out operations without putting in place measures of ameliorating the environmental impact. Signs of areas with illegal refinery activities are dirty water and sheen of oil visibly floating on the surface of the river, littering of river banks with lumps of oil, and dying vegetation along the riverbank and within the vicinity of the camp (Plate 1) (NRC, 2014). According to DPR (2018), the illegal refinery is the major source of pollution and the activities of artisanal refineries degrade the ecosystem which is the source of livelihood for rural people. The relatively low cost of sourcing the rudimentary materials for these illegal refineries also allows for quick setup of these operations and increases the numbers of "*kpo-fire*" refineries (SDN, 2015; Bello and Amadi, 2019).

Challenges and Implications of Cleanup and Illegal Oil Destruction

The common practice of certain contractors as well as security officers burning recovered stolen crude is not environmentally friendly and further damages the Niger Delta's ecosystem (Plate 2F). These activities cause serious soil, and water contamination, as well as the loss of mangroves. Although the Nigerian government has taken steps to control and mitigate oil pollution and the conservation of her biodiversity to improve and protect the air, land, water, forest, and wildlife by using the instrumentality of agencies, laws, and policies nothing much has changed in the region as its still plague with oil and gas pollution. There are regional and international instruments in place for the mitigation of oil pollution and the conservation of biodiversity

Institutions created by law for the control and mitigation of oil pollution such as the DPR saddled with the responsibility of the development of the nation's oil and gas resources, influence and achieve the optimum exploitation, conversion, and utilization of petroleum and its derivatives for the maximum benefit of Nigerians while ensuring minimal damage to the environment (Akinjide-Balogun, 2001). The Federal Environmental Protection Agency (FEPA) Act acknowledges DPR as the principal authority charged with the responsibility for the removal of oil-related pollution discharged into the environment but polluted sites are increasing daily.

Other agencies include the NOSDRA which was established in 2004 by the Ministry of Environment charged with the National Oil Spill Contingency Plan (NOSCP) in compliance with the International Convention on Oil Pollution Preparedness, Response, and Cooperation, of which Nigeria is a signatory. NOSDRA seeks to achieve zero tolerance for oil spill incidences in Nigeria, while advocating for the restoration and preservation of the environment by ensuring good practices in oil exploration, storage, and production, to achieve sustainable development. National Environmental Standards and Regulation Enforcement Agency (NESREA) an agency administered by the Ministry of Environment with the embodiment of laws and regulations focused on the protection and sustainable development of the environment and its natural resources and prohibits the discharge of hazardous substances into the environment.

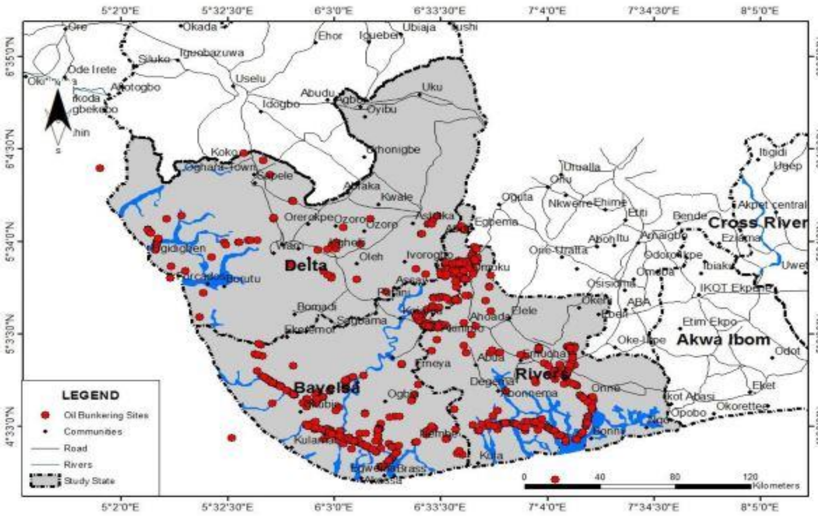

Figure 4: Showing the Artisanal Oil Refining Sites in the Mangrove of the Niger Delta
Source: Ikezam *et al.* (2021).

Plate 2: (A) A burnt canoe hull rests in a polluted creek after an oil pipeline explosion at Arepo village; (B) Vegetation visibly affected by oil spills and camp refinery fires (C) An oil pipeline belonging to Agip spews oil after a leak in the Kalaba community in Bayelsa State (D) Formerly functional Creek side refining camp, destroyed by the Joint t ask Force in 2012 (E) Crude saturates the mangroves and oil disturbs the surface water (F) Smoke rises as an illegal oil refinery is burned after a military chase in a creek near river Nun in Bayelsa State; (G) An oil slick clots the bottom of mangroves in Bodo creek in Ogoniland, near Nigeria's oil hub city of Port Harcourt, and (H) An oil slick flows near abandoned drums at an illegal oil refinery site after the military chased oil thieves near the river Nun in Bayelsa State (I) A passenger speedboat churns up the water, while in the background an illegal oil refinery is left burning after a military chase had occurred earlier. Source: A, C, F, G, H, I Atlantic (2013) and B, D, E by SDN, (2015)

While some of the laws and regulations put in place by the Nigerian government for environmental protection, planning, pollution prevention and control, and the conservation of Nigeria's biodiversity include; The Endangered Species (Control of International Trade and Traffic) Act was enacted to fulfill the obligation assumed under the Convention on International Trade in Endangered Species that focuses on the protection and management of Nigeria's wildlife and some of their species in danger of extinction due to overexploitation. The Sea Fisheries Act makes it illegal to take or harm fishes within Nigerian waters by use of explosives, poisonous or noxious substances. Inland Fisheries Act focuses on the protection of the water habitat and its species and prohibits the taking or destruction of fish by harmful means. In addition, Nigeria's regulations of the oil industry are weak and rarely enforced. Despite all the laws, policies, and agencies the wanton damage to the Niger delta ecosystems remains unabated.

Possible Solutions

Biological remediation, especially phytoremediation, has been used in the region to detoxify and repair oil spilled ecosystems (*Limson, 2002*). *Hibiscus cannabinus* an annual herbaceous West African plant species that was previously utilized for pulp manufacture and *Eupatorium capillifolium* a perennial herbaceous plant in the sunflower family (*Limson, 2002;* Wikipedia, 2022). These species have a high absorbency rate and may be used to absorb oil by laying it on top of the water. The oil-saturated plant material is then removed and sent to a safe area where microorganisms may break down and detoxify the hydrocarbons. *Vetiveria zizanioides* a perennial grass with a thick fibrous root network that can resist toxins in the soil as well as detoxify soils over time can be used as phytoremediation for polluted soils (*Limson, 2002;* Wikipedia, 2022).

Regardless of the multi-complex situation of artisanal refineries in the Niger Delta, there are certainly options that can be applied to protect the region from further pollution. Satellite imaging, in combination with Geographical Information Systems (GIS), may be used to swiftly locate and monitor oil spills. Regional cleanup sites along problem areas could help contain spills more quickly, speeding up the cleanup process. More funding from the oil industry's stakeholders is required to make these tasks possible. Meanwhile, there have been renewed calls to the Federal Government to provide modern modular refineries to curb the economic sabotage. Onuh *et al.* (2021) noted that the continual failure of the clean-up programme in the Niger Delta is responsible for the increasing numbers of the artisanal crude oil-refining economy in the region. However, the government through the Nigerian National Petroleum Corporation (NNPC) has disbursed $180m as a take-off fee for the 21 selected companies for the cleanup of Ogoni land which is part of the Niger Delta. The need for the project to be successful must be a priority for the government while creating synergy with security outfits to curb the oil refineries menace.

CONCLUSION AND RECOMMENDATION

Oil pollution has for so long a time perpetrated the Niger Delta environment and biodiversity with little or nothing being done to alleviate the menace. The impacts of these illegal artisanal refineries on the environment include the aquatic ecosystems, the mangrove ecology, soil, farms, water, air, flora, and fauna of the Niger Delta region. This in return has affected the general economy of the region negatively by reducing the number of persons involved in agriculture and fishing activities, it has also impacted negatively on the health of the people due to the improper refining methods employed. Total shutdown of all illegal refineries and appropriate improvement in the production and exploration process of crude oil and its products may mitigate its effects on the environment.

To bring a stop to the seemingly unstoppable situation which has constantly harmed the biodiversity of the region the study recommends the following: stakeholders (oil companies, government, and host communities) in oil exploration and exploitation should work together in mapping out measures to deal with possible oil pollution and biodiversity loss. More so, Oil exploration and production companies should sign agreements with the host communities and provide guarantors up-front to cover the cost of clean-ups and possible relocation of host communities in the event of oil pollution. Environmental Impact Assessment should be taken seriously and activities of oil companies should be properly scrutinized to ensure that they carry out due diligence and abide by best practices to prevent possible oil pollution and subsequent mishap to the environment. Furthermore, areas identified as having endangered species should be completely closed for oil production activity. Environmental education and youth empowerment through vocational training should be carried out and cleaning, afforestation, and reforestation of degraded sites.

REFERENCES

Adekola, O. and Mitchell, G. (2011). The Niger Delta wetlands: threats to ecosystem services, their importance to dependent communities and possible management measures, *International Journal of Biodiversity Science, Ecosystem Services and Management,* Vol. 7, No. 1, March 2011, 50–68

Akinjide-Balogun, O. (2001). Nigeria: Legal Framework of the Nigerian Petroleum Industry, http://www.mondaq.com/x/10726/legal+framework+of+the+nigerian+petroleum+ind user. Accessed 28/02/2022

Albert, O. N., Amaratunga, D., and Haigh, R. P. (2018). Evaluation of the impacts of oil spill disaster on communities and its influence on restiveness in Niger Delta, Nigeria. *Proc. Eng., 212,* 1054-1061. https://doi.org/10.1016/j.proeng.2018.01.136

Anejionu, O. C. D., Ahiarammunnah, P. A. N., and Nri-ezedi, C. J. (2015).

Hydrocarbon pollution in the Niger Delta: geographies of impacts and appraisal of lapses in the extant legal framework. *Resour. Pol., 45*, 65-77. https://doi.org/10.1016/j.resourpol.2015.03.012

Anifowose, B. (2008). Assessing the Impact of Oil and Gas Transport on Nigeria's Environment, U21 Postgraduate Research Conference Proceedings 1. The Uni. of Birmingham UK.

Anifowose, B., Lawler, D., Van der Horst, D., and Chapman, L. (2014). Evaluating interdiction of oil pipelines at river crossings using Environmental Impact Assessments: evaluating interdiction of oil pipelines at river crossings. *Area*, *46*, 4-17. https://doi.org/10.1111/area.12065

Asimiea, A. O. (2011). The effect of Climate Change on the Nigerian Coastline: A case study of the Niger Delta. *International Journal of Advanced Biotechnology and Research*. Vol. 2 Issue 2, pp 291-295. *www.bipublication.com*

Asimiea, A., and Omokhua, G. (2013). Environmental impact of illegal refineries on the vegetation of the Niger Delta, Nigeria. *J. Agric. Soc. Res.*, *13*(2), 121-126.

Avwiri, G. O. and Ononugbo, C. (2011). Assessment of the Naturally Occurring Radioactive Material (Norm) Content of Hydrocarbon Exploration and Production Activities in Ogba/Egbema/Ndoni Oil/Gas Field, Rivers State, Nigeria (c) African Society for Scientific Research Co-Published by Human Resource Management Academic Research Society 572.

Barenboim, G. M., Borisov, V. M., Golosov, V. N., and Saveca, A. Y. (2015). New problems and opportunities of oil spill monitoring systems. *Proc. Int. Assoc. Hydrol. Sci., 366*, 64-74. https://doi.org/10.5194/piahs-366-64-2015

Bebeteidoh , O. L., Kometa, S, Pazouki, K, and Norman, R. (2020). Sustained impact of the activities of local crude oil refiners on their host communities in Nigeria, *Heliyon 6* (2020) e04000 9 www.cell.com/heliyon

Bello, A. T., and Amadi, J. (2019). Oil Pollution and BiodiversityConservation in Nigeria: An Assessment of Legal Framework. Journal of Geoscience and Environment Protection, 7, 354-371.https://doi.org/10.4236/gep.2019.78024

Channels, T.V., (2022). Illegal Refineries Discovered In Rivers. Available online: https://www.channelstv.com/2022/01/23/112-illegal-refineries-discovered-in-rivers/ Accessed 20/3/22

Davies, I. C., and Ekperusi, A. O. (2021). Evaluation of Heavy Metal Concentrations in Water, Sediment, and Fishes of New Calabar River in Southern Nigeria. *Journal of Limnology and Freshwater Fisheries Research,* (2021); 7(3): 207-218. https://doi: 10.17216/LimnoFish.816030

Decker, J. C. (1981). Potential health hazards of toxic residues in sludge. In sludge-health risk of land application. *Ann. Arbon. Sci. Publ. Inc*, 85-102.

Decker, J. C. (1997). Potential health hazards of toxic residues in sludge. In sludge-health risk of land application. Ann. Arbon. Sci. Publ. Inc. 1997;85-102.

Directorate of Petroleum Resources (DPR) (2018). Illegal Artisanal Refining www.dpr.gov.ng/Illegal -artisanal Refining. accessed 22/2/2020

Dominic, A. A. (2016). Impact of the illegal oil business and Nigeria economy: the experience of crude oil theft, bunkering, and pipeline vandalism in the 21st century. *Int. J. Adv. Acad. Res.Arts Human. Educ., 2*(8).

Douglas, S. I. (2018). Effect of Illegally Refined Crude oil ("*kpo- fire*") Residue on Soil Fungi. *Int.J.Curr.Microbiol.App.Sci.* 7(12): 3309-3316. DOI: https://doi.org/10.20546/ijcmas.2018.712.382

Dublin-Green, C. O., Awosika, L. F. and Folorunsho, R. (1999). Climate Variability Research Activities in Nigeria, a report published by the Nigerian Institute for Oceanography and Marine Research, Victoria Island, Lagos, Nigeria.

Duke, N. C., (2016). Oil spill impacts on mangroves: recommendations for operational planning and action based on a global review. Mar. Pollut. Bull. 109, 700e715.

Efenakpo, O. D., Ijeomah, H. M., and Ayodele, A. I., (2018). Threat and Conservation of Wildlife Resources in Niger Delta Region of Nigeria, In Ogunjinmi, A. A, Oyeleke, O. O., Adeyemo, A. I., Ejidike, B. N., Orimaye, J.O., Ojo, V. A., Adetola, B. O. and Arowosafe, F.C. (eds.) Wildlife Management in Nigeria; the Roadmap for Biodiversity Conservation. Proceedings of the 2nd Wildlife Society of Nigeria (WISON) Conference held in Ondo, 16 – 19 September 2018. Pp.259 – 267

Gross, E, Jayasinghe, N., Brooks, A., Polet, G., Wadhwa, R. and Hilderink-Koopmans, F. (2021). A Future for All: The Need for Human-Wildlife Coexistence. (WWF, Gland, Switzerland).

Hammadina, M. K. and Anyanwu, D. I. (2012). A Cursory Review of the Consequences of Human Activities and Land-use Changes in the Niger delta. *Research Journal of Environmental and Earth Sciences* 4(5): 597-604, 2012, Maxwell Scientific Organization, 2012

Ikezam, P., Elenwo, E. I., and Oyegun, C. U. (2021). Effects of Artisanal Refinery on the Environment, Public Health and Socio-Economic Development of Communities in the Niger Delta Region. *Environmental Management and Sustainable Development*, 10 (3), 97-111.

IUCN Niger Delta Panel, (2018). Developing a biodiversity conservation strategy for the Niger Delta: Integrating biodiversity considerations into SPDC's operation. Gland, Switzerland: IUCN, 2018. viii+36pp

IUCN/UNEP/WWF (1980). World Conservation Strategy: Living Source Conservation for Sustainable Development (Para. 1.4). https://doi.org/10.2305/IUCN.CH.1980.9.en

Lang, J. M. and Benbow, M. E. (2013). Species Interactions and Competition. *Nature Education Knowledge* 4(4):8

Limson, J. (2002). Environmental Remediation in Nigerian oil Regions. scienceinafrica.co.za. Archived from the original on 22 August 2002. Retrieved 26 June 2020.

Martens, D. A., and Frankenberger Jr, W. T. (1995). Enhanced degradation of polycyclic aromatic hydrocarbons in soil treated with an advanced oxidative process—Fenton's reagent. *Soil and Sediment Contamination*, *4*(2), 175-190.

National Oil Spills Detection and Response Agency (NOSDRA) (2021). National Oil Spills Monitor, https://oilspillmonitor.ng/, accessed 28/5/2021

Ndidi, N., Bekinbo, D., and Gbenenee, T. J. (2020).Impact of Illegal Crude Oil Refining in Jike-ama River of Bille Kingdom, Rivers State, Nigeria, *International Journal of Biochemistry Research and Review* 29(6): 46-51

Nigerian NRC (NNRC) (2014). The Environment, Social and Economic Impact of Illegal Oil Refining in the Niger Delta. Http://nigerian nrc.org/blog/anonymous/envir-soc-andec.impactof-illegal-oil-refining-niger-delta

Nwankwoala, H. O., Harry, M. T., Amangabara, G. T. and Warmate, T. (2017). Impacts of Artisanal Refining Activities on Soil and Water Quality in Parts of Okrika and Ogu-Bolo Areas of Rivers State, Nigeria. Journal of scientific achievements volume 2, issue 9, September 2017, page: 13-19 ISSN: 2207-4236 page | 13

Odubo, T. R. and Onyige, C. D. (2019). Environmental degradation and livelihood vulnerabilities in the Niger Delta: Examining the role of artisanal crude oil refining. International Journal of Innovative Social Sciences and Humanities

Research 7(4): 45 -52, Oct. – Dec. 2019. ISSN: 2354-2926

Ogbuagu, D. H., Okoli, C. G., Gilbert, C. L., and Madu, S. (2011). Determination of the contamination of groundwater sources in Okrika Mainland with Polynuclear Aromatic Hydrocarbons (PAHs). *British Journal of Environment and Climate Change*, *1*(3), 90-103.

Okiwelu, S. N., and Anyawu, D. I. (2003). Dictionary of Ecology, Conservation and Environmental Sciences (p. 16). Lagos: Niyi Faniran Publishers.

Onakpohor, A., Fakinle, B. S., Sonibare, J. A., Oke, M. A., and Akeredolu, F. A. (2020). Investigation of air emissions from artisanal petroleum refineries in the Niger-Delta Nigeria. Heliyon. 2020 Nov; 6(11): e05608. DOI: 10.1016/j.heliyon.2020.e05608

Onuh, P. A., Omenma, T. J., Onyishi, C. J., Udeogu, C. U., Nkalu, N. C., and Iwuoha, V. O. (2021). Artisanal refining of crude oil in the Niger Delta: A challenge to clean-up and remediation in Ogoni land Local Economy 2021 36:6, 468-486

Onuoha, F. C., (2008). Oil pipeline sabotage in Nigeria: dimensions, actors and implications for national security L/C. Afr. Secur. Rev. Inst. Secur. Stud. 17 (3).

Onyena, A. P., and Sam, K. (2020) A review of the threat of oil exploitation to mangrove ecosystem: Insights from Niger Delta, Nigeria, Global Ecology and Conservation 22 (2020) http://www.elsevier.com/locate/gecco

Oredein, O. (2013) Shell Sees Rise in Crude Theft in Nigeria. Dow Jones News wire. *www.businessfox.com/news/2020/3/4*

Oyadongha, S. (2021). Kpo-fire: Anxiety as strange soot envelops Yenagoa, https://www.vanguardngr.com/2021/12/kpo-fire-anxiety-as-strange-black-soot-envelops-yenagoa/ Accessed 18/03/2022

Phil-Eze, P. O. and Okoro, I. C. (2009). Sustainable biodiversity conservation in the Niger Delta: a practical approach to conservation site selection, Biodivers Conserv 18:1247–1257

Romsom, E. (2022). Global oil theft: impact and policy responses. WIDER Working Paper. UNU-WIDER. United Nations University World Institute for Development Economics Research 47pp /16 https://doi.org/10.35188/UNU-WIDER/2022/147-1

Simbi-Wellington, S. W. and Ideriah, T. J. K. (2020). Assessment of Air Quality in Mangrove Forest around Gas Flare in Awoba Flow Station in Rivers State Nigeria. IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS). DOI:10.9790/2380-1302013847 e-ISSN: 2319-2380

SPDC (2004). Shell Petroleum Development Corporation, 2004 Annual report.

Stakeholder Democracy Network (SDN) (2015). 'Communities not Criminals – Illegal Oil Refining in the Niger Delta'. . London, United Kingdom. 46pp Available at: https://www.stakeholderdemocracy.org/sdn-report-communities-not-criminals-illegal-oil-refining-in-the-niger-delta/ (accessed January 2022).

Taylor, A. (2013). Nigeria's Illegal Oil Refineries. Available online at https://www.theatlantic.com/photo/2013/01/nigerias-illegal-oil-refineries/100439/ accessed 20/2/2022

Ubom, R. M. (2010). Ethnobotany and Biodiversity Conservation in the Niger Delta, Nigeria. *International Journal of Botany*. (6):310–322.

Ufuoma, V. (2022). NNPC calls for special court to prosecute oil theft, laments loss of $1.5bn to vandals. International Centre for Investigative Reporting (ICIR), 8/04/2022. Available at icir.org/ nnpc-calls-for-special-court-to-prosecute-oil-theft-laments-loss-of-$1.5bn-to-vandals/

Umechuruba, C. I. (2005) Health impact assessment of mangrove vegetation in an oil spilled site at the Bodo West Field in Rivers State, Nigeria.

Journal of Applied Sciences and Environmental Management (ISSN: 1119-8362) Vol 9 Num 1

Vidal, J. (2010). "Nigeria's agony dwarfs the Gulf oil spill. The US and Europe ignore it." The Observer. Retrieved 27 July 2010. Government's national oil spill detection and response agency (Nosdra) says that between 1976 and 1996 alone, more than 2.4m barrels spilled in the delta.

Wikipedia (2022). Environmental issues in the Niger Delta. https://en.wikipedia.org/wiki/Environmental_issues_in_the_Niger_Delta. 18/03/2022

World Bank (1995). Defining an Environmental Strategy for the Niger Delta. World Bank, Washington DC. Industry and Energy Operations Division, West/Central Africa Division.

Yebrade, M, Tanee, F. B. G. (2016). Assessing the impact of Artisanal Refining on Vegetation and Soil Quality: A case study of Warri Southwest Salt Wetland of Delta State, Nigeria. *Res. J. Environ. Toxic*. 10(4): 205-212

IMPACT OF HABITAT DEGRADATION ON SPECIES POPULATIONS IN THE TROPICS (REVIEW)

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ABSTRACT

Habitat includes all living and non-living factors or conditions of the surrounding environment.Wildlife populations are being exploited faster than ever before, negatively impacting sustainable human livelihood. Human activities have been the driving force to the decline and extinction of wildlife species. Hence, this paper focuses on the different types of habitat alteration, their impacts on wildlife, and ways to mitigate them. When resources in a habitat get depleted or disturbed by natural or man-made factors, it is termed habitat degradation, which poses severe threats to the wildlife and may lead to its extinction. The significant factors responsible for habitat degradation are habitat loss, soil erosion, deforestation, desertification, climate change, flooding, resource depletion, invasive species, and habitat fragmentation. An estimated 177,000 square kilometers of forests and woodlands are cleared annually to make space for farming or to harvest timber for fuel and wood products. Estimates suggest the earth has lost about half of its forests in 8000 years of human activity, with much of this occurring in recent decades. Habitat loss has affected animals' breeding, foraging, dispersal behaviours, and predation rate. Research has shown that about 2,000 mammals around the globe are affected by habitat loss. It is the primary threat to 85% of species. Thus, a great need for conservation and management practices to protect these vulnerable wildlife species and their habitats is needed. One key measure is establishing protected areas where human activity is restricted to conserve existing ecosystems and wildlife. Well-planned and well-managed reserves, parks, and forests can help safeguard freshwater and food supplies, reduce poverty, and reduce the impacts of natural disasters. Hunting laws, afforestation, and reforestation programmes should be implemented. Initiation of education and awareness programmes to the populace, stressing the direct and indirect values of wildlife and the scientific basis of traditional conservation, are also essential to be emphasised.

Keywords: *Conservation, Habitat Degradation, Wildlife, Population, Law promulgation*

INTRODUCTION

Wildlife refers to undomesticated plant and animal species and can be found in all ecosystems; deserts, rainforests, plains, grasslands, montane and other areas, including the most developed urban areas, all have distinct forms of wildlife (Harris and Brown, 2009). Wildlife plays a vital role in balancing the environment, provides stability to different processes of nature, provides food, clothing, and source of income to man. Our life is almost impossible without the support of wildlife (Shreshtha, 2019). Wildlife species are under threat from many human activities, inclusive directly destroying habitat, and spreading of invasive species and diseases. Most ecosystems are facing multiple threats. Each new threat puts additional stress on weakened ecosystems and wildlife (National Wildlife Federation, 2021). Every living creature needs room to exist and reproduce. Habitat is the natural home of plants, animals, and other organisms, and maintaining this space is crucial to the ongoing survival of both individuals and species (World Wildlife Fund, 2017). Habitats are important for predicting where wildlife can be found and for developing strategies for their conservation and management.

Wildlife is being exploited faster than ever before, with negative implications for sustainable human livelihood (Turner *et al*., 1990). Unfortunately, the habitats of large numbers of the earth's plant and animal species are under threat due to the impact of human beings on the planet. Habitat loss contributes to the permanent loss of species, which weakens the ecosystems. It impacts both the overall health of the earth and the quality of human life (World Wildlife Fund, 2017). Global wildlife populations have decreased by 68% since 1970 as a result of human activity, particularly overconsumption, population growth, and intensive farming, according to a 2020 World Wildlife Fund's *Living Planet Report* and the Zoological Society of London's Living Planet Index measure, which is further evidenced that humans have unleashed a sixth mass extinction event (Greenfield, 2020; Woodyatt, 2020). According to Convention on International Trade in Endangered Species (CITES), it has been estimated that the international wildlife trade annually amounts to billions of dollars and affects hundreds of millions of animal and plant specimens (CITES, 2020).

Hanski (2011) reported that human activities are causing a steep decline in biodiversity worldwide. At the same time, altered habitat availability, degradation, loss, and fragmentation present the most immediate threat to species.Humans are now responsible for causing environmental changes that hurt animals and plant species (Nature Works, 2021). According to WWF (2018), there has been an estimated 50 to 60% average decline in wildlife populations due to human activities over the past four decades. However, there is a shortage of information on the impact of habitat degradation on the wildlife population in the Tropics. We need to fill these gaps and proffer solutions to mitigate threats. Therefore, this review aims to assess the impacts of habitat degradation on wildlife population and recommend conservation strategies for wildlife and its habitat.

BENEFITS OF WILDLIFE IN THE TROPICS

Wildlife plays an essential role in balancing the environment. Wildlife provides stability to different natural processes of nature. The importance of wildlife can be categorized as ecological, economical, investigatory, conservation of biological diversities, etc., hencewildlife values can be grouped into:

- Economic values
- Socio-cultural values
- Ecological values
- Aesthetic values
- Education values

Economic values: Some wildlife and wildlife products do enter the marketplace. These include the pelts of fur-bearing mammals, the skins and meat of commercially raised game birds, commercially harvested alligators, and several kinds of fishes, crayfish, and frogs collected by commercial fishing. Since these items are marketable, assigning some dollar value to them is relatively easy. However, it is noted that the money earned each year by harvesting part of a wildlife population is not the actual value of the resource. Additionally, because wildlife resources are renewable, they produce income yearly. Thus, it is necessary to calculate the capital worth of each resource based on its ability to yield income (Telford, 2016).

Estimating the economic value of these wildlife uses is piecing a jigsaw together. Some pieces are missing or roughly hewn, but there is sufficient evidence to indicate that the economic benefits of wildlife on commercial land have increased in the last twenty years; that economic and local benefits on communal land have the potential to multiply; and that the protected areas, by anchoring the tourism industry, are maintaining one of the most critical sectors of the economy.

Wildlife also contributes economically to the wellbeing of a nation through the following:

- Sales of some wildlife products like timber, paper, gum, honey, leather, tusks, and ivory.
- Sales of the harvested herbal medicine.
- Employment opportunities to the locals, hence an improvement of economic status.
- The tourism industry generates a considerable amount of revenue for the government.
- Barter trade enhances economic development.

Socio-cultural values: As residents get more involved in tourism, social benefits like increased skills and institutional development are also derived. Apart from controlling money, social benefits, such as developing skills and institutions, may be gained from tourism enterprises in other ways. However, social costs also need to be taken into account. For religious purposes, many wildlife species have spiritual significance in different cultures worldwide, and they and their products may be used as sacred objects in religious rituals (Quiroz and Tinde, 2018). For example, eagles, hawks, and their feathers have great cultural and spiritual value to Native Americans as religious objects. For food, clothing, or shelter, anthropologists believe that the Stone Age peoples and hunter-gatherers relied on wildlife, both plant and animal, for their food. An example is a bushmeat. Also, wildlife has a significant impact in providing shrines to various communities like the Kikuyu community in Kenya. Some of the wildlife species, like the wildebeests, have been used to mark the beginning of particular seasons in the calendar due to their migratory nature. Some of the Kenyan communities have involved the use of wildlife in their rites of passage. An example is the Maasai community, which beliefs in killing the lions to mark adulthood (Enoch *et al.*, 2019).

Ecological Functions: It has long been recognised that the ecological roles of vertebrate species influence ecosystems. Only recently, however, has this been integrated into theory and practice. Examples of some ecological functions of vertebrate species include how:

- Browsing or grazing by ungulates can change plant communities.
- Animals can act as environmental engineers and influence geomorphology and ecosystem processes.
- Frugivores can support viable fruit-bearing plants.
- Pollinators can support plant diversity.
- Seed dispersers and frugivores can influence forest succession and regeneration.
- Carrion feeding can support the trophic structure of a community.
- Carnivore predation can affect populations of ungulate prey species.
- Rodents can serve to disseminate beneficial mycorrhizal fungi in the forests.
- Reptilian primary burrow excavators can provide avian secondary burrow users (Duncan and Chapman, 1999).

Tropical forests also owe their existence to animals because most trees rely on animals to distribute their pollen and seeds. Soil is partly the result of animal activity because earthworms and other invertebrates help break down dead remains and recycle the nutrients they contain. Without its animal life, the soil would soon become compacted and infertile. By preying on each other, animals also help keep their numbers in check. This prevents abrupt population peaks and crashes and helps to give living systems built-in stability. Animals also influence some nutrient cycles on which almost all life depends. For example, they distribute essential mineral elements in their waste and help replenish the atmosphere's carbon dioxide when they exhale. Plants then use this carbon dioxidein the process of photosynthesis. As a result, trees as wildlife have played a vital role in carbon sinking. This has, in turn, helped reduce the amount of carbon dioxide in the atmosphere, hence amelioration of global warming.

Aesthetic values: By their unique way of existence, wild creatures exaggerate the earth's natural beauty. This also promotes tourism as part of the country's economic pillars. For instance, tourism has boosted their GDP in Kenya, Tanzania, South Africa, etc.

Education values: By studying wildlife, scientists have gained valuable knowledge about various life processes and discovered essential medical products (Telford, 2016).

Another vital contribution of wildlife for human progress is the availability of a large gene pool for scientists to carry out breeding programmes in agriculture, animal husbandry and fishery.

WILDLIFE POPULATION: A population is a group of individuals of the same species which occupy the same geographical area, rely on the same resources, are influenced by the same environmental factors, and have a high likelihood of interacting and breeding with one another. Wildlife populations are rarely static but constantly dynamic. Animal and plant populations depend on many things for survival. In the natural world, limiting factors like the availability of food, water, shelter, and space can change animal and plant populations. Other limiting factors, like competition for resources, predation, and disease, also impact populations. If any limiting factors change, animal and plant populations also change. Some changes may cause a population to increase. If there are more plants than usual in an area, populations of animals that eat that plant may increase. If one animal's population grows, the population of animals that eat that animal might also increase (Prey-Predator Relationship). Prey-predator relationship plays a significant role in animal populations. If the balance between predator and prey is changed, populations are changed. In nature, populations usually balance themselves. Sometimes when man impacts populations, they cannot always re-establish a natural balance (Wildlife Journal Junior, 2021).

POPULATION DENSITY: Population density is the average number of individuals in a population per unit area. For example, a population of 100 *Gorilla gorilla diehli* that live in an area of 100km^2 has a density of 1 *Gorilla gorilla diehli* per square meter. Population density is often used as a simple relative measure of how an organism responds to local conditions. For example, suppose conditions are not suitable for the species. In that case, the density will be low (organisms will have died or emmigrated from the sampled area), whereas if conditions are suitable, the density will be high (organisms will have reproduced and/or immigrated into the area) (Brian, 2013).

Table 1: Population Density of some key Important Wildlife Species in Nigeria

SPECIES' COMMON NAME	SCIENTIFIC NAME	POPULATION DENSITY (km^2)	PROTECTED AREA (PA) FOUND	SITE OF PA	PERIOD	CITATIONS
Mona Monkey	*Cercopithecus mona*	4	Afi Mountain Wildlife Sanctuary	Afi Mountain Wildlife Sanctuary	Wet season	Oshita *et al.* (2016)
Red-capped Mangabey	*Cercocebus torquatus*	0.07	Omo Biosphere Reserve	Omo Biosphere Reserve	Wet/Dry Season	Orimaje *et al.* (2017)
	C. torquatus	0.05	Idanre Forest Reserve	Idanre Forest Reserve	Wet/Dry Season	Orimaje *et al.*(2017)
Tree Pangolin	*Manis tricuspis*	3.78	Cross River National Park	Oban Division	Wet season	Oruk *et al.*(2019)
Mona Monkey	*Cercopithecus mona*	58.44	Cross River National Park	Oban Division	Wet season	Oruk *et al.*(2019)
Gorilla	*Gorilla gorilla diehli*	0.4	Afi Mountain Wildlife Sanctuary			Edet *et al.*(2014)
Chimpanzee	*Pan troglodyte*	1.3	Gashaka Gumti National Park	Kwano		Sommer(2004)
	Pan troglodyte	0.118±0.021	Gashaka-Gumti National Park	Filinga Range	Wet season	Tyowua *et al.*(2020)
	Pan troglodyte	0.122±0.027	Gashaka-Gumti National Park	Filinga Range	Dry season	Tyowua *et al.*(2020)
Sclater guenon	*Cercopithecus sclateri*	24.2	Lagwa Sacred Forest	Lagwa		Baker *et al.*(2014)
	C. sclateri	36	Akpugoeze Sacred Forest	Akpugoeze		Baker *et al.*(2014)
Forest Elephant	*Loxodonta cyclotis*	0.15	Okomu National Park	Okomu National Park	Wet Season	Amusa *et al.*(2017)
	L. cyclotis	0.08	Okomu National Park	Okomu National Park	Dry season	Amusa *et al.*(2017)
	L. cyclotis	0.14	Omo Biosphere Reserve	Elephant Sanctuary, farmland, and settlement camp.	Wet Season	Amusa *et al.*(2017)

L. cyclotis	0.06	Omo Biosphere Reserve	Elephant Sanctuary, farmland, and settlement camp.	Dry season	Amusa *et al.*(2017)

TABLE 2: SOME FAUNA SPECIES AND THEIR CONSERVATION STATUS BASED ON IUCN RED LIST OF THREATENED SPECIES

SPECIES' COMMON NAME	ORDER	FAMILY	SUBFAMILY	SCIENTIFIC NAME	CONSERVATION STATUS
Aardvark	Tubulidentata	Orycteropodidae		*Orycteropus afer*	Least concern (LC)
Western Tree Hyrax	Hyracoidea	Procaviidae		*Dendrohyrax dorsalis*	LC
Rock Hyrax	Hyracoidea	Procaviidae		*Procavia capensis*	LC
Forest Elephant	Proboscidea	Elephantidae		*Loxodonta cyclotis*	Critically Endangered (CR)
Bush/Savanna Elephant	Proboscidea	Elephantidae		*Loxodonta africana*	Endangered (EN)
African Manatee	Sirenia	Trichechidae		*Trichechus senegalensis*	Vulnerable
Calabar Angwantibo	Primates	Lorisidae	Lorisoidea	*Arctocebus calabarensis*	Near Threatened (NT)
West African Potto	Primates	Lorisidae		*Perodicticus (potto) potto*	LC
Milne – Edward's Potto	Primates	Lorisidae		*Perodictus (potto) edwardsi*	LC
Bioko Allens Bush baby	Primates	Galagidae		*Sciurocheirus alleni*	NT
Prince Demidoff's Bush Baby	Primates	Galagidae		*Galagoides demidovii*	LC
Thomas' Bush Baby	Primates	Galagidae		*Galagoides thomasi*	LC
Senegal Bush Baby	Primates	Galagidae		*Galago senegalensis*	LC
Northern Needle Clawed Bush Baby	Primates	Galagidae		*Euoticus pallidus*	NT
Patas Monkey	Primates	Cercopithecidae		*Erythrocebus patas*	NT
Tantalus Monkey	Primates	Cercopithecidae		*Chlorocebus tantalus*	LC
White-throated Quenon	Primates	Cercopithecidae		*Cercopithecus erythrogaster*	EN
Red Eared Quenon	Primates	Cercopithecidae		*Cercopithecus erythrotis*	VU
Greater Spot Nose Monkey	Primates	Cercopithecidae		*Cercopithecus nictitans*	NT
Crowned Quenon	Primates	Cercopithecidae		*Cercopithecus pogonias*	LC

Preuss' Monkey	Primates	Cercopithecidae		*Cercopithecus preussi*	EN
Sclater's Quenon	Primates	Cercopithecidae		*Cercopithecus sclateri*	EN
Mona Monkey	Primates	Cercopithecidae		*Cercopithecus mona*	NT
Grey-cheeked Mangabey	Primates	Cercopithecidae		*Lophocebus albigena*	VU
Olive Baboon	Primates	Cercopithecidae		*Papio Anubis*	LC
Collared/Red Capped Mangabey	Primates	Cercopithecidae		*Cercocebus torquatus*	EN
Drill	Primates	Cercopithecidae		*Mandrillus leucophaeus*	EN
Mantled Guereza	Primates	Cercopithecidae	Colobinae	*Colobus guereza*	LC
Ursine Colobus	Primates	Cercopithecidae	Colobinae	*Colobus vellerosus*	CR
Olive Colobus	Primates	Cercopithecidae	Colobinae	*Procolobus verus*	VU
Niger Delta red colobus	Primates	Cercopithecidae	Colobinae	*Piliocolobus epieni*	CR
Peruss' red colobus	Primates	Cercopithecidae	Colobinae	*Piliocolobus preussi*	CR
Cross River Gorilla	Primates	Hominidae	Homininae	*Gorilla gorilla*	CR
Chimpanzee	Primates	Hominidae	Homininae	*Pan troglodytes*	EN
Nigerian mole-rat	Rodentia	Bathyergidae		*Cryptomys foxi*	Data Deficient (DD)
Crested porcupine	Rodentia	Hystricidae		*Hystrix cristata*	LC
Grasscutter/cane rat	Rodentia	Thryonomyidae		*Thryonomys swinderianus*	LC
Lord Derby's scaly-tailed squirrel	Rodentia	Anomaluridae	Anomalurinae	*Anomalurus derbianus*	LC
Beecrofti's scaly-tailed squirrel	Rodentia	Anomaluridae	Anomalurinae	*Anomalurops beecrofti*	LC
Stripped ground squirrel	Rodentia	Sciuridae	Xerinae	*Xerus erythropus*	LC
Thomas' rope squirrel	Rodentia	Sciuridae	Xerinae	*Funisciurus anerythrus*	DD
Red-cheeked squirrel	Rodentia	Sciuridae	Xerinae	*Funisciurus leucogenys*	DD
Fire-footed rope squirrel	Rodentia	Sciuridae	Xerinae	*Funisciurus pyrropus*	LC
Gambian Pouched rat	Rodentia	Cricetomyinae		*Cricetomys gambianus*	LC
African Savannah Hare	Lagomorpha	Leporidae		*Lepus victoriae*	LC
Four-toed hedgehog	Erinaceomorpha	Erinaceidae	Erinaceinae	*Atelerix albiventris*	LC
Straw-coloured fruit bat	Chiroptera	Pteropodidae	Pteropodinae	*Eidolon helvum*	LC

Zenker' fruit bat	Chiroptera	Pteropodidae	Pteropodinae	*Scotonycteris zenkeri*	NT
Morris' bat	Chiroptera	Pteropodidae	Myotinae	*Myotis morrisi*	VU
Beatrix' bat	Chiroptera	Pteropodidae	Vespertilioninae	*Glauconycteris arata*	NT
Long-tailed pangolin	Pholidota	Manidae		*Phataginus tetradactyla*	VU
Tree pangolin	Pholidota	Manidae		*Phataginus tricuspis*	EN
Giant pangolin	Pholidota	Manidae		*Smutsia gigantean*	EN
Blue whale	Cetacea	Balaenopteridae	Balaenopterinae	*Balaenoptera musculus*	EN
Fin whale	Cetacea	Balaenopteridae	Balaenopterinae	*Balaenoptera physalus*	EN
Sei whale	Cetacea	Balaenopteridae	Balaenopterinae	*Balaenoptera borealis*	EN
African golden cat	Carnivora	Felidae	Felinae	*Caracal aurata*	EN
Lion	Carnivora	Felidae	Pantherinae	*Panthera leo*	VU
Leopard	Carnivora	Felidae	Pantherinae	*Panthera pardus*	VU
African civet	Carnivora	Viverridae	Viverrinae	*Civettictis civetta*	LC
Crested servaline genet	Carnivora	Viverridae	Viverrinae	*Genetta cristata*	VU
Common genet	Carnivora	Viverridae	Viverrinae	*Genetta genetta*	LC
Hausa genet	Carnivora	Viverridae	Viverrinae	*Genetta thierryi*	LC
Spotted hyena	Carnivora	Hyaenidae		*Crocuta crocuta*	LC
Striped hyena	Carnivora	Hyaenidae		*Hyaena hyaena*	NT
African wild dog	Carnivora	Canidae		*Lycaon pictus*	EN
Speckle throated otter	Carnivora	Mustelidae		*Hydrictis maculicollis*	NT
African clawless otter	Carnivora	Mustelidae		*Aonyx capensis*	NT
Congo clawless otter	Carnivora	Mustelidae		*Aonyx congicus*	NT
Common warthog	Artiodactyla	Suidae	Phacochoerinae	*Phacochoerus africanus*	
Red river hog	Artiodactyla	Suidae	Suinae	*Potamochoerus porcus*	
Pygmy Hippopotamus	Artiodactyla	Hippopotamidae		*Choeropsis liberiensis*	EN
Hippopotamus	Artiodactyla	Hippopotamidae		*Hippopotamus amphibious*	VU
Water chevrotain	Artiodactyla	Tragulidae		*Hyemoschus aquaticus*	DD
Giraffe	Artiodactyla	Giraffidae		*Giraffa arateeralis*	VU
Hartebeest	Artiodactyla	Bovidae	Alcelaphinae	*Alcelaphus buselaphus*	LC
Dorcas gazelle	Artiodactyla	Bovidae	Antilopinae	*Gazella arate*	VU

Red-fronted gazelle	Artiodactyla	Bovidae	Antilopinae	*Gazella rufifrons*	VU
Dama gazelle	Artiodactyla	Bovidae	Antilopinae	*Nanger dama*	CR
African buffalo	Artiodactyla	Bovidae	Bovinae	*Syncerus caffer*	NT
Bushbuck	Artiodactyla	Bovidae	Bovinae	*Tragelaphus scriptus*	LC
Sitatunga	Artiodactyla	Bovidae	Bovinae	*Tragelaphus spekii*	NT
Bay duiker	Artiodactyla	Bovidae	Cephalophinae	*Cephalophus dorsalis*	NT
Maxwell's duiker	Artiodactyla	Bovidae	Cephalophinae	*Cephalophus maxwellii*	NT
Blue duiker	Artiodactyla	Bovidae	Cephalophinae	*Cephalophus monticola*	LC
Black duiker	Artiodactyla	Bovidae	Cephalophinae	*Cephalophus niger*	NT
Black-fronted duiker	Artiodactyla	Bovidae	Cephalophinae	*Cephalophus nigrifrons*	NT
Ogilbyi's duiker	Artiodactyla	Bovidae	Cephalophinae	*Cephalophus ogilbyi*	NT
Red-flanked duiker	Artiodactyla	Bovidae	Cephalophinae	*Cephalophus rufilatus*	LC
Yellow-backed duiker	Artiodactyla	Bovidae	Cephalophinae	*Cephalophus silvicultor*	NT
Roan antelope	Artiodactyla	Bovidae	Hyppotraginae	*Hippotragus equinus*	LC
Waterbuck	Artiodactyla	Bovidae	Reduncinae	*Kobus ellipsiprymnus*	LC
Kob	Artiodactyla	Bovidae	Reduncinae	*Kobus kob*	LC
Bohor reedbuck	Artiodactyla	Bovidae	Reduncinae	*Redunca redunca*	LC

Source: Adapted from IUCN, 2020

TABLE 3: CHECKLIST OF ENDEMIC WILDLIFE SPECIES OF NIGERIA

SPECIES'COMMON NAME	CLASS	SCIENTIFIC NAME	ORDER	FAMILY	CONSERVATION STATUS
Savanna White-toothed Swamp Shrew	Mammalia	*Crocidura longipes*	Eulipotyphla	Soricidae	
Corbet's Forest Shrew	Mammalia	*Sylvisorex corbeti*	Eulipotyphla	Soricidae	
Sclater's Monkey	Mammalia	*Cercopithecus sclateri*	Primates	Cercopithecidae	
Niger Delta Red Colobus	Mammalia	*Piliocolobus epieni*	Primates	Cercopithecidae	
Fox's Shaggy Rat	Mammalia	*Dasymys foxi*	Rodentia	Muridae	
Gotel Mountain Soft-furred Mouse	Mammalia	*Praomys obscurus*	Rodentia	Muridae	
Ibadan Malimbe	Aves	*Malimbus ibadanensis*	Passeriformes	Ploceidae	
Anambra Waxbill		*Estrilda poliopareia*			
Rock Firefinch		*Lagonosticta sanguinodorsalis*			
Plateau Indigobird		*Vidua maryae*			
West African Worm Lizard	Reptilia	*Baikia arate*	Squamata	Amphisbaenidae	

Okoloma Worm Lizard	Reptilia	*Cynisca gansi*	Squamata	Amphisbaenidae
Kigom Hills Worm Lizard	Reptilia	*Cynisca kigomensis*	Squamata	Amphisbaenidae
	Reptilia	*Cynisca nigeriensis*	Squamata	Amphisbaenidae
Giant Forest Gecko	Reptilia	*Cnemaspis gigas*	Squamata	Gekkonidae
Ondo Forest Gecko	Reptilia	*Cnemaspis petrodroma*	Squamata	Gekkonidae
Dunger's four-fingered Skink	Reptilia	*Leptosiaphos dungeri*	Squamata	Scincidae
Dunger's File Snake	Reptilia	*Mehelya egbensis*	Squamata	Lamprophiidae
??	Reptilia	*Baikia 1 spp.*	Squamata	Amphisbaenidae
Ibadan Thread Snake	Reptilia	*Tricheilostoma greenwelli*	Squamata	Leptotyphlopidae
Perret's Toad	Amphibia	*Sclerophrys perreti*	Anura	Bufonidae
Danko Puddle Frog	Amphibia	*Phrynobatrachus dank o*	Anura	Phrynobatrachida e
??	Amphibia	*Phrynobatrachus raine rguentheri*	Anura	Phrynobatrachida e
Puzzling Acraea	Insecta	*Acraea actinotina*	Lepidoptera	Nymphalidae
Kaduna Acraea	Insecta	*Acraea kaduna*	Lepidoptera	Nymphalidae
Kagoro Demon Charaxes	Insecta	*Charaxes chevroti*	Lepidoptera	Nymphalidae
Nigerian Striped Forester	Insecta	*Euphaedra arate*	Lepidoptera	Nymphalidae
??	Insecta	*Euphaedra eshu*	Lepidoptera	Nymphalidae
??	Insecta	*Euphaedra fusca*	Lepidoptera	Nymphalidae
??	Insecta	*Euphaedra larseni*	Lepidoptera	Nymphalidae
Knoop's Ceres Forester	Insecta	*Euphaedra knoopiana*	Lepidoptera	Nymphalidae
Gashaka-Gumpti Ceres Forester	Insecta	*Euphaedra luteolucens*	Lepidoptera	Nymphalidae
Brighter Ceres Forester	Insecta	*Euphaedra nigrocilia*	Lepidoptera	Nymphalidae
Wojtusiak’s Ceres Forester	Insecta	*Euphaedra wojtusiaki*	Lepidoptera	Nymphalidae
??	Insecta	*Euphaedra yemalla*	Lepidoptera	Nymphalidae
Knoop's Euptera	Insecta	*Euptera knoopi*	Lepidoptera	Nymphalidae
Nigerian Euptera	Insecta	*Euptera nigeriensis*	Lepidoptera	Nymphalidae
Kiki's Nymph	Insecta	*Euriphene kiki*	Lepidoptera	Nymphalidae
Saint Leger's False Sergeant	Insecta	*Pseudathyma legeri*	Lepidoptera	Nymphalidae
??	Insecta	*Bebearia oshogbo*	Lepidoptera	Nymphalidae
??	Insecta	*Bebearia wojtusiaki*	Lepidoptera	Nymphalidae
??	Insecta	*Euphaedra gashaka*	Lepidoptera	Nymphalidae
??	Insecta	*Euphaedra luteola*	Lepidoptera	Nymphalidae
??	Insecta	*Euphaedra umbratilis*	Lepidoptera	Nymphalidae
??	Insecta	*Euriphura mediata*	Lepidoptera	Nymphalidae
??	Insecta	*Euriphura viridissima*	Lepidoptera	Nymphalidae
??	Actinopterygii	*Doumea reidi*	Siluriformes	Amphiliidae
Fog Bushfish	Actinopterygii	*Ctenopoma nebulosum*	Anabantiforme s	Anabantidae
Green Kribensis	Actinopterygii	*Pelvicachromis sacrimontis*	Cichliformes	Cichlidae
??	Actinopterygii	*Pelvicachromis silviae*	Cichliformes	Cichlidae
??	Actinopterygii	*Notoglanidium akiri*	Siluriformes	Claroteidae

??	Actinopterygii	*Parauchenoglanis buettikoferi*	Siluriformes	Claroteidae	
??	Actinopterygii	*Barbus clauseni*	Cypriniformes	Cyprinidae	CR
??	Actinopterygii	*Garra trewavasae*	Cypriniformes	Cyprinidae	
??	Actinopterygii	*Labeo brachypoma*	Cypriniformes	Cyprinidae	
Domino Neolebias	Actinopterygii	*Neolebias powelli*	Characiformes	Distichodontidae	
??	Actinopterygii	*Synodontis guttatus*	Siluriformes	Mochokidae	CR
Russet Synodontis	Actinopterygii	*Synodontis robbianus*	Siluriformes	Mochokidae	DD
??	Actinopterygii	*Synodontis xiphia*	Siluriformes	Mochokidae	CR
Biafra Panchax	Actinopterygii	*Epiplatys biafranus*	Cyprinodontiformes	Nothobranchiidae	
Banded Panchax	Actinopterygii	*Epiplatys longiventralis*	Cyprinodontiformes	Nothobranchiidae	
Arnold's Lyretail	Actinopterygii	*Fundulopanchax arnoldi*	Cyprinodontiformes	Nothobranchiidae	
Black Aphyosemion	Actinopterygii	*Fundulopanchax powelli*	Cyprinodontiformes	Nothobranchiidae	
Emerald Aphyosemion	Actinopterygii	*Fundulopanchax scheeli*	Cyprinodontiformes	Nothobranchiidae	CR
Port Harcourt lampeye	Actinopterygii	*Poropanchax hannerzi*	Cyprinodontiformes	Poeciliidae	
Yellowtop Jewelfish	Actinopterygii	*Meganthias carpenteri*	Perciformes	Serranidae	DD

Source: Adapted from Living National Treasures, 2020

HABITAT STRUCTURE AND REQUIREMENTS IN THE TROPICS

Wildlifehabitat is the natural environment of a plant or animal and can be considered an output or product of forest and natural resource management. Habitat summarises the array of resources abiotic and biotic factors present in an area, such as supporting the survival and reproduction of a particular species. A species' habitat can be seen as the physical manifestation of its ecological niche. Thus, "habitat" is a species-specific term, fundamentally different from concepts such as environment or vegetation assemblages.
The abiotic factors may include soil, moisture, range of temperature, and light intensity. Biotic factors will consist of food availability and the presence or absence of predators. Every organism has specific habitat needs for the conditions in which it will thrive, but some are tolerant of wide variations while others are particular in their requirements. A species habitat is not necessarily a geographical area; it can be the interior of a stem, a rotten log, a rock, or a clump of moss; a parasitic organism has as its habitat the body of its host, part of the host's body (such as the digestive tract), or a single cell within the host's body.

TYPES OF HABITAT: There are different types of habitat;

Geographic habitat types include polar, temperate, subtropicaland tropical regions.

The terrestrial vegetation type may be forest, steppe, grassland, semi-arid,or desert.

The freshwater habitats include marshes, streams, rivers, lakes, and ponds.

Marine habitats include salt marshes, the coast, the intertidal zone, estuaries, reefs, bays, the open sea, the sea bed, deep water, and submarine vents.

Terrestrial habitattypes include forests, grasslands, wetlands, and deserts. Within these broad biomes are more specific habitats with varying climate, temperature regimes, soils, altitudes, and vegetation types. Many of these habitats grade into each other, and each one has its distinct communities of plants and animals. A habitattype may suit a particular species well. Still, its presence or absence at any precise location depends on chance, dispersal abilities, and its efficiency as a colonizer (Breed, 2011).

Aquatic Habitat: This is divided into:

Freshwater habitats include rivers, streams, lakes, ponds, marshes, and bogs. Although some organisms are found across most of these habitats, most have more specific requirements. For example, water velocity, temperature, and oxygen saturation are important factors. Still, there are fast and slow sectionsin the river systems, pools, bayous, and backwaters that provide a range of habitats. Similarly, aquatic plants can be floating, semi-submerged, submerged, or grow in permanently or temporarily saturated soils besides bodies of water. Marginal plants provide critical habitat for both invertebrates and vertebrates, and submerged plants provide oxygenation of the water, absorb nutrients, and reduce pollution (Cook *et al.,* 1974).

Marine habitats include estuaries, bays, the open sea, the intertidal zone, the sea bed, reefs, and deep/shallow water zones. Further variations include rock pools, sandbanks, mudflats, brackish lagoons, sandy and pebbly beaches, and seagrass beds supporting flora and fauna. The benthic zone or seabed provides a home for static organisms anchored to the substrate and an extensive range of organisms crawling on or burrowing into the surface. Some creatures float among the waves on the water's surface or raft on floating debris, others swim at a range of depths, including organisms in the demersal zone close to the seabed, and myriads of organisms drift with the currents and form the plankton.

Brackish water**:** This water contains more sea salts than freshwater but less than the open sea. Brackish water condition commonly occurs when freshwater meets seawater.

HABITAT REQUIREMENTS

Wildlife species have life requirements that their habitat for survival must meet. Components of habitat are food, water, cover, and space**.**

Food: All living organisms require food for nutrients to live, grow and reproduce. A key component of food is energy. The series of transfers of food energy from one organism to another is a biotic pyramid. The internal process by which an organism receives energy from food is metabolism.

Water: This is the basic need of life. Water's chemical structure is H_2O. Water determines what species of plants will grow in terrestrial habitats, and the plants impact which animals live in the habitat. There can be damaging pollutants (e.g., siltation, sewage, and other pollutants). Furthermore, some wild animal species receive most of their water through the food they consume, but many need a watering area for drinking once or twice a day.

Cover: This is needed for most wildlife species and is sometimes called"shelter".The cover is the vegetation or other material that provides safety in a habitat. Animals use cover for nesting, resting, protecting the pack, herd, etc., from predators and adverse weather.

Space: This provides air, food, and cover for wildlife species. It is the area around an organism. Space requirements vary with season, animal and habitat quality. The space an animal usually uses for living inthe home range; is where the animal obtains food, water, and cover. However, an animal may establish a territory within a home range, that is, an area smaller than the home range. For example, squirrels may only travel a few feet around their den in a tree to acquire food.

THREATS AND IMPACT TO WILDLIFE SPECIES IN THE TROPICS

When resources in a habitat are depleted or disturbed by natural or man-made factors, habitat degradation poses serious threats to the wildlife, leading to its extinction. The significant factors responsible for environmental degradation are habitat loss, soil erosion, deforestation, desertification, climate shift, flooding, resource depletion, invasive species, and habitat fragmentation. All these factors are responsible for upsetting the environment, and the resulting environment is unfit for the survival of animals, so significant wildlife is lost. Human population growth is the primary driving force for the degradation of habitat (Masanja, 2014).

Human Population growth: This is an indirect driver of wildlife loss. As humans demand for bio-resources, like food and fuel, they play a crucial role in biodiversity degradation. The planet's human population has doubled in the past 50 years. The pressure to house and feed more than seven billion people has dramatically increased incursions into previously pristine natural habitats. At the same time, human impacts on the earth's climate are radically changing weather patterns and, as a result, the spread and nature of wild habitats.Moreover, it exacerbates every other factor having an impact on the ecosystem. For example, Nigeria's high rate of population increase has led to an unceasing search for more arable land for food production and livestock grazing and wood for fuel, construction, and energy. As a result, humans have tended to settle in areas of high biodiversity, which often have relatively rich soils and other attractions for human activities. This constitutes a significant threat to biodiversity, especially since many areas have numerous endemic species. Additionally, such high population pressure has resulted in the high intensity of logging, poaching, illegal exploitation, agricultural expansion, and collection of fuelwoods has continued to pose severe threats to the country's forest resources.

Habitat Loss/Fragmentation: Habitat fragmentation refers to the discontinuity or 'break down' of significant contiguous habitats into smaller, isolated patches of habitats. Such fragmentation negatively impacts the species interactions, community structure, and the general ecosystem of those fragments. In Nigeria, habitat fragmentation is currently the main threat to terrestrial biodiversity. Human activity is by far the most significant cause of habitat loss. The primary individual cause of loss of habitat is clearing land for agriculture. An estimated 177000 square kilometers of forests and woodlands are cleared annually to make space for farming or to harvest timber for fuel and wood products. Estimates suggest that the earth has lost about half of its forests in recent decades in 8000 years of human activity. About 3% of forests have been lost since the 1990s alone. And it is not just forest clearing that leads to habitat loss. The loss of wetlands, plains, lakes and other natural environments all destroy or degrade habitat, as do other human activities such as introducing invasive species, polluting, trading in wildlife, and engaging in wars. Some 40% of the global population live within 100 kilometers of the coast, placing significant strains on wetlands and oceans (World Wildlife Fund, 2017). The fragmentation and destruction of natural habitats lead to population size and abundance reduction, genetic diversity change, and wildlife extinction. Due to patches of habitat, the food chain length becomes smaller, changing the species interaction and reducing the specialists and large species of wildlife. Habitat loss also affects the animal's breeding, foraging, dispersal behaviours, and predation rate (Lenore, 2003). Figures from the International Union for Conservation of Nature (IUCN) suggest about 2000 mammals around the globe are affected by habitat loss. It is the primary threat to 85% of species on the union's Red List, which lists organisms whose existence is vulnerable, endangered, or critically endangered (IUCN, 2013).

Plate 1: Degraded habitat
Source: Sreela (2018).

Invasive species: According to the IUCN (2017),'Invasive alien species are species that are introduced, accidentally or intentionally, outside of their natural geographic range and that become problematic'. These species can cause damage to the environment by modifying ecosystem processes, which could potentially lead to the extinction of native species. Threats from invasive species include direct predation of native wildlife, competition for resources, and ecosystem damage (e.g. removing a key species such as pollinators). In Nigeria, some of the invasive species are Nypa palm (*Nypa fruticans*), Water hyacinth (*Eichhornia crassipes), and* Typha grass *(Typha latifolia).* Most of these weed species smother native species into extinction, while others produce allelopathic substances that eliminate other species around them (National Biodiversity Report, 2015).

Poverty and over-exploitation: Poverty is a big threat to biodiversity conservation in the tropics. When people who reside in a rural environment with a large chunk of its biodiversity are impoverished, biodiversity becomes their resort. There is a significant direct relationship between poverty and environmental degradation. The potential for Nigeria to become one of the leading economies in the world is not in dispute. This is so due to the abundant human capital and natural resources the country is blessed with. But it is shocking to note that reality conveys the opposite. Nigeria has overtaken India as the country with the most significant number of people living in extreme poverty. An estimated 87 million Nigerians, or around half of the country's population, live on less than $1.90 a day. Additionally, there has been an over-reliance on herbal medicine to seek primary health care in Africa. It is estimated that about 80% of the population of Nigeria uses traditional medicine, of which 85% of traditional therapy involves the use of plant extracts (National Biodiversity Report, 2015). The use of plants for herbal medicines requires collecting plant parts such as roots for herbaceous plants and stem bark for trees. The excessive peeling of stem bark affects the phloem, which could harm the plant. Such practices can lead to the death of the plant and for more vulnerable species; it could even result in extinction. According to the National Biodiversity Strategy and Action Plan, more than 80% of forest cover in Nigeria has been lost since 1990, with only 5.04% now remaining. Most protected areas lack adequate protection because illegal logging, encroachment by farmers and cattle herders, firewood gatherers, and poaching continue. The continuous exploitation of tree species to the international market has significantly impacted negatively on the biodiversity of Nigeria. Hence, tree species such as the mahoganies, Opepe (*Nauclea diderrichii*), Odigbo (*Terminalia ivorensis*), Afara (*Terminalia superba*), Obeche (*Triplochiton sceleroxylon*) are now endangered. The high intensity of logging and illegal exploitation of these and other species has continued to pose severe threats to the country's forest resources.

Plate 2: Logs of wood extracted from the forest
Source: National Biodiversity Report (2015)

Administrative factor: In Nigeria and other countries in the tropics, various factors militate are against the effective implementation of conservation policies. However, the lack of adequate data on the status of biodiversity remains a fundamental issue. The convention on biological diversity requires its member states to report on the status of biodiversity within their countries regularly and implement conservation actions and policies to maintain healthy species populations within their jurisdiction. Regarding the above mandate, CBD recommends developing the Red List assessment process to effectively assess and maintain the status of species at the country level. This deficiency has made it challenging to design adequate conservation programs for species facing high extinction risks in Nigeria. Additionally, policies are mostly made on the hoof without the proper consultation of specialists.

Deforestation: This is the disturbance of the forest ecosystem due to agricultural activities, grazing, and industrial development and causes shrinkage of forest land, changes forest cover, results in biodiversity loss, changes global water cycle, and enhancesthe greenhouse effect through reduction in carbon sequestration. People contribute to the degradation process when they illegally cut the trees for wood and construction; as a result, it leads to increase human and wildlife conflict, soil erosion, water pollution, and habitat loss (Leah, 2008). Forests are the significant storehouses of wildlife, e.g. tropical forests contain 2/3rd of all species and many wildlife endangered species (Chakravarty *et al.*, 2012). For example, from 2002 to 2020, Nigeria lost 141kha of humid primary forest, making up 14% of its total tree cover loss in the same period; the total area of humid primary forest in Nigeria decreased by 7.4% (Global Forest Watch, 2020).

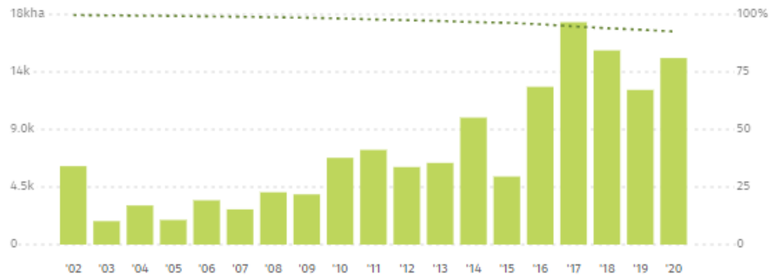

Fig.1: Deforestation rate in Nigeria from 2002–2020
Source: Global Forest Watch (2020).

Soil Erosion: The loss of soil (due to rain or wind) from land surfaces affects the productivity of all-natural ecosystems. Loss of biodiversity due to soil erosion is a potential problem worldwide. The food and productivity depend upon the fertility of the soil, and human-induced changes over soil are significant, resulting in valuable soil becoming unproductive. Additionally, the usefulplants, microbes, and animals are destroyed, leading to wildlife extinction because they depend upon plants and soil organisms for their food (Pimentel, 2006).

Global climate change: Sometimes, the effect of climate change is local, and sometimes other regions are also affected through linked food chains, circulation of nutrients, and ocean flow. Some species benefit from these environmental changes while others are negatively affected, and some species adapt to these changes andcan live in that habitat. And the species that are affected may be due to unavailability of food, habitat loss, or difficulty in migration from one place to another. Several other climate changes, for example, rise in temperature, change of rainfall pattern, humidity, and other weather changes. Due to climatic changes,species extinction is reduced, reducing biodiversity. But it is argued that climate change is not harmful to all species. On the contrary, it may benefit some species; for example, migratory birds migrate for breeding. Some scientists say that it is not always deprived, even if some species become extinct because there is greater biodiversity in the tropical region. Warm conditions and more significant rainfall are beneficial for these species. Scientists also said that some species develop particular traits and behaviour due to climate change, and they are adapted according to these conditions. But climate changes occur much more rapidly, and species evolution is a prolonged process (Salma and Mubashar, 2016).

Desertification: This is the disturbance in the ecosystem due to changes in soil, vegetation, and climate. Due to desertification, that particular area becomes unproductive and spreadslargely. Human activities such as over-cultivation, deforestation, overgrazing, poor irrigation practices, and other unsuitable land-use practices are responsible for desertification. As a result of desertification, there is a climate shift, species migrate to other areas, and there is a disturbance in biogeochemical cycles. Desertification cause decreasing production and increasing poverty because people become poor and exploit the land for survival (D'Odoricoa *et al.*, 2013).

Pollution: The production and use of toxic chemicals pose a significant and relatively new threat to humankind and the environment. Emissions from vehicles, industrial processes, liquid and solid waste, pesticides, and chemical fertilizers for agricultural and domestic purposes release toxic substances into the air, soil, or water, thereby affecting aquatic and other organisms in the environment (National Biodiversity Report, 2015). Heavy metals and persistent organic pollutants such as polychlorinated biphenyls, dioxins, and DDT are of particular concern since they do not degrade quickly. They accumulate and are lethal to plants, animals, fishes, and human beings, resulting in the ecosystem loss of species (National Biodiversity Report, 2015). Pollution has become one of the most severe problems of our time, and water pollution is one of the prime reasons for the loss of aquatic genetic diversity. Oil pollution in many intertidal creeks has therefore left mangroves denuded of leaves and stems, leaving roots coated in a bitumen-like substance sometimes 1 cm or morethick. With oil spills on land, fires often break out, killing vegetation and creating a crust over the land, making remediation or re-vegetation difficult. Gas flaring contributes to acid production in acid rain and increased carbon emissions into the atmosphere. One local study (Pollutec, 1996) estimated that 12 million tons of methane gas are released into the atmosphere in Rivers and Delta States. It also subjects flowering plants to heat radiation, high temperatures, and excessive light and gas deposits (dry and wet depending on the season). In the Niger Delta, Pollutec (1996) noted that affected plants show signs of chlorosis (leaf discoloration), scorching, browning and desiccation, stunting, and death after prolonged exposure. The same study also indicated that gas flares attracted yam beetles and grasshoppers that destroy crops.Noise pollution causes stress, loss of reproductive success, physiological disturbance and limits the long-term survival of wild animals. Animal health and its survival are greatly affected by noise pollution. So, we must protect the wildlife and reduce the noise pollution in animals' natural habitats (Radle, 2007). For example, frogs and toads are highly vocal, and their reproductive behaviour often involves the use of vocalizations. There have been suggestions that increased noise levels caused by human activities may be contributing to their declines (Sun *et al.*, 2005).

Plate 3: A Polluted water body
Source: Adapted from National Biodiversity Report (2015).

Table 4: Some Threatened wildlife species affected by habitat degradation

SPECIES' COMMON NAME	SCIENTIFIC NAME	MAJOR THREATS	POPULATION	CONSERVATION STATUS
Cross River Gorilla	*Gorilla gorilla diehli*	Habitat loss and illegal hunting	200–300 individuals	Critically Endangered (CR)
Amur Leopard	*Panthera pardus orientalis*	Illegal Wildlife Trade	More than 84 individuals	CR
Forest Elephant	*Loxodonta cyclotis*	Illegal hunting/illegal wildlife trade		CR
Savannah/Bush Elephant	*Loxodonta Africana*	Illegal hunting/illegal wildlife trade		Endangered (EN)
Black Rhinoceros	*Diceros bicornis*	Habitat loss/fragmentation and Illegal Wildlife Trade	Around 5,600 individuals	CR
Long-tailed Pangolin/African Black-bellied Pangolin	*Phataginus tetradactyla*	Illegal wildlife trade and habitat loss		Vulnerable (VU)
White-bellied Pangolin/Tree Pangolin/Three-cusped Pangolin	*Phataginus tricuspis*	Illegal wildlife trade and habitat loss		EN

Giant Ground Pangolin	*Smutsia gigantea*	Illegal wildlife trade and habitat loss		EN
Temminck's Ground Pangolin	*Smutsia temminckii*	Illegal wildlife trade and habitat loss		VU
Tiger	*Panthera tigris*	Habitat loss, climate change, and illegal wildlife trade	Around 3,900 individuals	EN
Giant Panda	*Ailuropoda melanoleuca*	Habitat loss	1,864 individuals in the wild	VU
Whooping Crane	*Grus Americana*	Illegal hunting		
Sumatran Orangutans	*Pongo abelii*	Habitat loss and illegal hunting	About 13,846	CR
Bornean Orangutan	*Pongo pygmaeus*	Habitat loss and illegal hunting	about 104,700	CR
Tapanuli orangutan	*Pongo tapanuliensis*	Habitat loss and illegal hunting	About 800	CR
Sea Turtle	*Chelonia mydas*	Overharvesting, pollution, climate change, Habitat loss, and Illegal trade		Endangered (EN)
Chimpanzee	*Pan troglodytes*	Illegal wildlife trade	172,700–299,700	EN
Red Panda	*Ailurus fulgens*	Illegal hunting	less than 10,000 individuals	EN
Blue Whale	*Balaenoptera musculus*	Habitat loss and Pollution	10,000–25,000 individuals	EN
Niger Delta red colobus	*Piliocolobus epieni*	Habitat loss		CR
African Lion	*Panthera leo*	Habitat loss and fragmentation, illegal wildlife trade, extractives, and conflicts with humans	Nearly 20000 world populations (645 genetically wild lions left in Western and Central Africa with as few as 34 remaining in Nigeria)	VU
Red-eared Quenon/Red-eared Monkey/Russet-eared Quenon	*Cercopithecus erythrotis*	Illegal wildlife and habitat loss		VU
Fin whale	*Balaenoptera physalus*	Habitat loss and pollution		EN
Sei whale	*Balaenoptera borealis*	Habitat loss and pollution		EN

African wild dog	*Lycaon pictus*	Habitat loss	EN
Dama gazelle	*Nanger dama*	Habitat loss and illegal hunting	CR
African golden cat	*Caracal aurata*	Habitat loss	EN
Calabar Angwantibo	*Artocebus calabarensis*	Illegal hunting and habitat loss	NT
African manatee	*Trichechus senegalensis*	Illegal wildlife trade, pollution, and habitat loss	VU
White-throated guenon	*Cercopithecus erythrogaster*	Illegal hunting and habitat loss	EN
Sclater guenon	*Cercopithecus sclateri*	Illegal hunting and habitat loss	EN
Collared/red-capped mangabey	*Cercocebus torquatus*	Illegal hunting, illegal wildlife trade, and habitat loss	EN
Ursine Colobus	*Colobus vellerosus*	Illegal hunting and habitat loss	CR
Cameroonian Forest Shrew	*Sylvisorex camerunensis*	Habitat loss	VU
Peruess' red colobus	*Philocolubus preuss*	Illegal hunting and habitat loss	CR

Source: Adapted from World Wildlife Fund (2021).

Plate 4:One silverback male and three female mountain gorillas killed in the Virunga National Park in the eastern Democratic Republic of Congo (DRC)

Source: WWF (2007)

Plate 5: Rangers removing a poached Gorilla from the forest after it was shot and killed at Cross River National Park, Nigeria

Source: Amanda (2017)

MITIGATION MEASURES TOWARDS THREATS AND IMPACT

POPULATION GROWTH: This can be achieved through;

- Human population control should be implemented by limiting the population's birth rate.

- National policy on population should be reviewed to assign a particular number of children to a couple and not just to a woman.
- Improving the economic status of women would lead to improved financial standing, which could allow them to have fewer children. Additionally, women should be encouraged to be educated, making the delay in marriage occur naturally. Family planning is another effective means of regulating birth. Therefore, awareness campaigns on family planning should be intensified in the tropics.
- Government should make a concerted effort to check the population growth rate annually.

HABITAT FRAGMENTATION: Shifting cultivation should be discouraged, and farmers should be encouraged to use organic fertilizer in enriching the soil. Investments and sustained attention to developing critical infrastructures to prevent the populace from indulging in activitiesthat lead to habitat destruction should be made. For instance, to discourage the use of wood as fuel, government should make natural gas and allied products available to the populace through subsidies.

POVERTY: In the rural economy, almost all small farms presume stable rainfall patterns in their choice of seeds and planting times. Therefore, government strategies for poverty reduction in arid and arable regions are at risk of the vagaries of climate change and more normal social and economic pressures. The interim Poverty Reduction Strategy and Green Agenda 2010 of the Federal Government of Nigeria developed under the Office of the Vice President with broad Stakeholder inputs are today two government policies that have ensured cross-sector coordination in policy development. Additionally, the Climate Change debate and the emergence of the National Adaptation Strategy are landmarks in policy development as they link biodiversity, livelihoods, and policy action in Nigeria.

OVERCONSUMPTION: Hunting laws should be enforced as part of measures to prevent poaching. Also, the populace should be enlightened on the importance of sustainable use of resources for posterity purposes.

INVASIVE SPECIES: Priority should be given to native species when carrying out afforestation or reforestation programmes.

CLIMATE CHANGE: Climate change mitigation involves measures that reduce the amount of emission or enhance the absorption capacity of greenhouse gases. Measures that could improve climate change mitigation are; carbon sequestration use of bio-energy.

Protection of water resources from pollution through necessary legal and institutional instruments and implementation programmes to sustainably extend and improve water supply and water management infrastructure.

Promotion of the adaption of an improved agricultural system for both crops and livestock by diversifying livestock and improved range management, increase access to drought-resistant crops livestock feeds, adapt better soil management practices, provide early warning/meteorological forecasts, increase planting of native vegetation cover, promotion of re-greening efforts and intensification of crops and livestock production in place of slash and burn.

In land use, forestry and biodiversity, governments shall promote afforestation and reforestation programmes, particularly with fast maturing tree species and conservation of remaining forested area; promotion of alternative energy sources to reduce dependency on biomass for energy needs in both urban and rural areas; strengthening the enforcement of laws and good governance of forest and other natural resources; implementation of legislative and control measures such as fencing to limit access to protected forests and designation of more protected zones to protect endangered species.

EROSION: Afforestation and reforestation programmes should be timely to rehabilitate the degraded ecosystem. Ornamental grasses/plants should also be planted in residential areas.

POLLUTION: As per solving the pollution problem, it is suggested that alternative energy sources should be developed to reduce the risk posed by the use of hydrocarbon as fuel; environmental education should be encouraged. People need to be taught how to use the environment's resources without causing damage to the environment. This can be achieved through media publication and creating awareness, including building environmental education into the school curricula.

DESERTIFICATION: Afforestation and reforestation programmes should be timely to rehabilitate the degraded ecosystem.

CONCLUSION

Summarily, wildlife (undomesticated plants and animals) is important for our survival and even the planet. Every living being in this world has been created for some or other use. So, destroying the wildlife means destroying ourselves. Anthropogenic activities have been responsible for the extinction of many wildlife species through habitat destruction and unsustainable exploitation of natural resources. Most species have gone extinct, which is attributed to several factors like hunting, habitat destruction, agriculture, infrastructural development; sequel to these, there is a great need for conservation and management practices to protect these vulnerable species and their habitats.

Recommendations

Based on the findings of this review, the following recommendations are of importance;

- Initiation of education and awareness programmes targeted at children and the youth, stressing the direct and indirect values of wildlife and the scientific basis of traditional conservation.
- Integration of conservation education into national curricula at all levels
- Afforestation and reforestation programmes should be timely carried out to rehabilitate/restore degraded ecosystems.
- Hunting laws should be enforced to prevent poaching or illegal hunting activities.
- Provision of adequate financial resources for agencies involved in wildlife conservation to enhance their efficiency and performance.
- Provision of alternative sources of income for the local people to reduce pressure on the already depleted biodiversity.
- Establish protected areas where human activities are restricted to conserve existing ecosystems and wildlife.

REFERENCES

Amanda, R. (2017). "Why is the Cross-River Gorilla Endangered?" Study.com. Retrieved study.com/academy/lesson/why-is-the-cross-river-gorilla-endangered.html.

Amusa, T. O., Omonu, C., Olabode, E. and Newton, N. J. (2017).Population Status and Distribution of Forest Elephant (*Loxodonta cyclotis*) in Okomu National Park and Omo Forest Reserve, south-western Nigeria.*Journal of Research in Forestry, Wildlife and Environment.*9(2): 44-56.

Baker, L. R., Tanimola, A. A., and Olubode, O. S. (2014). Sacred populations of Cercopithecus sclateri: analysis of apparent population increases from census counts. *American journal of primatology*, *76*(4), 303–312.https://doi.org/10.1002/ajp.22234.

Brian, H. M. (2013). Population Density. Retrieved 03/08/21 https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/population-density.

Breed, M. D. and Moore, J. (2011). Animal Behavior.Academic Press.p. 248. ISBN 978-0-08-091992-8. Retrieved 20-06-21.

Cook, C. D., Gut, B. J. Rix, E. M. and Schneller, J. (1974). Water Plants of the World: A Manual for the Identification of the Genera of Freshwater Macrophytes. Springer Science and Business Media.p. 7. ISBN 978-90-6193-024-2.

Chakravarty, S, Ghosh, S. K., Suresh, C. P., Dey, A. N. and Shukla, G. (2012) Deforestation: Causes, Effects and Control Strategies. *Journal of ecology* 40(3), 266-273.

Convention on International Trade in Endangered Species – CITES. (2020). Retrieved on 20/06/21.

D’Odoricoa, P., Bhattachana, A., Davisa, F., Ravib, S. and Runyan, W. C. (2013). Global desertification: Drivers and feedbacks. Advances in Water Resources: 326-344.

Duncan, R. S., and C. A. Chapman. (1999). Seed dispersal and potential forest succession in abandoned agriculture in tropical Africa.*Ecological Applications* 9: 998-1008.

Edet, D. I., Ajaji, S. and Ovat, I. O. (2014). Population estimate of the Cross River gorilla (*Gorilla gorilla diehli*) using a sweep survey of nests in Afi Mountain Wildlife Sanctuary, Southern Nigeria.

Enoch, M. O., Martin, O., Anthony, K., Paula, k., Lance, W. R., Tom, C. and Dave, J. H. (2019). Maasai Pastoralists Kill Lions in Retaliation for Depredation of livestock by Lions. *People and Nature*.2019; 1:59–69.

Fifth National Biodiversity Report. (2015). Nigeria: Fifth National Biodiversity Report.

Greenfield, P. *(2020).* "Humans exploiting and destroying nature on unprecedented scale – report". The Guardian.

Global Forest Watch (2020). Primary Forest Loss in Nigeria. Retrieved on 4/7/21

Harris, J. D. and Brown, P. L. (2009). Wildlife: Destruction, Conservation and Biodiversity. Nova Science Publishers.

Hanski, I. (2011). Habitat loss, the Dynamics of Biodiversity and a Perspective on Conservation. AMBIO: A Journal of the Human Environment, 40(3), 248-255.

International Union for Conservation of Nature (IUCN) (2013).IUCN Red List of Threatened Species.Accessed June 29, 2021.http://www.iucnredlist.org.

International Union for Conservation of Nature (IUCN) (2017). Invasive Alien Species.https://www,iucn.org/regions/europe/our-work/biodiversity-conservation/invasive-alien-species.

International Union for Conservation of Nature (IUCN) (2020). IUCN Red List of Threatened Species.

Leah, B. (2008). The impact of environmental degradation on refugee-host relations: a case study from Tanzania. *Policy Development and Evaluation Service*.1-25.

Lenore, F. (2003). Effects of habitat fragmentation on biodiversity.*Annu. Rev. Ecol.* Evol. Syst. 34:487- 515.

Living National Treasures.(2020). Retrieved on 11/07/2021 http://lntreasures.com/nigeriamf.html.

Masanja, G. F. (2014). Human Population Growth and Wildlife Extinction in Ugalla Ecosystem, Western Tanzania.*Journal of Sustainable Development Studies*. 2:192-217.

Nature Works. (2021). Natural and Human Impacts on Wildlife. Retrieved 20/06/21 https://nhpbs.org/natureworks/nwep16b.htm.

National Wildlife Federation. (2021). Threats to Wildlife. Retrieved on 19/06/21 https://www.nwf.org/Educational-Resources/Wildlife-Guide/Threats-to-Wildlife.

Oshita, B. J., Atim, A. N., Tawo, V. E. and Ubua, E. M. (2016). Population Densisty of the Mona Monkey (*Cercopithecus mona*) in Afi Mountain Wildlife Sanctuary, Cross River State, Nigeria. *Journal of Agriculture, Forestry and Fisheries.*5(6): 261-265.

Orimaje, J. O., Ogunjemite, B.G. and Agbelusi, E. A. (2017). Density and Abundance of the Red-capped Mnagabey (*Cercocebus torquatus*) in Omo Biosphere Reserve and Idanre Forest Reserve, south western Nigeria. *MOJ Protteomics Bioinform.* 5(2): 63-67.

Oruk, E. K., Ukpong, E. E. and Ijeoamah, H. M. Diversity and Population of Mammals in Cross River National Park, Cross River State, Nigeria. *African Journal of Agriculture and Environment.*8(1): 133-148.

Pimentel, D. (2006). Soil erosion: A food and environmental threat. Environment, development and sustainability. 8:119-137.

Pollutec Nigeria Limited. (1996). Proceedings of the First Consensus Workshop on the Preparation of Rivers and Bayelsa State Environmental Action Plan. Port Harcourt, Nigerian Federal Environmental Protection Agency and World Bank.

Quiroz, D. and Tinde, V. A. (2018).The Cultural Importance of Plants in Western African Religions. *Econ Bot* **72,** 251–262. https://doi.org/10.1007/s12231-018-9410-x.

Radle, L. A. The Effect of Noise on Wildlife: A Literature Review. 1-16.

Salma, B. and Mubashar, H. (2016). Wildlife in the perspective of environmental degradation: A review. *Journal of Entomology and Zoological Studies.* 4(5): 508-511.

Shreshtha, B. (2019). Importance of Wildlife. Retrieved 0n 19/06/21 https://sites.google.com/gsbi.org/gvc1702/wildlife/india/importance-of-wildlife.

Sreela, D. (2018). The Effects of Habitat Destruction on the Environment.Sciencing.Retrieved on 01/07/21 https://sciencing.com/humans-disrupt-ecosystem-5968.html.

Sommer, V., Adanu, J., Faucher, I., and Fowler, A. (2004). Nigerian chimpanzees (Pan troglodytes vellerosus) at Gashaka: two years of habituation efforts. *Folia primatologica; international journal of* *primatology*, *75*(5), 295–316.https://doi.org/10.1159/000080208.

Sun, Jennifer W.C., Narins. and Peter, M. (2005). "Anthropogenic Sounds Differentially Affect Amphibian Call Rate". *Biological Conservation*. **121**(3): 419–427. doi:10.1016/j.biocon.2004.05.017.

Telford, G. (2016). The Value of Wildlife Resources.Texas A&M University 2588 TAMUS College Station, Texas 77843-2588.

Turner, B. L., Clark W. C., Kates R. W., Richards J. F., Matthews J. T. and Meyers W. B. (ed.) (1990). The earth as transformed by human action. Cambridge University Press, Cambridge.

World Wildlife Fund.(2007). Endangered Mountain Gorillas Killed in Congo; Population at Risk.https://wwf.panda.org/wwf_news/?109801/Endangered-mountain-gorillas-killed-in Congo-population-atrisk#:~:text=Virunga%20National%20Park%2C%20Congo%20%E2%80%93%20One,the%20pa%20by%20local%20rangers.

World Wildlife Fund.(2017). What Impacts Do Human Activities Have on Habitats and Wildlife?

World Wildlife Fund. (2018). Living Planet Report - 2018: Aiming higher. Grooten, M. and Almond, R. (Eds).WWF, Gland, Switzerland, p 148.

World wildlife Fund.(2021). World Wildlife.https://worldwildlife.org/species.

Woodyatt, A. (2020). "Human activity has wiped out two-thirds of world's wildlife since 1970, landmark report says". *CNN*.

Wildlife Journal Junior. (2021). Population. Retrieved 03/08/21 https://nhpbs.org/wild/population.asp.

A REVIEW OF THE IMPACTS OF QUARRY ACTIVITIES AND HEAVY METAL CONTAMINATION ON SOIL AND FOOD CROPS IN EBONYI STATE, NIGERIA

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ABSTRACT

Quarry activities are considered to be one of the most significant sources of heavy metals which pose risks to environment and human wellbeing. Heavy metal pollution has become a global problem due its persistence in the environment, and has many adverse effects on human health, agricultural productivity and natural ecosystems. Available literatures have shown that abundance of heavy metals in the soil in Ebonyi state is attributed to anthropogenic activities such as mining and quarrying. Severe health effects of humans are inevitable as these heavy metals can disturb human metabolomics, contributing to morbidity and even mortality. Therefore, constant re-evaluating of heavy metals and its effects in water, soil and plants in the area is greatly required.

***Keywords**: Heavy metals, Contamination, Quarry, Waste Materials, Bioaccumulation*

INTRODUCTION

Heavy metals represent one of the possible environmental hazards experienced in regions where extractive activities are carried out. These extractive activities like quarry and mining which involves blasting, crushing of rocks, use of explosives are sources of additional heavy metals in the environment. Quarry activities produce large quantities of waste materials, such as waste rock, tailings and slag (Chu *et al*., 2010). These waste materials usually contain high concentration of heavy metals, irreclaimable reagents and chemicals used in the extraction processes (Onyedikachi *et al*., 2018). This increases the natural metal content of the soil leading to heavy metal contamination of the environment. Heavy metals once released into the atmosphere often return to soil and cause water and soil contamination (Adamu *et al*., 2015), and negatively impact soil structure and plant growth. Tailing produce acid mine and its acidification increases the dissolution of heavy metals. This is as a result of exposure of certain sulphide minerals mostly pyrite and arsenopyrite to air and water in both active and abandoned quarry site (Zuhairi *et al*., 2009). These toxic metals are non-degradable and persist in the ecosystem, thus posing a serious public health challenge.

The contamination of soil by heavy metals can be problematic in several levels because they are non-biodegradable and thus result in soil dysfunction. High concentration of these metals in the soil may bioaccumulate in plant tissues. Animals that graze on such contaminated plants and drink from polluted waters, as well as marine lives that breed in heavy metal polluted waters also accumulate such metals in their tissues (Anup and Biswajit, 2015).

The water environment is increasingly exposed to metal pollution as an enormous portion of heavy metals is directed toward aquatic surroundings and accumulated in the sediments (Ahamad *et al*., 2020). The heavy metals contaminate the water by altering the environmental parameters such as pH, temperature, bioturbation, etc, causing the death of a regional aquatic population and accumulate in plants by means of irrigation. Continued heavy metal accumulation in sediments can also contribute to groundwater pollution.

During quarrying process, dusts containing various heavy metals and toxicants are released into the air and in most cases deposited on the surface of the plant leaves. Plants that are very close to quarry sites tend to accumulate dusts and heavy metals, which reduce carbohydrate and chlorophyll levels, thus reducing the photosynthetic activity and causing delayed flowering (Ke, 2007). Results have shown that particulate matters coming from the dust have the potential to induce morphological changes on the plant leaves (Rai, 2016). Dust deposition on plants surfaces can induce aging of plants and reduced plant growth (Farahat *et al.*, 2016). Plants are one pathway for toxic metal mobilization into human system. Prolong exposure and increased accumulation of such heavy metals may have detrimental effects on human life and aquatic biota in terms of poor health.

Quarry has the potential of destroying habitats and the species they support (Samant, 2014). Even if the habitats are not directly removed by excavation, they can be indirectly affected and damaged by environmental impacts of these activities. Therefore, the objective of this review was to highlight the impacts of mining and quarry activities on soil and food crops in Ebonyi State, Nigeria.

Quarry Activities in Ebonyi State

Ebonyi State, lies within the Southern Benue Trough with a sedimentary succession of pre-Santonian periods that span from Albian and Turonian age. The state is associated with the occurrence of igneous intrusion and volcanic with sedimentary rocks. Due to its geologic formation, the state is blessed with abundant natural resources like granite, limestone, marble, slate, etc (Edet *et al.*, 2011). The abundance of these natural resources in the state has triggered the excavation and exploitation of these resources for economic benefits and this has led to increased quarry activities, quarry sites and industries. Ebonyi State has vibrant quarrying industries that date back to the 1950s (Chima *et al*., 2010). Over time, the state has experienced a considerable increase in quarrying operations with about 400 private operators producing over 100,000 metric tons of stone materials per annum (NEITI, 2013). The influx of these industries and their unsustainable practice are inimical to conservation of vegetation cover and land use systems of the host communities. Ebonyi state is characterized by abandoned mining ditches, open pit, heaps of overburden and tailing. The The ditches become areas of wasteland and sources of acid and metal-rich runoff from land-sited tailings piles or waste-rock heaps which subsequently lead to soil, surface water and groundwater pollution.

Plates 1-3 show some of the sites in the state at varying stages.

Plate 1. Active Quarry site in Nkalagu

Plate 2. Heap of overburden at quarry site in Amasiri Community

Plate 3. Abandoned site at Izzi

Quarry Activities and the release of Heavy Metals to the Environment

The discoveries and exploitation of mineral resources in Nigeria have led to the economic development of most sectors but the people's livelihood and natural resources have been negatively impacted. Extractive activities like quarry generate tailings, overburden, gangue mineral, etc and are the hazardous sources of toxic elements which have caused noticeable significant environmental problem among local communities. Heavy metals present in tailings can also be released to surrounding soils, streams, and groundwater mediated by erosion, weathering, and leaching over a long duration even after the cessation of mining activity. Also, the fine-grained particles of mine tailings or the ore are blown or diffused into adjacent areas while acid-mine drainage contamination has led to the contamination of nearby terrestrial and aquatic habitats (Oyebamiji *et al.*, 2017). The environmental impacts of quarry activities have similar effects worldwide and these effects are determined by the chemical attributes of the parent rock, the method of extraction and the environmental conditions (Khan *et al*., 2016). The mobility and bioavailability of these elevated heavy metals in the environment mostly depend on some physical and chemical characteristics of the surrounding environment such as pH, textural characteristics, organic matter content, speciation or chemical form, and electrical conductivity (Adewuyi and Osobamiro, 2016).

Soil is not only a geochemical habitat for the contaminants, but also serves as a natural buffer for transportation of heavy metal in the air, water, and biomass (Oyebamiji *et al.*, 2018). These heavy metals can be easily inhaled into human bodies from suspended dust or by uptake in plants when consumed (Benson, *et al.,* 2017). Due to the high elevated values of heavy metals in soils, they have posed a huge adverse effect on human health and aquatic environment.

Impacts of Quarry Activities in Ebonyi State

The extractive industries have increased enormously in the last sixty (60) years in response to increasing demands for more energy and primary commodities**.** This has resulted in a serious contamination in the state due to large quantities generated and scattered all over the place without proper treatment.

These waste materials are mostly dumped on slopes or stacked on farmland near villages. According to Osuocha *et al.* (2015), the dumps contain harmful minerals and chemicals that contaminate the soil, plant and water, and impair air quality. When exposed to weathering, leaching and decomposition, water containing heavy-metal slowly drain into the soil. The vicinity of most sites in Ebonyi State is often used as arable farmlands for cultivating edible food and medicinal plants. In some communities in Ebonyi State, a large proportion of cultivable land has been contaminated with heavy metals as reported by some researchers. For example, the study on Lead-Zinc mining site in Ezza south of the state, revealed that many heavy metals (Pb, Zn, Fe, Cu, Ni, Mn, Cr) are present in the soil samples collected from different farmlands (Aloh *et al*., 2016). Also, a study near operational and abandoned mines in Enyigba, Ameri and Ishiagu in Ebonyi State identified the following heavy metals Pb, Zn, Ni, Co, Mn and Ag in the soil samples above the normal soil composition (Nnabo, 2015). Another study in Ishiagu revealed that vegetables grown on soils into which mining effluent was discharged accumulated high levels of trace metals compared to those from the control site (Osuocha *et al.,* 2016a). This indicates potential health risk associated with prolonged consumption of edible vegetables grown in these soils. However, after 8-10 years of mining activities in Ishiagu Community, an estimated 6-7 excavates were abandoned and 3-4 mining pits with average depth of 40 m and surface area of between 900-1200 m^2 each existing in the area without any sign of being remedied (Essaghah *et al.,* 2013). These pits contain a large amount of tailings and are therefore unable to support any form of living things and have resulted to erosion of the soil and continued contamination of the surrounding from littered waste, and release of leachate.

In terrestrial ecosystem, soil is an important component which supports plant growth and biogeochemical cycling of nutrients that are vital to the ecosystem. The presence of heavy metals in the soil interacts with the soil system thereby changing the physical and chemical properties. Also, the long-term input of heavy-metal elements could result in decreased buffering capacity of soil, threatening the ecological environment. High level of heavy metals in soil could indicate similar concentration in plants by accumulation at high concentration causing serious risk to human health when consumed. Accumulation of heavy metals in crops grown on metal-polluted soil may easily cause damage to human health through food chain which results in number of diseases. Most of the farmlands are located near the quarry sites, thus increasing the potential of contaminant uptake by these crops and increase the risk of human intoxication.

The uptake of heavy metals by plants through absorption and subsequent accumulation along the food chain is a potential threat to animal and human health. A study in Ishiagu indicated that well water samples near Ishiagu quarry mining sites are contaminated with heavy metals (Osuocha *et al.,* 2016b). This suggested negative impact on nutritional composition of vegetables grown on soils receiving irrigated waste water particularly during the dry season. Also, the result of a study on some food crops and vegetables collected from a farmland near Enyigba mining site showed that these food crops bioaccumulated to toxic levels these metals above the proposed values set by world health organization (Orji *et al*., 2021). This can significantly contribute in its transfer into the human body through ingestion via the hand–mouth pathway, inhalation and dermal contact.

According to USEPA (2008), quarry activities have significantly contributed to particulate matters in the environment among all pollutants. It has been associated with inhalable dust which is produced during processing, grading and during the transit by the vehicles. There are occupational hazards which significantly predispose the workers and residents of the surrounding community to high vulnerability to air pollution and other health problems. The study on dust related health problems on workers from selected local government areas in Ebonyi state shows that the dust related health problems are higher in quarry workers when compared to other occupation like famers and Traders (Nwazunku *et al.,* 2020). The observed health related problems include sneezing, short breath, coughing, sore throat, asthma. The particular concern in quarry is the inhalation of dust containing silica which can lead to silicosis, lung cancer, pulmonary tuberculosis and airway diseases (Isara *et al*., 2016; Gholami *et al.,* 2020). A study conducted on some haematological parameters among workers at Umuoghara shows significant haematological changes which are as a result of occupational exposure (Chukwurah *et al*., 2020). According to (Guguloth *et al.,* 2012), this is an indication of effect of quarry dust on pathophysiology of blood and reticuloendothelia system of factory workers and in general human health.

Children, apart from engaging in processing the mineral ore commodities, also play on the mine tailings and dumps. During these activities, they inhale mine dusts from the atmosphere or ingest it through hand to mouth contact, thereby exposing them to hazardous substances which portend grave danger to their health. This also increases the release of heavy metals in the surrounding environment. These activities, coupled with prolonged human exposure and ingestion of the contaminated edible food plants, have effects on the people living within vicinity of the site. This finding implies that quarry in the area have negative impacts on different environmental media including plants.

The Loss of natural vegetation as a result of extractive activities like quarry poses risk for the surrounding area as it increases soil erosion, local flooding and water pollution and siltation. Mining and quarry have long been in existence; some of the pits have been abandoned and over the years have developed into gully sites. Several active major gully sites are spatially distributed in the state and have caused massive damage to land and vegetation cover (Akanwa *et al*., 2016). The absence of these vegetation cover facilitates lateral wind erosion of metal contaminated particles and enhances the volume of water percolating through the soil and eventually contaminating the underlying ground water.

Water resources are under severe strain in developing countries as industrial and mining pollutants are dumped into bodies water with little or no concern for the bodies' ability to absorb them. The activities of quarry in Ebonyi State have impacted greatly on water bodies, the explosives used during rock blasting leads to release of particulate matters which causes water pollution (Guach, 2001). A study on water quality from some selected locations in Ebonyi shows that Pb, Cd, Fe and Zn are higher than the standard limit (Okafor and Njoku, 2021). According to the observed results, quarry activities have impacted the water and aquatic organisms residing in the waterbodies in the areas. Water available within the Enyigba mine vicinity has been contaminated by potentially toxic elements from tailings emanating from mining activities through wind and water within the vicinity of the mine area. The study in Enyigba has also shown that open cast mining evidently impacted on the water usage, thus leading to heavy metal contamination of surface water bodies such as river, stream, pond (Okolo *et al.,* 2018).

EFFECT OF QUARRY AND HEAVY METAL CONTAMINATION

The various impacts of dust and waste containing heavy metals generated from quarry operations are on the air, water, soil, earth surface, flora and fauna, and human beings. Generally, humans are exposed to these metals by ingestion through drinking of contaminated water or inhalation of dust and fumes bearing heavy metals.

Effect on Soil health

Quarry activities have contributed immensely to Soil heavy metal contamination throughout the industrialized world. These activities contaminate the soil leading to high presence of metals. This has not only resulted to adverse effects on plant quality and yield but has also caused changes in the size, composition and activity of the soil microbial community. Heavy metals indirectly affect soil enzymatic activities by changing the microbial community which synthesizes enzymes. Soil enzyme activity is considered to be one of the biochemical indicators of soil health and the effect of heavy metals on soil enzyme activity vary with the types and concentrations of metals, the sensitivity of the enzymes and soil properties (Caldwell, 2005). For example, a study showed inhibiting urease activity in the decreasing order of Cr > Cd > Zn >Mn>Pb (Shen *et al.*, 2005). In conclusion, the result revealed that soluble forms of heavy metals (Ag, Cu, Hg and Zn) were considered to be more toxic to enzyme activities (urease, dehydrogenase and acid phosphatase) due to their high bioavailability. Cadmium is more toxic to enzymes than Pb because of its greater mobility and lower affinity for soil colloids whereas Cu inhibits β- glucosidase activity more than cellulose activity (Chaperon and Sauve, 2007). The resultant effects of the above toxicity include destroying the spatial structure of the active groups of the enzyme; the growth and reproduction of microorganisms are inhibited, thus reducing the synthesis and metabolism of the microbial enzyme (Chu, 2018). There is a very close relationship between soil enzymes and soil microbes, and some microorganisms and enzymes secreted by microorganisms participate in the circulation of soil ecosystems and energy together. These toxic effects towards soil biota affect key microbial processes and decrease the number and activity of soil microorganisms.

Diversity and activity of soil microbes play important roles in soil quality such as recycling of plant nutrients, maintenance of soil structure, detoxification of noxious chemicals, the control of plant pests and plant growth communities. e.g. Chromium is usually present in soils as Cr (III) and Cr (VI), which are characterized by distinct chemical properties and toxicities. The Cr (VI) is a strong oxidizing agent and is highly toxic, whereas Cr (III) is a micronutrient and a non-hazardous species 10 to 100 times less toxic than Cr (VI) (Gariner *et al.,* 2006). According to Shun-hong *et al.* (2009), Cr (VI) has caused shifts in the composition of soil microbial populations and cause detrimental effects on microbial cell metabolism at high concentrations. The heavy metal toxic effects on soil microorganism result in the change of the diversity, population size, and overall activity of the soil microbial communities and influenced the metabolism of soil microbes in all cases.

Effects of heavy metals on plants

Different stages of quarry mining processes cause permeation of metals into environmental media like soil, water, and plant species around the operation areas. Heavy metals at excessive levels are detrimental to plant growth and potential threat to animal and human health. For example, Mn, Pb, Cd, Cr and Co are shown to reduce growth of maize (*Zea mays* L.) and the toxic effects increased with increasing metal concentrations (Ghani, 2010). A similar study on oat plants (*Avena sativa* L. cv. Kassandra) grown in a soil contaminated by heavy metal, showed that plant chlorophyll content and photosynthesis decreased resulting to decline in plant height and biomass yield (Singh *et al.,* 2011).

Heavy metals at elevated concentrations can cause oxidative stress in plants, damage cell structure by substituting the deficient element with the toxic heavy metals, and hamper photosynthetic reactions in plant cells. For example the growth of pea plants (*Pisum sativum*, cv. Citrine) was reduced in the presence of excessive Zn while the uptake of Zn by the roots and its transport to the shoot increased as the Zn concentration in the nutrient solution increased (Doncheva *et al*., 2001).

Heavy metals affect seed germination in different ways and thus potentially reduce crop production. A study shows that some enzyme activity (amylase, protease and ribonuclease) was retarded due to Ni toxicity and thus affected seed germination and crop growth (Ahmad and Ashraf, 2011). Other negative effects of Ni in seed germination and plant growth include; the digestion and mobilization of proteins and carbohydrate, reduced plant height, root length, chlorophyll content, carbonic anhydrase enzyme activity (Siddiqui *et al*., 2011). Also increased malondialdehyde content reduced photosynthetic pigments and accumulation of Na^+, K^+ and Ca^{2+} in mung bean (Sethy and Ghosh, 2013).

High content of Pb in soils may decrease soil productivity, and a very low Pb concentration may inhibit some vital plant processes, such as photosynthesis, mitosis and water absorption with toxic symptoms of dark green leaves, wilting of older leaves, stunted foliage and brown short roots (Bhattacharyya *et al.*, 2008). The potential toxic and phytotoxicity effects include chlorosis, weak plant growth, delay seed germination, yield depression, reduced nutrient uptake, disorders in plant metabolism, and reduced ability to fix molecular nitrogen in leguminous plants (Guala *et al.,* 2010).

Heavy metal accumulation in plants depends on plant species and the efficiency of different plants in absorbing metals is evaluated by either plant uptake or soil to plant transfer factors of the metals. Several studies have found that heavy metals are easily accumulated in various edible vegetables and fruits through contaminated soil (Zhou *et al.*, 2016). According to Wang *et al.* (2006a), lead and cadmium accumulated in basil, ginger, turmeric, lemon grass, parsley, onion and coriander glory. The results of the study in Enyigba, Ebonyi State revealed that bitter leaf and garden egg leaf, waterleaf accumulated As, Cr and Pb above World Health Organization (WHO) acceptable limit (Oti and Nwabue, 2013). These three vegetables are in high demand in Abakaliki and other areas within the locality because they are part of daily staple food.

EFFECT ON HUMAN

These rocks when crushed produce dust exposing the people to risks of inhaling the heavy metals, which are known carcinogens. Humans are exposed to these metals by ingestion, by drinking contaminated water or inhalation of dust and fumes bearing heavy metals. Inhalation of the dust can cause severe health problems including respiratory and pulmonary problems, while dust deposition causes skin and eye problems.

The plant uptake of heavy metals from soils at high concentrations may result in a great health risk taking into consideration food-chain implications. Also the chronic low-level intake of soil through ingestion or inhalation has a serious negative effect on human health. Heavy metals become toxic because they are not metabolized by the body and therefore accumulate in the soft tissues. Chronic level ingestion of toxic metals has undesirable impacts on humans and the associated harmful impacts become perceptible only after several years of exposure.

When these heavy metals are transferred into food chains, they accumulate in vital organs, such as the liver, kidney, bones, and this poses a threat to human health which results to several health disorders. For example, chronic exposure to Cd is associated with harmful effects such as lung cancer, prostatic proliferative lesions, bone fractures, kidney dysfunction, and hypertension (Satarug *et al.*, 2003). The chronic effects of Arsenic (As) include bladder cancer, kidney cancer, skin cancer, lung cancer, and liver cancer (Jolly *et al.*, 2013). Exposure to lead (Pb) may cause plumbism, anaemia, nephropathy, gastrointestinal colic, and central nervous system symptoms (Li *et al.,* 2014). Heavy metal contaminated vegetables can cause gastrointestinal cancer and heart disease, damage the memory and intellectual abilities of human beings, disrupt numerous biochemical processes, and lead to cardiovascular, nervous, kidney, and bone diseases (Zafarzadeh *et al.*, 2018).

Zinc (Zn) is known to be relatively non-toxic, especially if taken orally. However, excess amount can cause system dysfunctions which results in impairment of growth and reproduction. The clinical signs of zinc toxicities include vomiting, diarrhea, bloody urine, icterus (yellow mucus membrane), liver failure, kidney failure and anaemia (Singh *et al*., 2010).

Copper (Cu) is an essential element in mammalian nutrition. Conversely, exposure to excessive levels of Cu can result in a number of adverse health effects such as severe mucosal irritation and corrosion, widespread capillary damage, hepatic and renal damage and central nervous system irritation followed by depression (Turkdogan *et al*., 2003). Severe gastrointestinal irritation and possible necrotic changes in the liver and kidney can also occur.

Nickel exposure and inhalation have resulted to several acute toxic effects like nausea, vomiting, vertigo, irritation, all types of respiratory disorders (asthma, bronchitis), damage to the lungs, nervous system, and mucous membranes (Das *et al*., 2008). It has been reported that nickel contact caused allergic dermatitis and immunologic urticarial, hence, nickel can be marked as both immune sensitive as well as an allergen (Das and Buchner 2007; Das *et al.*, 2018).

Chromium (Cr) is the 10th abundant element in the earth's mantle and persists in the environment as either Cr (III) or Cr (VI). Cr (VI) is toxic to plants and animals and its toxicity is derived from its ability to diffuse through cell membranes and oxidize biological molecules (Jeyasingh and Philip, 2005). Chromium enters the body through the lungs, gastrointestinal tract and to a lesser extent through skin. Inhalation is the most important route for occupational exposure, whereas non-occupational exposure occurs through ingestion of chromium-containing food and water. Regardless of route of exposure, Cr (III) is poorly absorbed whereas Cr (VI) is more readily absorbed. Generally, chromium is very toxic by dermal and inhalation routes and causes lung cancer, nasal irritation, nasal ulcer, hypersensitivity reactions and contact dermatitis.

Effect on Land use and Vegetation cover

Mining and quarry are destructive enterprises and involve complete destruction of the habitat of an area where they are carried out. The destruction and fragmentation of habitat is the greatest threat to biodiversity and the primary cause of species extinction. A study on vegetation and landform in Niger State shows that quarry operations have destroyed the landscapes, caused loss of vegetation and species extinction (Ako *et al.*, 2014). One of the biggest negative impacts of quarry on the environment is the damage to biodiversity hence destroying the habitats and the species they support. Even if the habitats are not directly removed by excavation, they can be indirectly affected and damaged by environmental impacts such as changes to ground water or surface water that causes some habitats to dry out or others to become flooded. Even noise pollution can have a significant impact on some species and affect their successful reproduction. A study in Odeda L.G.A, Ogun State also revealed that quarry has led to destruction of the landscape, loss in vegetation cover, alteration of water courses, occurrences of landslides and soil erosion along quarrying site (Adedeji *et al.,* 2020).

Quarry activities affect vegetation cover by hindering it from performing its biological roles among which is the photosynthesis process by which environmental pollutant, carbon dioxide is converted to life sustaining oxygen. In active sites, removal of the top soils, trees and vegetation with heavy machines deprives the land of its nutrients, renders the soil infertile for agricultural purposes and causes soil compaction, which reduces infiltration and increases surface runoff and erosion. A study on a site in Ishiagu area of Ebonyi State showed that the land had been covered by rocks and other debris from quarry activities (Akanwa *et al*., 2017). This has not only impeded plant growth on the land but has also rendered the surface rugged, making it impossible for productive farming.

In most developing countries, quarry is not well managed for environmental sustainability. The methods used are very poor and there is no order in resource exploitation. Most of the quarries collapse and there is no measures taken to rehabilitate it, thereby leaving them open. During Field observations such pits were observed at Nkalagu, Amasiri, Akpoha with depths ranging from about 50-85 m deep. They are either covered with rocks or water or are converted into waste pits where effluent and other toxic materials are deposited. These deep pits and ponds may contain various minerals and heavy metals, some of which are toxic in nature and affect the environment when their concentration exceeds the permissible levels.

Effect on water resources and quality

Mining and quarry are source of water contamination and most pollutants are adsorbed by the suspended particles in water (Yi *et al.*, 2020). Furthermore, the quarry operations surrounding the natural water, stream had led to the contamination of the natural stream with mud and rendered the stream inaccessible, especially during the rainy season. On the other hand, open pits within quarry sites act as water collection points/pools during rainy season and this prompts quarry operators to empty these pits by pumping water into an open environment (Ozean *et al*., 2012). This is a challenge to the surrounding community who use shallow wells as their potential water sources because quarry wastewaters end up polluting these sources. Uncontrolled dust from drilling and crushing activities normally finds its way into community water sources, especially rivers and shallow wells making water unsuitable for consumption, creating a source of unending conflicts between the community and quarry owners. The study on water sources around quarry community in Ishiagu shows that the metals (Al, Cd, Fe, Zn, Pb, Ca, Cu, and Mn) occurred above WHO permissible limits for drinking water (Akubugwo *et al*., 2012). Therefore, the water sources are contaminated and unfit for human consumption. Also, a study on water sources around quarry site in cross Rivers revealed that mean concentration of some heavy metals Ba, Cu, Mn, Pb and Zn are above the recommended standard for drinking water quality. This result showed that the water is not suitable for human consumption.

Effect on Air Quality

Quarry activities operate in complex and intricate ways which require drilling, blasting, and the use of machinery to grade rock materials thereby generating airborne particulates such as dust, sulphur dioxide (SO_2), Nitrogen dioxide (NO_2), Carbon monoxide (CO), and black smoke (Ayodele *et al.*, 2014). A study in Abuja showed that air pollutants such as particulate matter ($PM_{2.5}$ and PM_{10}) and greenhouse gases like CO, CO_2, NO_2 and SO_2 are detected within the quarry site (Owoicho *et al.*, 2021). Particulate matter (PM) or fugitive dust is the primary source of air pollution in quarries (Peter *et al.*, 2018). These quarry dusts significantly lead to production of considerable amounts of wastes harbouring a number of heavy metals which pose risk to human health. According to Oyinloye and Olofinyo (2017), the particulate air pollution especially PM10 is associated with a wide range of health effects. When inhaled, it affects the respiratory and cardiovascular systems, causes asthma which could lead to death. Particulates from blasting and crushing areas are considered to be more dangerous, because they are occasionally inhaled deeply into the tracts, hence settling in areas where the body's natural cleaning mechanisms cannot remove them (Leon-kabamba *et al.*, 2020). Inhalation of dust and fumes bearing heavy metals air severely affects the respiratory system, causing shortness of breath and destruction of mucus membrane (Godt *et al.,* 2006). Exposure to high concentrations of dust causes silicosis and fibrosis, a thickening of the lung walls leading to development of scar tissue (Jaishankar *et al.*, 2014).

CONCLUSION

The rate at which Quarry activities affect human, plants, aquatic organism and even the environment within the Ebonyi State is a major source of concern. Hence, there is an urgent need to constantly re-evaluate quarry activities and heavy metals contamination status at regional scale. This will help to avert several damages that heavy metals pose to human, plants and aquatic organisms and if possible reinstate water resources and soil to its natural state. The review revealed that soil and food crop is affected by leaching of heavy metals from quarry waste within the State.

REFRENCES

Adamu, C.I., Nganje, T.N. and Edet, A. (2015) Heavy metal contamination and health risk assessment associated with abandoned barite mines in Cross River State, southeastern Nigeria, *Environmental Nanotechnology, Monitoring and Management,* 3, 10–21.

Adedeji, O.H., Olayinka, O.O., Tope-Ajayi, O.O. & Azeez, O.I. (2020) Land use/Land cover changes due to Quarrying in Odeda Local Government Area of Ogun State, Nigeria: An Assessment and Implication for Rural

Livelihood , *Journal of Meteorology and Climate Science*, 18(1): 28-40.

Adewuyi, G. O., & Osobamiro, M. T. (2016).Chemical speciation and potential mobility of some toxic metals intropical agricultural soil. *Research Journal of Environmental Toxicology*, 10, 159–165.

Ahmad, M. S. & Ashraf, M. (2011) Essential roles and hazardous effects of nickel in plants.*Rev. Environ. Contam.Toxicol*., 214, 125–67.

Ahamad I.M., Song J. Sun H., Wang X., Mehmood S.M., Sajid M., Su P., Khan J.A.(2020) Heavy metals in the hyporheic zone of the Weihn River China, *International Journal of Environmental Research and Public health*, 17(1070), 1-17.

Akanwa O. A., Onwuemesi E. F., Chukwurah O. G. & Officha C.M. (2016) Effects of Open Cast Quarrying Technique on Vegetation Cover and the Environment in South-Eastern Nigeria , *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)*, 21(1), 227-240.

Akanwa O. A., Chike M.H. and Uloma J.U (2017) Effects of Quarrying Activities on Local Vegetation Cover in Ebonyi State, *Nigeria, International journal of science and Research methodology*, 6(2), 35-50.

Ako, T., Onoduku, U., Oke, S., Essien B., Idris, f., Umar, A. & Ahmed, A. (2014) Environmental effects of sand and gravel mining on land and soil in luku, Minna, North central Nigeria, *Journal of Geoscience and Geomatics*, 2(2), 42-49.

Akubugwo I.E., Ude C.V., Uhuegbu O.F. & Ugbogu O. (2012) Physicochemical properties and heavy metal content of selected water sources in Ishiagu, Ebonyi state-Nigeria, *Journal of Biodiversity and Environmental Sciences (JBES)*, 2(2), 21-27.

Aloh O.G., Obasi N.A., Chukwu K.E. & Agu A.N.(2016) Effects of Lead-Zinc Mining Activities on Water and Soil Quality in Ameka Mining Area of Ezza South, Ebonyi State, Nigeria, *International Research Journal of Natural and Applied Sciences* Vol. 3, Issue 7

Anup K.G. & Biswajit P.(2015) Ecorestoration of coal mine overburden Dump to prevent environmental degradation; A Review. *Research Journal of Environmental Science*, 9(7), 1-13.

Ayodele O.J., Shittu O.S. & Balogun T. (2014). Heavy metal pollution assessment of granite quarrying operations at Ikole-Ekiti, Nigeria. *Int. Journal of Environmental Monitoring and Analysis*, 2(6), 333-339.

Benson, N. U., Anake, W. U., Adedapo, A. E., Fred-Ahmadu,O. H., & Ayejuyo, O. O. (2017). Toxic metals in cigar-ettes and human health risk assessment associated with inhalation exposure. *Environmental Monitoring and Assessment*, 189(12), 619.

Bhattacharyya P., Chakrabarti K., Chakraborty A., Tripathy S. & Powell M.A., (2008) Fractionation and bioavailability of Pb in municipal solid waste compost and Pb uptake by rice straw and grain under submerged condition in amended soil. *Geosciences Journal,* **12**, (1), 41 –45.

Caldwell, B. A. (2005). Enzymatic activities as a component of soil biodiversity: A review. *Pedobiology*, 49, 637–44.

Chaperon, S. & Sauve, S. (2007). Toxicity interaction of metals (Ag, Cu, Hg, Zn) to urease and dehydrogenase activities in soils. *Soil Biol. Biochem.*, 39, 2329–38.

Chima, G. N., Nwaugo, V. O. & Ezekwe., I. C.(2010) The impact of Rock Quarrying on Akwukwo Tributary of Ivo River in Ishiagu, Ebonyi State. *Journal of App. and Enviro. Sci*., 6(2), 68-73.

Chu D. (2018) Effects of heavy metals on soil microbial community, IOP Conf. Ser.: *Earth Environ. Sci.* 113, 012009.

Chu N. K., Nguyen V. N., Le T. S., Ha M. N., Sota T., Takuro N. & Kōzō I. (2010) Heavy metal contamination of agricultural soils around a chromite mine in Vietnam, *Soil Science & Plant Nutrition*, 56(2), 344-356.

Chukwurah E.F., Nwambeke W. N., Chukwurah F.C. (2020) Effects of

Quarry Dust on Some Haematological Parameters among Workers at Okposi Umuoghara, Ebonyi State – Nigeria, *Saudi Journal of Biomedical Research*, 5(5): 82-86

Das K.K., Das S.N., & Dhundasi S.A.(2008) Nickel, its adverse health effects & oxidative stress. *Indian J Med Res*; 128: 412–25.

Das K.K. & Buchner V. (2007) Effect of nickel exposure on peripheral tissues: role of oxidative stress in toxicity and possible protection by ascorbic acid. *Rev Environ Health*, 22: 133–49

Das K.K., Reddy C. R., Bagoji B. I., Das S., Bagali S., Mullur L., Khodnapur P. J. &Biradar S. M (2018) Primary concept of nickel toxicity – an overview, *J. Basic ClinPhysiolPharmacol*, 1-12.

Doncheva, S., Stoynova, Z. &Violeta, V. (2001). Influence of Succinate on zinc toxicity of pea plants. *J. Plant Nutr.*, 24 (6), 789–804.

Edet, A., Nganje, A. J., Ekwere, A. S. &Ukpong, A. J.(2011) Groundwater Chemistry and Quality of Nigeria: A Status Review. *Afr. J. of En. Sc. and Tech.*, 5(13), 1152 -1169.

Essaghah A., Ogbonna C., &Alabi O. M. (2013) Environmental and Socio-Economic Impacts of Lead and Zinc Ores Mining in Shaiagu Community of Ebonyi State, Nigeria. *Journal of Geography and Earth Science* 1(1), 30-38.

Farahat, E.A., H.W. Linderholm and M.J. Lechowicz, 2016. Influence of dust deposition and climate on the radial growth of Tsuga canadensis near its Northern range limit. *European Journal of Forest Research*, 135: 69-76.

Garnier J., Quantin C., Martins E.S. & Becquer T., (2006) Solid speciation and availability of chromium in ultramafic soils from Niquelandia, Brazil. *Journal of Geochemical Exploration*, 88, 206–209**.**

Ghani, A. (2010). Toxic effects of heavy metals on plant growth and metal accumulation in maize (*Zea mays* L.).*Iranian J. Toxicol.*, 3 (3), 325–34.

Gholami, A., Tajik, R., Atif, K., Zarei, A. A., Abbaspour, S., Teimori-Boghsani, G., & Attar, M. (2020). Respiratory Symptoms and Diminished Lung Functions Associated with Occupational Dust Exposure Among Iron Ore Mine Workers in Iran. *The Open Respiratory Medicine Journal*, 14(1):1-7.

Godt, J., Franziska S., Grosse-Siestrup, C., Esche, E., Brandenburge, P., Reich, A. & Groneberg, D.A.(2006).The toxicity of cadmium and resulting hazards for human health. *Journal of Occupational Medicine and Toxicology*, 1:22

Guala S.D., Vega F. A. & Covelo E.F., (2010) The dynamics of heavy metals in plant–soil interactions. *Ecological Modelling*, 221, 1148– 1152**.**

Gauch, H.G. (2001). Multivanate Analysis in Community Ecology Cambridge University Press. Pp. 85.

Guguloth, M. R., Sambanaik, A., & Mude, J. (2012). The Effect of Cement Dust Exposure on Haematological Parameters of Cement Factory workers in Nalagonda, Andhra Pradesh. *International Journal of Advancements in Research & Technology*, 1(5), 46-52.

Isara, A. R., Adam, V. Y., Aigbokhaode, A. Q., & Alenoghena, I. O. (2016). Respiratory symptoms and ventilatory functions among quarry workers in Edo state, Nigeria. *Pan African Medical Journal*, 23(1); 212

Jaishankar M., Tseten T., Anbalagan N., Mathew B.B & Beeregowda K.N. (2014). Toxicity, mechanism and health effects of some heavy metals. Interdisciplinary Toxicology, 7(2): 60–72.

Jeyasingh J. & Philip L. (2005) Bioremediation of chromium contaminated soil: optimization of operating parameters under laboratory conditions. *Journal of Hazardous Materials*, 118, 113–120.

Jolly, Y.N., Islam, A., & Akbar, S. (2013) Transfer of metals from soil to vegetables and possible health risk assessment.*Springerplus*, 2, 385.

Ke, S.S., 2007. Effects of copper on the photosynthesis and oxidative metabolism of Amaranthus tricolor seedlings. Agricultural Science in. China, 6(10): 1182-1192

Khan, A. M., Yusoff, I., Bakar, N. K. A., Bakar, A. F. A., & Alias, Y. (2016). Assessing anthropogenic levels, speciation, and potential mobility of rare earth elements (REEs) in ex-tin mining area. *Environmental Science and Pollution Research*, 23(24), 25039–25055.

Leon-Kabamba, N., Ngatu, N.R., Muzembo,B.A., Kakoma, S., Michel-Kabamba, N., Danuser, B., Luboya, O. & Hirao, T. (2020) Air Quality in the Working Environment and Respiratory Health of Female Congolese Stone Quarry Workers, *Tropical Medicine and infection disease*, 5(4), 171.

Li, Z.Y., Ma, Z.W., Kuijp, T.J., Yuan, Z.W., & Huang, L.S. (2014) A review of soil heavy metal pollution from mines in China: Pollution and health risk assessment. *Sci. Total Environ*. 468, 843–853.

NEITI (2013). Solid Minerals Industry Audit Report 2007 – 2010. https://eiti.org/files/documents/2007-2010_nigeria_eiti_report_mining.pdf. Assessed on 17th July 2021

Nnabo P. N. (2015) Heavy Metal Contamination in Soils in EnyigbaPb& Zn Mines District, South Eastern Nigeria Using Metal Enrichment and Pollution Indices. *International Journal of Research in Environmental Science (IJRES)*, 1(2), 48-59.

Nwazunku A.A., Amadi C.O.A., Ede A.O., Obasi K.O., Abonyi I.C., & Amadi A.N (2020) Assessment of Quarrying Activities and Dust-related Health Problems among Quarry Workers and Residents Communities in Ebonyi State, Nigeria, *International Journal of Health, Safety and Environment (IJHSE)*, 6(03), 519 – 525.

Nweke F.N., Okaka A.N.C. & Offor E.C. (2008) Lead, Zinc and pH concentration of Enyigba soils in Abakaliki Local Government Area of Ebonyi state Nigeria, *African Journal of Biotechnology*,7 (14), 2441-2443.

Ogbonna C.E., Adinna E.N., Ugbogu O.C. & Otitoju O. (2013). Heavy metal concentration and Physicochemical properties of soil in the lead-zinc mining area of Ishiagu, Nigeria. *Journal of Biodiversity Environmental science(JBES)*, 3(10):61-69.

Okafor C. O. and Njoku C. (2021) Water quality as affected by quarry activities in Ebonyi state Nigeria, *Research square*, 1-16.

Okolo C.C., Oyedotun T.O.T, & Akamigbo F.O.R (2018) Open cast mining ,threat to water quality in rural community of Enyigba in South –Eastern Nigeria, *Applied water Science* 8(204), 2-11.

Onyedikachi U., B., Belonwu D., C., &Wegwu M., O. (2018) Human health risk assessment of heavy metals in soils and commonly consumed food crops from quarry sites located at Isiagwu,Ebonyi State, *Ovidius University Annals of Chemistry*, 29(1), 8-24

Orji O.U., Ibiam U. A. Awoke J.N. Obasi O.D. Uraku A.J., Alum E.U. and Eze A.G. (2021) Assessment of levels and Health risks of Trace metals in soils and food crops cultivated on farmlands near Enyigba mining sites Ebonyi state. *Journal of .Food Protection*, 84(8), 1288-1294.

Osuocha K.U., Akubugwo E.I., Chinyere G.C., &Ugbogu E.A. (2015). Seasonal impact on physicochemical characteristics and enzymatic activities of Ishiagu quarry mining effluent discharge soils. *International journal of Current Biochemistry Research*, 3(3):55-66.

Osuocha K.U., Akubugwo E.I., Chinyere G.C. &Ugbogu A.E. (2016a) Seasonal impacts on phyto-accumulation potential of selected edible vegetables grown in Ishiagu quarry mining effluent discharge soils. *African journal of Environmental Science and Technology*, 10(1), 34-43.

Osuocha K. U., Chukwu E. C., Ugbogu E. A., Atasie O. C. &Ogbonna C. E. (2016b)Effects of Quarry Mining Activities on the Nutritional Composition of Edible vegetables in Ishiagu, Ebonyi State, Nigeria, *Journal* *of Experimental Biology and Agricultural Sciences,* 4(5), 467.474.

Oti W. J.O. &Nwabue F.I.(2013) Heavy Metals Effect due to Contamination of Vegetables from Enyigba Lead Mine in Ebonyi State, Nigeria , *Environment and Pollution*; 2,(1),19-26.

Owoicho C., Duru T.C.,Abdulsalam, B.,Ameh, R.A. and Abubakar U.M.(2021) Analysis of RCC Grainte Quarry site on air quality of yangoji kwali area council, Abuja, Nigeria. *International journal of social science and management Review,* 4(4), 115-121.

Oyebamiji, A., Odebunmi, A., Ruizhong, H., &Rasool, A.(2017). Assessment of trace metals contamination instream sediments and soils in Abuja leather mining, southwestern Nigeria.*ActaGeochimica*,1–22

Oyebamiji A., Amanambu A., Zafa T., Adewumi J. A., &Akinyemi S.D. (2018) Expected impacts of active mining on the distribution of heavy metals in soils around Iludun-Oro and its environs, Southwestern Nigeria . *Cogent Environmental Science,* 4: 1495046.

Oyinloye, M. A. & Olofinyo, B. O.(2017) Environmental Impact of Quarry Activities on Resident of Akure Region, Nigeria, *SCIREA Journal Environment*, 2(2), 11–29.

Ozean, O., Musaoglu, N. and Seker, D. Z. (2012) Environmental Impact Analysis of Quarrying Activities Established on and near a River Bed by Using Remotely Sensed Data. *Fresenius Environmental Bulletin*, 21 (11), 3147–3153.

Peter, C.; Alozie, M.; Azubuine, C.(2018) Stone Quarrying Impact on Air Soil Water in Ebonyi State, *Nigeria. Journal Pollution Effects & Control*, 6(2), 2–5.

Rai, P.K., 2016. Impacts of particulate matter pollution on plants: Implications for environmental biomonitoring. *Ecotoxicol. Environ. Saf.*, 129: 120-136.

Samant J.S., (2014). Environmmental and social impact of stone quarrying: Acase study of Koloapur district. *International Journal of Current Research*, 6 (3):5664-5669

Satarug, S., Baker, J.R., Urbenjapol, S., Haswell-Elkins, M., Reilly, P.E., Williams, D.J. & Moore, M.R. (2003) A global perspective on cadmium pollution and toxicity in non-occupationally exposed population. *Toxicol.Lett.* , 137(1-2), 65–83.

Sethy, S. K. & Ghosh, S. (2013). Effect of heavy metals on germination of seeds. *Journal of Natural Science, Biology and Medicine.*, 4 (2), 272–275.

Shen, G., Lu, Y., Zhou, Q. & Hang, J. (2005).Interaction of polycyclic aromatic hydrocarbons and heavy metals on soil enzyme. *Chemosphere*, 61, 1175–82

Shun-hong H., Bing P., Zhi-hui Y. Li-yuan C., & Li-cheng Z.,(2009) Chromium accumulation, microorganism population and enzyme activities in soils around chromium-containing slag heap of steel alloy factory. *Transactions of NonferrousMetals Society of China*, **19**, 241-248**.**

Siddiqui M.H., Al-Whaibi M.H., &Basalah M.O.(2011) Interactive effect of calcium and gibberellin on nickel tolerance in relation to antioxidant systems in Triticumaestivum L. *Protoplasma*, 248(3), 503-511.

Singh A., Sharma R.K., Agrawal M. & Marshall F.M. (2010). Health risk assessment of heavy metals via dietary intake of foodstuffs from the wastewater irrigated site of a dry tropical area of India, *Food and Chemical Toxicology*, 48(2):611–619.

Singh, H. P., Kaur, G., Batish, D. R. &Kohli, R. K. (2011). Lead (Pb)-inhibited radicle emergence in Brassica campestris involves alterations in starch-metabolizing enzymes. *Biology Trace Element Research*, 144(1-3), 1295–1301.

Song, W. Y., Mendoza-Cozatl, D. G., Lee, Y., Schroeder, J. I., Ahn, S. N., Lee, H. S., Wicker T. & Martinonia E. (2014). Phytochelatin–metal (loid) transport into vacuoles shows different substrate preferences in barley and *Arabidopsis*. *Plant Cell Environment*, 37(5), 1192–1201

Turkdogan MK, Kilicel F, Kara K, Tuncer I., & Uygan I.(2003) Heavy metals in soil, vegetables and fruits in the endemic upper gastrointestinal cancer region of Turkey. *Environmental Toxicology Pharmacology*, 13(3):175–179

USEPA (United State Environmental Protection Agency). (2008). Region 4: Laboratory and field operations PM2.5 Objectives and history.

Wang, G.; Su, M.Y.; Chen, Y.H.; Lin, F.F.; Luo, D. &Gao, S.F.(2006) Transfer characteristics of cadmium and lead from soil to the edible parts of six vegetable species in southeastern China. Journal of *Environmental Pollut*ion, 144, 127–135.

Yi, L., Gao, B., Liu, H., Zhang, Y., Du, C., & Li, Y. Characteristics and Assessment of Toxic Metal Contamination in Surface Water and Sediments near a Uranium Mining Area. *International Journal Environmental Research and Public Health*, 17(2), 548.

Zafarzadeh A., Rahimzadeh H. &Mahvi H. A. (2018) Health Risk Assessment of Heavy Metals in Vegetables in an Endemic Esophageal Cancer Region in Iran. *Health Scope. In Press(In Press)*, 12340.

Zhou H, Yang W.T., Zhou X., Liu L., Gu J.F., Wang W.L., Zou J.L., Tian T., Peng P.Q., Liao B. H.(2016) Accumulation of Heavy Metals in Vegetable Species Planted in Contaminated Soils and the Health Risk Assessment. *International Journal of Environmental Research and Public Health*, 13(3):289

Zuhairi W, Yaacob W, Syuhadah N, Pauzi M, Mutalib H.A. (2009). Acid mine drainage and heavy metals contamination at abandoned and active mine sites in Pahang. *Geological Society Malaysia Bulletin*, 55:15-20.

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Mucuna pruriens (L.) DC (VELVET BEAN), AN UNDERUTILIZED LEGUME IN AGRICULTURAL PRODUCTION – EFFECT OF DURATION OF STORAGE ON VIABILITY OF SEEDS

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ABSTRACT

Mucuna pruriens is a nodulating tropical legume that plays numerous roles in agriculture. These include rejuvenation of soil, management of some noxious weeds and forage for livestock. In Nigeria, Mucuna pruriens is still underutilized due to paucity of information on its germination and growth attributes. This study sought to provide information on duration of seed storage and germination of two varieties of Mucuna pruriens seeds in Ibadan, Nigeria.

Seeds of two varieties of Mucuna pruriens (semilas-cream and black-utilis) stored in envelopes and kept in the laboratory at room temperature (27°C to 32°C) were used for the study. At monthly intervals for twenty four months, twenty seeds each of two varieties of Mucuna pruriens were placed in Petri-dishes laid with 9-cm Whatman No. 1 filter papers adequately moistened with distilled water. The Petri-dishes were arranged in a completely randomized design with three replicates on laboratory bench where they were exposed to 12/12 hours of alternating day/night. The Petri-dishes were watered and inspected daily for the emergence of radicle which indicates germination. Data were analysed using descriptive statistics and ANOVA at $\alpha_{0.05}$.

Percentage germination of seeds of semilas-cream variety was significantly higher ($P \leq 0.05$) than black-utilis at only 8 (88.3 and 83.3%), 13 (73.3 and 58.3%), 14 (70.0 and 51.7%), 15 (68.3 and 50.0%), 16 (56.7 and 45.0%), 17 (53.3 and 35.0%), 18 (50.3 and 30.0%), 19 (50.0 and 30.0%), 22 (30.0 and 16.7%) and 23 (28.3 and 16.7%) months after storage. Percentage germination reduced in the two varieties with length of storage.

Seeds of Semilas-cream were more viable than Black-utilis over the study period of two years.

***Keywords**: Legume, underutilised, black-utilis,semilas-cream, germination, cover-crop*

INTRODUCTION

Mucuna is a genus of plants that thrives in tropical and sub-tropical regions of the world (Kavitha and Thangamani, 2014) and includes about 100 to 150 species of short and long lived legumes (Ortiz-Ceballos*et al*., 2012). *Mucuna pruriens* is a bushy, twining annual plant (Baligar and Fageria, 2007). It can be found in tropical and sub-tropical climates around the world (Lucia *et al*., 2011). The common names of *M. pruriens* are velvet bean, cowhage, cowitch and devil bean. The local names are werepe, igekpe and karara (Nigeria), eesin, ejokun and esinsin (other West African countries). The pubescence on the pod, the seed colour, and the number of days it takes to harvest the pod differ significantly among species (Lucia *et al*., 2011).

The importance of *M. pruriens* is numerous as it plays significant roles in agriculture. These include; rejuvenation of soil, management of some noxious weeds and serves as forage plants. Its ability to fix atmospheric nitrogen and high biomass production makes it an ideal plant for improving the quality of soil when used as sown fallow or green manure. Report from Blanchart *et al*. (2006) revealed that the inclusion of velvet bean in cropping systems improved soil quality by increasing the diversity and structure of soil microbes.

Velvet bean inhibits the growth of other weeds through its rapid growth rate, early canopy closure and release of allelochemicals. Reports from Kavitha and Vadivel (2008) and Ochekwu and Udensi (2015) revealed the efficacy of velvet bean in the biological control of some noxious weeds. The legume also serves as a fodder crop. In tropical and subtropical climates around the world, velvet bean is used as a cover and forage plant (Marchiosi*et al*., 2016). The plant can supply significant energy because it contains high quantity of proteins, vitamins and minerals (Kalidass and Mahapatra, 2014). Pugalenthi *et al*. (2005) and Rudra*et al*. (2020) reported that velvet bean seeds have nutritional contents, macromolecules, phosphorus and total ash that are comparable to those of traditional legume seeds.

In Nigeria, *Mucuna puriens* is still an underutilised legume due to paucity of data on its germination and growth attributes. This study looked into the effect of duration of seed storage at room temperature on the germination of two varieties of *Mucuna pruriens* seeds in Ibadan, Nigeria.

MATERIALS AND METHODS

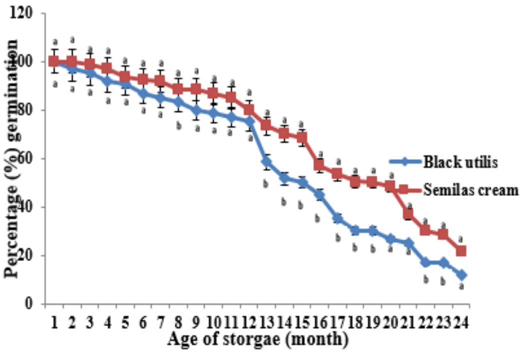
The experiment was carried out at the Ecology Laboratory of the Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan in 2020. Viability test of seeds of *Mucuna pruriens* was conducted on a monthly basis over a period of two years. Seeds of two varieties of *Mucuna pruriens* (semilas-cream and black-utilis) collected in January, 2019 stored in envelopes and kept in the laboratory at room temperature (27^{o}C to 32^{o}C) were used for the study. Twenty seeds of each treatment were placed in Petri-dishes laid with 9-cm Whatman No. 1 papers that were moistened with distilled water. The Petri-dishes were arranged in a completely randomized design (CRD) with three replicates on a laboratory bench, where they were exposed to 12/12 hours of alternating day/night.On daily basis the filter paper in each Petri-dishes was moistened and seeds were inspected for the emergence of radicle, which indicated germination. The germination test was conducted every month till December 2020. The percentage germination was calculated as;

$$Germination\ (\%) = \frac{Total\ number\ of\ seeds\ that\ germinated}{Total\ number\ of\ seeds\ in\ Petri\ dish} x \frac{100}{1}$$

Statistical analysis was carried out using DSAAT software. The data obtained were analysed using Analysis of Variance (ANOVA) at 5% level of significance. Means were separated using Tukey HSD test at 5% level of significance.

RESULTS

Viability of seeds of *Mucuna pruriens* (Black-utilis and Semilas-cream) decreased as the storage period increased. Percentage germination of seeds of semilas-cream variety was significantly higher (P≤ 0.05) than black-utilis at 8, 13, 14, 15, 16, 17, 18, 19, 22 and 23 months after sowing (Figure 1).



Paired percentage germinations with the same letters are not significantly different at α0.05

Figure 1: Germination Profile of two varieties of *Mucuna pruriens* seeds stored in envelopes at ambient temperature over two years (2019-2020) in Ibadan, Nigeria

DISCUSSION

In the study, seeds of Semilas-cream and Black-utilis exhibited high percentage germination in the first 12 months after storage. This high percentage germination agrees with Gurumoorthi *et al.* (2003) in their study of seeds of seven ascensions of *M. pruriens* var. *utilis*. In addition, Semilas-cream seeds exhibited a higher percentage germination compared to Black-utilis seeds in the first 12 months of storage.

Furthermore, results from the study also showed that seeds of *Mucuna pruriens* were not dormant unlike some leguminous seeds. Baskin and Baskin (2014) observed that annual plants with small seeds produce more dormant seeds than longer-lived plants with big seeds. Although dormancy of seeds as a result of hard seed coat is a major feature of most legumes in the family Fabaceae (Tanimola and Awodoyin, 2020), seeds of velvet bean is an exception.

CONCLUSION

The study revealed that seeds of velvet bean (Black-utilis and Semilas-cream) exhibited high percentage germination in the first 12 months. Seeds of Semilas-cream were more viable than Black-utilis over the study period of two years. Storage of velvet bean (black-utilis and semilas cream) seeds should not be more than a year as viability declined from the period.

REFERENCES

Baligar, V.C. and Fageria, N. K. 2007.Agronomy and Physiology of Tropical Cover Crops.*Journal of Plant Nutrition* Volume 30(8): 1287 – 1339.

Baskin, J.M. and Baskin, C.C. 2014. What kind of seed dormancy might palms have? *Seed Science Research*. Volume 24: 17-22.

Blanchart, E., Villenave, C., Viallatoux, A. and Barthès, B. 2006.Long-term effect of a legume cover crop (*Mucuna pruriens* var. utilis) on the communities of soil macrofauna and nematofauna, under maize cultivation, in southern Benin.*European Journal of Soil Biology*, 42 (Supplement 1), S136-S144.

Gurumoorthi, P., Senthil Kumar, S., Vadivel, V. and Janardhanan, K. 2003. Studies on agrobotanical characters of different accessions of velvet bean collected from Western Ghats, South India. *Tropical and Subtropical Agroecosystems* Volume 2: 105-115.

Kalidass, C. and Mahapatra, A. K. 2014.Evaluation of the proximate and phytochemical compositions of an underexploited legume *Mucuna pruriens* var. *utilis*(Wall ex Wight) L.H.Bailey.*International Food Research Journal* Volume 21(1): 303-308.

Kavitha, C. and Thangamani C. 2014.Amazing bean *"Mucuna pruriens"*: A comprehensive review. *Journal of Medicinal Plants Research*.8(2): 138-143.

Kavitha, C. and Vadivel, E. 2008.Effect of organic manures and inorganic fertilizers on dry matter production and L DOPA content of *Mucuna pruriens* (L.) DC. – A leguminous medicinal plant. *Legume Research* Volume 31(1): 44-47.

Lucia, R.L., Alessio, C., Roberto, G., Claudia, S. and Giuseppe, V. 2011.The Magic Velvet Bean of *Mucuna pruriens*.*Journal of Traditional and Complementary Medicine* Vo1ume. 2 (4): 331-339.

Marchiosi, R., de Souza Bido, G., FeitozaBohm, P.A., Soares, A.R., da Silva, H.A., Ferro, A.P., LucioFerrarese, M.L. and Ferrarese-Filho, O. 2016. Photosynthetic response of soybean to L-DOPA and aqueous extracts of velvet bean.*Plant Growth Regulation* Volume 80(2):171-182.

Ochekwu, E.B. and Udensi, E.U. 2015. Evaluation of Potential Allelopathic Relationship between Velvet bean (*Mucuna cochinchinensis* (Lour.) A. Chev) and Speargrass (*Imperatacylindrica* (L.)Raeushel) with Selected Methods.*Journal of Agriculture and Ecology Research International* Volume 3(3):89-96.

Ortiz-Ceballos AI, Aguirre-Rivera JR, Osorio-Arce MM, Peña-Valdivia C. 2012.Velvet Bean (*Mucuna pruriens* var. *utilis*) a cover crop as bio herbicide to preserve the environmental services of soil. *Herbicides-environmental impact studies and management approaches*. Ed. Alvarez- Fernandez R University of Cambridge, Cambridge pp 167-184.

Pugalenthi, M., Vadivel, V. and Siddhuraju, P. 2005. Alternative food/feed perspectives of an underutilized legume *Mucuna pruriens* var. utilis - a review.*Plant foods for Human Nutrition* Volume 60(4): 201.

Rudra, V., Shankaraswamy, J., Nagaraju, K., Nikhil, B.S.K. and Sathish, G. 2020.Velvet Bean (*Mucuna pruriens* (L.) DC. var. *pruriens*): An Eminent Legume in Indian Agriculture. *VigyanVarta*Volume 1(7): 10-12.

Tanimola, O.O. and Awodoyin, R.O. 2020.Germination of *Mimosa diplotricha*C. Wright and its critical period of interference with maize *(Zea mays* L.*)* in Ibadan, Nigeria.*African Journal of Agriculture, Technology and Environment* Volume 9(1): 62-72.

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COMPARATIVE ANALYSIS OF PHYSICAL AND CHEMICAL PROPERTIES OF SOILS FROM BASEMENT COMPLEX AND COASTAL PLAIN SAND PARENT MATERIAL IN SOUTHWESTERN NIGERIA

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ABSTRACT

*The study was intended to compare the physical and chemical properties of soils formed on two parent materials. A total of twenty soil samples were collected at 20cm depth intervals of soil profiles at two physiographic positions (upper slope and middle slope) of two geological formations which were basement complex and coastal plain sands at Ibadan (Oyo State) and Epe (Lagos State), respectively. Soil samples were subjected to routine analyses using standard laboratory procedures. Data were subjected to descriptive statistics and the relationships among the soil properties were examined using correlation analysis. Results shows that the soil textural class were between sand clay loam and sandy clay in basement complex but between sand and sandy loam on the coastal plain sand. Bulk density of the soils on basement complex were higher than that of coastal plain sands. Soil pH was slightly acidic in basement complex derived soils (5.4 – 6.2) but strongly acidic in soils on coastal plain sands (4.4 - 4.7), in both upper and middle slope positions. Soil organic matter ranging from 12.10 - 30.62 g/kg on basement complex soils was generally higher than those in the Coastal plain soils though similar trends were observed for soils in the middle slope for both parent material. Total Nitrogen (0.28 - 4.76 g/kg) was higher in coastal sands compared with those on the basement complex soils. Available P was moderately high in soils of the two parent materials (9 - 16 mg/kg and 10 - 15 mg/kg, respectively) and considered adequate for crop production, when compared with critical values recommended for most tropical crops. Effective Cation Exchange Capacity (ECEC) for soils from both parent materials were low. Soil micronutrients were in this order $Mn^{2+}>Fe^{2+}>Cu^{2+}>Zn^{2+}$ and $Fe^{2+}>Zn^{2+}>Mn^{2+}>Cu^{2+}$ in the Basement complex and Coastal plain soils respectively. Soil pH has high positive significant correlation with soil organic matter, exchangeable calcium, ECEC, copper, Zinc (r= 0.9572, 0.7769, 0.7878, 0.7641 and 0.8434, respectively in Basement complex soils while in Coastal plain soils, Total nitrogen content has high positive significant correlation with available P and base saturation (r= 0.8720** and 0.7514**, respectively). The study concluded that physical and chemical properties of soils derived from different parent materials differ and are important to determine the best land use.*

Keywords: *Basement complex, Coastal plain soils, Upper slope, Micronutrients and cations*

INTRODUCTION

Different soils have varying potential to support different land use types. The productivity of a soil depends largely on its physical and chemical properties. These properties are as a result of the interaction among the five soil forming factors, namely, parent material, living organism, climate, relief and time (Esu, 1999). Where the relative influence of these factors differs, this will give rise to different kinds of soils, with different productivity potential. Therefore, in order to derive the maximum benefit from a soil, it is necessary to know its physical and chemical properties. Such information will enable the user to manage the soil resources in such a way to derive maximum yield and performance from the land.

Parent material (PM) is defined as the unconsolidated, chemically weathered mineral or organic matter from which the A and B horizons (Solum) of soils may have developed by pedogenic processes (Brady and Weil, 2008). Parent material are considered as an important soil forming factors exerting a strong force that produces changes in soil properties (Esu, 1999). The effects of the other factors of soil formation such as climate (temperature and precipitation) coming Organisms (Plants and animals), relief (topography) and time are considered to be uniform in the study areas. The only variable under consideration is the soil parent material. The influence of parent materials on soil has been studied in several parts of the world and various observations highlighted. Soil physical and chemical properties are important characteristics used to determine the texture and the fertility content of any soil which are of extreme important for crop production, project planning and design because they form the basis for many of the more costly operations that are required in project development (Law-Ogbomo and Nwachokor, 2010). Natural resources including soils cannot be properly managed without proper understanding of their characteristics (Idoga *et al*., 2005). Influence of parent materials on soil properties must be studied in order to enhance efficient agricultural use and management.

Most farmers in Southeastern Nigeria have regarded the soils to be the same in every respect simply because they are all in the same geographical location. The present study is intended to critically examine the physical and chemical properties of the soils derived from two parent materials. It is hoped that such information will enable potential users to appreciate the uniqueness of soils derived from these soil parent materials, so that they can use them appropriately to derive maximum productivity.

MATERIALS AND METHODS

Description of the study area

The study areas are underlain by rocks of Basement Complex of the granite gneiss in parry road University of Ibadan, Ibadan Oyo state and coastal plain sand parent material (CPS) in Noforija, Epe, Lagos State with a coordinate of 7° 27′ 05.5′′ N, 3° 53′ 20.5′′ E and 6° 63′ 47.6′′ N, Longitude 3° 99′ 86.3′′ E, respectively. The climate is humid tropical, characterized by distinct rainy and dry seasons. As a result of cultivation, the vegetation of the areas consists of mixture of bush re-growth, arable crop farms and tree crop plantations.

Soil Sampling and Laboratory Analyses

A total of four profile pits were established at the two locations comprises of one at the upper and middle slope in both parry and Epe study area. Genetic surface horizons alone were sampled. A total of 20 core and bulk samples were collected using cores and spade respectively and preserved in boxes and sampling bags for laboratory analysis. The samples were processed and used for the following analysis.

The particle size distribution analysis was determined using the hydrometer method described by Gee and Or (2002). Bulk density was determined using core sample method described by Grossman and Reinsch (2002). Soil pH was determined in water and in 1N potassium chloride (KCl) solution using the method described by Burt (2004). Soil organic matter was determined using the chromic acid digestion method (Blakemore *et al.,* 1987). Total Nitrogen was determined by Kjeldahl method as was described by Burt (2004). Exchangeable cations were determined using the Ammonium ion displacement method (Udo and Ogunwale (1986). Exchangeable acidity was determined using the KCl extraction method as described by Blakemore *et al.* (1987).

Statistical Analyses

The data collected were subjected to descriptive statistic and the relationships between the distribution and variability of soil properties of two parent materials were evaluated with correlation analysis using Genstat 4th discovery edition 2019.

RESULTS AND DISCUSSIONS

Physical properties of the study areas

The physical properties of the soils are shown in Table 1 and 2. The sand content of parry upper slope profile pit were between 552 g/kg and 842 g/kg with the topsoil having the highest while the clay content ranged from 133 g/kg to 342 g/kg with the topsoil having the least and the silt content were between 25 g/kg and 265 g/kg. The silt content was generally low which correspond with the findings of Esu *et al.* (2008) who recognized that soils formed from basement complex in the humid tropical lowlands of Southwestern Nigeria have low silt content. The silt: clay ratio was between 0.16 and 1.24 while the textural class were sand clay loam except the topsoil which was loamy sand as indicated in table 1.

The sand content of Epe upper slope profile pit were between 778 g/kg and 938 g/kg with the topsoil having the highest while the clay content ranged from 48 g/kg to 148 g/kg with the topsoil having the highest which generally decreases down the profile depth and the silt content were between 14 g/kg and 74 g/kg which also reduces down the profile depth. The silt: clay ratio was between 0.29 and 0.69 while the textural class were between sand and loamy sand. Sand content had the higher mean value of 862 g/kg in coastal plain sand in the upper slope pits than that of basement complex mean value of 654 g/kg. Clay content had the higher mean value of 237 g/kg in the basement complex parent material than that of coastal plain sand mean value which was 92 g/kg. Same trend was observed in silt content with the higher mean value of 109 g/kg obtained for basement complex rocks and the least mean value of 46 g/kg for coastal plain sand. Generally, the two parent materials had silt: clay ratio less than unity, indicating moderate to highly weathered soils vulnerable to destruction and may be difficult for mechanized farming involving heavy earth moving implements. Bulk density of the basement complex ranges from 1.47 mg/m^3 to 1.52 mg/m^3 with a mean of 1.52 mg/m^3which was higher than that of coastal plain sand of a mean of 1.46 mg/m^3 which values ranges from 1.41 $mg/m^3$to 1.50 mg/m^3.

Table .1: Physical properties of the upper slope of the two parent materials of the study areas

Depth	SAND (g/kg)	CLAY (g/kg)	SILT (g/kg)	TC	SILT/CLAY	Bd (mg/m^3)
			PARRY 1 (Basement Complex)			
0-20	842	133	25	LS	0.19	1.47
20-40	752	213	35	SCL	0.16	1.53
40-60	522	213	265	SCL	1.24	1.53
60-80	602	283	115	SCL	0.41	1.54
80-100	552	342	105	SCL	0.31	1.52
Mean	654	237	109		0.46	1.52
SD	137.4	79.2	96.1		0.5	0.03
			EPE 1 (Coastal Plain Sands)			
0-20	778	148	74	SL	0.50	1.41
20-40	818	108	74	LS	0.69	1.45
40-60	898	68	34	S	0.50	1.46
60-80	878	88	34	LS	0.39	1.48
80-100	938	48	14	S	0.29	1.50
Mean	862	92	46		0.47	1.46
SD ±	63.9	±38.5	26.8		0.1	0.03

TC= Textural Class, S= Sand, SL= Sandy Loam, SC= Sandy Clay, SCL= Sandy Clay Loam, LS= Loamy Sand, Bb= Bulk density

These bulk density values are within the range of 1.0 to 1.7 mg/m^3 by Wild (1993) as ideal for agronomic activities for most mineral soils and permit easy penetration of most adventitious roots (Amalu, 2016). Generally, the bulk density increases as the profile depth increases in the two profiles of the upper slope.

The sand content of Parry middle slope profile pit was between 542 g/kg and 852 g/kg with the second horizon having the highest while the clay content ranged from 123 g/kg to 373 g/kg with the least horizon having the highest values and the silt content were between 25 g/kg and 115 g/kg. The silt: clay ratio was between 0.15 and 0.37 while the textural class were between sandy clay and sand clay loam as indicated in table 4.2.

The sand content of Epe middle slope profile pit were between 778 g/kg and 938 g/kg with the third and fourth horizons having the highest while the clay content ranged from 48 g/kg to 168 g/kg with the topsoil having the highest which generally reduces down the profile depth and the silt content were between 14 g/kg and 94 g/kg. The silt: clay ratio was between 0.29 and 0.87 while the textural class were between sand and sandy loam.

Sand content had the higher mean value of 870 g/kg in coastal plain sand in the middle slope pits than that of basement complex mean value of 722 g/kg. Clay content had the higher mean value of 221 g/kg in the basement complex parent material than that of coastal plain sand mean value which was 88 g/kg. Same trend was observed in silt content with the higher mean value of 54 g/kg obtained for basement complex rocks and the least mean value of 42 g/kg for coastal plain sand. Generally, the two parent materials had silt: clay ratio less than unity, indicating moderate to highly weathered soils vulnerable to destruction and may be difficult for mechanized farming involving heavy earth moving implements. Bulk density of the basement complex of middle slope ranges from 1.47 mg/m^3 to 1.52 mg/m^3 with a mean of 1.50 mg/m^{3}which was higher than that of coastal plain sand of a mean of 1.45 mg/m^3 which values ranges from 1.41 mg/m^{3}to 1.51 mg/m^3. All the bulk density increases with depth as a result of decrease in cultivation and organic matter as depth increases as observed by Eyong *et al*., 2008. The bulk densities values showed mechanical resistance to root penetration, decrease in air filled porosity and permeability.

Table 2: Physical properties of the middle slope of the two parent materials of the study areas

Depth	SAND (g/kg)	CLAY (g/kg)	SILT (g/kg)	TC	SILT: CLAY	Bd (mg/m^3)
			PARRY 2			
0-20	812	163	25	SL	0.15	1.47
20-40	852	123	25	LS	0.20	1.49
40-60	832	133	35	LS	0.26	1.50
60-80	572	313	115	SCL	0.37	1.50
80-100	542	373	85	SC	0.23	1.52
Means	722	221	57		0.24	1.50
SD	155.7	114.3	40.9		0.08	0.02
			EPE 2			
0-20	778	168	54	SL	0.32	1.41
20-40	798	108	94	SL	0.87	1.41
40-60	938	48	14	S	0.29	1.45
60-80	938	48	14	S	0.29	1.49
80-100	898	68	34	S	0.50	1.51
Means	870	88	42		0.46	1.45
SD	±76.9	±51.0	±33.5		±0.2	±0.05

TC= Textural Class, S= Sand, SL= Sandy Loam, SC= Sandy Clay, SCL= Sandy Clay Loam, LS= Loamy Sand, Bd= Bulk density

Chemical properties of the study areas

The results of the chemical properties of the soils are shown in the Tables 3 and 4. The values of the pH (H_2O) ranged from 5.4 to 5.8 with an average of 5.5 which was slightly acidic in the upper slope in basement complex and were between 4.5 and 4.7 with an average of 4.6 which was strongly acidic in the coastal plain sand upper slope using Myers, (2010) acidity scale as shown in the table 3. The values of the pH (H_2O) were between 5.7 and 6.2 with an average of 5.8 which was slightly acidic in the middle slope in basement complex and were between 4.4 and 4.6 with an average of 4.5 which was strongly acidic in the coastal plain sand middle slope using Myers, (2010) acidity scale as shown in the Table 4.

The organic matter content of the basement complex soil of the upper slope ranges between 12.10 and 30.62 g/kg with a mean of 19.51 g/kg while that of coastal plain sand soil of the upper slope were lower and were between 5.67 and 12.47 g/kg with an average of 10.01 g/kg as shown in table 3. Generally organic matter was considered to be below the critical level in all the soils content of these nutrients might be attributed to the iso-hyperthermic temperatures from solar radiation and constant bush burning according to Manjoka *et al.*, (2007). This has direct relationship as both organic carbon and nitrogen decreases with depth in soils because litter fall is on the soil surface as observed by Manjoka *et al.*, (2007).

The organic matter content of the basement complex soil of the middle slope ranges between 20.41 and 54.81 g/kg with a mean of 30.41 g/kg while that of coastal plain sand soil of the middle slope were significantly lower and were between 10.21 and 16.25 g/kg with an average of 13.30 g/kg as shown in table 4. Generally, the organic matter content of middle slope profile of basement complex was above the critical limit while that of coastal plain sand was below the critical limit Obigbesan, (2001).

Table 3: Chemical properties of the upper slope of the two parent materials of the study area

	pH	SOM	TN	Av.P	Ex.A	Ca	Mg	K	Na	ECEC	BS	Mn	Fe	Cu	Zn
		g/kg		mg/kg			cmol/kg				g/kg		mg/kg		
	PARRY 1 (Basement complex)														
0-20	5.8	30.62	1.40	15	1.9	0.22	0.65	0.21	0.31	3.29	422.0	346	263	10.3	8.55
20-40	5.6	25.33	2.52	15	1.4	0.14	0.79	0.21	0.24	2.78	496.6	358	261	7.6	5.11
40-60	5.4	13.61	0.28	10	0.7	0.29	1.09	0.36	0.24	2.68	738.5	261	159	5.8	4.44
60-80	5.5	12.10	0.28	9	1.0	0.24	1.28	0.38	0.26	3.16	683.5	243	127	6.2	4.94
80-100	5.4	15.88	0.28	9	1.0	0.24	1.19	0.43	0.26	3.13	680.9	245	145	2.2	3.8
Mean	5.6	19.51	0.95	12	1.2	0.23	1.00	0.32	0.26	3.01	604.3	290.6	191	6.42	5.36
SD	0.2	8.07	1.00	3	0.46	0.05	0.27	0.10	0.03	0.26	13.69	56.64	65.80	2.94	1.85
	EPE 1 (Coastal Plain Sands)														
0-20	4.6	10.58	0.56	10	0.7	0.04	0.05	0.03	0.18	1.00	300.5	1.5	37.20	1.2	4.63
20-40	4.5	5.67	0.28	11	0.6	0.03	0.05	0.03	0.20	0.91	337.1	1.1	27.20	0.8	4.05
40-60	4.7	11.72	0.28	12	0.5	0.03	0.04	0.03	0.19	0.79	369.7	0.9	18.80	1.0	4.04
60-80	4.6	9.83	1.96	12	0.5	0.03	0.04	0.05	0.20	0.83	394.8	1.3	27.30	0.4	3.90
80-100	4.7	12.47	3.36	13	0.3	0.04	0.04	0.03	0.20	0.61	508.7	0.9	42.60	0.5	3.64
Mean	4.6	10.05	1.29	12	0.52	0.03	0.04	0.03	0.19	0.83	382.2	1.14	30.62	0.78	4.05
SD	0.1	5.03	1.35	1.14	5.03	6.14	0.01	0.01	0.01	20.4	7.91	16.74	9.34	1.76	0.36

Table 4: Chemical properties of the middle slope of the two parent materials of the study areas

	pH	SOM	TN	Av.P	Ex.A	Ca	Mg	K	Na	ECEC	BS	Mn	Fe	Cu	Zn
		g/kg		mg/kg	cmol/kg						g/kg	mg/kg			
	PARRY 2														
0-20	6.2	54.81	0.28	16	1.8	1.08	1.17	0.46	0.25	4.75	621.2	415	283	9.6	12.0
20-40	5.7	25.70	0.56	12	1.1	0.15	0.98	0.38	0.26	2.88	618.2	396	275	8.3	4.98
40-60	5.7	26.84	0.28	9	0.8	0.26	1.08	0.38	0.29	2.81	715.8	292	171	6.7	3.86
60-80	5.7	24.57	2.52	9	0.5	0.32	1.12	0.46	0.35	2.76	818.7	251	135	7.3	4.37
80-100	5.7	20.41	1.12	10	1.1	0.36	1.19	0.49	0.30	3.44	680.1	245	140	6.8	4.41
Mean	5.8	30.47	0.95	11	1.06	0.43	1.11	0.43	0.29	3.33	690.8	319.8	200.8	7.7	5.9
SD	0.2	18.09	0.94	6.01	18.03	0.44	0.36	0.09	1.70	35.09	1427.5	95.8	112.7	2.6	3.4
	EPE 2														
0-20	4.5	13.61	0.28	11	0.7	0.02	0.05	0.04	0.19	0.99	295.6	1.4	33.7	0.6	4.05
20-40	4.5	15.12	0.28	11	0.7	0.02	0.04	0.05	0.20	1.01	309.0	1.2	33.1	0.8	4.34
40-60	4.4	10.21	1.96	13	0.5	0.03	0.03	0.03	0.21	0.80	374.7	1.3	19.3	0.6	3.65
60-80	4.6	11.34	4.76	15	0.5	0.03	0.04	0.05	0.22	0.83	400.5	1.4	21.3	0.5	4.12
80-100	4.5	16.25	0.28	12	0.7	0.03	0.04	0.04	0.22	1.02	316.0	1.8	31.6	0.5	3.77
Mean	4.5	13.30	1.51	12	0.6	0.03	0.04	0.04	0.21	0.93	339.2	1.42	27.8	0.6	3.99
SD	0.1	6.58	1.96	6.6	6.9	0.01	0.01	0.01	0.01	17.65	45.7	14.65	6.93	1.8	0.28

Total Nitrogen

Results indicated that total N were between 0.28 and 2.52 g/kg with the mean of 0.95 g/kg in the first pit of basement complex soil while that of coastal plain sand were between 0.28 and 3.36 g/kg with an average of 1.29 g/kg as shown in table 3. Generally, all the horizons in the two profiles were below critical limit of 1.5 g/kg except in the second horizon of the basement complex soil.

Total N were between 0.28 and 2.52 g/kg with the mean of 0.95 g/kg in the second pit of basement complex soil while that of coastal plain sand were between 0.28 and 4.76 g/kg with an average of 1.51 g/kg as shown in table 4. Using the average, coastal plain sand total N was above the critical limit while that of basement complex was below the critical limit (Obigbesan, 2001).

Available P

The available phosphorus of the soil in the basement complex upper slope were between 9 mg/kg and 15 mg/kg with an average of 12 mg/kg while that of coastal plain sand were between 10 mg/kg and 13 mg/kg with a mean of also 12 mg/kg as shown in table 3. Available P was generally above the critical limit in all the profiles and considered adequate for crop production, when compared with critical values recommended for most tropical crops (8-15 mg/kg) (Obigbesan, 2001). The available P of the basement complex soil in the middle slope were between 9 mg/kg and 16 mg/kg with an average of 11 mg/kg while that of coastal plain sand were between 11 mg/kg and 15 mg/kg with a mean of also 12 mg/kg as shown in table 4. Likewise, the available P was generally above the critical limit in all the profiles and considered adequate for crop production, when compared with critical values recommended for most tropical crops (8-15 mg/kg) (Obigbesan, 2001).

Exchangeable acidity

The exchangeable acidity of soil in the upper slope of the basement complex parent material ranges from 0.7 to 1.9 cmol/kg with a mean of 1.2 cmol/kg while that of the coastal plain sand parent material were somehow lower than basement complex and ranges from 0.3 to 0.7

cmol/kg with an average of 0.5 cmol/kg as shown in table 3. The exchangeable acidity of soil in the middle slope of the basement complex parent material ranges from 0.5 to 1.8 cmol/kg with a mean of 1.06 cmol/kg while that of the coastal plain sand parent material were somehow lower than basement complex and ranges from 0.5 to 0.7 cmol/kg with an average of 0.6 cmol/kg as shown in table 4.

Exchangeable Bases

The Ca^{2+}, Mg^{2+}, K^+ and Na^+ contents of the soil in the upper slope profile pit of basement complex parent material ranges from 0.14 to 0.29 cmol/kg with mean of 0.23cmol/kg, 0.65 to 1.28 cmol/kg with mean 1.00 cmol/kg, 0.21 to 0.43 cmol/kg with mean 0.32 cmol/kg and 0.24 to 0.31 cmol/kg with mean 0.26 cmol/kg, respectively as shown in table 4.3. The effective cation exchange capacity were between 2.68 and 3.29 cmol/kg with a mean of 3.01 cmol/kg while the base saturation were between 422.0 and 738.5 g/kg with a mean of 604.3. The Ca^{2+}, Mg^{2+}, K^+ and Na^+ contents of the soil in the upper slope profile pit of coastal plain sand parent material ranges from 0.03 to 0.04cmol/kg with mean of 0.03cmol/kg, 0.04 to 0.05cmol/kg with mean 0.04cmol/kg,0.04 to 0.05 cmol/kg with mean 0.03 cmol/kg and 0.18 to 0.20cmol/kg with mean 0.19cmol/kg, respectively. Sodium (Na) was slightly higher than potassium (K), indicating the very low levels of potassium (K) in these soils of coastal plain sand. The effective cation exchange capacity were between 0.61 and 1.00cmol/kg with a mean of 0.83cmol/kg while the base saturation were between 300.5 and 508.7 g/kg with a mean of 382.2. The calcium, magnesium and potassium contents were generally above the critical level in the basement complex soil while they were below, in the coastal sand soil using the critical limit of Enwezor *et al.,* 990.

The Ca^{2+}, Mg^{2+}, K^+ and Na^+ contents of the soil in the middle slope profile pit of basement complex parent material ranges from 0.15 to 1.08 cmol/kg with mean of 0.43cmol/kg, 0.98 to 1.19 cmol/kg with mean 1.11 cmol/kg, 0.38 to 0.49 cmol/kg with mean 0.43 cmol/kg and 0.25 to 0.35 cmol/kg with mean 0.29 cmol/kg, respectively as shown in table.4. The effective cation exchange capacity were between 2.76 and 4.75 cmol/kg with a mean of 3.33 cmol/kg while the base saturation were between 618.2 and 818.7 g/kg with a mean of 690.8. The Ca^{2+}, Mg^{2+}, K^+ and Na^+ contents of the soil in the middle slope profile pit of coastal plain sand parent material ranges from 0.02 to 0.03 cmol/kg with mean of 0.03cmol/kg, 0.03 to 0.05 cmol/kg with mean 0.04 cmol/kg, 0.03 to 0.05 cmol/kg with mean 0.04 cmol/kg and 0.19 to 0.22cmol/kg with mean 0.21 cmol/kg, respectively. Sodium (Na) was slightly higher than potassium (K), indicating the very low levels of potassium (K) in these soils of coastal plain sand. The effective cation exchange capacity was between 0.80 and 1.02cmol/kg with a mean of 0.93 cmol/kg while the base saturation was between 295.6 and 400.5 g/kg with a mean of 339.2. Magnesium and potassium contents were generally above the critical level in the basement complex soil while they were below, in the coastal sand soil using the critical limit of Enwezor *et al.*,1990. Soils derived from coastal plain sand was higher than the critical level of 0.02 cmol/kg sodium in soils as reported by Amalu, (2016). The above values certainly would not constitute a problem for growth and development of most crops, particularly, as the exchangeable sodium percentage saturation of the exchange complex hardly reached the generally accepted 15%, at which deleterious effects begin for most crops. According to Amalu (2016), most soils contain sufficient sodium for crop growth and responses to sodium fertilizers are confined to crops with definite sodium requirements such as sugar beet and Marigolds.

The ECEC was generally low. The low ECEC can be attributed to the fact that soils in this region are strongly weathered, have little or no content of weathered materials in sand and silt fractions and have predominantly kaolinite in their clay fraction. This is in line with Eyong, *et al*. (2008) that stated that at ECEC < 15 cmol/kg, the soils will suffer from significant cation losses through leaching.

Micronutrient

The micronutrient contents of the soil in all the profiles could be classified in order of their abundance in basement complex soil as: $Mn^{2+}>Fe^{2+}>Cu^{2+}>Zn^{2+}$ with a mean of 290.6, 191.0, 6.4 and 5.4 mg/kg and 319.8, 200.8, 7.7 and 5.9 mg/kg, in profile 1 and 2, respectively and have an order of abundance in coastal plain sand soil as: $Fe^{2+}>Zn^{2+}>Mn^{2+}>Cu^{2+}$ with an average of 30.6, 4.1, 1.1 and 0.8 mg/kg and 27.8, 4.0, 1.4 and 0.6 mg/kg in profile 1 and 2, respectively.

Correlation between physical properties of basement complex parent material

Sand content had high significant ($p < 0.01$) negative correlation with clay and silt content with r of -0.8743 and -0.7960, respectively as shown in table 4.5. There was also negative significant ($p < 0.05$) correlation with sand and bulk density = r -0.6980). This result indicates that there was a strong inverse relationship between sand and silt, sand and clay, likewise sand and bulk density, suggesting that an increase in sand leads to decrease in silt, clay and bulk density. There was high positive significant correlation between silt and silt: clay ratio which correspond to finding of Abam and Orji, (2019)

Table 4.5: Correlation between physical properties of basement complex parent material

	Sand	Clay	Silt	Silt: Clay
Clay	-0.8743**			
Silt	-0.7960**	0.4020		
Silt: Clay	-0.5568	0.0851	0.9441**	
Bulk Density	-0.6980*	0.5864	0.5854	0.4423

* Significant at the probability level of 5%, ** Significant at the probability level of 1%

Correlation between physical properties of coastal plain sand parent material

Sand content had high significant ($p < 0.01$) negative correlation with clay and silt content with Correlation coefficient r) of -0.9582 and -0.9049, respectively as shown in table 4.6. There was also high positive significant correlation with sand and bulk density (r = 0.8242). This result indicates that there was a strong inverse relationship between sand and silt, sand and clay, likewise strong relationship between sand and bulk density, suggesting that an increase in sand leads to decrease in silt and clay. Clay had high positive significant correlation with silt and high negative significant correlation with bulk density (r = 0.7453 and -0.7910, respectively). Silt content have high positive significant correlation with silt: clay ratio and high negative significant correlation with bulk density which was in line with finding of Abam and Orji (2019).

Table 6: Correlation between physical properties of coastal plain sand parent material

	Sand	Clay	Silt	Silt: Clay
CLAY	-0.9582**			
SILT	-0.9049**	0.7453**		
SILT: CLAY	-0.5593	0.3053	0.8491**	
Bulk Density	0.8242**	-0.7910**	-0.7440**	-0.4145

* Significant at the probability level of 5%, ** Significant at the probability level of 1%

Correlation between chemical properties of basement complex parent material

Soil pH has high positive significant correlation with soil organic matter, exchangeable calcium, effective cation exchange capacity, copper, Zinc (r = 0.9572, 0.7769, 0.7878, 0.7641 and 0.8434, respectively) as shown in the table 7. As the soil pH also increases, available P and manganese content of the soil also increases at $p < 0.05$ (r = 0.6553* and 0.6945*, respectively). Abam and Orji, (2019). Soil organic matter had high positive relationship with exchangeable calcium content of the soil, effective cation exchange capacity, manganese and Zinc contents of the soil (r = 0.7983**, 0.7764**, 0.7759** and 0.8696**, respectively). Likewise, as the soil organic matter also increases, available P, exchangeable acidity, copper and iron contents of the soil also increases at $p < 0.05$ (r = 0.7352*, 0.6465*, 0.6767* and 0.7064*, respectively). Abam and Orji, (2019).

Available P has high positive significant correlation with exchangeable acidity, copper, iron, manganese and Zinc contents of the soil (r = 0.8869**,0.7292**, 0.9115**, 0.8585** and 0.8036**, respectively). Available P also had an inverse relationship with base saturation (r = -0.8029**) and exchangeable magnesium content (r = -0.6395*). Abam and Orji, (2019).

Exchangeable acidity of the soil had positive significant correlation with effective cation exchange capacity (r = 0.6597*) and high positive significant correlation with iron and Zinc contents of the soil (r = 0.7674** and 0.8146**, respectively). It also have inverse relationship with base saturation (r = -0.8704**). Abam and Orji, (2019).

Exchangeable calcium was positively and highly significant correlated with effective cation exchange capacity and Zinc micronutrient (= 0.9084**and 0.7897**, respectively). Exchangeable magnesium was positively and highly significant correlated with exchangeable potassium and base saturation (r = 0.8672** and 0.7992**, respectively), it also has inverse relationship with iron (r = -0.6574*). Exchangeable sodium and base saturation were positively and highly significantly correlated (r = 0.2404**). Effective cation exchange capacity had positive and highly significant correlation with zinc (r = 0.8571**). Base saturation had an inverse relationship with iron (r = -0.7460**. Abam and Orji, (2019).

Table 7: Correlation between chemical properties of basement complex parent material

	pH	SOM	TN	Av.P	Ex.A	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	ECEC	BS	Cu^{2+}	Fe^{2+}	Mn^{2+}
SOM	0.9572**													
TN	0.0470	0.0250												
AV.P	0.6553*	0.7352*	0.2409											
Ex.A	0.6153	0.6465*	0.0060	0.8869**										
Ca^{2+}	0.7769**	0.7983**	-0.2657	0.4117	0.3980									
Mg^{2+}	-0.1294	-0.1925	-0.4961	-0.6395*	-0.5251	0.3382								
K^{+}	0.1470	0.0569	-0.3394	-0.5132	-0.4407	0.4600	0.8672**							
Na	0.1726	0.0100	0.4723	-0.2753	-0.2260	-0.1168	-0.0737	0.2156						
ECEC	0.7878**	0.7764**	-0.2974	0.5312	0.6597*	0.9084**	0.2171	0.3302	-0.1468					
BS	-0.2700	-0.3180	-0.1969	-0.8029**	-0.8704**	0.0832	0.7992**	0.7775	0.2404**	-0.2095				
Cu^{2+}	0.7641**	0.6767*	0.2913	0.7292**	0.6117	0.3292	-0.5520	-0.3396	0.2066	0.3753	-0.5211			
Fe^{2+}	0.6144	0.7064*	0.1104	0.9115**	0.7674**	0.2755	-0.6574*	-0.4925	-0.3109	0.3797	-0.7460**	0.7075*		
Mn^{2+}	0.6945*	0.7759**	0.0313	0.8585**	0.6984*	0.3870	-0.5069	-0.3418	-0.3194	0.4500	-0.6131	0.7085*	0.9768**	
Zn^{2+}	0.8434**	0.8696**	-0.0944	0.8036**	0.8146**	0.7897**	-0.2168	-0.0876	-0.1211	0.8571**	-0.4774	0.6895*	0.6746*	0.6965*

**significant at the probability level of 1%, *significant at the probability level of 5%

Coastal plain sand parent material

Total nitrogen content has high positive significant correlation with available P and base saturation (r= 0.8720** and 0.7514**, respectively) as shown in table 8. Total nitrogen content also has inverse relationship with exchangeable acidity and effective cation exchange capacity (r = -0.7025* and -0.6521*, respectively Ng *et al*., 2022). Abam and Orji, (2019).

Available P has positive significant correlation with exchangeable sodium and base saturation of the soil (r = 0.7327* and 0.6554*, respectively). Available P also have inverse relationship with exchangeable acidity (r =-0.6462*) Abam and Orji, (2019).

Exchangeable acidity of the soil had high positive significant correlation with effective cation exchange capacity (r = 0.9942**) and it also have high negative significant correlation with base saturation (r =-0.9749**).

Exchangeable sodium had negative significant correlation with copper contents of micronutrients of the soil (r = -0.7055*) Azeez *et al*., 2021

. Effective cation exchange capacity had high negative significant correlated with base saturation (r = -0.9556**) and positive significant correlation with contents manganese content of micronutrients of the soil (r = 0.6916*). Copper contents of micronutrients of the soil has positive relationship with zinc (r= 0.7398**) Azeez *et al*., 2021.

Table 8: Correlation between chemical properties of coastal plain sand parent material

	pH	SOM	TN	Av.P	Ex.A	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	ECEC	BS	Cu^{2+}	Fe^{2+}	Mn^{2+}
SOM	-0.0062													
TN	0.3039	-0.1166												
AV. P	0.1627	0.0300	0.8720**											
Ex. A	-0.5331	0.2810	-0.7025*	-0.6462*										
Ca^{2+}	0.5175	-0.3173	0.3523	0.1179	-0.4984									
Mg^{2+}	0.1455	-0.2185	-0.4023	-0.6211	0.4729	0.0000								
K^{+}	-0.1001	0.3648	0.2556	0.2565	0.2170	-0.5441	-0.1147							
Na	-0.3218	0.2090	0.4868	0.7327*	-0.1743	-0.1295	-0.5735	0.3947						
ECEC	-0.5359	0.2818	-0.6521*	-0.6022	0.9942**	-0.4933	0.4559	0.2918	-0.1042					
BS	0.5555	-0.1602	0.7514**	0.6554*	-0.9749**	0.5247	-0.4401	-0.1211	0.2401	-0.9556**				
Cu^{2+}	0.1618	-0.1878	-0.5279	-0.6142	0.3799	0.1954	0.4258	-0.4821	-0.7055*	0.3194	-0.4589			
Fe^{2+}	0.2045	0.3171	-0.1046	-0.4239	0.0919	0.2744	0.4535	-0.0763	-0.3392	0.0895	0.0727	0.0331		
Mn^{2+}	-0.4952	0.3737	-0.1286	-0.0860	0.6487*	-0.1216	0.0897	0.3353	0.3529	0.6916*	-0.5604	-0.1616	0.0653	
Zn^{2+}	0.0923	-0.0489	-0.3111	-0.5257	0.6011	-0.0653	0.5975	0.1531	-0.5465	0.5927	-0.5920	0.7398**	0.1564	0.1532

**significant at the probability level of 1%, * significant at the probability level of 5%

CONCLUSION

This project research was conducted to determine the comparative analysis of physical and chemical properties of soils on basement complex and coastal plain sand parent materials in South Western Nigeria. A total of four profile pits were constructed in two locations along a *toposequence* taking in to cognizant upper and middle slope. Each profile was sampled on the basis of identified horizons starting from the least horizon to avoid contamination.

The soils were air-dried and subjected to routine laboratory physical and chemical analyses using standard laboratory procedure. The data was then subjected to descriptive statistic using Genstat 4th discovery edition and the relationships among the soil properties was done using correlation analysis.

Results obtained shows that sand separate had the higher mean value in coastal plain sand than that of basement complex along the toposequence. Clay separate had the higher mean value in basement complex than that of coastal plain sand. Same trend was observed in silt content. The textural class were between sand clay loam and sandy clay in basement complex while it was between sand and sandy loam in coastal sand. Bulk density of the basement complex was higher than that of coastal sand along the toposequence which increases with depth of pits as a result of decrease in cultivation as depth increases as observed by Eyong *et al*., 2008.

The soil pH was slightly acidic in the basement complex and strongly acidic in coastal plain sand. Soil organic matter of basement complex was generally above the critical limit while that of coastal plain sand was generally low. Using the mean, coastal plain sand total N was above the critical limit while that of basement complex was not. The available P was generally above the critical limit in the two parent materials and considered adequate for crop production, when compared with critical values recommended for most tropical crops. The ECEC was generally low in the two parent materials. The micronutrient contents of the soil in all the profiles could be classified in order of their abundance in basement complex soil was $Mn^{2+} > Fe^{2+} > Cu^{2+} > Zn^{2+}$ while that of coastal plain sand soil was $Fe^{2+} > Zn^{2+} > Mn^{2+} > Cu^{2+}$.

Sand content had inverse relationship with clay, silt and bulk density which in basement complex likewise in coastal plain sand except with bulk density which have positive relationship with sand.

The study concluded that physical and chemical properties of soils derived from different parent materials differ and are important to determine the best land use. Therefore, their potential to support various types of land use are expected to differ from different parent materials. This means that if their productivity must be enhanced and these maximized differences should be appreciated and taken into consideration in the planning and management of the various potential use types.

REFERENCE

Abam, P. O. and Orji, O. A. (2019). Morphological and physio-chemical properties of soils formed from diverse parent materials in Cross River State, Nigeria. *Journal of Applied Geology and Geop*hysics. 7 (1): 1-7

Amalu, U. C. (2016) Properties and Fertility status of Soils supporting Pineapple (*Ananascomosus* L. [Merr.] in select – Communities of Cross River State, South – East Nigeria. *Nigeria Journal of Crop Science*. 3 (1): 78 – 91

Azeez, M.O., Adesanwo, O.O and Adepetu, J. A. (2021). Effects of Copper fungicides Spray on Nutrient Contents in Soils of Cocoa Growing Areas of Southwestern Nigeria. *Tanzania Journal of Science* 47(5): 1-14

Blakemore, L. C., P. L. Searle, and B. K. Daly. 1987. Methods for Chemical Analysis of Soils. NZ Soil Bureau Sci. Rept. 80.

Boul, S. W., F. D. Hole and R. J McCraken. (1997). Soil genesis and Classification 4th ed. Iowa State University Press Ames, ISBN 0-8138-2873-2 pp

Brady, N. C. and Weil, R. R (2002). Elements of the Nature and Properties of Soils. Prentice Hall, New Jersey.

Brady, N.C. and Weil, R.R. (2008) The nature and properties of soil, 14 ed. Prentice-Hall, Upper Saddle River, New Jersey.

Burt, R. (2011) Soil Survey Investigations Report No. 45 Version 2.0 February 2011 Compiled and Edited by Rebecca

Burt United States Department of Agriculture Natural Resources Conservation Service National Soil Survey Center Lincoln, Nebraska

Day, P. R. (1953). Experimental confirmation of hydrometer theory. *Soil Sci.* 75:181.

Enwezor, W. O; Ohiri, A. C., Opuwaribo, E E and Udo, E. J. (1990). Literature review on soil fertility investigations in Nigeria. *Federal Ministry of Agriculture and Natural Resources, Lagos.* 460 pp

Esu I. E, Akpan-Idiok A. U and Eyong M. O (2008). Characterisatioon and Classification of soils along a typical Hillslope in Afikpo Area of Ebonyi state, Nigeria. *Nigerian Journal of Soil and Environment* 8: 1-6

Esu, I. E. (2010). Soil characterization, classification and survey. HEBN Publishers Plc. Nigeria. 232pp.

Esu, I.E.(1999). Fundamentals of pedology. Stirling-Horden Publishers (Nig.) Ltd, Ibadan, Nigeria, pp: 136

Eyong, M.O., Esu, J.E. and Ogbiji, P.O. (2008). Classification and evaluation of soils under rubber (*HaveabrazilliensiMuellargo*) plantation at Nko, Cross River State of Nigeria. *Global Journal of Pure and Applied Science;* 14(1) : 9-24

Gay, Parker (2002) Mapping Geologic Structure of Basement and Role of Basement in Hydrocarbon Entrapment, Search and Discovery Article #40052pp (adapted from: AAPG Explorer (November and December, 1999)

Gee G. W and Or D. (2002) Particle size analysis. In: Methods of soil analysis. Part 4.Pyhsical methods. J.H Dane and G.C.P Topp (eds.). American society of Agronomy, Madison, WI. 2002;255-293

Grossman, R.B. and T.G. Reinsch. (2002). Bulk density and linear extensibility. p. 201-228. *In* J.H. Dane and G.C. Topp (eds.) Methods of soil analysis, Part 4. Physical methods. Soil Sci. Am. Book Series No. 5. ASA and SSSA, Madison, WI.

Idoga, S and Azagaku, D. E., (2005). Characterization and classification of soils of Janta Area, Plateau State of Nigeria. Journal of Soil Science, 15:116-122.

Law-Ogbomo, K.E and M.A. Nwachokor, 2010. Variability in Selected Soil Physico-chemical Properties of Five Soils Formed on Different Parent Materials in Southeastern Nigeria. *Journal of Agriculture and Biological Sciences* 6(1): 14-19.

Manjoka, J. Yerokun, O.R, Lungu, O.I and Munyinda, K (2007). Changes in soil organic matter and soil aggregation of a Zambian Oxisols after applying lime. *International Journal of Soil Science* 2: 190-196

Myers, RJ. One (2010) – Hundred years of pH .*Journal of Chemical Education* 87: 30 -32

Ng, J.F., Ahmed, O.H., Jalloh, M.B., Omar, L., Kwan, Y.M., Musah, A.A and Poong, K.H. (2022). Soil Nutrient Retention and pH Buffering Capacity Are Enhanced by Calciprill and Sodium Silicate. Agronomy 2022, 12, 219. https://doi.org/10.3390/ agronomy12010219 Academic Editor: Magdi

Obigbesan, G.O. (2001) Plant Mineral Nutrition in Nigeria: My Experience. In: Akoroda, M.O., Ed., *Agronomy in Nigeria*, Department of Agronomy, University of Ibadan, Ibadan, 188-194.

Ojo-Atere, J.O., Ogunwale, J.A and Oluwatosin, G.A. (2011). Fundamentals of Tropical Soil Science. Pp ISBN 13: 978—978-020-976-6.

Ritter, M.E. (2006). The Physical Environment: An Introduction to Physical Geography. Visited on October 20, 2019.

Smyth, A.J. and Montgomeny, R.F. (1962) Soils and land use in central Western Nigeria. Government Printer, Ibadan, Nigeria 265pp

Udo, E. J. and Ogunwale, J. A. (1986). Laboratory manual for analysis of soil, plant and water samples (2nd ed., p. 174). Imperial Binding Service

Wild, A (1993). Soils and the Environment: An Introduction. Cambridge University Press, Britain, 287 pp.

EDAPHIC FACTORS AND SOIL ORGANIC CARBON STORAGE POTENTIALS UNDER DIFFERENT LAND USE TYPES IN OMO BIOSPHERE RESERVES NIGERIA

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ABSTRACT

*The regulatory functions of the soil are getting attention among scientists and Soil Organic Carbon (SOC) is an important indicator of soil health. A study was carried out to investigate the SOC storage potentials under different land use types (Tectona grandis, Gmelina arborea, Acacia siamea, Pinus carrribea, and Natural forest) in Omo Biosphere Reserves Nigeria. The impact of the five important land use types on SOC and other soil properties were analyzed. Soil core samples were taken at two depths (0-10 and 10-30cm) to observe the changes in soil properties with depth. Laboratory analyses were carried out to determine the bulk density, soil pH, soil moisture, and soil organic carbon. The data obtained were analyzed using the Analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) was used to separate the means while Principal Component Analysis (PCA) was used to examine the relationship between the soil parameters. Correlation analysis was carried out to examine if a relationship exists between soil depth and different land use on soil organic content and all other soil properties. The result showed that at both depths there is no significant difference between depths in pH, soil organic carbon, and soil moisture except for bulk density. Total Soil Organic Carbon stored in soil was highest in Teak plantation (3.1), followed by Acacia (2.17), and Natural forest (0.92), and at depth SOC was high in 0-10cm depth. The maximum value of bulk density (gcm^3**)** was found high in 0-10cm at depth and was found high in Teak plantation (1.68) followed by Pinus plantation (1.67) and Acacia plantation (1.53). The distribution of moisture content showed no significant difference but the highest moisture was stored in Natural forest plantation (39.04), followed by Teak plantation (34) and Gmelina plantation (20), and the lowest in Pinus carribea plantation (10). Moisture content across depth showed that 0-10cm depth stored the highest but the 10-30cm depth () had the highest pH. Among the land use types, Teak plantation (5.84) had the highest pH, followed by Gmelina plantation (5.4) and Natural forest plantation (5.23). Results showed that SOC storage in soils can be influenced by different land use systems.*

Keywords: *Soil Organic Carbon, land use, edaphic, plantations, natural forest*

1.0 INTRODUCTION

Soil Organic Carbon (SOC) is the major terrestrial pool of carbon due to soils carbon storage potential which is generally greater than that of vegetation (Post and Kwon, 2000). Soil Organic Carbon content plays a crucial role in sustaining soil quality, crop production, and environmental quality (Bauer and Black, 1994; Robinson *et al.*, 1994) due to its effects on soil's physical, chemical, and biological properties (Sbih *et al*., 2012). Cultivation practices disturb soil's physical properties and release physically protected soil organic matter resulting in the oxidation of soil organic matter and organic carbon content (Christensen, 2001).

According to Milne (2009) Soil Organic Carbon content refers to the carbon component of the soil organic matter. Soil organic matter is all of the organic matter that is found in the soil; by definition all organic material contains carbon. Examples of soil organic matter include microbial biomass and the decomposing litter layer. Louw (2011) explains that SOC content is measured because it is a convenient way of demining the amount of organic matter found in a particular soil. Soil Organic Carbon is the basis of soil fertility, it releases nutrients for plant growth, promotes the structure, and biological and physical health of the soil, and is a buffer against harmful substances.

In contemporary times, the influence of humans and the agricultural system have been the most significant human activities that have caused massive losses of Soil Organic Carbon although exact quantities are difficult to measure. First was the use of fire which removes soil cover and leads to immediate and continuing losses of soil organic carbon. Eventually, Soil Organic Carbon can be lost as CO_2 or CH_4 emitted back into the atmosphere, eroded with soil material, or dissolved organic carbon washed into rivers and oceans.

Land use affects soil properties, Soil Organic Carbon inclusive and this may either make or mar the productive capacity of the soil and the possibility of retaining organic carbon content. Soil can be a sink or source of atmospheric carbon dioxide depending on land use management with significant losses occurring when native ecosystems are converted for other land uses such as plantation establishment, and agricultural lands (Davidson and Ackerman, 1993). There is therefore, the need to ascertain the effect of different land use types defined by planted forest species on Soil Organic Carbon hence, this study. The objective of this study is to assess Soil Organic Carbon storage potentials and its effect on selected soil properties in *Acacia siamea*, *Gmelina arborea*, *Tectona grandis*, *Pinus carribea* and natural forest.

MATERIALS AND METHODS

The study was carried out in Area J4, Ijebu-Ode which is located within Omo Biosphere Reserve, Ogun State. The Reserve is located between latitudes 6°35' to 7°05'N and longitudes 4°19' to 4°40'E in the South-west of Nigeria and covers an area of about 130,500 hectares (Ojo, 2004). The study was carried out on five different land use *Pinus carribaea*, *Nauclea diderrichii*, *Gmelina arborea*, *Acacia siamea* plantations, and Natural Forest.

Soil Sample Collection and Analysis

A total of thirty (three replicates/ per soil depth/land-use) soil samples were collected at two different soil depths namely 0-10cm and 10-30cm.with the aid of soil auger. Dry soil bulk density (gcm^3) at 105°c was estimated by wet oxidation method. Soil pH was measured in 1M KCL suspension of 1:5(soil: liquid) using a pen type digital pH meter. Soil moisture was calculated on dry weight basis and soil temperature for each depth was measured using soil thermometer. Soil analysis was done separately for each sample at each soil depth. The Soil Organic Carbon was calculated

Soc =B-S x1.995….Eqn (1)

Where

Soc = soil organic carbon

B = blank

S= sample

Data Analysis

The statistical analysis of the data was conducted using Analysis of Variance (ANOVA) on the General Linear Model of SAS software. Duncan Multiple Range Test (DMRT) was further used to separate the means that were significantly different. Principal Component Analysis was used to examine the relationship between the soil parameters and Correlation analysis was carried out to examine the relationship between soil depth and different land use on Soil Organic Carbon content and all other soil properties.

RESULTS

Table1 shows the effect of depth on soil parameters. It shows that at the depths of 0-10 and 10-30cm considered, there is no significant difference between and soil pH (5.25 and 5.27), Soil Organic Carbon (1.74 and 1.09), Moisture content (22 and 15.71), however, bulk density of 1.38 at 0-10cm depth was significantly higher than 1.25 obtained at 10-30cm depth. In the two depths, pH increases from 5.25 at surface (0-10 cm) top to 5.27 at lower 10-30 cm layer) which showed no significant difference between them. Soil Organic Carbon decreases from top to lower layer and Moisture content decreases with depth from top to lower layer and maximum change was noticed when we compare 0-10cm and 10-30cm depth. Moisture content decreases from 22.00 to 15.71 and it showed no significant difference between them. Bulk density increases were significantly higher in 0-10cm depth (1.38) than in 10-30cm (1.25).

Table 1: Effect of soil depth on soil parameters

LANDUSE	pH (H20) 1:2	SOC/%	MC/%	BD/gcm^3
0-10cm	5.25	1.74	22.00	1.38
10-30cm	5.27a	1.09a	15.71a	1.25b

Means with the same letter are not significantly different.

BD = Bulk density, SOC = Soil Organic Carbon, MC= Moisture Content

Table 2 shows the effect of land use on soil parameters. There was no significant difference among the various land uses in soil pH, except for *Pinus carribea* (4.57*)*, and the highest was recorded in *Tectona grandis* plantation, followed by *Gmelina arborea* (5.4), *Acacia siamea* (5.3), Natural Forest (5.23). The distribution of Moisture Content in the various land uses showed no significant difference among the various land use but was found high in NF (39.04), followed by Teak (34) and Gmelina (20). It was found to be lowest in *Pinus carribea*, For Bulk density, there was no significant difference between the various land use types but was highest in Teak (1.68) and was found relatively low in *Gmelina arborea* (0.73). The distribution of Soil Organic Carbon among the various land use showed no significant difference between them but was highest in Teak (3.1) and was lowest in *Pinus carribea* (0.3).

Table 2: Effect of land use on soil parameters

SPP	pH (H20) 1:2	BD/gcm^3	SOC/%	MC/%
Tectona grandis	5.84a	1.68a	3.10a	34a
Gmelina arborea	5.40a	0.73c	0.63b	20a
Acacia siamea	5.30a	1.53a	2.17a	14a
NF	5.23a	0.98b	0.92b	39.04a
Pinus carrribea	4.57b	1.67a	0.30b	10a

Means with the same letter are not significantly different.

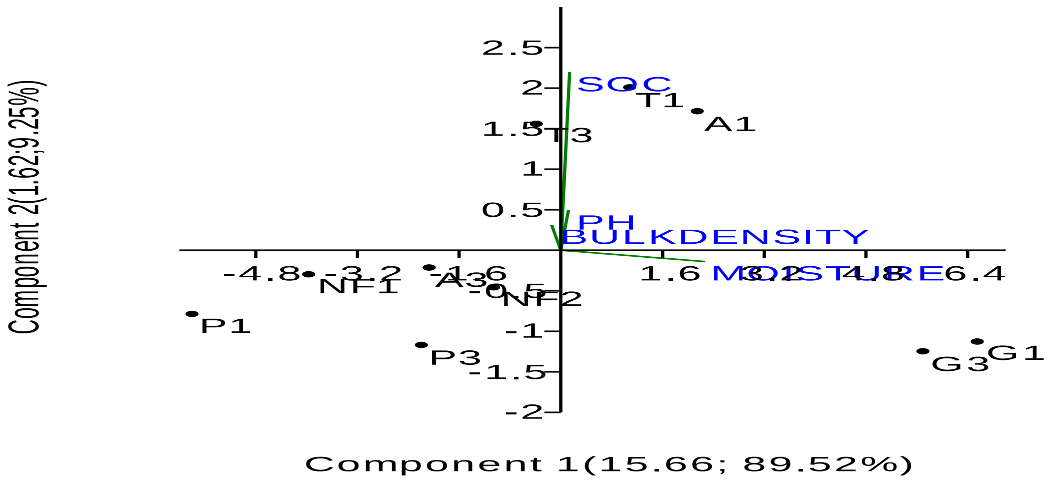
BD = Bulk density, SOC = Soil Organic Carbon, MC= Moisture Content, NF= Natural forest

Table3 shows the correlation matrix among the variables. A positive relationship exists between pH and Soil Organic Carbon (r = 0.371) but it is not correlated. pH and moisture content (-0.05793) negative correlation relationship between them and it is not significant. pH and Bulk density (-0.11161), no correlation relationship between them and it is not significant. Soil Organic Carbon and Moisture content (-0.08406), no correlation relationship between them and it is not significant. Soil Organic Carbon and Bulk Density (0.22749), no correlation relationship between them and it is not significant. Moisture Content and Bulk Density (-0.2305), no correlation relationship between them and it is not significant.

Table 3: Correlation analysis among soil parameter

VARIABLES	pH	SOC	MC	BULK
PH	1			
SOC	0.37	1		
MC	-0.02	-0.080	1	
BD	-0.110	0.24	-0.336	1

PCA generated an eigen value of 15.66 with 89.52% variation for axis 1 and 1.62 with variation of 9.25% for axis 2. PCA recorded a significant variation of some edaphic factors in different depth and the various land use, where *Gmelina arborea* showed maximum moisture content in all the depth. Soil Organic Carbon was found maximum in *Teak* and *Acacia* at 0-10cm depth. The location of Pinus1 and Pinus3 in the third quadrat of the component showed low value of Soil Organic Carbon in the two depths.



Principal Component Analysis based on some edaphic factors (Moisture, pH, Soil Organic Carbon and Bulk density) along different depths (0-10cm and 10-30cm) under five land use systems (Natural forest, *Gmelina arborea, Pinus carribea, Tectona grandis, Acacia siamea* in Area j4, Ogun state. P1-pinus 1, P2-pinus 2, G1-Gmelina1, G2- Gmelina2, A1-Acacia1, T1-Teak1.

DISCUSSION

Soil Organic Carbon shows significant differences among the five land-use systems, and it was highest in the Teak plantation and least quantity was stored in *Pinus carribea* plantation. This reflects the abundance or presence of decomposing liter, significant differences recorded can also be adduced to variations in soil moisture and temperature contents. The low quantity of C stored in *Pinus carribea* plantation could be as a result of continuous cropping or may be the specie are allelopathic in nature. Similarly, Bationo *et al*., (2007) in a study Soil Organic Carbon dynamics, functions, and management in West African agro-ecosystems reported a rapid decline of SOC levels with continuous cultivation. Similarly, low value of SOC observed in the *Pinus carribea* plantation could be as a result of the inability of organic manures to act as net carbon sink in forest lands in line with the observation of Schlesinger, (2000).

Water also influences SOC storage through several processes. Since well-aerated, moist soils are optimal for microbial activity, decomposition rates decrease as soils become drier. In contrast, organic matter decay rates are decreased in flooded soils due to restricted aeration, often yielding soils with very high amounts of SOC (e.g., peat and muck soils) (FAO and ITPS, 2015). In these water-saturated soils, other abiotic properties, namely physical properties such as peat depth and bulk density also influence the biological processing of C cycling.

Variation in soil bulk density values (Table 2) could be as a result of compaction resulting from a combination of factors such as; human and animal trafficking, raindrop impacts, and wetting and drying cycles in soil (Anikwe *et al.*, 2003).

According to (Hunt and gikes, 1992) compaction increases bulk density and reduces crop yields and the vegetative cover available to protect soil from erosion. Soils with a higher bulk density than 1.6g/cm^3 tend to restrict root growth. Sandy soils are more prone to high bulk density. It is generally desirable to have soil with a low bulk density ($\leq$1.5g/cm^3) for optimum movement of air and water through the soil. The critical value of bulk density for restricting root growth varies with soil type.

According to (NLWRA 2001; Cresswell and Hamilton,2002). Bulk density increases with compaction at depth and very compact subsoils or strongly indurated horizons may exceed 2.0g/

$cm^{3.}$ Bulk density increases with soil depth since subsurface layers are more compacted and less organic matter, less aggregation and less root penetration compared to surface layers, therefore containing less pore spaces. Bulk density values are important for calculating the total quantities of carbon stored at a particular time and soil depth. High bulk density is an indication of low soil porosity resulting from soil compaction.

The percentage of pH in the five land use appears to be strongly acidic except for Teak which is moderately acidic according to the USDA (1993).

According to Paul and Skyll (2012) the accumulation of alkalinity in soil occurs when there is insufficient water flowing through the soils to leach soluble salts. This may be due to arid conditions, or poor internal soil drainage; in these situations, most of the water that enters the soil is transpired or evaporates rather than flowing through the soil. pH increases when the total alkalinity increases. Its influences plant growth by its effect on the activity of beneficial microorganisms. Soil pH is considered a master variable in soils as it affects many chemical processes. It specifically affects plants' nutrient availability by controlling the chemical forms of the different nutrients and influencing the chemical reactions they undergo. The pH of a soil depends on the mineral composition of the parent material of the soil and the weathering reactions undergone by that parent material according to USDA-NRCS (2017). Studies carried out by Van Breemen *et al.*,1984 and Sparks, Donald (2003) Showed that some factors are responsible for the acidity of the soil. Some of these causes are rainfall, acid rain, fertilizer use, oxidative weathering, and plant growth. The increase in pH may be due to one of these factors majorly high rainfall.

PCA Analysis suggested that Axis -1showed that maximum variation and eigen value due to different land use types. A significant difference in edaphic factors along the two soil depths was also controlled by PCA. When pH, BD, SOC, are mainly in quadrat 1 and moisture in quadrat 4 along the positive axis. Moisture content was relatively in G1 and G3. SOC was high in TI, AI and T3. Soil pH and SOC are however in the same direction on this axis. This possibly indicates the influence of soil pH on SOC by regulating microbial activities. (Motavalli *et al.*, 1995, Balkrishan *et al.*, 2016).

REFERENCES

Anikwe M. A. N., Obi, M. E., Agbin, N. N. (2003). Effect of soil and crop management prcompatability in maize and groundnut Plant and Soils. 253: 457–465.

Bationo, A, Kihars J, Vanlauwa B, Waswa B, Kimetu J (2007). Soil organic carbon dynamics, functions and management in West A African agro-ecosystems. Agricultural systems 94: 13–25.

Bauer, A., Black, A.L. (1994). Quantification of the effect of soil organic matter content on soils productivity. *Soil Science Society of America Journal* 58: 186-193.

Christensen, B.T., (2001). Physical fractionation of soil and structural and functional complexity in organic matter turnover. European Journal of Soil Science 52: 345-353

Cresswell H. P and Hamilton (2002) Particle Size Analysis. In: Soil Physical Measurement and Interpretation for Land Evaluation. (Eds. NJ McKenzie, HP Cresswell and KJ Coughlan) CSIRO Publishing: Collingwood, Victoria. pp 224-239.

Davidson, E. A and Ackerman. I. L (1993). change in soil carbon inventories following cultivation of previously vatilted soil Biogeochem, 20:161-193.

Donald L. Sparks. (2003). Environmental Soil Chemistry. Second Edition. University of Delaware, Academic Press, An imprint of Elsevier Science, Pp 367, http://www.academicpress.com.

FAO and ITPS. (2015). Status of the World's Soil Resources, Rome: s.n

Hunt, N. and Gilkes, R. (1992) Farm Monitoring Handbook. The University of Western Australia: Nedlands, WA.

Louw, G., (2011). Practical guidelines for the establishment of old man's salt bush in winter rainfall regions. Grootfontein, Agricultural Development Institute, Republic of South Africa

McCarthy, J.F., Ilavsky, J., Jastrow, J.L., Mayer, L.M., Perfct, E., Zhuang, J., (2008). Protection of organic carbon in soil micro aggregates via restricting aggregate porosity and filling of pores with accumulating organic matter. *Geochimica et Cosmochimica Acta* 72 : 4725-4744.

Milne, E., Sessay, M., Paustian, K., Easter, M., Batjes, N.H., Cerri, C.E.P., Kamoni, P., Gicheru, P., Oladipo, E.O., Minxia, M., Stocking, M., Hartman, M., McKeown, B., Peterson, K., Selby, D., Swan, A., Williams, S. and Lopez, P.J. (2010). Towards a standardized system for the reporting of carbon benefits in sustainable land management projects. Grassland carbon sequestration: management, policy and economics (Proceedings of the Workshop on the role of grassland carbon sequestration in the mitigation of climate change, Rome, April 2009). Integrated Crop Management, 11, 105-117

Motavalli, P. P., Frey, S. D. and Scott. N. A. (1995). Effects of filter type and extraction efficiency on nitrogen mineralization measurements using aerobic leaching soil incubation method. Biol. Fertil. Soils 20: 197–204.

NLWRA (2001) 'Australian Agricultural Assessment 2001'. National Land and Water Resources Audit

Noellemeyer E, Frank F, Alvarez C, Morazzo G., Quiroga A (2008). Carbon contents and aggregation related to soil physical and biological properties under a land-use sequence in the semiarid region of central Argentina. Soil Till. Res., 99: 179-190.

Ojo LO. (2004). The fate of a tropical rainforest in Nigeria: Abeku sector of Omo Forest Reserve, Global Nest 6(2), 116 – 130.

Post, W.M.M., and Kwon, K.C.C., (2000). Soil carbon sequestration and land-use change: processes and potential Global change Biology 6: 317-27

Robinson SL, Kraatz MS, Rousseau DM. (1994). Changing obligations and the psychological contract: a longitudinal study. Academy of Management Journal 37: 137±152

Sbih, M., Karam, A., N 'Dayegamiye, A., Bensid, Z., Boukaboub, A.,(2012). Dynamic of the active fraction of organic matter in some meDOW SOILS. Eurasian Journal of Soil Science 1: 22-27.

Schlesinger WH (2000). Carbon sequestration in soils, some caution amidst optism. Agric. Ecosystem, Environ; 82(100) 121-127.

Van Breemen; N., Driscoll, C.T. and Mulder, J., (1984). Acidic deposition and internal proton sources in acidification of soils and waters. Nature (London), 307: 599-604.

ON THE CONCEPTS AND INTERRELATIONSHIPS OF LIFE, LIVING ENTITY, INFORMATION AND CONSCIOUSNESS IN NATURE: A REVIEW

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ABSTRACT

This review is on the concepts of life, living entity, information and consciousness from different fields of science in search of interrelationships linking the phenomena in nature. The cell theory advanced the understanding of cellular constituents of organisms but does not provide explanation for considering 'cells as living entities'. Darwinian evolution theory postulated that the current forms of humankind are attained through stages of events superimposed upon random variations by natural selection. The basic properties of life which are replicated are information varying through natural selection. Homo sapiens are distinctive among other organisms due to accrued information and learning abilities passed from one generation to another generation, not only due to the current physical structures. However, a zygotic cell grows to form specialized and self-organized systems; similarly, the universe emerges from a zero volume in the big bang theory and has evolved to form order and self-organized systems. Cell theory lies in the realm of biology which is the science studying nature from animated perspective while big bang theory is in the realm of cosmology and astrophysics that are scientific fields studying nature from inanimate perspective. Ecology as a field of science studying nature from both inanimate and animate perspectives is a discipline that could reconcile the limitations in these two theories (cell theory and big bang theory). Order and disorder are thermodynamically equivalent to anabolism and catabolism, respectively. Essentially, the non-cellular expanding universe and the growing cellular organisms are exhibiting self-organizations as a basic characteristic. Growth model could be used in studying cellular and non-cellular matters as expansion of the universe and the growth of organisms are physically an increase in size per time unit hence, a linking characteristic. Interdisciplinary research is highly recommended for advancing the understanding of concepts of life, living entities and related concepts. This will form a strong foundation for a unified theory of everything.

***Keywords**: Cell theory, Darwinian evolution theory, Big bang theory, Growth model, Ecology, Cosmology.*

INTRODUCTION

Benner (2010) gave an account of the experience of Daniel Koshland (Koshland, 2002) in respect to a committee that met to come forth with a consensus on the definition of life and while the committee was about to conclude that the essential characteristics of life is the ability to reproduce; a voice from among the participants was heard saying that "one rabbit is dead and two rabbits (male and female) are alive." This made the committee to conclude that although everyone knows what life is, there is no simple definition of life. The imprecise use of language in the sense that the concept of "being alive" (living) was confused with the concept of "life" even by the elites is eminent (Benner, 2010). Here, it could be inferred that the concept of living or not living and the concept of life are different phenomena. The botanist, Mathias J. Schleiden and zoologist, Theodore Schwann independently discovered that plants and animals were made up of cells in 1838 and 1839, respectively. Several researches backed up their findings culminating to the cell theory which states that, 'cell is the element from which all plant and animal tissues are made up', hence, the unit of life and every living entity is made up of cell (Gupta and Jangir, 2010). The cell theory provides explanation for the constituent of plants and animals, but does not explain the consideration of cellular forms of matter as living entities. However, a zygotic cell grows to form several specialized and self-organized parts and systems (Tortora and Derrickso, 2012). Similarly, the universe as a whole emerges from a single finite volume in the big bang theory and has evolved to form order and specialized self-organized parts and systems (Wilkinson Microwave Anisotropy Probe [WMAP], 2011).

Cell theory lies in the realm of biology which is science studying nature from animated perspective while big bang theory is in the realm of cosmology and astrophysics that are scientific fields studying nature from inanimate perspective. Ecology on the other hand is a field of science studying nature from both inanimate (abiotic) and animate (biotic) perspectives with levels of integrations, therefore, it is a discipline that could reconcile the limitations in these two theories.

Overview of the Concepts of Life and Living Entity

Owing to the current trend that there is no universally accepted definition of life, the search for extra-terrestrial life forms is based on exploration of organic molecules and water (Chyba and Hand, 2005). In the views of Oliver and Perry (2006), lack of definition of life might be necessary for future progress to be made in modern biology. There is need for researches to take this advantage of such progress while being part of the progress too. It has been postulated that living things could have forms different from their earthly counterparts and there could be alternative forms of life on earth too (Cleland and Copley, 2005; Schalze-Makuch and Irwin, 2006). Discovery of GFAJ-1 bacteria in Mono lake that are capable of utilising arsenic instead of phosphorus is likely a step forward in confirming alternative forms of life even on earth (Wolfe-Simon *et al*., 2010 in Chodasewicz, 2014).

In an attempt to resolve the problem of definition of life, Koshland (2002) proposed features of "life" referred to as PICERAS definition of life: Programme, Improvisation, Compartmentalisation, Energy, Regeneration, Adaptability and Seclusion (Benner, 2010). Quite broader features but the fact that all life forms must exhibit all the PICERAS features questioned the universality of this definition of life. National Aeronautics and Space Administration (NASA) adopted working definition in search for possibility of extra-terrestrial life forms is that "life is self-sustaining chemical system capable of undergoing Darwinian evolution" (Joyce, 1994). Conversely, definitions are within the premise of theories that give them meaning (Cleland and Chyba, 2002). Also, a definition-theory provides frame work for experiment to test the definition by testing the theory (Benner, 2010).

Defining life is not a prerequisite standard practice in biology because some fruitful biological researches can be carried out without the definition (Emmeche, 1992). However, modern biological researches involving fields like astrobiology, the origin of life, artificial life (Alife) and synthetic biology are strongly dependent on the definition of life (Chodasewicz, 2014). According to Pross (2011), there are interrelated three questions that are needed to be answered: what is life? How did life emerge? How can simple living object be made by man?

Another alternative form of life posing challenges to definition of life is the perspective that characteristics of living entities can be formulated and exhibited in non-organic compounds: a concept often referred to as artificial life (Alife) (Emmeche, 1992; Boden, 2000; Swan, 2009). Several artificial objects which are mainly computer simulation models have exhibited some characteristics of life like reproduction, evolution, self-sustainability, thereby confirming the concept of Alife and specific examples include Thomas Ray's Tierra and Christopher Langton's loops (Chodasewicz, 2014).

Zhuravlev and Avetisov (2006) admitted that the current life is a complex, multi-level and diverse phenomenon that can hardly be captured in a short definition. However, there is progress in the understanding of what life is as more important characteristics of life such as whole system, ecosystem and information have been recently included in definition of life. In many literatures on the origin of life, the interchangeable usage of "living", "life" and "living organisms" shows vagueness of insight about the different levels of the living system. Rather than emphasising on a short and complete definition of life; a definition characterising life as a state, a structure and a process might be appropriate (Zhuravlev and Avetisov, 2006).

With the great development in the understanding of the molecular basis of biological phenomenon, yet without a generally agreed-upon definition of life, it could be conceived that what is meant by life's origin is somewhat imprecisely defined and the endeavours to define life is likely to remain at best, a work in progress (Tirard *et al*., 2010).

May be the restrictions to cellular forms of life might be actually questionable; hence, there might be need for broader concept of life and living entity. Ma (2016) while discussing on essence of life in respect to cellular forms of life admitted, that clear idea is yet to be obtained on, 'what is life?'

Comparison between Cellular and Non-cellular Matters relative to Life and Living Entity

The definition of a "living system" should use only non-biological terms as it must come before anything in biology. Conversely, defining living systems with respect to biological terms is quite recursive which is always making the concept of life in biology subjective by accepting the first case as a matter of faith referred to as postulates (Shonkwiler and Herod, 2009). The storage, replication and transmission of information taking place at molecular level in form of nucleic acid and enzyme catalysis in cellular living entity (Abercrombie *et al.*, 1990) are still taking place within the universe at even photonic level. According to Landauer's principles which states that every physical system registers information by merely existing (Landauer, 1988).

This gives a second thought as to, 'what is the most fundamental structural and functional characteristic(s) of a living entity?' Thus, the universe as a non-cellular matter has some similar characteristics of life with cellular matters. The big bang theory also establishes the emergence of the universe from zero but finite volume and has been expanding for the past 13.798 ± 0.037 billion years (Mukhanov, 2005; Possel, 2010; WMAP, 2011); could this be implying that the universe is living? The theory does not account for the cause of the origin of the universe (WMAP, 2011). However, biological growth and expansion of the universe are both physically an increase in size of an entity; comparatively, the zygotic cell of a cellular matter and universe as a non-cellular matter emerged from zero volumes with subsequent increase in their sizes with time characterised by self-organisation in their respective systemic structures and functions.

Life, Living Entity, Information and Consciousness in context of Thermodynamics

The first law of thermodynamic establishes the principle of conservation of energy and mass. The second law of thermodynamic commonly referred to as law of entropy states that the entropy of an isolated physical system can never decrease; at least, entropy remains constant and usually increases (Bekenstein, 1972). Cellular living things are characterised by a very high degree of structure and assembly right from level of molecules, genetic information, cell, tissue, organ, organ system and population of organisms (Udgankar, 2001). How do living things preserve their low level of entropy for a span of time? By constantly interacting with their external environment, they receive energy such as in form of food. This food is broken down (disorder) through catabolism while they are subsequently translated into building body tissue and maintain physiological activities through anabolism leading to orderliness.

Anabolism and catabolism are collectively metabolic processes referred to as metabolism in cellular forms of matter. Anabolism involves synthesis of simpler substances into complex molecules while catabolism is the breaking down of large molecules into smaller molecules. Anabolism is constructive process while catabolism is destructive process (Panawal, 2017). Anabolism and catabolism are analogous or have their generalised form to be order and disorder respectively in thermodynamics. However, catabolism could generally be considered as a reduction (differential) constructive process like meiosis and same is entropy rather than being a destructive or disorderly process. Catabolism releases energy in form of ATP just like the dissipation of energy in entropy. Udgankar (2001) extends the concept of irreversibility of time to be analogous to evolution: a natural progressive developmental process leading to more complicated biological structures through adaptation to their environment and accumulation of small constructive random changes (information) in the DNA. Entropy has been the driving force for protein unfolding and catalysis of enzymes which involves reaction that progress to equilibrium subsequently leading to free energy which could be released as heat or used to support entropy.

The emergence of orderliness in structures during embryonic development spontaneously from a single cell leading to morphogenesis and organogenesis is a process of differentiation and self-organisation. The mechanism is undergoing studies. However, Chattopadhyay and Tapaswi, (1993) logically assumed the followings as prior conditions for biological system to enter differentiation: Successive mitosis (incremental cell division) and Communication among neighbouring cells by the diffusion of certain signals in the form of chemicals through cells. Wolpert (1969) discussed the cells communication pattern as positional information whereby each cell knows its position in the ensemble cells. According to Michaelides (2008), entropy is one of the physical properties of a system that can only be deduced or calculated from other properties but cannot be measured directly. Same author further criticised associating entropy with disorder. However, when entropy is understood as an irreversible flow of energy from top down in contrast to implying irreversible increase of disorder; the change in entropy when derived for statistical mechanics of an open system has shown to map directly to decrease in free energy without association to disorder (Annila and Baverstock, 2016). In the authors' view, association of disorder with entropy is erroneous and do result from the assumption that a system could undergo change of state without dissipation, that is change in energy.

Information theory got an applicability status prominently from the works of employees of Bell Telephone Company which form the basis for the Shannon's "Mathematical Theory of Communication" (Nesterov, 2012). Same author analysed that Shannon's work deals with substitution of "information" and "amount of information" concepts but did not explain information as a physical stuff like mass and energy; however, quantum entropic logic theory regards information as material category, hence, it follows conservation law. Quantum entropic logic theory is dealing with negentropic properties of information which is the measure of order or structure complexity of surrounding system related to entropy process in the physical world as a measure of disorder of certain system. With the generalisation of De Broglie wave-particle characteristics to all mass and energy, similarly, quantum entropic logic theory links information (I) with energy (E) and wave particles as $I = E / h^{1/2}$ where h is Planck's constant. Rolf Landauer in 1961 linked information with heat energy by reasoning that erasure of information is a dissipative process which requires minimal quantity of heat proportional to the thermal energy dissipated. The minimum quantity of heat energy was referred to as Landauer bound and is necessarily produced when a classical bit of information is deleted (Berut *et al*., 2012).

Berut *et al.* (2012) conducted an experiment to verify the aforementioned Landauer's principle linking information and thermodynamics. When an output of a device cannot be uniquely determined from its input, such a device's operation is said to be irreversible logically (Bennet, 1973 in Berut *et al*., 2012). Logically, it implies that a Boolean function maps several input states onto an output state. Consequently, the erasure of information, that is, relating to one operation is logically irreversible and lead to an entropy increase of "kln2" per erased bit (Shizume, 1995). To verify the erasure principle experimentally, the original Landauer's work was followed describing an over damped colloidal particles in a double-well potential as a generic model of one-bit memory (Berut *et al.*, 2012). By virtue of the universality of thermodynamic, the results was generalised to be fundamental physical limit to irreversible computations. According to Miguel-Tome (2013) information and computation are distinct and fundamental in nature that deserves new epistemic scheme than mostly defined for the epistemic scheme of energy. In other words, information is physical and deeper aspect of nature. Same author gave a historical account that mathematical definition of algorithm was by Alian Turing in 1936 even though the algorithm was pioneered by Al-Koarizm in the 9th century. Also, the definition of computer was traced to the work of Turing as a universal computing machine.

On the other hand, the concept of information theory mathematics was developed for thermodynamics by Ludwig Boltzmann and Josiah Willard Gibbs while Claude Elwood Shannon contributed to information theory in context of engineering and applicability with technical orientation. Several works by numerous scientists linked information to entropy and energy prominent of whom is Landauer (Berut *et al*., 2012; Landauer, 1961). Computation limit is the feature of the universe; therefore, Turing-computation, super computation or hyper computation is possible value for a feature of nature (Abdo *et al*., 2009). According to Miguel-Tome (2013), the main goal of science is to achieve a unification of the different natural sciences or natural concepts and this could be achieved through a physical theory of information and computation.

Information in the sense of semantics is the quality of energy and the only existing energy in the biological nature (Johannsen, 2005). The author proposed Evolutionary Energetic Information Model (EEIM) which is based on assumption that semantics ligated to life, in essence, without life, "meaning" is meaningless. Therefore, semantics as the very base of meaning is part of life which results from biological evolution on earth. Energy comes with information as the potential structure which depends on a biological receiver to classify and process such received energy as information relative to the meaning perceived from it as the semantics.

Davies (2009) noted that the key properties of life which are replication with variation and natural selection do not necessarily require material structure to be replicated, what is replicated is information. Thus, proposing that life might have started with some sort of quantum replicator. Weiner cited in Johannsen (2005) argued that information is not identical to material that composes it rather considered information to be "pattern of organisation" of that material. In order to support this view, various roles which information is playing in biological organisms (cellular forms of matter) were highlighted by identifying lines of information flow such as genetic and extra-somatic. Also, Min (1999) stressed that information has capability of self-replication and organisms (cellular forms of matter) do apply communication channel like in Shannon's model in the sense that RNA molecules form channel in getting inputs from DNA (source) and delivering output to protein (receiver).

Discussing on the semantic information in nature; Johannsen (2005) asserts that organisms (cellular forms of matter) first appear with information, that is, information has been existing since the beginning of evolution which is linked to meaning. Therefore, meaning is produced by evolution as part of the organisms (cellular forms of matter) that are created in the process of evolution partly relative to the internal environment and partly by allowing external information to enter the organisms from the external environment for further processing. The organisms depend on the information that comes from the external environment but with varying senses which began from evolution with life as biological biggest mystery. With the great development in the understanding of the molecular basis of biological phenomenon, yet without a generally agreed-upon definition of life, it could be conceived that what is meant by life's origin is somewhat imprecisely defined and the endeavours to define life is likely to remain at best, a work in progress (Tirard *et al*., 2010). However, it could be argued that the evolution of information is an intrinsic property of life for both cellular and non-cellular forms of matter. Johannsen (2005) considered catching of information as the first and Loevenstein (2003) argued that the most fundamental level of life is photosynthesis. On the contrary, this might be restrictive to cellular forms of matter but the fundamental level of life could be more general to consider both the cellular and non-cellular matters.

Ma (2016) postulated that for life to be understood, two completely distinct aspects of life: Darwinian evolution and self-sustaining must be split by defining "life form" and "living entity" separately. Also, for implementation of life as self-sustaining (in cellular matters), three crucial mechanisms were identified:

i. Replication of DNA/RNA – like polymer by residue pairing
ii. Sequencing dependent folding of RNA/protein – like polymer dictating separate functions and
iii. Assembly of phospholipid – like amphophils forming vesicles

While information was deemed significant for comprehending life phenomena in terms of genetic information being passed from one generation to another through Darwinian evolution. If "Darwinian evolution" could be extended beyond cellular forms of matter, there could be progressive paradigm shift in current concept of life and more mechanisms of life and living could be investigated which will deepen human's understanding of nature .

The information contained in the genome, despite its complexity, is not sufficient for the control of organism development, thus, the actual operational directives and functions of the genome remain obscured. Radical scientific advancement need new methodology, although, functioning of living system could be studied physically and chemically but is better understood from information control approach (Berkovich, 2001). The DNA molecular structure does not contain enough variety to serve as a registry of control of directives for living organisms (Claverie, 2001). The idea that life is associated with immaterial information process in the universe had been around through human history. Therefore, to understand the phenomenon of life, it is necessary to consider informational structure underlying the material world (Berkovich, 2001). The existing information pathways in the universe are yet to be completely discovered, however, the impact of quantum entanglement behind material processes spreads at least 10^7 times faster than speed of light C in a vacuum (Siefe, 2000). Biological processes are related to the holographic mechanism of the universe (Talbot, 1991).

Bekenstein (2003) gave account of studies on black holes in terms of knowing the ultimate capacity of information a region of space or a quantity of matter and energy can hold. The outcome of such investigation suggested that the perceived three spatial dimensions (volume) is equivalent to the two spatial dimensions (surface) like a hologram. The author further explained that most fundamental physical entities (building blocks of the universe) are electrons and quarks which are considered to be excitations of superstring. However, there could be more fundamental entities than the known ones. Information is the fundamental component of the universe according to Wheeler (1988), that is why is credited with the adage "It's from bit" (Wheeler, 1999). According to Bekinstein (2003) the ultimate capacity of information of a chunk of matter can be calculated or its thermodynamic entropy equivalence only when the ultimate constituents of matter are known to its deepest level referred to as "level X." When matter disappears into a black hole, its entropy is gone but this seems to be violating the second law of thermodynamic (the law of entropy).

Bekenstein (2001) showed that mass of black hole surface area A will have its entropy less than A/4 and this assumption was generalised leading to holographic bound which is independent of the constituents of the system or nature of level X rather depends on the generalised second law (GSL). The holographic bound reveals that the maximum entropy of a system depends on its area not volume while the GSL states that entropy of an isolated physical system can never decrease, at least, entropy remains constant and usually it increases (Bekenstein, 2003). Earlier, Christodoulou (1970) independently proved that in various processes such as black hole mergers, the total area of the event horizons never decreases. Also, Bekeinstein (1972) showed that black hole has entropy directly proportional to its event horizon.

Velmans (2009) opined that definition of consciousness should be sufficiently broad to include all forms of conscious states and as well narrow to exclude entities, events and process that are not conscious. Contrary to this opinion is that "conscious entities" are themselves systems of processes for instance *H. sapiens* is a "system organ" processes. Also, states of consciousness are themselves events characterized by "time frame" whether concrete or abstract. However, the word consciousness means different thing to different persons owing to the "psychological data" possessed by every individual in adjudging or defining what it means to have consciousness (Miller, 1962 in Velmans, 2009). Crick (1994) and Dennet (1991) regarded consciousness as a state of function of the brain. Baars (1988) considered consciousness as some aspects of human information processing.

Velmans (2009) identified two main approaches of studying consciousness by scientists:

i. Third person perspective approach based on information about brain and behavioural pattern observed
ii. Phenomenological approach based on every day understanding of consciousness in terms of presence or absence of experienced phenomenon such as what is experienced whether awake or in dream as being conscious or not being conscious of something awake or in dreamless state.

Same author further differentiated between consciousness and mind by regarding the mind as for psychological states and processes that may or may not be "conscious" such as pre-conscious and unconscious mental processing related to the brain functioning. Farthing (1992), Velmans (1996) and Velmans and Schneider (2007) made distinction between knowledge and consciousness in terms of remembrance and forgetfulness such that knowledge could be unconscious if not remembered and conscious if remembered while life term knowledge points to memory.

Cell Theory as a Dogma in Science

The cell theory is mostly credited to the botanist Mathias Jacob Schleiden and the zoologist Theodore Schwann for their independent discovery that plants and animals were made up of cells in 1838 and 1839, respectively. Several researches backed up their findings culminating to the cell theory which states that cell is the element from which all plant and animal tissues are made up, hence, the unit of life and every living entity is made up of cell (Gupta and Jangir, 2010). The cell theory conceptualizes the cell as the minimum quantum of life, capable of independent development, while still an integral part of the organism as a whole. However, Schleiden advanced the theory for plant cells while Schwann generalized it to all living organisms (animals as well as plants). Some years later, Rudolf Virchow contributed his quota to cell theory in a famous aphorism "*Omnis cellula e cellula*", which means that all cells arise only from pre-existing cells (Tavassoli, 1979).

Historically, Robert Hooke coined the term "Cell" in describing the compartment he observed in a thin cork layer with microscope. The perspective offered by Scientists who pioneered the cell theory and advancing its understanding has brought a golden age to biological sciences. Although, there are controversies and scepticism about the cell theory, but it has ushered in a new era in biology by providing a unifying mechanistic concept, necessary for inductive science (Tavassoli, 1979).

According to Welch and Clegg (2010), the origin of the "system" view of the cell throughout the 150-year history of the role of "protoplasm" in cell biology was found that the "protoplasmic theory," instead of the "cell theory," was the key 19th-century construct that catalysed the study of the structure and function of living cells and laid a foundation for the development and advancement of modern cell biology. Modern large-scale and high-throughput experimental methods are generating massive quantities of data at all levels of complexity in the living cell. The "systems biology" is striving to establish order in this information-rich empirical realm, with a new found view of the cell as a "system" (Welch and Clegg, 2010).

Cell Theory was generally more accepted when the cellular nature of brain tissues was confirmed towards the end of the 20th century, since then, cell theory turned into a more dogmatic cell doctrine held among scientists to date (Balusika *et al.*, 2004). However, the cell theory answers the question what plants and animals are made up, but did not answer why cellular forms of matter are considered living entities? Currently, all known characteristics of a living entity: respiration, nutrition, growth, reproduction and so forth were based on cellular forms of living matter since 1830s to date.

The reasons for the cell theory to have been held like a doctrine can be summarised in the following syllogism:

i. Human beings discovered that Plants, animals and humans are made up of cells in nature
ii. Human beings that are investigating nature pre-scientifically believe (outside the realm of science) that they are living entities
iii. Plants and animals are also living entities as they are made up of cells like humans
iv. Hence, every living entity must be made up of cells
v. Therefore, cell is the unit of all living entities.

Where is the evidence for definition of a living thing within the realm of science? Cell theory only provides evidence of what plants, animals and humans are made up of but did not provide evidence of why they are considered living not to talk of extending or generalizing that all living entities must be made up cells. Plants and animals are considered to be living things by induction that they have similar constituents – cells – like humans who are believed based on pre-scientific presumption that are living entities. What might have led to the dogma of cellular basis of a living entity or this conditioned definition of life intertwined with living concept could be due to the fact that coincidently, human beings were found to be made up cells and man subjectively, outside the realm of science, believes that is a living entity. Similarly, outside the realm of science, there are other entities believed to be living such as fairy, demons, angels, ginny, aliens, the rocks, planet earth, the universe as a whole and so forth. They were only excluded from being considered living entities because probably science does not know what some of them were made up or because they were not made up of cells but does that justified classifying them as inanimate or even non-existents? These led to the need of revisiting the questions: what is life? What is a living entity? And why anything is to be considered to be a living entity?

Evolutionary Perspective of *Homo sapiens* as a Cellular Matter

Darwinian evolution theory postulated that the current forms of humankind were attained through stages of events superimposed upon random variations by natural selection (Benner, 2010). The history of humankind dates back to the first "bipedal apes" about seven million years ago (Tattersall, 2009). *Homo erectus* (meaning Upright man) is considered to be extant species of archaic human from the Pleistocene, about 2 million years ago (Herries *et al*., 2020). Few million years ago, after *H. erectus*, *Homo habilis* developed learning ability through making of tools (Hung *et al*., 1995). However, this ability of learning to make tools confirmed extra genetic (epigenetic) fitness which was passed from parents to off springs not by DNA (endogenetic) but through education. This epigenetic factor which is the ability to learn that makes *H. sapiens* more fitting today was not passed on as a random variation whereby novel variations are introduced based on foresight of its potential value (Benner, 2010).

Human beings are unusual in many ways but unique in their symbolic form of processing information about the world around them. Although with a long evolutionary history, the modern human cognitive style is not predicted by that history. The modern human cognition seemingly has emerged as a product of an incremental process of refinement. *Homo sapiens* has distinctive physical features anatomically but the biological potential for symbolic thinking offered it new capacity that had to be discovered through cultural stimulus and this stimulus was plausibly the invention of language. This enhanced expression of symbolic reasoning thus, advancing technological changes in response to environmental challenges. This also promotes sedentary lifestyles making *H. sapiens* a co-actor with nature (Tattersall, 2009). Fossil records of the past several hundred thousand years, showed a variety of morphologically different hominids, partly due to their large brains, though not up to the modern average, but were classified as “archaic Homo sapiens.” However, in recent years, paleoanthropologists have come to recognized that classifications are meaningless (Schwartz and Tattersall, 2005).

The transformation of predecessors of modern humans from a readily recognizable variation on the primate theme to the current entity was both recent in geological terms and complex in its unfolding. As modern *Homo sapiens* the attainment of the current state of consciousness of qualitative difference in the world lies not among the possessed physical attributes alone but also in the unprecedented form of cognition. The ability to mentally simplify the world into discrete symbolic ideas, which are combined and recombined in the minds in search for new possibilities and asking questions which the quest for their answers made *H. sapiens* to live not solely in the world as nature presents it to it but substantially in the world as it can re-create it (Tattersall, 2009).

The currently living *H. sapiens* is highly distinctive in its bony structure. Cranially, the species is remarkable for its short in length, tall-domed, rather balloon-like braincase, beneath the front of which a very small facial skeleton is distinctly retracted. Other details of the face are typically very small ridges above the orbits – eye sockets - that are bipartite and a complex chin structure at the front of the lower jaw that essentially takes the shape of an inverted “T” with the body skeleton being lightly constructed, with a slender, parallel-sided thorax matching a narrow pelvis below (Schwartz and Tattersall 2000 and 2005). Restricting the use of *Homo sapiens* in the fossil record to specimens which share a significant number of features in the skeleton with extant *H. sapiens*, the origin of our species would be placed in the African late middle Pleistocene, considering fossils like Omo Kibish 1, Herto 1 and 2, and the Levantine material from Skhul and Qafzeh (White *et al*., 2003; McDougall *et al*,. 2005; Stringer, 2016).

Genetic data indicate that modern humans and sister species like *Homo neanderthalensis* shared a last common ancestor in the middle Pleistocene which is approximately 400–700 ka, about 200 000 years earlier than the species origin indicated from the fossils record (Tattersall, 2009; Stringer, 2016). This fossil record is supported by molecular studies of modern human populations which confirms that *H. sapiens* emerged as a recognizable anatomical entity in the period closely following 200,000 years ago populations (Harpending and Rogers 2000). Analyses of DNA diversity among peoples globally indicate that the ancestral human population originated in Africa, where genetic diversity is greatest and have longest history of accumulation (Tattersall, 2009). In fact, recent studies are suggesting the population might have lived in south western Africa from where they spread to colonize other parts of the globe (Tishkoff *et al*. 2009),

It is evident that the timeline of appearance of *H. sapiens* as an anatomically distinct entity (about 200,000 years ago) was far earlier than the first unequivocal expressions of symbolic cognitive processes (less than 100, 000 years ago). Plausible explanation to this is that through the routine evolutionary phenomenon whereby existing structures are recruited for new purposes which are typical pattern for biological and behavioural innovations in human evolution; for instance, the four limbs of 'tetrapod' (four limbs: two fore limbs and two hind limbs) were acquired in an aquatic context long before they are used for terrestrial locomotion; birds possessed feathers for many millions of years before being used for flight. Similarly, it is arguable that the neural substrate responsible for symbolic cognition was initially acquired in the major developmental reorganization that gave rise to the distinctive modern human anatomy. However, this new potential inherent in the reorganized brain remained unexpressed until it was discovered through the action of a cultural stimulus such as language which is an ultimate symbolic activity and one that is inextricably entwined with symbolic consciousness as modern humankinds are experiencing today (Ohnuma *et al.*, 1997; Klein, 1999; Tattersall, 2009).

The transition of *H. sapiens* from a non-symbolic, non-linguistic cognitive state to a symbolic, linguistic condition is an extraordinary switch which was a qualitative change rather than being an additive refinement of a pre-existing system. This was based on long accretionary history of vertebrate brain evolution, and would not be possible in the absence of such history. Also, symbolic cognition is not just a better version of what was there before but a superimposed on a pre-existing cognitive system, symbolic reasoning is a truly new method of processing information about the surrounding world (Tattersall, 2009). *Homo sapiens* in Latin mean the wise man is included in this review by virtue of the central position of being the major observer of the world and a cellular living entity.

Cosmology and Ecology: Need for Interdisciplinary Approach and New Methods

Wilkinson Microwave Anisotropy Probe (WMAP) (2011) defines Cosmology as the scientific study of the large-scale properties of the universe as a whole through the use of scientific methods to understand the origin, evolution and ultimate fate of the entire universe. Cox (2008) defines ecology as the study of ecological systems. The ecological systems could be understood as described by Kormondy (2009), that ecology is study of all complex interactions (systems), a study that is characterized, in addition to other scientific methods, by careful attentions to details, recognition and interpretation of variables, awareness and questioning of previous contributions to theory, and development of new tools of analysis. Ecological studies are carried out from three perspectives: descriptive, functional and evolutionary. While dealing primarily with three levels of integrations: populations, communities and ecosystems collectively referred to as synecology. This is the study of group of organisms in relation to their environment and autecology is the study of a single organism in relation to its environment (Krebs, 1978). The autecology is also dealing with six levels of integrations: molecular, sub cellular organelles, cells, tissue, organ and organ-systems.

Krebs (1978) pointed out three methodological approaches in ecological studies to be mathematical, laboratory and field. The mathematical approach is the primary intersection between ecology and cosmology from astrophysical viewpoints followed by similarity in terms of observations of space (heavenly) events as a field approach in observational cosmology (astronomy) and collection of data on biotic and abiotic factors from field in ecology. Mautner (2002a, 2002b) contributed worthwhile researches to astro-ecology which is a field that overlaps with astrobiology or exobiology as both sub disciplines are essentially search for possibility of life beyond earth in space and how extra-terrestrial phenomena are affecting life as an attempt to understand evolution of life. Ecology becomes linked with cosmology under the ecological cosmology which is a sub discipline with interdisciplinary researches in search for origin and evolution of life and related aspects like phenomenon of consciousness concurrently through the understanding of origin and evolution of the entire universe (Lombardo, 2011).

Model is any abstraction or simplification of a system and a system is any structural or functional phenomenon, having at least two separable interacting components (Hall and Day, 1977 in Yusuf and Abdulkarim, 2015). Sparre and Venema (1998) considered model as a process linking input and output usually in the form of mathematical expression comprising variables, parameters and operators. Mathematics forms the basis of modelling in sciences because its output is considered to be objective and universal in its generalization; though, mathematics is artistic in its mastery and in employment of its methodology (Yusuf and Abdulkarim, 2015). Modelling of natural phenomena being it through the use of analytical models or computer simulation models involves simplification of natural phenomena in order to enhance understanding and prediction of other complicated aspects by using fewer variables that are well known (Goodman, 1975 in Hall and Day, 1977). Models can be used to generate hypothesis, to formulate scientific theories and to test validity of theories, particularly, in terms of prediction through extrapolation and interpretations (Hall and Day, 1977).

Growth of an organism is quite a complex phenomenon involving physiological, biochemical, cytological, morphological processes, however, some aspects could be quantitatively analysed as to observe or model connection between metabolism and growth of an organism (Bertalanffy, 1957). Such growth models do serve as quantitative laws of generalized applicability. Von Bertalanffy Growth Model found great application and unparalleled importance in fishery, particularly, in stock assessment (Sparre and Venema, 1998; Abdulkarim *et.al*, 2009). Growth model could be used in studying cellular and non-cellular matters. For instance, the expansion of the universe and the growth of organisms like the zygotic cell are physically an increase in size per time unit and is a linking characteristic between cellular and non-cellular matters.

Biometric index is the quantitative measurement of a morphological characteristic or feature of an organism and the statistical relationship of two or more of such features. The commonest biometric index of fish is its length measured as total length (TL), standard length (SL), or fork length (FL), followed by its weight as a measure of its biomass which yields an important statistical relationship called length-weight-relationship (LWR). Length could be used to define legal size, that is minimum size for harvest or catch from water body (Weithman and Anderson, 1978; Abdulkarim *et al.,* 2009). Weight-height equations (models) of *H. sapiens* are used for determining body-mass indices that are of relevance to human health status. Human volume equations could be used in predicting body fat (Damon and Goldman, 1964). Variations may occur in female or male bodies' models. The importance of measurement of human body volume, density or fat content cannot be over emphasised.

Ecological Cosmological Approach to Consciousness, Mind and Soul in context of Life and Living Entity

It is a philosophical common place that Aristotle's definition of the soul as a form of body contains an important anti-dualist solution to the mind-body problem in which the intellect is not the form of any type of body but capable of existence as a functioning entity separate from the body. This refers to the existence of a soul which is an immaterial living being, the prime mover that carries on the psychic activity of thinking. Aristotle treats soul as the principle of life; things are with soul if and only if they have life. The definitions which Aristotle offers could be harmonized thus; soul is the substance, the first actuality of a natural body which has life potentially, the essence and defining principle which has within itself a source of its change and stability (Bolton, 1978).

Substance dualism is the view that the seat of consciousness is an immaterial entity, often referred to as a soul and this is inherently considered to be violating the first law of thermodynamic, in the sense that the interaction of immaterial soul with the brain will be violating law of conservation of energy (Dennett, 1991; Searle, 1992). Physics of the Soul is central to the theory of survival after death and reincarnation which crucially depends on a concept called quantum memory. The idea is that part of our memory (quantum memory), specifically that of our learning, is nonlocal, that is, the memory resides not locally in the brain but outside of space and time. Therefore, this memory can transmigrate across space and time without signals, without transfer of energy. The question of energy is important because antagonists of the idea of survival after death make big hoopla about the fact that the weight of a living body does not change with death. Nonlocal communication without signal is a quantum concept which has been experimentally verified, yet many physicists are sceptical about its validity, especially in the macroscopic domain of reality (Goswami, 2013).

The development of functional Magnetic Resonance Imaging (fMRI) techniques has catalysed neuroscience researches in psychological sciences. The techniques revealed neural correlates for many psychological phenomena observed to be central to human experience including moral judgments, emotion and personal agency (Le Doux, 1996; Greene *et al*., 2001; Farrer and Frith, 2002). Neuroscience has rejuvenated long time debates of mind–body dualism and the soul but while some scientists use neuroscience to support a material account of consciousness, others use unexplained neural phenomena in defending dualism and a spiritual perspective of the mind (Crick, 1994; Schwartz, *et al*., 2005; Preston *et al*., 2013). In two experiments by Preston *et al*. (2013) on how exposure to neuroscience research impacts belief in soul was assessed; it was found that belief in soul decreases when neuroscience provides strong mechanistic explanations for mind but belief in soul increases when there are explanatory gaps in neuroscience research implying that physical and metaphysical explanations may be used reflexively as alternative theories for mind. According to the views of these authors, mind and soul are substitutive alternative phenomena, but are they?

Belief in the soul as a non-physical essence (dual substance) of a being has been an important age long subject of thought and investigation (Descartes, 1641; Plato, 2005). It has been argued that belief in souls is culturally universal and hard-wired in cognitive processes that could be used in agency detection (Bloom, 2004; Bering, 2006). Apart from understanding other people's minds, belief in the soul also helps in explaining personal experience of one's mind. The mind appears to arise from some extra physical force, and the concept of the soul is commonly explored as the source of this ineffable essence of self whereby, belief in the soul is used as a metaphysical explanation for the mind (Preston *et al*., 2013). Whenever one thinks or feels emotion, subjective experience does occur which is not usually tied to any physical event (Wegner, 2003). Introspection is a qualitative difference between the mental and the physical processes and makes one feels as though one is made of two parts: mind and body (Descartes, 1641; Ryle, 1949). However, the vivid images of the brain ''lighting up'' during mental activity as revealed by fMRI research provides evidence that the mind is a physical phenomenon and much interests are captured to belief in psychological research when it contains information from neuroscience (McCabe and Castel, 2008; Preston *et al*., 2013). But when scientific explanations are weakly framed, they can actually bolster belief in supernatural and metaphysical explanations (Preston and Epley, 2009). As neuroscience is discovering neural correlates of more and more essential psychological processes, the brain could substitute the soul as the prevailing explanation for the mind (Farah, 2005; Clark, 2010). However, with the breakthroughs of fMRI studies, one epistemological issue of the mind that neuroscience is yet to resolve is the concept of consciousness which still creates an explanatory gap (Levine, 1983; Chalmers, 1996). Although, neural correlates associated with mental processes were identified, how activity in the brain creates the experience of these mental phenomena are yet to be precisely explained and if the neural activity captured by fMRI demystifies the mind, awareness of an explanatory gap may re-mystify the mind (Preston *et al*., 2013).

Ecological reciprocity as applicable to human psychology conceptualises that human and the environment are open and interpenetrating systems that form an interdependent whole. Hence, there is no absolute boundary between humans and the environment and neither can one be defined independently of the other. Mind, intelligence, personal self-identity, and even consciousness are ecological emergent realities realized in a supporting environment (Lombardo, 2009). The idea of ecological reciprocity is based on Gibson's ecological psychology which is anti-dualistic perspective that neither mind and matter, nor conscious entity and universe, are ontologically distinct realities rather, there is a reciprocal connection between self-awareness and other-awareness; awareness of persistence and change; awareness of the spatiotemporal arrangements of objects and events in the universe inclusive of the observers' life; the psychological spacetime are relative and ecological (Gibson, 1979; Lombardo, 1987). Reciprocity considered existence as a set of complementary opposites, thereby rejecting all forms of dualism whereby, the classic philosophical dichotomies are all interdependent: reality is both a whole and plurality necessarily of order and chaos. In respect to human psychology, individuals are both distinct beings and interdependent: the conscious self is both a unity and a diversity and of both conscious order and chaos (Fraser, 1978; Prigogine, 1980 and 1997; Prigogine, and Stengers, 1984).

Reality or existence is fundamentally evolutionary and dynamic. The evolutionary model of reality considers order, complexity, intelligence, consciousness and other similar qualities to be advancing through time (Fraser, 1982 and 1987) whereby, principles like self-organization, punctuated equilibrium and non-linear jumps in complexity, efficiency characterise evolutionary process (Eldredge, and Gould, 1972; Gould, 2002; Davies, 1988;

Kauffman, 1995a and 1995b; Smolin, 1997; Laszlo, 2008; Gell-Mann, 1994; Anderson, 1996; Kurzweil, 1999; Kurzweil, 2005). Also, applying evolutionary model of reality to humans implies that there is no stable human nature or human psychology as it is inherent in the nature of the human mind to strive towards a greater evolutionary status (Csikszentmihalyi, 1993; Lombardo, 2006). Reciprocity and evolutionary models works hand in hand such that Order and chaos; stability and change, life and death, and freedom and determinism are reciprocally complementary process of progressive evolution that could be referred to as reciprocal evolution (Fraser, 1987; Sahtouris, 2000; Morowitz, 2002). An instance of the reciprocal evolution is as in the theory of Gaia where geological, chemical, and atmospheric components of the earth have co-evolved**,** interactively with the biosphere (Lovelock, 1979 and 2006; Sahtouris, 2000). Similarly, humankinds and their environment (natural, social and technological) evolve interactively as a system (Lombardo, 2009). The ecological evolution of human psychology asserts that minds and basic psychology are interdependent with the environment. The lives led by humankinds are dependent on the affordances and availability of resources in the environment whether gotten naturally as provided by nature or gotten artificially through inventions. Passively and actively, adaptation is sustained by utilizing what is available in the environment and by modifying the environment to better fits contemporary needs (Gibson, 1979; Ponting, 2007).

The human nature is transformative and evolving and as self-conscious and self-evaluative beings with values, ideals and thinking abilities; with the increasing understanding of nature, human psychology, and the basic principles of change, these will increase the technological and psychological capacities of humankind, therefore, becoming more empowered and knowledgeable on how to tailor future evolution purposefully. The size and complexity of the brain have undergone changes. Similarly, the basic psychology is intimately tied to the functioning of the brain. The psychological capacities and traits have also transformed as brains have transformed. These psychological changes as contemporary psychology demonstrates, the human mind is an interactive whole, and changes in one fundamental dimension do impact changes in other psychological dimensions (Lovelock, 1979, 1988 and 2006; Sahtouris, 2000; Lombardo, 2009). Purposeful evolution is a long-standing fact in the history of humanity and is a primary factor accelerating rate of changes in the history (Nisbet, 1994).

Psycho-social evolution as applies to the ecology of human mind is based on the facts that hardly can an individual live in isolation, rather exist relatively in an organized plurality of other human beings with various social structures, organizations, and processes that affect individual's thinking and behaviour. This is another reciprocal loop where society affects individual psychology while individuals in turn influence their social environment (Lombardo, 2009). In like manner, the evolution of various technologies affects human psychological evolution. Human beings could be considered as "natural cyborgs" and that technologies are both extensions of their bodies and minds modifying the environment (Clark, 2003). The technological evolution makes humankinds to transcend their anatomical structures and increase their capacities. Genetically, human psychology is modifiable through both somatic gene therapy and germ line gene therapy, though identifiable psychological traits or capacities are mostly polygenic (Pinker, 2002; Naam, 2005; Garreau, 2005).

The nature of consciousness and its connection to the physical universe has been a historical puzzle (Baars, 1997; Searle, 1997; Edelman, and Tononi, 2000; Blackmore, 2004). Kurzweil (1999 and 2005) extrapolated on the idea of a global mind emerging on the earth for the possibility of the "noosphere" of the earth, that is, the global mind and consciousness of future humanity could progressively spread outward through space, enveloping in mentality and intelligence of the physical universe. Tipler (1994) proposed that in the far distant future an entity with cosmic mind will emerge, permeating the entire universe and gaining mental control over the cosmos. In essence, the ultimate future evolution of mind and consciousness would be an omniscient, omnipotent mind integrating and controlling everything that exists in the universe. The universe was described as information processing mechanism while evolution is the acceleration of more powerful and efficient forms of information processing within the universe. Moreover, higher intelligence may be observed as the capacity for processing information increases (Kurzweil, 1999 and 2005; Davies, 2009).

Lombardo (2009) considered minds to evolve and expand through the universe, bringing with them advancing forms of technology, enriching and empowering surrounding environments. The universe as a whole will increase in intelligence; hence, cosmic consciousness will evolve in a universe that will become increasingly intelligent in the process. Therefore, based on reciprocal evolution, mind and consciousness evolved relative to the universe as a whole dimly from a local and elementary level progressively more brilliantly as awareness expands to a cosmic level. The Gaia Theory postulated that biosphere is the earth becoming self-conscious; Lombardo (2009) similarly extends the phenomenon that biosphere is the universe becoming self-conscious taking into account that there may be other intelligent minds spread throughout the cosmos and such minds may also participate in this process of evolving self-consciousness. This on-going evolution will simultaneously bring greater illumination to both inner understanding subsequently leading to the cosmic ambience realizing a consciousness that is ecological in nature (Sahtouris, 2000).

CONCLUSION

The cell theory offered perspective which advanced the understanding of what cellular matter are made up and has brought a golden age to biological sciences. Although, there are controversies about the cell theory but it has ushered in a new era in biology by providing a unifying mechanistic concept, necessary for inductive science. However, it was found that the cell theory was limited and restrictive in its generalisation that all living things must be made up of cell as it does not provide evidence within the realm of science why cellular forms of matter were considered to be living entities. This opens room for research into the possibilities of having non cellular forms of matter as living entities. The linking characteristic – growth – biometric indices and model can be promising new approaches and method for the comparative study of cellular and non-cellular matters in order to explore the concepts of life, living and other related concepts like consciousness. Also, exploring the information theory and thermodynamic principles can go a long way in deepening the understanding of the concepts of life and living entities. Undoubtedly, interdisciplinary researches such as in fields like ecological cosmology are inevitable towards conceptualizing life and living.

The emergence of the universe from explosion expresses the disorderliness in the universe. However, the constructive nature of this explosion poses challenges to the entropy law paving way for the information theory where order emerged from disorderliness. The phenomena of order and disorder in physics are equivalent to the anabolism and catabolism in biology respectively. Essentially, both the non-cellular expanding universe and the growing cellular organisms are exhibiting self-organizations as a basic characteristic. These fundamental observations alongside the facts that both the universe and the cellular organisms are composed of mater with mass-energy and spacetime relative to an environment raised the questions: what is life and living entity? And why a living entity is considered living? It can be argued that the evolution of cellular forms of matter from the expanding universe at about 14 billion years old indicates a stage of maturity of the universe comparable to sexual maturity with development of new structures and functions in cellular matters like *Homo sapiens*. If so, what made *H. sapiens* distinctive in current dispensation, from less than 100,000 years ago, among other cellular forms of matter is the accrued information and learning abilities that are passed on from generations to generations not the current physiques which has been attained for over 200,000 years ago. With projected life span of the universe to about 100 billion years; more is yet to be mined and explored in nature from information perspective.

Consciousness is the state of knowing or being aware of, that is being informed of oneself and/or other entities. Information is carried in and by energy that can be transmitted and decoded visually (light energy)/in audio form (sound energy)/ as feelings in form of impulses (electrical/heat/chemical energy). All these forms of energy are characterised by speeds, waves and frequencies within spacetime (Gravo-electromagnetic field) with mass and energy being equivalent. The intrinsic nature of these characteristics generates quantifiable ranges of values which are specific to the sensitivity of each entity to communicate in order for an entity to be aware of the constituent information. Therefore, by exploring the information theories and other related theories, the understanding of the concepts of life, living and related concepts in nature will be deepened.

RECOMMENDATIONS

Interdisciplinary research is highly recommended for advancing the understanding of concepts of life, living entities, consciousness and related concepts such as soul. This will form a strong foundation for a unified theory of everything which is long cherished dream of most prominent scientists.

REFERENCES

Abdo, A. A., Ackemann, M., Ajello, M., Granot, J., Guiriec, S. Ohno, M. (2009). A limit on the variation of the speed of light arising from quantum gravity effects. *Nature,* 462: 331 – 334

Abdulkarim, M. , Yusuf, Z. A. , Musa, B. L. and Ezra, A. G. (2009). Population Parameters of *Clarias gariepinus* (cat fish) in Gubi dam, Bauchi State, Nigeria. *Journal of Animal and Plant Sciences* 5(2): 531 – 538. Retrieved February 10, 2914 from: http://www.biosciences.elewa.org/JAPS

Abercrombie, M., Hickman, M., Johnson, M. L. and Thain, M. (1990). The New Penguin Dictionary of Biology (8th Ed.). Penguin Group, London, England.

Anderson, W. T. (1996). Evolution Isn't What It Used To Be: The Augmented Animal and the Whole Wired World. New York, W. H. Freeman and Company.

Annila, A. and Baverstock, K. (2016). Discourse on Order Vs. Disorder. *Commun. Integr. Biol.* 9(4):e1187348, DOI:10.1080/19420889.2016.1187348

Baars, B. J. (1988). A Cognitive Theory of Consciousness. Cambridge University Press, Psychology. 448 Pp.

Baars, B. J. (1997). In the Theatre of Consciousness: The Workplace of the Mind. New York, Oxford University Press.

Balusïka, F., Dieter Volkmann1, D., and Barlow, P. W. (2004). Eukaryotic Cells and their Cell Bodies: Cell Theory Revised. Annals of Botany 94: 9 – 32, doi:10.1093/aob/mch109, available online at www.aob.oupjournals.org

Bekenstein, J. D. (1972). Black holes and the Second Law. *Lett. Nuovo Cimento,* 4: 737 – 740 DOI: 10.1007/BF02757029

Bekenstein, J. D. (2003). Information in the Hologrphic Universe. Scientific American Inc. 59 – 65 retrieved 26th November 2014 from http://www.sci,am,com

Benner, S. A. (2010). Defining Life. *Astrobiology,* 10(10): 1021 – 1030. DOI: 10.1089/ast.2010.0524

Bennett, C. H. (1973). "Logical Irreversibility of Computation". *IBM J. Res. Develop.* 17(6): 525 – 532 DOI: 10.1147/rd.176.0525

Bering, J. M. (2006). The cognitive science of souls: Clarifications and extensions of the evolutionary model. Behavioral and Brain Sciences, 29: 486 – 498

Berkovich, S. (2001). On the "barcode" functionality of the DNA, or The phenomenon of Life in the Physical Universe. 55pp

Bertalanffy, L. V. (1957). Quantitative Laws in Metabolism and Growth. *The Quarterly Review of Biology Vol. 32, No.3* Retrieved February 16, 2014 from: http://www.ms.uky.edu/~ma138/spring14/art1.pdf

Berut, A., Arakelyan, A., Petrosyan, A., Ciliberto, S., Dillenschneider, R. and Lutz, E. (2012). Experimental Verification of Landauer's Principle Linking Information and Thermodynamics. *Nature*, 483: 187 - 190

Blackmore, S. (2004). Consciousness: An Introduction. Oxford, Oxford University Press.

Bloom, P. (2004). Descartes' baby: How the science of child development explains what makes us human. New York, NY: Basic Books.

Boden, M. A. (2000). Autopoiesis and Life. *Cogn. Sci.* Q1:117 – 145.

Bolton, R. (1978). Aristotle's Definitions of the Soul: "De Anima" ii, 1-3 Reviewed work. *Phronesis,* 23 (3): 258 – 278 retrieved 25th November, 2014 from BRILL Stable URL: http://www.jstor.org/stable/4182048

Chalmers, D. J. (1996). The conscious mind: In search of a fundamental theory. New York, NY: Oxford University Press.

Chattopadhyay, J. and Tapaswi, P. K. (1993). Order and Disorder in Biological Systems through Negative Cross – diffusion of mitotic inhibitor – A Mathematical Model. Mathematical Computational Modelling 17 (1): 105 – 112.

Chodasewicz, K. (2014). Evolution, reproduction and definition of life. *Theory Biosc.*, 133:39 – 45. DOI: 10.1007/s12064+013.0184.5

Christodoulou, D. (1970). Reversible and Irreversible Transformations in Black-Hole Physics. *Phys. Rev. Lett.* 25: 1596 DOI: 10.1103/PhysRevlett.2

Chyba, C. F., and Hand, K. P. (2005).Astrobiology: the study of the living universe. *Annal Rev, Astron. Astrophys.* 43: 31 – 71

Clark, A. (2003). Natural-Born Cyborgs: Minds, Technologies, and the Future of Human Intelligence. Oxford: Oxford University Press,

Clark, A. (2010). There is no non-materialist neuroscience. *Cortex: A Journal Devoted to the Study of the Nervous System and Behavior*, 46: 147–149.

Claverie, J. M. (2001). What if There are only 30,000 Human Genes?, *Science,* 291: 1303

Cleland, C. E. and Chyba, C. E. (2002). Defining "life". *Orig. Life Evol Bios ph.* 32:387 – 393

Cleland, C. E. and Copley, S. D. (2005).the possibility of alternative microbial life on Earth. *Int. J. Astrobiol.* 4 (3 and 4): 165 – 173

Cox, G. W. (2008). Designing an Ecological Studies. Retrieved September 26 From: http://facultyfiles.deanza.edu/gems/heyerbruce/DesgnEcologicalStudies.pdf

Crick, F. (1994). The Astonishing hypothesis. The Scientific Search for Soul. London, Simon and Schuster

Csikszentmihalyi, M. (1993). The Evolving Self: A Psychology for the Third Millennium. New York, Harper Collins.

Damon, A. and Goldman, R. T. (1964). Predicting fat for body measurement: desnsitometric validation of ten anthropometric equations. *Human Bioligy*36: 32 – 44.

Davies, P. (1988). The Cosmic Blueprint: New Discoveries in Nature's Creative Ability to Order the Universe. New York, Simon and Schuster.

Davies, P. (2009). The quantum Life. *Phys. World*, 7: 24 – 28

Dennet, D. C. (1991). Consciousness Explained. Little Brown and Co., USA Pp511.

Descartes, R. (1641). Meditations on first philosophy. In: R. Ariew (Ed.), *René Descartes Philosophical essays and correspondence* (pp. 97–141). Indianapolis, IN: Hackett, Publishing Company, Inc.

Edelman, G. and Tononi, G. (2000). A Universe of Consciousness: How Matter Becomes Imagination. New York, Basic Books.

Eldredge, N. and Gould, S. (1972). "Punctuated Equilibria: An Alternative to Phyletic Gradualism" in Schopf, T. J. M. (Ed.) *Models in Paleobiology*. San Francisco: Freeman Cooper.

Emmeche, C. (1992). Life as an abstract phenomena: as artificial life possible? In: Bour gine, P., Verela, F. I. (eds). Towards a practice of autonomous system. *Proceedings of the First European Conference on Artificial Life,* MIT Press, Cambridge Pp 466 – 474

Farah, M. J. (2005). Neuroethics: The practical and the philosophical. *Trends in Cognitive Sciences*, 9: 34–40.

Farrer, C., and Frith, C. D. (2002). Experiencing oneself vs. another person as being the cause of an action: The neural correlates of the experience of agency. *NeuroImage*, 15: 596–603.

Farthing, G. W. (1992). The Psychology of Consciousness. Prentice-Hall Inc. 542 Pp

Fraser, J. T. (1987). Time, the Familiar Stranger. Redmond, Washington, Tempus Books of Microsft Press. Pp388

Fraser, J.T. (1978). Time as Conflict. Basel and Stuttgart, Birkhauser Verlag.

Fraser, J.T. (1982). The Genesis and Evolution of Time: A Critique of Interpretation in Physics. Amherst, Massachusetts, University of Massachusetts Press.

Garreau, J. (2005). Radical Evolution: The Promise and Peril of Enhancing Our Minds, Our Bodies –And What it Means to be Human. New York, Doubleday.

Gell-Mann, M. (1994). The Quark and the Jaguar: Adventures in the Simple and the Complex. New York, W.H. Freeman and Company.

Gibson, J. J. (1979). The Ecological Approach to Visual Perception. Boston, Houghton Mifflin.

Goodman (1975). Personal communication. [in Hall, C. A. S. and Day, J. W. J. (1977)]

Goswami, A. (2013). Physics of the Soul. Hampton Roads Publishing Company, Inc. Canada Pp20

Gould, S. J. (2002). The Structure of Evolutionary Theory. Cambridge, Massachusetts, Harvard University Press,

Greene, J. D., Sommerville, R. B., Nystrom, L. E., Darley, J. M., and Cohen, J. D. (2001). An fMRI investigation of emotional engagement in moral judgment. *Science*, 293: 2105 – 2108

Gupta, M. L. and Jangir, M. L. (2010). Cell Biology: Fundamentals and Applications. Student edition, Jodhpur. Pp 729

Hall, C. A. S. and Day, J. W. J. (1977) Systems and Models: Terms and Basic Principles. In C. A. S. Hall, and J.W.J., Day (Eds.); Ecosystem Modelling in Theory and Practice: An introduction with Case Histories. New York. John Willey and Sons. P 6 – 36.

Harpending, H. and Rogers, A. (2000). Genetic perspectives on human origins and differentiation. *Ann Revs Genomics Hum Genet.* 1:361–385.

Herries, A. I. R., Martin, J. M., Leece, A. B., Adam, J. W., Boschian, G., Joannes-Boyau, R., *et al.* (2020). Contemporaneity of Australopithecus, Paranthoopus, and aerly *Homo erectus* in South Africa. *Science*, 368 (6486): eaaw7293.doi: 10.1126/science.aaw7293

Huang, W., Gochon, R., Gu, Y., Larick, R., Fang, Q., Schwarcz, H., *et al.* (1995). Early Homo and associated artefacts from Asia, *Nature*, 378: 275 – 278

Johannsen, W. (2005). On Semantic Information in Nature. *Information*, 6:411 – 431 DOI: 10.3390/info6030411. Reyreived from http://www.mdpi.com/journal/information

Joyce, G. F. (1994). Forward. In Origin of Life. The Central Concepts, D. W. Deamer and s system. omouFliers Chacker, G. Junes and Barlett, Boston.

Kauffman, S. (1995a). "Order for Free" In: Brockman, J. (Ed.) *The Third Culture*. New York, Touchstone.

Kauffman, S. (1995b). At Home in the Universe. Oxford, Oxford University Press.

Klein, R. G. (1999). The human career: human biological and cultural origins (2nd ed.) Chicago: University of Chicago Press. 810pp

Kormondy, E. J. (2009). Concept of Ecology. (4th ed.). Learning Private Limited, USA, Pp559

Koshland, D. E. (2002). The Seven Pillars of life. Science, 295: 2215 – 2216

Krebs, C. J. (1978). Ecology: The experimental analysis of distribution and abundance (2nd ed.). Harper and Row Publisher, New York. Pp539.

Kurzweil, R. (1999). The Age of Spiritual Machines: When Computers Exceed Human Intelligence. New York, Penguin Books.

Kurzweil, R. (2005). The Singularity is Near: When Humans Transcend Biology. New York, Viking Press.

Landauer, R. (1961). Irreversibility and heat generation in the computing process. IBM J. Res. Dev. 5 (3):183 – 191

Landauer, R. (1988). Dissipation and noise immunity in computation and communication. *Nature*, 335 (6193): 779 – 784.

Laszlo, E. (2008). Quantum Shift in the Global Brain: How the New Scientific Reality Can Change Us and Our World. Rochester, Vermont, Inner Traditions.

Le Doux, J. E. (1996). The emotional brain: The mysterious underpinning of emotional life. New York, NY: Simon and Schuster.

Levine, J. (1983). Materialism and qualia: The explanatory gap. *Pacific Philosophical Quarterly*, 64: 354–361.

Loevenstein, W. (2003). Physics in Mind. Basic Books., New York, NY, USA

Lombardo, T (2011). The Ecological Cosmology of Consciousness. Centre for future consciousness. Pp15. Retrieved January 12, 2014 from: http://www.centreforfutureconsciousness.com/pdf_files/Articles/Consciousness_Expanded_Final_May2011pdf.

Lombardo, T. (1987). The Reciprocity of Perceiver and Environment: The Evolution of James J. Gibson's Ecological Psychology. Hillsdale, N.J.. Lawrence Erlbaum Associates.

Lombardo, T. (2006). Contemporary Futurist Thought: Science Fiction, Future Studies, and Theories and Visions of the Future in the Last Century. Bloomington, IN: Author House, Pp.. 303-315.

Lombardo, T. (2009). The Future Evolution of the Ecology of Mind. Center for Future Consciousness, Pp26 Retrieved November 26, 2014 from https://www.odysseyofthefuture.net

Lovelock, J. (1979). Gaia. Oxford, Oxford University Press.

Lovelock, J. (1988). The Ages of Gaia. New York, W. W. Norton.

Lovelock, J. (2006). The Revenge of Gaia. Santa Barbara, Allen Lane.

Ma, W. (2016). The Essence of Life. *Biology Direct*, 11:49 DOI: 10.1186/s13062-016-0150-5

Mautner, M. N. (2002a). Planetary Bio-resources and Astroecology: Micro Bio-assay of Martian and Carbonaceous Chondrite Materials: Nutrients, Electrolytes Solution, and Algal and Plant Responses. Icarus 158, 72-86 doi:10.1006/icar.2002.6841

Mautner, M. N. (2002b). Planetary Resources and Astroecology: Planetary Macrocosm Models of Asteroid and Meteorite Interiors: Electrolyte Solutions and Microbial Growth – Implication for Space Population and Panspermia. Astrobiology Vol. 2, No. 1:59-76. Retrieved December 30, 2013 from: http://www.researchgate.net/publication/11019236

McCabe, D. P., and Castel, A. D. (2008). Seeing is believing: The effect of brain images on judgments of scientific reasoning. *Cognition*, 107: 343–352.

McDougall I., Brown, F. and Fleagle, J. G. (2005). Stratigraphic placement and age of modern humans from Kibish, Ethiopia. *Nature.* 433:733–736.

Michaelides, E. E. (2008). Entropy, Order and Disorder. *The Open Thermodynamic Journal*, 2: 7 – 11

Miguel-Tome, S. (2013). Nature from the bit and beyond. Pp 1 – 11 retrieved 12th December, 2014 from https://www.fqxi.org/community

Miller, G. A. (1962). The Science of Mental Life. Gretna LA:Pelican Books

Min, J. (1999). Information definition, Origin and Evolution: in the quest for a unified Theory of Information. *Proceedings of the second international conference on the Foundation of Information Science,*Vienna, Austria. 11 – 15 June, 1996, Hfkirchiner, E. Ed. Routledge: New York, NY, USA

Morowitz, H. (2002). The Emergence of Everything: How the World Became Complex. Oxford, Oxford University Press.

Mukhanov, V.(2005). Physical Foundations of Cosmology. Cambridge University Press, New York (www.cambridge.org/9780521563987). Pp 421. Retrieved February 6, 2014 from: http://www.astro.Caltech.edu/~george/ay21/readings/Mukhanov_PhysFoundCosm.pdf

Naam, R. (2005). More Than Human: Embracing the Promise of Biological Enhancement. New York, Broadway Books.

Nesterov , V. I. (2012). Information in the Structure of the Universe. *Academic Research International*, 2 (1):11-19. Retrieved March 13, 2014 from http://www.journals.savap.org.pk

Nisbet, R. (1994). History of the Idea of Progress. New Brunswick, Transaction Publishers.

Ohnuma, K., Aoki, K., and Akazawa, T. (1997). Transmission of tool-making through verbal and non-verbal communication: preliminary experiments in Levallois flake production. *Anthropol Sci.* 105(3):159–68.

Oliver, J. D. and Perry, R. S. (2006). Defining life but not definitively. *Orig. Life Evol. Bios.* 36: 515 – 521

Panawala, L. (2017). Differences between Anabolosim and Catabolism. EPAEDIAA. Science, Biology. 11Pp Retrieved on 1st January, 2018 from http://pediaa.com/difference-between-anabolosim-and-catabolism/

Pinker, S. (2002). The Blank Slate: The Modern Denial of Human Nature. New York, Penguin Books.

Plato. (2005). Phaedo. In: S. M. Cohen, P. Curd, and C. D. C. Reeve (Eds.), *Readings in Ancient Greek Philosophy: From Thales to Aristotle*. Indianapolis, IN: Hackett Publishing Company, Inc. Pp. 229 - 281.

Ponting, C. (2007). A New Green History of the World: The Environment and the Collapse of Great Civilizations. New York, Penguin.

Possel, M. (2014). "A tale of two big bangs" in Einstein Online, Vol. 04 (2010). Max Planck Institute for Gravitational Physics. Retrieved June 19, 2014 from: http://www.einstein_online.info/spotlights/big_bangsandei

Preston, J. l., Ritter, R. S., Hepler, J. (2013). Neuroscience and the soul: competing explanations for the human experience. *Cognition*, 127:31–37 http://dx.doi.org/10.1016/j.cognition.2012.12.003

Preston, J., and Epley, N. (2009). Science and god: An automatic opposition between ultimate explanations. *Journal of Experimental Social Psychology*, 45: 238–241.

Prigogine, I. (1980). From Being to Becoming: Time and Complexity in the Physical Sciences. San Francisco: W. H. Freeman and Company.

Prigogine, I. (1997). The End of Certainty: Time, Chaos, and the New Laws of Nature. New York, The Free Press.

Prigogine, I. and Stengers, I. (1984). Order out of Chaos: Man's New Dialogue with Nature. New York, Bantam.

Pross, A. (2011). Towards a general theory of evolution: extending Darwinian theory to inanimate matter. *Journal of synthetic Chenistry*, 2: 1

Ryle, G. (1949). The concept of mind. Oxford, England: Barnes and Noble.

Sahtouris, E. (2000). Earth Dance: Living Systems in Evolution. Lincoln, Nebraska Universe Press.

Schulze-Makuch, D., and Irwin, L. N. (2006). The prospect of alien life in exotic forms on other worlds. *Naturwissen-Schaften* 93: 155 – 172. DOI: 10.1007/s00-114.005-0078-6

Schwartz, J. H, and Tattersall, I. (2005). The human chin revisited: what is it and who has it? *Jour Hum Evol.*, 38:367–409.

Schwartz, J. H, and Tattersall, I. (2000). The Human Fossil Record: Craniodental Morphology of Early Hominids (Genera Australopithecus, Paranthropus and Orrorin) and Overview. Vol. 4. New York: Wiley-Liss

Searle, J. (1997). The Mystery of Consciousness. New York, New York Review Book, 1997.

Searle, J. (1992). The Rediscovery of the Mind. Cambridge, MA: The MIT Press.

Seife, C. (2000). 'spooky Action' passes s Relativistic Test, *Science*, 287: 1909 - 1910.

Shizume, K. (1995). Heat generatio required by information erasure. *Phys. Rev.* E 52:3495 – 3499

Shonkwiler, R. W. and Herod, J. V. (2009). Mathematical Biology (2nd Ed.), Springer, New York. Pp 551. DOI.10.1007/978-0-387-70984-0

Smolin, L. (1997). The Life of the Cosmos. Oxford, Oxford University Press.

Sparre, P. and Venema, S. C. (1998). Introduction to tropical fish assessment. Part 1 Manual, FAO Fisheries Technical Paper. No.306,1, Rev. 2, Rome.

Stringer C. (2016). The origin and evolution of Homo sapiens. *Phil. Trans. R. Soc.* B 371: 1 – 12 http://dx.doi.org/10.1098/rstb.2015.0237

Swan, L. S. (2009). Synthesising insight: artificial life as thought experimentation in biology. *Biol. Philos.* 24:687 – 701 DOI: 10.1007/s10539-009-9156-2

Talbot, M. (1991). The holographic Universe, Haper Perennial, New york

Tattersall, I. (2009). Becoming Modern Homo sapiens. *Evo Edu Outreach (Springer Science + Business Media)* 2:584–589, DOI 10.1007/s12052-009-0164-x

Tavassoli, M. (1979).The Cell Theory: A Foundation to the Edifice of Biology. Selected Items From the History of Pathology, 1p

Tipler, F. (194). The Physics of Immortality: Modern Cosmology, God, and the Resurrection of the Dead. New York: Doubleday.

Tirard, S., Morange, M. and Lazcano, A. (2010). The Definition of Life : Breif History of an Elusive Scientific Endeavour. *Astrobiology* 10(10): 1003 – 1009

Tishkoff, S. A., Reed, F. A., Fredlaender, F. R., Ehret, C., Ranciaro, A., Froment, A. *et al.* (2009). The genetic structure and history of Africans and African Americans. *Science* 324:1035–1044.

Tortora, G. J. and Derrickso, B. (2012). Principles of Anatomy and Physiology (13th Ed.). John Wiley and Sons, Inc., USA. Pp.1222

Udgankar, J. B. (2001). Entropy in Biology. *Resonance*, 61 – 66

Velmans, M. (1996). Consciousness and the 'Causal Paradox." *Behavioral and Basic Sciences*, 19 (3): 538 – 542

Velmans, M. (2009). How to define Consciousness – and how not to define consciousness, *Journal of*

Consciousness studies 16 (5): 139 – 156

Velmans, M., and Schneider, S. (Eds) (2007). The Blackwell Companion to Consciousness. Blackwell Publishing, New York DOI: 10.1002/9780470781466

Wegner, D. M. (2003). The mind's best trick: How we experience conscious will. *Trends in Cognitive Science*, 7: 65–69.

Weithman, A. S. and Anderson, R. O.(1978). A Method for Evaluating Fishing Quality. Fisheries 3 (3):6-10.

Welch, G. R, and Clegg, J. S. (2010). From protoplasmic theory to cellular systems biology: a 150-year reflection. *Am J Physiol Cell Physiol* 298: C1280 – C1290, Doi:10.1152/ajpcell.00016.2010

Wheeler, J. A. (1988). Information, Physics, quantum: the search for links, in complexity. entropy and the Physics of Information: the proceedings of the 1988 workshop on complexity, entropy and physics of information held 29 May – 10 June, 1989 in Santa Fe, New Mexico, Volume 8, (Westview Press, 1990).

Wheeler, J. A. (1999). In: Faynman and Computational Chap. Information, Physics, quantum: the search for links, Pp 309 – 336

White, T. D., Asfaw, B,, DeGusta, D, ,Gilbert, [illegible]ards, G. D., Suwa, G. *et al.* [illegible] Pleistocene Homo sapiens from Middle Awash, Ethiopia. *Nature.* 423:742–747.

Wilkinson Microwave Anisotropy Probe (2011). Cosmology: The Study of the Universe. Pp50. Retrieved March 13, 2014 from: http://map.gsfc.nasa.gov./universe/WMAP_universes.pdf

Wolfe-Simon, F., Blum, J. S., Kulp, T. P., Gordon, G. W., Hoeft, S. F., Pett-Ridge, J. *et al.* (2010). A bacterium that can grow by using arsenic instead of phosphorus. *Sci.*, http://www.scienceexpress.org/2D

Wolpert, L. (1969). Positional Information and the Spatial Patern of Cellular Differentiation. *Journal of Theoretical Biology* 25: 1 – 47

Yusuf, Z. A. and Abdulkarim, M. (2015). Fundamentals of Tropical Fish Stock Assessment. Sagir Press, Bauchi. Pp 112.

Zhuravlev, Y. N. and Avetisov, V. A. (2006). The definition of life in the context of its origin. *Biogeosciences*. 3: 281 – 291.

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EFFECTS OF IRRIGATION WATER SOURCE ON THE NUTRITIONAL AND BIOCHEMICAL QUALITIES OF HARVESTED VEGETABLES

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ABSTRACT

Farmlands are typically irrigated by groundwater and surface water. Research works on the effects of irrigation water on crop quality abound, but it is desirable to have more information on the comparative effects of groundwater and surface water irrigation on the nutritional quality of harvested crops. Hence, in this study, we compared the nutritional and biochemical qualities of vegetable crops harvested from groundwater and surface water-irrigated farmland situated within the same proximity. Telfairia occidentails, Amaranthus hybridus and Corchorus olitorius were harvested from the two farm types, *and evaluated for nutritional and biochemical parameters, using spectrometry method. Vegetables irrigated with groundwater had higher values of all the assessed parameters, except carbohydrate and total energy. Corchorus olitorius was highest in moisture (27.83 ± 0.08%) while A. hybridus recorded the highest ash (24.15 ± 0.05%). Telfairia occidentalis had higher values of protein (21.66 ± 0.05%), crude fibre (12.45 ± 0.06%) and fat (3.40 ± 0.05%). The result of the biochemical analysis showed that A. hybridus grown on groundwater-irrigated farmlands had higher content of starch, reducing sugar and total sugar relative to those grown on surface water irrigate farmland. Since the vegetables grown on groundwater water-irrigated farm showed improved nutritional qualities, we recommend sustainable groundwater irrigation practices for the production of quality vegetables.*

Keywords: *Irrigation, vegetables, Telfairia occidentails, Amaranthus hybridus, Corchorus olitorius,*

INTRODUCTION

Agricultural productivity and sustainable food production are key activities needed to confront the problem of hunger. However, in the face of an ever-growing global population size, accelerating pace of urbanization, and effects of climate change, there is more pressure on the limited natural resources for agriculture (FAO 2017). Water availability is a major limiting environmental factor affecting crop production. In arid and semi-arid regions, plants are often subjected to periods of drought (Fahad *et al.*, 2017; Kyei-Mensah, *et al.*, 2019). Interventions such as irrigated agriculture have played a vital role in maintaining food productivity and security in developing countries (Bjornlund, *et al.*, 2020). At present, irrigated agriculture utilises more than two-third of the total available freshwater in about 20% of the total arable land (Parkash and Singh, 2020). This is in direct competition with other water uses in the growing urban centres, industrial areas and other agricultural applications, such as fishery.

Irrigated agriculture is essential to attaining food security, as conventional rain-fed farming does not suffice to cope with the current food demands. Two major sources of water for irrigation are groundwater and surface water. Water from rain and surface is stored in underground spaces between rock particles, as it moves slowly through geologic formations of soil, sand and rocks, called aquifer (Lachassagne, 2020). Access to the stored water could either be via natural means such as from springs or manmade methods such as drilled wells. Groundwater is generally less prone to contamination, having passed through layers of filtration. The choice of water for irrigation could be influenced by the sensitivity of plants to water-related environmental contamination and the quality of plant produce. Global withdrawals of freshwater have created uncertainty on the volumes and spatial distribution of groundwater (Siebert *et al.*, 2010; Cosgrove and Loucks, 2015). Insufficient protection of surface water against contamination raises concern alongside questions of global climate impact, accessibility and affordability issues created by artificial means of accessing groundwater for irrigated agriculture and quality of food.

Vegetables are an important portion of culinary and diet, as they serve as a functional food and a major source of vitamins, minerals, proteins and dietary fibre (Ülger *et al.*, 2018). Vegetables are enjoyed by different ethnicities, and some hold cultural significance. However, vegetable cultivation presents a unique challenge due to its perishability and high sensitivity to environmental factors such as quality of water and contamination during growth (FAO, 2020). Several human health issues are tied to diet, this calls for the need to investigate the effect of water sources on vegetable cultivation. This study aimed to compare the nutritional and biochemical quality of three tropical leafy vegetables important to West Africa culinary – *Telfairia occidentails* (Ugwu), *Amaranthus hybridus* (Tete), *Corchorus olitorius* (Ewedu), each cultivated on plots of surface water-irrigated farm and groundwater-irrigated farm.

MATERIALS AND METHODS

Experimental Site and Plant Collection

Seeds of selected tropical leafy vegetables (*Telfairia occidentails*, *Amaranthus hybridus*, *Corchorus olitorius*) (Table 1) were grown in sections on two experimental farm plots irrigated with groundwater and surface water, within the premises of Federal Government College (FGC) Ijanikin, Badagry, Lagos, Nigeria (latitude-6°29'32.6"N, longitude-3°08'06.4"E). The vegetables were harvested on maturity from each plot and cleaned under running tap water. The edible portions of the leaves were detached from the stalk, air-dried and packed in zipper plastic bags. Samples were taken for analysis at the Federal Institute of Industrial Research Oshodi (FIIRO) laboratory.

Table 1: Names of Selected Green Leafy Indigenous Vegetables

Species	Family	Common name (English)	Local name (Dialect)
T. occidentalis Hook. F.	Cucurbitaceae	Fluted pumpkin	Ugwu (Igbo), Ikong-ubong (Efik)
A. hybridus Linn.	Amaranthaceae	African spinach	Tete (Yoruba), Inyangafia (Efik)
C. olitorius Linn.	Tiliaceae	Bush okra, Vegetable juts	Ewedu (Yoruba), Etinyung (Efik)

Proximate analysis

The Proximate analysis was determined using the protocols of the Association of Official Analytical Chemist and other standard procedures. Moisture, crude protein, ash, crude fibre and crude lipid content were measured using the oven-dry (105°C), Kjeldahl nitrogen, dry ashing (600°C), digestion, soxhlet extraction methods, respectively. Protein was calculated from the total nitrogen value of the Kjeldahl result using the conversion factor of 6.25, while the Carbohydrate and Total Energy were determined by difference and Atwater factor, respectively. All analyses were performed in triplicates.

Moisture Content

The moisture content of vegetables was determined using the AOAC method (Adegbaju *et al.*, 2019; Salisu *et al.*, 2020). Porcelain cups were dried for 30 minutes in an oven at 110°C, the cups were cooled in a desiccator and weighed (W1). Two grams of each of the samples were added to the known weight of porcelain cups (W2) and heated in an oven at 105 ºC until a constant weight was obtained (W3). The percentage moisture content was calculated as;

$$Moisture\ content\ (\%) = \frac{W2 - W3}{W2 - W1} \times 100$$

Crude Protein Content

The crude protein of each vegetable sample was determined using the Kjeldahl Nitrogen method. Two grams of each sample with two tablets of digestion catalyst (potassium sulfate, copper sulfate) were subjected to reaction with 15ml sulphuric in a Kjeldahl tube. The tubes were set up in a digestion block heater (370ºC) until a clear green colour was obtained. The organic nitrogen in the sample was converted to ammonium sulphate. The digest was cooled to room temperature and diluted to 100ml with distilled water, which was further distilled in an alkaline condition of 40% sodium hydroxide. The liberated ammonium hydroxide was trapped in a 2% boric acid solution and titrated against a 0.1 N hydrochloric acid solution (Olajire *et al.*, 2022; Ullah *et al.*, 2021). The crude protein was calculated from total nitrogen in the sample using the conversion factor 6.25, based on the assumption that the average protein contains about 16% nitrogen.

Total Ash Content

Ash Content was determined using the AOAC method as described by Olajire *et al*. (2022). Lab crucibles were dried in the oven to a constant weight at 110ºC for 10 min, cooled in a desiccator and weighed (W1). Two grams of vegetable samples were added to pre-weighed crucibles (W2) and heated in a muffle furnace at 600°C for 6 hours to ensure proper ashing. The crucibles containing ashes samples were cooled in desiccators and reweighed (W3). The percentage ash content was calculated as;

$$Ash\ content\ (\%) = \frac{W2 - W3}{W2 - W1} \times 100$$

Crude Fiber Content

To analyze the dietary fibre of the vegetables, two grams of samples was defatted with n-hexane and placed in a crucible of known weight. The sample was left to heat in an extraction unit and digest for 30 minutes with 100ml of the solution containing 1.25% sulphuric acid. The condenser was allowed to cool. The solution was filtered and the filtrate was washed with boiling distilled water to remove the remaining acid. The filtrate was digested for 30minutes with 100ml of alkaline solution (1.25% sodium hydroxide) to dissolve alkaline-soluble matter from the sample. The final residue was washed with water, oven-dried at 105°C, cooled in a desiccator and weighed (W1). The weighed sample was incinerated in a muffle furnace at 550 °C for 2 h, the crucible and ash were cool in a desiccator and weighed (W2) (Galyean 2010; Obembe *et al.*, 2021). The percentage crude fibre was calculated as;

$$Crude\ fibre\ content\ (\%) = \frac{W2 - W1}{Initial\ Sample\ Weight} \times 100$$

Crude Lipid

Exhaustive soxhlet extraction was used to determine the crude lipid/fat with petroleum ether using a modified version of the Zaklouta *et al.*, (2011) protocol. Two grams of the sample was put into pre-weighed thimbles and covered in a wad of cotton. A soxhlet extraction cup was weighed and 150ml of petroleum ether was added into each flask fitted with soxhlet extraction units and condenser. The heating mantle was switched on with cool tap water circulation in the connected condenser. The heating rate was adjusted until the solvents were refluxing at a steady rate. Extraction was carried out for 6 h, after which the solvent was evaporated. The extraction cup was removed and placed in an oven for drying at 105^{o}C. The extraction cup was removed from the oven after 60 minutes and allowed to cool in desiccators and then weighed. The lipid was measured by re-weighing the extract cup and the crude lipid content was determined by percentage difference.

Carbohydrate content and Total Energy Determination

The nitrogen-free extract (carbohydrate) was determined with the equation stated below.Total Carbohydrate (%) = 100-(moisture + protein + fat + crude fibre + ash)

While, Atwater factors of 4, 9 and 4 kcal were employed to calculate the caloric value by summing the multiplied values for crude protein, crude lipid and carbohydrate respectively as:

Energy value (kcal/100 g) = (crude protein × 4) + (crude lipid × 9) + (total carbohydrate × 4).

Determination of Reducing Sugar Content, Total Sugar and Starch Content

Reducing sugars of vegetable extracts was estimated using the Dinitrosalicylic acid (DNS) method. Samples were centrifuged at 3,500 rpm for 5 min and diluted with distilled water. and added DNS reagent was further added to the mixture and incubated in a boiling water bath for 5 minutes. The optical density was read at 540 nm wavelength and the absorbance was correlated to the concentration of reducing sugar using a standard glucose curve (Fernandes *et al.*, 2021). Total soluble sugars and starch were estimated according to the anthrone-sulphuric acid reported by (Sung, *et al.*, 2017) with some modification. 0.2% anthrone in concentrated $H_2SO_4$was used as a reagent. The tubes were cooled under tap water and the optical density was read using 660 nm wavelengths. The concentration of total sugar was calculated using the concentration factor using glucose as standard. The concentration of starch was determined by multiplying the obtained value by 0.9 for converting the glucose value to starch content.

Chlorophyll a, b & Total Chlorophyll

Chlorophyll content of vegetables were extracted with 15ml of 80% acetone (v/v) per gram of samples and homogenized using the Phillip type harmonizer at 1000 rpm for one minute. The homogenate was filtered and centrifuged at 5000 rpm for ten minutes. The absorbance of the supernatant was read with a UV spectrophotometer at 663 nm and 645nm wavelength (Ni, *et al.*, 2009; Kumari *et al.*, 2018). The chlorophyll a and chlorophyll b contents were calculated with the equation below, while total chlorophyll content is the sum of the contents of chlorophylls a and b.

Chlorophyll a (Ca) = 12.7(A663) – 2.69 (A645)

Chlorophyll b (Cb) = 22.9 (A645) – 4.68 (A663)

Statistical Analysis

The data generated from the study were subjected to independent t-test, to check the differences in nutritional and biochemical values of sampled vegetables irrigated with groundwater and surface water, using SPSS v

26 statistical software (IBM Corp., USA). Statistical significance was determined at the level $P \leq 0.05$. Results were presented as mean ± SD for all variables. The graphs were plotted using Graph PadPrism 8.0.1.

Results

Proximate composition of vegetables irrigated with groundwater and surface water

The proximate composition of *Telfairia occidentails*, *Amaranthus hybridus* and *Corchorus olitorius* irrigated with groundwater and surface water is shown in Table 2. Generally, vegetables irrigated with groundwater recorded marginally higher nutritional values, relative to those irrigated with surface water. *C. olitorius* had the highest moisture (27.83 ± 0.08%) while *A. hybridus* recorded the highest ash (24.15 ± 0.05%). *T. occidentalis* had the highest value 21.66 ± 0.05%, 12.45 ± 0.06% and 3.40 ± 0.05% for protein, crude fibre and fat respectively, which resulted in a total energy value of 214.8 to 217.44 kcal/100g. The total energy values of the vegetables ranged from 176.94 to 217.44 kcal/100g.

Table 2: Proximate composition of vegetables irrigated with groundwater and surface water

Proximate (%)	***Telfairia occidentalis***		***Amaranthus hybridus***		***Corchorus olitorius***	
	GW	**SW**	**GW**	**SW**	**GW**	**SW**
Moisture	25.45±0.05	25.20±0.05	23.65±0.05	23.35±0.05	27.83±0.08	27.30±0.05
Protein	21.66±0.05	20.41±0.05	15.43±0.04	15.11±0.05	13.24±0.04	12.76±0.05
Ash	12.65±0.05	12.35±0.05	24.15±0.05	23.90±0.05	20.80±0.05	20.40±0.05
Crude Fibre	12.45±0.06	12.09±0.05	9.34±0.02	9.16±0.02	8.26±0.02	8.11±0.02
Crude Lipid	3.40±0.05	3.20±0.05	1.10±0.05	0.90±0.05	1.35±0.05	1.20±0.05
Carbohydrate	24.39±0.28	26.75±0.16	26.33±0.05	27.58±0.04	28.52±0.01	30.23±0.13
Total Energy (kcal/100g)	214.8	217.44	176.94	178.86	179.19	182.76

GW = groundwater irrigated; SW = Surface water irrigated. Each value was expressed as the mean ± standard deviation (n=3).

Reducing sugar contents of vegetables irrigated with groundwater and surface water

Groundwater-irrigated and surface water irrigated *A. hybridus* had reducing sugar values of 8.413 ± 0.165 mg/100g and 7.427 ± 0.083 mg/100g, respectively. Surfacewater irrigated *C. olitorius* had higher reducing sugar 6.45 ± 0.070 mg/100g compared to groundwater irrigated (5.940 ± 0.095 mg/100g). *Telfairia occidentalis* had the lowest reducing sugar of 4.217 ± 0.081 mg/100g and 3.553 ± 0.070 mg/100g for groundwater and surface water irrigated farms, respectively (Figure 1). Vegetables irrigated with groundwater generally recorded higher starch content, relative to those irrigated with surface water. Groundwater irrigated *A. hybridus* had the highest starch content of 25.5 ± 0.5 mg/100g (Figure 2).

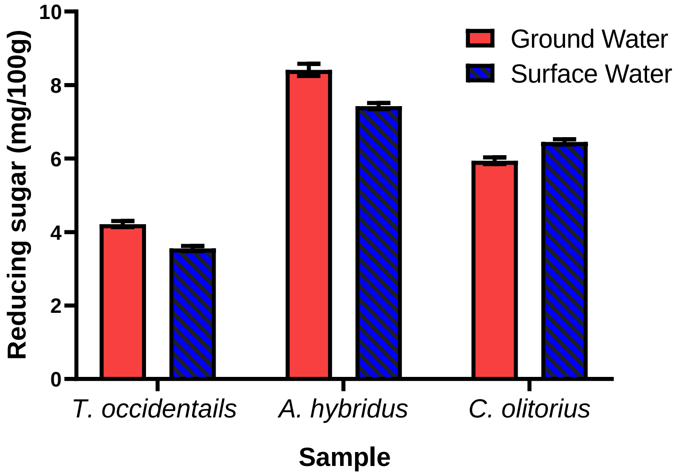

Figure 1: Reducing sugar contents of vegetables irrigated with groundwater and surface water

Starch contents of vegetables irrigated with groundwater and surface water

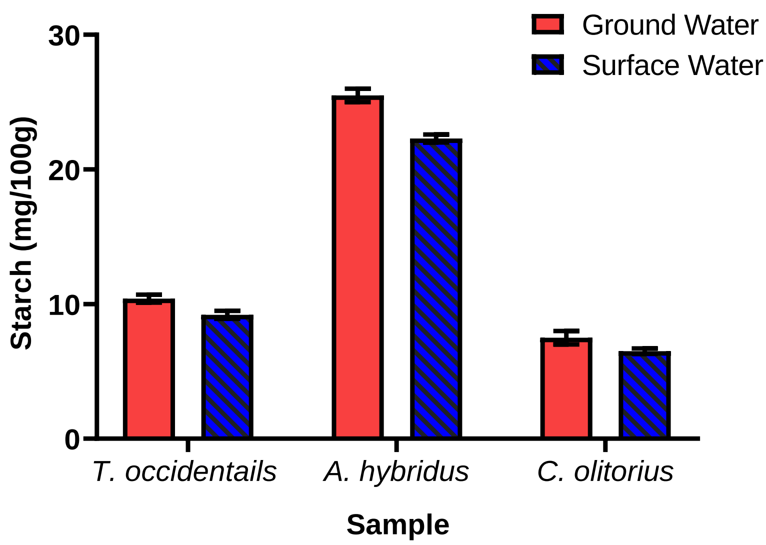

Figure 2: Starch contents of vegetables irrigated with groundwater and surface water

Total sugar contents of vegetables irrigated with groundwater and surface water

Groundwater irrigated vegetables had higher total sugar contents. Groundwater and surface water irrigated *A. hybridus* had total sugar contents of 24.66 ± 0.22 mg/100g and 22.95 ± 0.15 mg/100g, respectively. *Telfairia occidentalis* and *C. olitorius* irrigated with groundwater had total sugar contents of 19.540 ± 0.303 mg/100g and 20.46 ± 0.145 mg/100g, respectively (Figure 3).

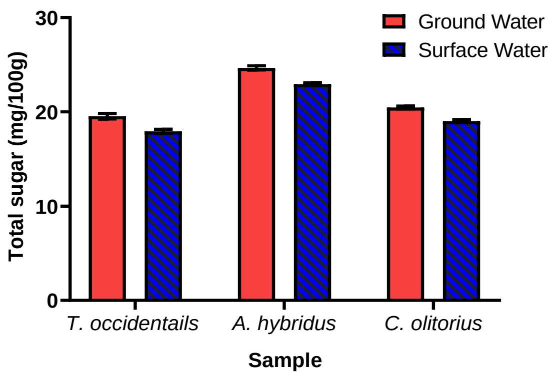

Figure 3: Total sugar contents of vegetables irrigated with groundwater and surface water

Chlorophyll a, b and total chlorophyllof vegetables irrigated with groundwater and surface water

Figure 4 shows the concentration of chlorophyll a, b and total chlorophyll of *T. occidentails, A. hybridus* and *C. olitorius* grown on groundwater and surfacewater irrigated farms. Chlorophyll a, chlorophyll b, and total chlorophyll in vegetables were generally lower in vegetables irrigated with surface water. The chlorophyll a concentrations of *T. occidentails* irrigated with groundwater and surface water were 62.98 ± 0.36 mg/100g and 53.31 ± 0.48 mg/100g, respectively. *Amaranthus hybridus* irrigated with groundwater and surface water recorded chlorophyll a concentrations of 44.10 ± 0.40 mg/100g and 42.55 ± 0.45 mg/100g, respectively.

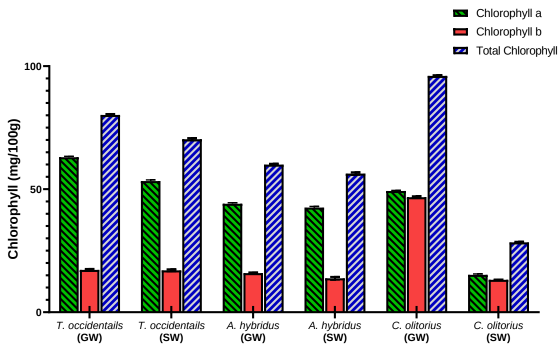

Figure 4: Chlorophyll a, b and total chlorophyll of vegetables irrigated with groundwater and surface water

DISCUSSION

Green leafy vegetables play a vital role in diets, especially among the populace of many developing countries. The consumption of indigenous vegetables serves as an affordable and important source of protein, amino acid, minerals, vitamins and dietary fibre, which are beneficial in the maintenance of good health and prevention against diseases (Omara-Achong, *et al*., 2012; Njume, *et al.*, 2014).

Our study showed a considerable stable range of moisture content among all the vegetable species, which could indicate that they were all subjected to similar environmental factors. While high moisture contents of vegetables could be an indicator for freshness, it could also facilitate spoilage in storage through microbial activities, often observed in many vegetables with very short shelf life (Adeyeye *et al*., 2018). The result of the protein content for *T. occidentalis* and *C. olitorius* in our study is similar to the range reported by Arowosegbe *et al.* (2015). Protein is important in the diet for growth, especially in children. Protein is also needed for the constant replacement of worn-out tissues (Arowosegbe *et al*., 2015).

In this study, the concentrations of crude lipid/fat and fibre of *C. olitorius* was less, and ash content was higher; this compared favourably with the findings of Arowosegbe *et al.* (2015). Dietary fibres aid digestion in the bowel, while creating the feeling of satisfaction, and preventing constipation. It is worth noting that vegetables generally contain low sugar and calories, which is beneficial in treating disease conditions such as obesity.

While vegetables is attributable to the presence of chlorophyll, their productivity and photosynthetic rate is directly dependent on the quantity and concentration per unit area of the chloroplast (Baruah, *et al.*, 2014). In this study, the high chlorophyll concentration in *T. occidentails* directly correlated with its high protein value. However, *A. hybridus* generally had lower chlorophyll concentration, but high concentrations of reducing sugar, total sugar and starch. These variations in parameters could be explained by the different mechanisms of conversion of primary products by different plant species.

Since the vegetables grown on groundwater water-irrigated farm showed improved nutritional qualities, we recommend increased production of these vegetables with sustainable groundwater irrigation practices. This is because *C. olitorius, A. hybridus, T. occidentalis* among others, play important roles in traditional medical practice, in addition to their use as sources of food (Rahal *et al.*, 2014; Adeyeye *et al*., 2018). The vegetables have been identified as rich sources of sources of vitamin E, iron, anti-inflammation, anti-ageing, and anti-cancer agents (Rahal *et al.*, 2014; Onuminya *et al.*, 2017; Dawodu *et al*. 2020).

CONCLUSION

In this study, we compared the nutritional and biochemical qualities of vegetable crops harvested from groundwater-irrigated farmland and surface water-irrigated farmland, situated within the same proximity. Vegetables irrigated with groundwater generally recorded increased nutritional values. We therefore recommend increased production of these vegetables through sustainable groundwater irrigation practices.

REFERENCES

Adegbaju O.D., Otunola G.A., and Afolayan, A. J. (2019). Proximate, mineral, vitamin and anti-nutrient content of *Celosia argentea* at three stages of maturity. *South African Journal of Botany*. 124:372–379. doi:10.1016/j.sajb.2019.05.036

Adeyeye A., Ayodele O.D., Akinnuoye G.A. and Sulaiman W. (2018). Proximate Composition and Fatty Acid Profiles of Two Edible Leafy Vegetables in Nigeria. *American Journal of Food, Nutrition and Health*. 3(2):51-55.

Arowosegbe S., Oyeyemi S.D., and Alo O. (2015). Investigation On The Medicinal And Nutritional Potentials Of Some Vegetables Consumed In Ekiti State, Nigeria. *International Research Journal of Natural Sciences*. 3(1):16-30

Baruah P., Saikia R.R., Baruah P.P. and Deka S. (2014). Effect of crude oil contamination on the chlorophyll content and morpho-anatomy of *Cyperus brevifolius* (Rottb.) Hassk. *Environmental Science and Pollution Research*. 21(21):12530–12538. doi:10.1007/s11356-014-3195-y

Bjornlund V., Bjornlund H., and Van Rooyen A.F. (2020). Why agricultural production in sub-Saharan Africa remains low compared to the rest of the world – a historical perspective. *International Journal of Water Resources Development*. 36(1):S20-S53. doi:10.1080/07900627.2020.1739512

Cosgrove W.J. and Loucks D.P. (2015). Water management: Current and future challenges and research directions. *Water Resources Research*. 51(6):4823–4839. doi:10.1002/2014wr016869

Dawodu O.G., Olanike J.O. and Akanbi R.B. (2020). Determination of Iron Content in Indigenous Vegetables in South West Nigeria. *Annual Research & Review in Biology*. 35(4): 32-37

Fahad S., Bajwa A.A., Nazir U., Anjum S.A., Farooq A., Zohaib A., Sadia S., Nasim W., Adkins S., Saud S., Ihsan M.Z., Alharby H., Wu C., Wang D. and Huang J (2017). Crop Production under Drought and Heat Stress: Plant Responses and Management Options. *Frontiers in Plant Science* 8:1147. doi: 10.3389/fpls.2017.01147

FAO 2017. The State of Food and Agriculture - Leveraging Food Systems For Inclusive Rural Transformation. Food and Agriculture Organization of the United Nations, Rome. https://www.fao.org/3/i7658e/i7658e.pdf

FAO. 2020. Fruit and vegetables – your dietary essentials. The International Year of Fruits and Vegetables, 2021, background paper. Rome. https://doi.org/10.4060/cb2395en

Fernandes F., Farias A., Carneiro L., Santos R., Torres D., Silva J., Souza J. and Souza É. (2021) Dilute acid hydrolysis of wastes of fruits from Amazon for ethanol production. *AIMS Bioengineering*. 8(3): 221-234. doi: 10.3934/bioeng.2021019

Galyean M.L. (2010). *Laboratory Procedures in Animal Nutrition Research*. Department of Animal and Food Sciences Texas Tech University, Lubbock

Kumari R., Ashraf S., Bagri G.K., Khatik S.K., Bagri D.K. and Bagdi D.L. (2018). Extraction and estimation of chlorophyll content of seed treated lentil crop using DMSO and acetone. *Journal of Pharmacognosy and Phytochemistry*. 7(3):249-250

Kyei-Mensah C., Kyerematen R. and Adu-Acheampong S. (2019). Impact of Rainfall Variability on Crop Production within the Worobong Ecological Area of Fanteakwa District, Ghana. *Advances in Agriculture*. Article ID 7930127. doi:10.1155/2019/7930127

Lachassagne P. (2020). What Is Groundwater? How to Manage and Protect Groundwater Resources. Annals of Nutrition and Metabolism, 76(1), 17–24. doi:10.1159/000515024

Ni Z., Kim E.D., Ha M., Lackey E., Liu J., Zhang Y., Sun Q. and Chen, Z. J. (2009). Altered circadian rhythms regulate growth vigour in hybrids and allopolyploids. *Nature*. 457(7227):327–331. https://doi.org/10.1038/nature07523

Njume C., Goduka N.I. and George G. (2014). Indigenous leafy vegetables (imifino, morogo, muhuro) in South Africa: A rich and unexplored source of nutrients and antioxidants. *African Journal of*

Biotechnology. 13(19):1933–1942. doi:10.5897/ajb2013.13320

Obembe O.M., Ojo D.O. and Ileke K.D. (2021). Effect of different drying methods and storage on proximate and mineral composition of fluted pumpkin leaf, *Telfairia occidentalis* Hook f. *Journal of Horticulture and Postharvest Research*. 4(2):141-150

Olajire A.S., Ogunlakin G.O., Olapade T.P. and Onifade T.B. (2022). Effect of Different Drying Methods on the Drying Kinetics and Proximate Composition of Garden Egg. *Asian Journal of Advances in Research*. 12(2):31-41

Omara-Achong T.E, Edwin-Wosu N.L., Edu E.A. and Nkang A.E. (2012). Survey of indigenous vegetables species in parts of Ogoja and Calabar, Cross River State, Nigeria. *European Journal of Experimental Biology*. 2(4):1289-1301.

Onuminya T.O., Shodiya O.E. and Olubiyi O.O. (2017). Comparative Proximate and Phytochemical Analyses Of Leafy Vegetables In Lagos State. *Nigerian Journal of Pure and Applied Sciences*. 30(3):3097-3103

Parkash V. and Singh S. (2020). A Review on Potential Plant-Based Water Stress Indicators for Vegetable Crops. *Sustainability*. 12:3945; doi:10.3390/su12103945

Rahal A., Mahima , Verma A.K., Kumar A., Tiwari R., Kapoor S., Chakraborty S. and Dhama K. (2014). Phytonutrients and Nutraceuticals in Vegetables and Their Multi-dimensional Medicinal and Health Benefits for Humans and Their Companion Animals: A Review. *Journal of Biological Sciences*. 14:1-19. doi:10.3923/jbs.2014.1.19

Salisu A., Adamu A.U., Abdulmumin Y. and Muhammad I.U. (2020). Comparative Analysis of Heavy Metals And Proximate Composition of *Capsicum annuum* (Pepper) and *Allium cepa* L.(Onion). *South Asian Research Journal of Agriculture and Fisheries*. 2(2) 18-24

Siebert S., Burke J., Faures J. M., Frenken K., Hoogeveen J., Doll P. and Portmann F. T. (2010). Groundwater use for irrigation – a global inventory. *Hydrology and Earth System Sciences*. 14:1863–1880

Sung J., Lee S., Chung J.W., Edwards G., Ryu H. and Kim T. (2017). Photosynthesis, Metabolite Composition and Anatomical Structure of *Oryza sativa* and Two Wild Relatives, *O. grandiglumis* and *O. alta*. *Rice Science*. 24(4):218–227. doi:10.1016/j.rsci.2017.04.002

Ülger T.G., Songur A.N., Çırak O. and Pınar Çakıroğlu F. (2018). Role of Vegetables in Human Nutrition and Disease Prevention. In M. Asaduzzaman, & T. Asao (Eds.), Vegetables - Importance of Quality Vegetables to Human Health. *IntechOpen*. https://doi.org/10.5772/intechopen.77038

Ullah H., Gul B., Khan H. and Zeb U. (2021). Effect of salt stress on proximate composition of duckweed (*Lemna minor* L.). *Heliyon*. 7(6):e07399. doi:10.1016/j.heliyon.2021.e07399

Zaklouta M., Hilali M., Nefzaoui A. and Haylani M. (2011). Animal nutrition and product quality laboratory manual. ICARDA, Aleppo, Syria. viii pp. 92

ASSESSMENT OF BIODIVERSITY RESOURCES IN EX-SITU CONSERVATION AREAS IN IBADAN OYO STATE

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ABSTRACT

Ex-situ conservation involves a series of activities varying from managing captive populations of animals to creating awareness about conservation education, supporting research activities and also assisting in-situ conservation efforts. It is used as an invaluable tool in studying and conserving biological resources for different purposes through different methods of ex-situ conservation such as zoos, botanical gardens, captive breeding, gene banks and aquarium. This paper focuses the assessment of biodiversity resources in two ex-situ conservation facilities in Ibadan which included Agodi zoological garden and the Zoological Garden, University of Ibadan using both primary and secondary data. The two zoological gardens were compared based on species of animals in captivity and feeding regime of the animals. The methods used in data collection include oral interviews and regular visual observations at the zoological gardens. A standard wild animal book guide was used for identification and naming of the animals in the two zoological gardens. Results showed the total number of wildlife species on display at the two zoological gardens. University of Ibadan zoological garden had more animal species than Agodi Park and Zoo. The two zoological gardens should improve on their management system for better animal welfare with the aim of increasing patronage by visitors. Also, there is need for the zoological gardens to increase their animal diversity.

Keywords: Conservation, Biodiversity, zoological garden, tourism.

INTRODUCTION

Nigeria is rich in natural resources, which are utilised directly or indirectly for the livelihood of individuals and national economic development. The declining animal population in Nigeria at an alarming rate due to anthropogenic factors, aggravated by climate change, shows that ex-situ conservation has an important role to play. Therefore, there is need to revise and improve the contributions that ex-situ approaches can make to conservation. Though the conservation of biodiversity in Nigeria has a long history, its progress, coverage and assessment are still weak.

Wildlife conservation has its ultimate goal to maintain, improve and protect species in their natural habitats. It is the science of analysing and protecting the earth's biological diversity (Soule, 1989). Wildlife conservation is also defined as the activities of individuals and/or organizations to protect and preserve the species through conservation policy, which entails preservation of habitat and management of wildlife species (Douglas, 1978). Thus, wildlife conservation is the preservation, management, protection, and wise use of natural species.

Conservation techniques can be grouped into two basic, complementary strategies which are in-situ and ex-situ (Brutting *et al.*, 2011). Conservation efforts, either in-situ or ex-situ involve the establishment and management of protected areas and relevant research institutes or academic institutions, which establish and manage arboreta, botanical or zoological gardens, tissue culture, and gene banks (Borokini *et al*., 2010).

Ex-situ conservation is a method of conservation of biological diversity outside its natural habitats. Ex- situ conservation means that conservation actions are located "outside" species natural habitat. It is defined in the Article 9 of the convention on Biological Diversity (CBD) as "the conservation of components of biological diversity outside their natural habitats". Ex-situ conservation (especially zoos) support conservation by educating the public, raising money for conservation programs, developing technology that can be used to track wild populations, conducting scientific research, advancing veterinary medicine, and developing animal handling techniques (Carrizo *et al.*, 2013).

Ex-situ conservation targets all levels of biodiversity such as the species and ecosystems (Borokini *et al*., 2010). Its concept was developed earlier before its official adoption under the Convention on Biological Diversity signed in 1992 in Rio de Janeiro (Antofie, 2011). In general, ex-situ conservation is applied as an additional measure to supplement in-situ conservation, which refers to conservation of biological diversity in its natural habitats (Kjaer *et al*., 2001). Ex-situ conservation includes a variety of activities, ranging from managing captive populations, education and creating awareness, supporting research initiatives and collaborating with in-situ conservation efforts (Melfi, 2012). It is used as a variable tools in studying and conserving biological resources (plants, animals and microorganisms) or different purposes through different techniques of ex-situ conservation such as zoos, captive breeding, aquarium, botanical gardens and gene banks (Melfi, 2012). The commonest ex-situ conservation facility for wild animals in Nigeria is zoological garden with a number of it spread across the nation (Table 1).

Table 1: Zoological gardens in Nigeria

No	Zoological Garden	Ownership	Year founded
1	Ahmdu Bello University, Zoo	Ahmadu Bello University , Zaria	1967
2	Biological Garden, Enugu	Enugu State government	1971
3	Calabar Zoo	Cross River State government	1970
4	Agodi Garden and Zoo	Oyo state government	1967
5	Jos Museum Zoo	Federal Government of Nigeria	1952
6	Univversity of Ibadan Zoo	University of Ibadan	1948
7	Markudi Zoo	Benue state government	1976
8	Obafemi Awolowo University Zoological Garden	Obafemi Awolowo University, Ile-Ife	1956
9	Zoo Park Port-Harcourt	Rivers State Government	1975
10	Kano State Zoo	Kano State Government	1976
11	Ikogosi Zoo	Ekiti State Government	1988
12	University of Ilorin, Zoo	University of Ilorin	1984
13	Ogba Zoo, Benin City	Edo State Government	1915
14	University of Nigeria Nsukka, Zoo	University of Nigeria, Nsukka	1972
15	Jos Wildlife Park	Plateau State Government	1972
16	Kyarimi Park, Maiduguri	Borno State Government	1971

Source: Omonona and Ayodele, (2011)

Zoological garden is a place where various wild animals and possibly strange domestic animals are kept for the purpose of exhibition to the general public (Abe, 2007). They are educationally planned with life animals presented to visitors in the most pleasant and interesting way. Zoological gardens where they exist portray a balanced natural ecological relationship of various animals. Zoo helps learners and researchers in the identification of life specimen. They are important in teaching, tourism, excursion programs, general entertainment and amusement of the public. Other major roles of zoo include picnic sites, advertisement/television programs, captive breeding and animal hire service (Jamieson, 1985; Abe, 2007). Shackley (1996) indicated eight roles which zoos fulfil, many of which are similar to those identified by Jamieson (1985);

- Conservation of endangered species
- Breeding animals to halt the species decline in the wild
- Safeguarding the welfare of visitors
- Educating people about animals
- Entertaining visitors to generate revenue
- Providing visitor activities, such as catering and merchandising
- Re-introducing captive bred animals into the wild
- Carrying out zoological and veterinary research to improve animal welfare in the wild and in captivity.

Are the zoological gardens in Nigeria providing the above listed services? This study sought to assess two zoological gardens located in Ibadan, Agodi zoological garden and the Zoological Garden, University of Ibadan, based on their diversity and welfare of animals in captivity to answer the research question.

MATERIALS AND METHODS

Description of Study Area

Agodi Gardens and University of Ibadan zoological gardens are located in Ibadan the capital Oyo state, in the South Western geographical zone in Nigeria. Ibadan is said to be the largest city in West Africa and has some tourist centres like Agodi gardens, University of Ibadan zoological garden, University of Ibadan botanical garden, Bower tower, etc. Also, Ibadan has some major recreation centres like Fun factory, Ibadan golf course, The Ibadan polo club, Trans Amusement park.

Agodi Garden and Zoo

The Agodi zoological garden was founded in 1967 by the old Western region but now managed by Oyo state government. It remains one of the foremost tourist centres in the Western region of Nigeria. It was abandoned after the Ogunpa flood disaster in 1980 swept away most of the animals and left the garden in a bad condition. In 2012, the Oyo state government later revamped the garden into a 21st century park and garden. The Agodi garden boasts of a mini zoo with different animal species. Agodi garden is managed by the Ministry of Trade and Commerce of the Oyo state government. The Agodi garden has a Director who receives order from the Ministry. The Director oversees the affairs in the garden and zoo and ensures the effectiveness of the workers. There are zoo keepers who ensure that animals remain in captive and are well fed.

University Of Ibadan Zoological Garden

The University of Ibadan zoo was founded in 1948 with the Department of Zoology. It was first a menagerie where few animals were kept until it was upgraded to a full fledge zoological garden in 1974. The zoo parades a wide array of animal species from different ecological zones of Nigeria and beyond. As a major point of attraction for visitors to the University, the zoo has received millions of visitors from its creation. The zoological garden is located in the South Eastern part of the University of Ibadan main campus (Field Survey, 2019).

The soil of the zoological garden is both sandy-loam and loamy. Further observation showed that soils under tree canopies are very rich in potassium since leaching or erosion is reduced to the barest minimum by the canopy cover. The type of soil in a place within the zoological garden determines the site selection of a particular animal species. For example, herbivores are sited close to the stream due to some ecological reasons which can be due to the growth of plants that they feed on or the coolness of the surrounding. The garden attracts a large number of visitors to the university, particularly during the week-ends and festive periods. It opens everyday of the year from 8:00am till 6:00pm (Student Information Handbook, 2012).

Data Collection

Information was collected from both primary and secondary sources. The primary source of data includes oral interview and regular visual observations of the two zoological gardens. The secondary source includes the extraction of information from books, journals, thesis and internet. Also, the animal book guide was used for identification of the animals in the two zoological gardens.

RESULTS AND DISCUSSION

Wildlife Resources Observed At Agodi Garden and Zoo

Table 2: Wild animals at Agodi garden and zoo

Scientific Name	Common Name	Family	Order
Balearica pavonina	Black crowned crane	Gruidae	Gruiformes
Dendrocygna viduata	White faced whistling duck	Anatidae	Anseriformes
Numida meleagris	Guinea fowl	Numididae	Galliformes
Struthio camelus	Ostrich	Struthionidae	Struthioniformes
Cercopithecos mona	Mona monkey	Cercopithecidae	Primates
Erythrocebus patas	Patas monkey	Cercopithecidae	Primates
Varanidae varanus	Monitor lizard	Varanidae	Squamata
Thonyx triunquis	Soft shelled turtle	Trionychidae	Testudines
Equus ferus	Horse	Equidae	Perrissodactyla
Panthera leo	Lion	Felidae	Carnivora
Pavo cristatus	Peacock	Phasianidae	Galliformes
Anseranas semipalmata	Goose	Anatidae	Anseriformes

Source: field survey, 2019

Tree Species in Agodi garden and Zoo

The tree species within Agodi garden and Zoo include
Gmelina arborea, *Termilalia spp.*, *Triplochiton scleroxylon*, *Phyllantus spp.*, *Elaeis guineensis*.

Facilities and Structures in Agodi Park and Zoo
Water park, Boat ride, Lake, Lush garden, Paintballing, Restaurant, Forest area, Swimming pool, Children play ground, Bouncing castle, Hoverboard

Table 3: Wildlife species at the University of Ibadan Zoological Garden

Scientific Name	Common Name	Family	Order
Numida meleagris	Guinea fowl	Numididae	Galliformes
Porphyrio porphyyrio	African purple swamp hen	Rallidae	Gruiformes
Pavo cristatus	Peafowl	Phasianidae	Galliformes
Dendrocygna viduatata	White faced whistling duck	Anatidae	Anseriformes
Ciconia ciconia	White stork	Ciconiidae	Ciconiiformes
Plectropterus gambensis	Spur Winged goose	Anatidae	Anseriformes
Balearica pavonina	Black crowned Crane	Gruidae	Gruiformes
Columba guinea	Speckled pigeon	Columbidae	Columbiformes
Tyto alba	Barn owl	Tytonidae	Strigiformes
Necrosytree monachus	Hooded vulture	Accipitridae	Accipitriformes
Gypohierax angolensis	Palmnut vulture	Accipitridae	Accipitriformes
Pava criastus	White peafowl	Phasianidae	Galliformes
Falco tinnuulus	Common kestrel	Falconidae	Falconiformes
Porcephalus senegalus	Senegal parrot	Psittcidae	Psittaciformes
Melopsittcus undulates	Budgerigar parrots	Psittcidae	Psittaciformes
Milvus migrans	Yellow billed kite	Accipitridae	Accipitriformes
Leptoptilos crumenifer	Marabous' stork	Ciconiidae	Ciconiiformes
Pelicanus occidenalis	Brown pelican	Pelecanidae	Pelecaniformes
Anas platyrhynchos	Mallard duck	Anatidae	Anseriformes
Strepopelia seneglensis	Laughing dove	Columbidae	Columbiformes
Struthio camelus	Ostrich	Struthionidae	Struthioniformes
Dromaius novacholiandiae	Emu	Casuariidae	Casuariiformes
Psittacus eriathacus	African grey parrot	Psittacini	Psittaformes
Cercocebus torquatus	Collared mangabey	Cercopithecidae	Primates
Hlorocebus sabeus	Green monkey	Cercopithecidae	Primates
Cercopithecus mona	Mona monkey	Cercopithecidae	Primates
Erythrocebus patas	Patas monkey	Cercopithecidae	Primates

Cercopithecus erythogaster	White throated monkey	Cercopithecidae	Primates
Papio Anubis	Baboon	Cercopithecidae	Primates
Pan troglodytes	Chimpanzee	Hominidae	Primates
Cercopithecus mandrillus	Drill monkey	Cercopithecidae	Primates
Python reqius	Royal python	Pythonidae	Squamata
Python sebae	African rock python	Pythonidae	Squamata
Bitis gabonica	Gabon viper	Viperidae	Squamata
Naja nigricollis	Black neck spiting cobra	Elapidae	Squamata
Naja naja	Elapidae	Elapidae	Squamata
Causus rhombeatus	Common night adder	Viperidae	Squamata
Varanidae varanus	Monitor lizard	Varanidae	Squamata
Pulusios castaneus	West African mud turtle	Pelomedusidaes	Testudines
Archachatina marginata	African Giant land snail	Achatinidae	Stylommatophora
Osteolamus tetraspis	Dwarf crocodile	Crocodylidae	Crocodilia
Crocodylus niloticus	Nile crocodile	Crocodylidae	Crocodilia
Thonyx triunquis	Soft shelled turtle	Trionychidae	Testudines
Chelonoidis nigra	Giant land tortoise	Testudinidae	Testudines
Giraffa camelopardis	Giraffe	Giraffidae	Artiodactyla
Philanomba debranus	Dorcas gazelle	Bovidae	Artiodactyla
	Giant eland	Bovidae	Artiodactyla
Equus ferus	Horse	Equidae	Perrissodactyla
Camelus dromedaris	Camel	Camelidae	Artiodactyla
Phacochoerus africnus	Warthdog	Suidae	Artiodactyla
Euus africanus	Donkey	Equidae	Perrissodactyla
Sus scrofa	Domestic pig	Suidae	Artiodactyla
Hystrix hystrix	Crested porcupine	Hystricidae	Rodentia
Thyronomys swinderianus	Cane rat	Thryonomydae	Rodentia
Oryctolagus cuniculus	Rabbit	Leporidae	Lagomorpha
Mellivora capensis	Honey badger	Mustelidae	Carnivora
Hyaena hyaena	Stripped hyena	Hyaenidae	Carnivora
Crocuta crocuta	Spotted hyena	Hyaenidae	Carnivora
Civetticitis civetta	African civet cat	Viverridae	Carnivora
Canis aureus	Jackal	Canidae	Carnivora
Panthera leo	Lion	Fellidae	Carnivora

Source: Field Survey, 2019

Tree Species in the University of Ibadan Zoological Garden

The dominant tree species within the University of Ibadan Zoological garden includes *Musa sepientum, Termilalia catappa, Senna siamea, Bambusa vulgaris, Eucalyptus camaldulensis, Elaeis guineensis, Hura crepitans, Azadirachta indica, Mangifera indica.*

Facilities and Structures in Universiy Of Ibadan Zoological Garden

- Museum: It is located just after the children zoo. Curious values are significant and important parts of the animals or plants that have prestige, ;conservation importance and also have monetary value. Animals like tortoise, gorilla and snake are taxidermized and kept in the museum.
- Restaurant: This is located at the picnic site inside the zoological garden where different dishes are served. Snacks and soft drinks are also available at the entrance of the zoo for visitors.
- Picnic site: It is situated at the centre of the garden with chairs and tables provided for the tourists' use during organised picnic at the garden.
- Children zoo: This is a kind of mini-zoo situated at the left side of the ape house in the zoo. Animals like rabbit, cane-rat, porcupine, civet cat, and giant rat are kept in the children zoo.

Feeding Arrangement of animals in both Zoological Gardens

The feeding regime in the two zoological gardens depend on the animals feeding behaviour. Some animals in University of Ibadan zoological garden are fed with grasses, herbs, shrubs etc. Animals in this category are giraffe, horse, donkey, and so on. They are referred to as herbivorous animals. They are fed two times daily.

Another section of the zoo is the carnivorous animals that feed on flesh of other animals. They include animals like Lion, Hyena, Jackal, Snake, etc. Lions are fed with slaughtered goat and they are feed thrice a week in the University of Ibadan zoological garden. In Agodi park and zoo lions are fed once or twice a due to inadequate funding.

Monkey, Baboon and Chimpanzee are majorly fruit eaters (frugivores). They are fed twice daily with varieties of fruits like banana, pineapple, watermelon, orange and apple. At times, they are fed with beans and yam. Monkey is common to the two zoological gardens.

In the University of Ibadan zoological garden, there are Warthogs and Domestic pig which are fed with both flesh and fruits. These animals are referred to as omnivorous animals because of their feeding habits.

Birds are fed with grain (granivorous birds) and flesh or intestines of goat (carnivorous birds). Some of the birds are fed with cooked beans, boiled yam and palm oil.

Problems of Ex-Situ Conservation

Ex-situ conservation requires a multi-disciplinary approach and involves different kinds and levels of management. It involves input from experts on aquarium and zoo husbandry, ex-situ breeding, gene banking and reintroduction (Conway, 2011). Other experts input may include taxonomy, ecology, conservation, ethnography, and sociology. For outreach program, there is a need to liaise with local communities, ministry of environment and international (non- governmental and inter-governmental) conservation bodies (Reid *et al*, 2013).

A range of common problems faced by Ex-situ conservation includes:

1. Lack of knowledge of the biological and ecological parameters of the species: breeding necessities, feeding, behaviour, habitat needs germination protocols, etc.
2. Lack of suitable animals in captivity.
3. Occurrence of diseases and pests (Joao *et al.*, 2000).
4. Inadequate gene pool of initial breeding stock, which can cause inbreeding problems in captive populations.
5. Inability of animals to adapt to the new ex-situ environment.
6. Starting the ex-situ programme too late to enable the recovery and future reintroduction of the species.
7. Inadequate co-ordination of administration involved in the programs.

CONCLUSION

The assessment of wildlife resources in Agodi garden and zoo and University of Ibadan zoological garden showed that the two gardens has high ex-situ conservation potentials**.** This also showed that University of Ibadan has more animals than Agodi garden and zoo and most of the animals are native to Africa. There is need for the Agodi park and zoo to increase its species diversity as visitors would be enthused to see more animals in the zoo. The two zoological gardens should improve on their level of management activities to enhance animal welfare and attract visitors. The relaxation facilities in the two zoological gardens should be modernized in such a way that the visitors will be able to eat and also enjoy themselves by watching animal documentaries, which can be that of the zoo or others to educate people about the animals. Nurses and anti-venom injection as well as first aid boxes should be provided in the two zoological gardens. The use of feedback comment card on the zoological garden services should be encouraged in the two gardens.

REFERENCES

Abe, O. A. (2007). *Handbook on zoo and national* parks *in Nigeria*

Antofie, M. (2011). *Current political commitments' challenges for ex-situ conservation o plant genetic resources for food and agriculture.* 157-163Pp

Baatay, E. and Hardonim-Fugier, E. (2002). Zoo: A history of zoological gardens in the West. London: Reaction books.

Borokini, T.I., Okere, A.U., Giwa, A.O., Daramola, B.O. and Odofin, W.T. (2010). Biodiversity and conservation of plant genetic resources in Field Gene-bank of the National Centre for Genetic Resources and Biotechnology. Ibadan: *The International Journal of Biodiversity and Conservation. 2:37-50Pp*

Brutting, C. Hensen, I. and Wesche, K. (2013). Ex-situ conservation affects genetic structure and diversity in arable plants. 15: 505-513Pp

Carrizo, S.F., Smith, K.G. and Darwall, W.R.T. (2013). *Progress towards ssglobal assessment of the status of freshwater fishes. International Zoo Yearbook. 47:46-6 Pp*

Conway, W.G. (2011). *Buying time or wild animals in zoo. 30:1-8 Pp*

Cain, M.L. Bowman, W.D. and Hacker, S.D. (2008). *Ecology*. Manssachusetts: Sinauer associates publication.

ChrsiTie, S. (2010). *Why keep tigers in zoos? In Tigers of the World: The science, politics and conservation of Panthera tigris (*eds. Tilson, R. & Nyhus, P) London. 205 Pp

Douglas, J. (1978). *Biologists urge as endowment for conservation.* Nature publication. 14Pp

Dulloo, M.E., Hunter, D. and Borelli, T. (2010). *Ex-situ and in-situ conservation of agricultural biodiversity: Major advances and research needs.123-135Pp*

Joao, P.S. Justin, T., Wendy, J. and Jon, E. (2000). *LIFE preventing species extinction: Safeguarding endangered flora a fauna through ex-situ conservation*. Luxembourg: LIIE publication

John, E.F. Diana, J.P., Sara O. and Stuart, R.P. (2011). *Bring the captive closer to the wild: redefining the role of ex-situ conservation.* Cambridge: Fauna and flora international publication. 1Pp

Kjaer, ED., Graudal, L. and Nathan, I. (2001). *Ex-situ conservation of commercial tropical trees: Strategies, Options and Constraints.* Humlebaek: Danida Forest Seed Centre

Kanailal, G. (2002). *Ex-situ and in-situ conservation of wildlife with reference to zoo gardens and sundarban tiger reserve in West Bengal*. Bengal

Koebner, L. (1994). *Zoo books: The evolution of wildlife conservation centre.* New York: Forge publication

Leus, K. (2011). *Captive breeding and conservation: Zoology in the Middle East. 54:3.151-158*Pp

Melfi, V.A. (2012). *Ex-situ gibbon conservation: Status, management and birth.* International zoo yearbook 46:1. 241-251Pp

Omonona, A.O. and Ayodele, I.A. (2011). *Principles of zoo management in Nigeria.* Ibadan: University Press.7Pp

Reid, G.M., Macbeth, T.C. and Csatadi, K. (2013). *Global challenges in freshwater-fish conservation related to public aquariums and the aquarium industry. 47: 6-45iPp*

Shackley, M(1996). *Wildlife tourism.* London Thompson Business Press

Soule, M.E. (1989). *The science of scarcity and diversity sinaver associates. 584Pp*

Student Information Handbook. (2012), *The zoological garden. 183Pp*

World Zoo Conservation Strategy. (1991). Zoo Education in the World Zoo Conservation Strategy and its Evolution in International Conventions. ZEB publication.

AVIFAUNAL ASSEMBLAGE OF A POST-COAL MINING ARTIFICIAL WETLAND AND RECLAIMED WOODLAND IN MAIGANGA, GOMBE STATE

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ABSTRACT

Wetlands are unique ecosystems that support biodiversity, different livelihood options, as well as ecosystem services such as flood control and water purification. Regrettably, wetlands are threatened by anthropogenic activities such as the inadvertent release of agro-chemicals and post extraction effluents/heavy metals into floodplains and underground water. These contaminants may alter wetland ecosystems, water resources and adversely affect biodiversity. This study examined the abundance and diversity of avian species in the post-mining reclaimed woodland and artificial wetlands of Maiganga, Gombe State. Avian species were used for this study because; they are notable as good indicators of the health of any environment. Point count census was used to determine avian diversity and abundance. Each point was monitored twice a day (06:30 - 09:30am and 03:30 - 06:30pm) in the morning and evening respectively. A total of 1,983 individuals from 111 species in 84 genera and 42 families were recorded at the end of three months during the dry season. Sixty eight (68) bird species were recorded in October; 93 in November, and 41 species in December, 2021. Most species occurred in all the months while a few were exclusive to either of the three months. The most abundant/sighted bird species, totalling 188 individuals was the white face whistling duck; a water bird of the Anatidae family. Abundance data shows that 64.9% of species had between 1 to 10 individual sightings. The families Accipitridae and Columbidae had the highest richness (8 species each, as well as 4 and 6 generic groups, respectively). The families Meropidae, Anatidae, Hirundiniidae, Estrildidae and Columbidae had the most number of individuals from the component species, accounting for (260, 212, 178, 114 and 113) individuals respectively.Nineteen (19) species of water birds were recorded; 16 of which are among the 255 species listed under the African-Eurasian Water-bird Agreement (AEWA). Of significant note, was the record of Pallid Harrier an IUCN rated near threatened (NT) raptor. These findings affirm the potential status of Maiganga artificial wetland and reclaimed woodland as avifaunal habitat that may be crucial to the survival and persistence of water-birds, Palearctic migrants and intra-African visitors. The results emphasize the avian richness of Maiganga as it supports about 11.4% of the 975 avian species that occur in Nigeria. Prioritization of the study area for conservation is recommended, as this will inevitably host over 10% of Nigeria's avifauna.

Keywords: Wetland, Avifauna, Abundance, Maiganga, Diversity

INTRODUCTION

A wetland is a distinct ecosystem that is inundated by water, either perpetually or seasonally, where oxygen-free processes prevail (Keddy, 2010). Wetlands are typically distinguished from other land forms or water bodies by the inimitable vegetation of aquatic plants, adapted to the unique hydric soil (Butler, 2010). Wetlands play a number of roles which depends on the wetland type and the structure of the adjoining vegetation. These roles may include but not limited to water purification, water storage, flood control, nutrients/carbon processing, and support of plants and animals. Wetlands are variously defined under the Ramsar international wetland conservation treaty, thus; Article 1.1 defines wetlands "as areas of marsh, fen, peatland or water, natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres". Similarly, Article 2.1 extends the definition to incorporate "riparian and coastal zones adjacent to the wetlands or bodies of marine water deeper than six metres at low tide, lying within the wetlands" (rsis.Ramsar.org, 2019).

Comparable to the iconic rainforest, wetlands are considered the second most biologically diverse of all ecosystems, and serves as home to a range of floral and faunal species. As centres of biological diversity, most inland wetlands host a variety of aquatic/ terrestrial biodiversity which may include but not limited to various species of crocodiles, fishes, hippopotamus, aquatic reptiles, and most noticeably water-birds. The ecological importance of these unique landscapes is the reason behind some biological conventions and intercontinental agreements, such as; Ramsar Convention, African-Eurasian Water-bird Agreement (AEWA), the Convention on the Conservation of Migratory Species of Wild Animals (CMS) etc. These conventions seek to protect migratory species of wildlife such as birds across geographical regions as well as strengthen international capacities for conservation actions and collaborations.

Birds rank tops among species that cover great distances during migration and they often rotate between continents in the course of their annual life-cycles. They are unique in morphology and abilities. Birds are the only extant vertebrates that possess feathers with modified forelimbs for flight. Their unique ability to fly and high mobility gives them advantage to colonize and utilize a wide variety of habitats; thus, birds occupy almost every part of the earth (Cheke and Mann, 2001; Borrow and Demey 2014).

Birds are highly sensitive to environmental change, which makes them very useful as indicators of the state of health of the environment and various ecological systems (Gregory et al., 2003). Thus, birds are very useful in studies designed to address the effects of human and other environmental disturbances on community stability and productivity (Nsor, 2015). Their distributions follow patterns that reflect ecological parameters of habitat suitability for species in other taxa; because birds mirror changes in other biodiversity. More so, places of high bird diversity and endemism are often rich in other forms of biological diversity; and so birds contribute substantially to the overall species richness of West African forests, presently recognized as biodiversity hotspots of global importance (Orme *et al*., 2005).

Spatio-temporal distribution, abundance and diversity of avian species serve as a mirror reflection of the state of wellbeing of any environment, because bird species select habitats based on quality and productivity (Tilman 1996). The most suitable habitats are often the first to be taken by the fittest competitors leaving sub-optimal habitats for less fit conspecifics (optimal foraging theory). Abundance therefore plays a crucial role in determining habitats of good quality or habitats recovering from perturbation (Nsor 2015). Moreover, research has shown that habitat and ecosystem productivity is directly linked with species composition and diversity as well as patterns of distribution and nature of interactions (trophic structure) among species Pringle *et al.*, 2010).

We studied the avifaunal diversity and abundance of the Maiganga coal mine and environs to determine the avian assemblage, as well as dominant families and feeding guilds. The main goal was to determine the state of wellbeing and suitability of the modified and reclaimed landscape of Maiganga Coal Mine; and most importantly the artificial wetland created as a waste water management system.

The Maiganga wetland to the best of our knowledge is the first purposeful man made wetland in Nigeria. We know for a fact that most post mined wetlands were inadvertently created without conscious strategies to assuage the negative impact on the environment. These accidental water bodies often pose serious debilitating effects on the biological diversity and human population that depend on them. The rationale behind this study therefore was to measure the extent to which the Maiganga artificial wetland has become habitable for birds especially those that prefer wetland habitats or species that may depend directly or indirectly on wetland resources and associated habitats. More so by estimating the abundance and diversity of water-bird species we could potentially authenticate the status of the artificial and engineered water area as an ecologically functional wetland. This will substantiate the views of Oruonye *et al*., (2016); who opined that it is more sustainable and environmentally friendly to practice progressive reclamation of mined land areas concurrent with mineral extraction processes.

The study became imperative as a result of on-going efforts by Lafarge Africa to progressively restore the post coal mine landscape of Maiganga back to its original semi pristine state. This stewardship obligation of the mining company is in keeping with goal 2, 3, 9, 12, 13 and 15 of the 17 Sustainability Development Goals (SDGs). More so, Nigerian environmental safety regulators expect a high level of compliance to environmental safety statutes during mineral exploration. This is in alignment with global standards considering the fact that Nigeria is signatory to several environment focused treaties and agreements with the cardinal objective of maintaining and protecting biodiversity and the environment.

MATERIALS AND METHODS

Study Area

Maiganga village is located in Akko Local Government Area (LGA) of Gombe state. The village is located 8km off Gombe – Yola road; west of Kumo town between Latitude 09^{o} 18’, and 11^{o} 59’E. The total area originally occupied by the community covers an area of about 48.16 Km2 (Benjamin *et al*., 2016). However, the area marked out for mining is about (66.78 hectares). The study area is typically distinct as dry savannah, predominated by grasses, shrubs and thorn-scrub interspersed by few trees; example *Pakia biglobosa*, *Tamarindus indica*, *Balanites aegyptiaca*, *Butyrospermum paradoxa*, *Afzelia africana* and *Adansonia digitata*). It lies within the tropical continental type of climate characterized by well-marked wet and dry season. Rainfall ranges between 850 to 1000 mm^3 and the rainy season last between 5 to 6 months (Oruonye *et al*., 2016). It is also home to some extant vertebrates such as squirrels, bats, giant monitor lizards, venomous snakes and small rodents. The coal mine is characterized by two ponds and an engineered wetland which is designed as the third phase of the water treatment process for eventual discharge or use for irrigation agriculture by the host communities. The first pond (Plate 1c) is located at the current active mine site where water is channelled to a sedimentation pond (Plate 1d) about 2200 metres from the primary source. The sedimentation pond periodically feeds the on-going wetland where water plants like *Typha domingensis* and Common reed *Phragmites australis* have been planted to rid the water of any remaining traces of heavy metals after sedimentation.

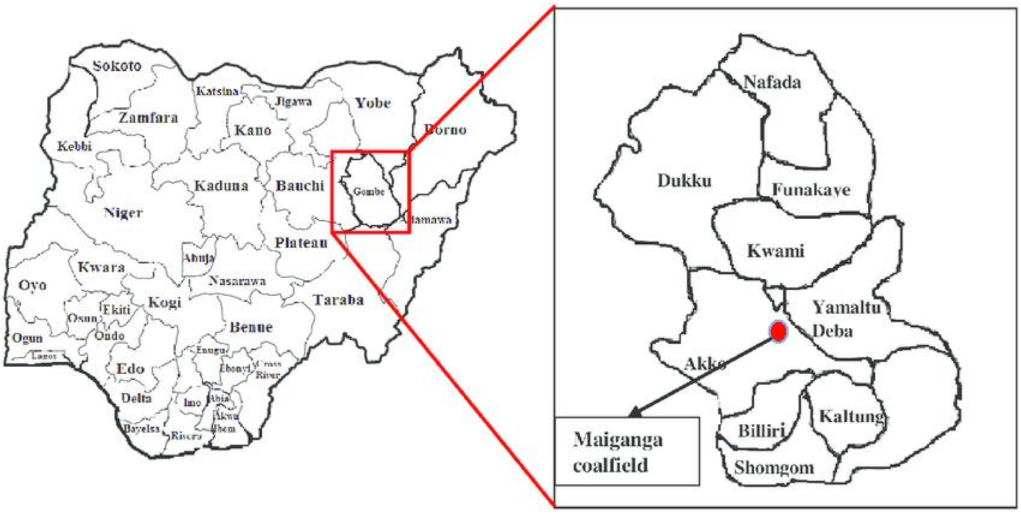
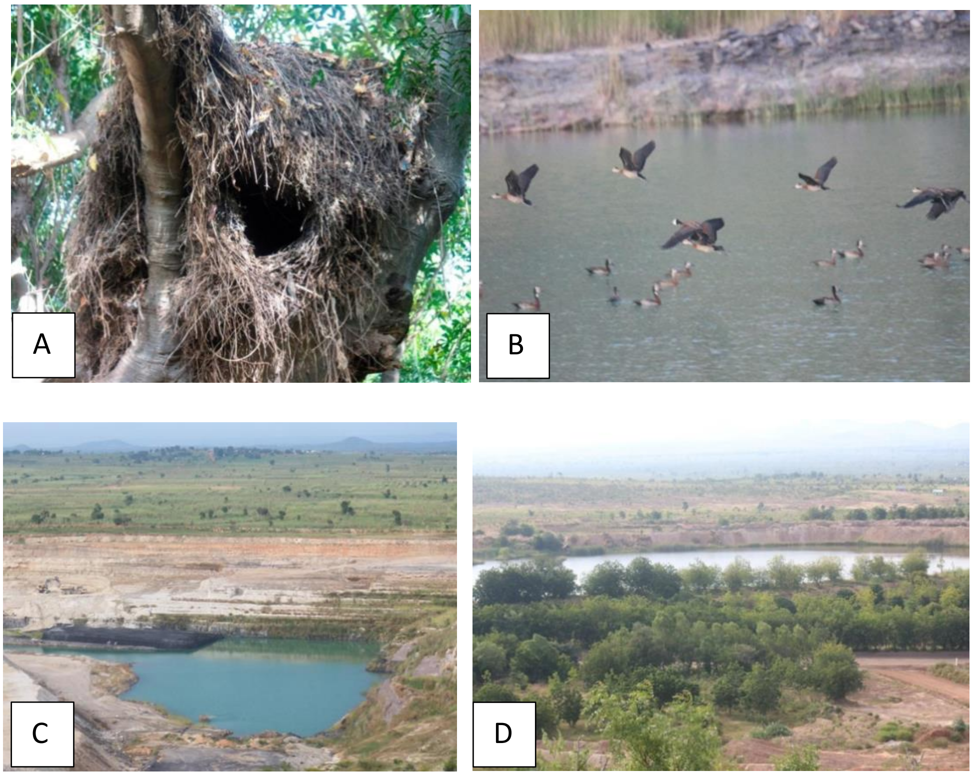


Figure 1: Map of Akko LGA showing Maiganga coal mine field. (Source Koko *et al*., 2016)



Plates 1 (a-d): (a) Nest of Hamerkop *Scopus umbretta* (b) White Faced Whistling Ducks *Dendrocygna viduata* (c) Active mine pond (d) A cross section of the sedimentation pond showing a strip of reforested woodlot.

MATERIALS ANS METHODS

Point count method (Bibbly *et al*., 2000) was used for the avian diversity and abundance survey. Each point was monitored twice a day (between the hours of 06:30 - 09:30am and 03:30 - 06:30pm) for morning and evening sessions respectively.

The study was spread across three months (3 days in October; 7 days in November and 2 days in December, 2021). A total of 12 days was spent in the field during focal observation. Survey was conducted weekly; two days each visit, across three months. The study commenced just after the onset of the dry season. The study is designed to cover both wet and dry season's avian assemblage and will monitor abundances and diversity across seasons and years. The data was analysed using simple descriptive statistics in SPSS version 21.0. The data was subjected to normality test and equality of variance to justify the use of parametric tests.

RESULTS

A total of **1, 983** individuals of **111** species across **84** genera and **42** families were observed. 68 bird species were recorded in the month of October; 93 species in November, and 41 species in December, 2021. Most species occurred in all the three months while a few were exclusive to some months. As can be seen more diversity was recorded during the month of November followed by October and December. However, abundance and diversity was directly proportional to the study effort (Survey time). 7 days > 3days > 2days, for 93, 68 and 41species for the month of November, October and December respectively (Figure 2).

The most abundant and most sighted bird species were the white faced whistling ducks, a water bird of the Anatidae family (188 sightings), followed by the white throated bee-eaters of the Meropidae family (163 sightings) (Appendix 2). Abundance data shows that 64.9% of species were among bird species sighted 1-10 times or with between 1 to 10 individuals recorded during the 12 days of focal observation and survey (Appendix 2). The families Accipitridae (raptors or birds of prey) and Columbidae (doves and pigeons) were the most species rich with 8 species each and 4 and 6 generic groups respectively. These families were closely followed by Hirundiniidae family with 7 species and 6 generic groups (Appendix 1). The families Meropidae, Anatidae, Hirundiniidae, Estrildidae and Columbidae had the most number of individuals sighted, accounting for (260, 212, 178, 114 and 113) individuals respectively.

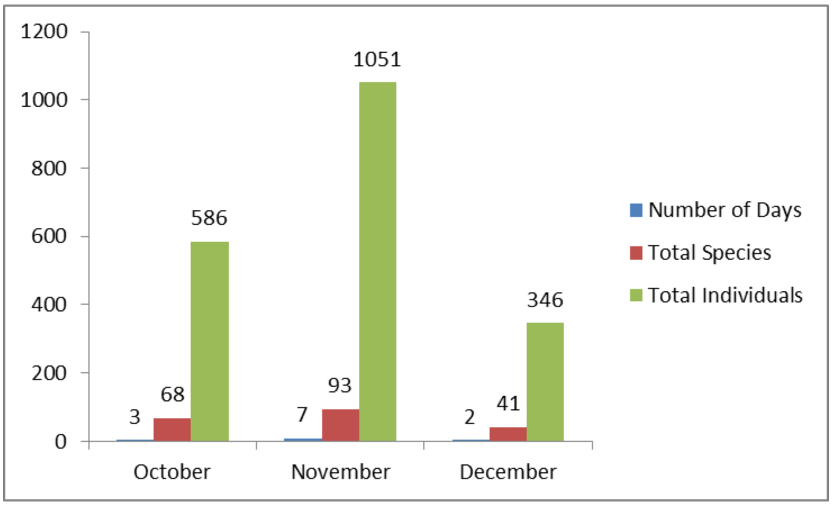


Figure 2: Species Accumulation/Effort Chart.

Table 1. Avian Species Feeding Guild across Families in study area 2021/2022

S/N	Feeding Guilds	Families	Ecosystem Service
1	Carnivore	5	Bio-equilibrium
2	Frugivore	3	Dispersal/Forest Restoration
3	Granivore	12	Secondary Dispersal/FR
4	Herbivore	2	Bio-equilibrium and Regeneration
5	Insectivore	28	Bio-control, Agro-services
6	Omnivore	10	Multi-function

Table 2: Water-birds of Maiganga 2021/2022
(Values in table are counts; LC = Least Concern, N/A = Not Applicable)

S/N	Species	Scientific Name	No	Family	Feeding Guilds	IUCN Status	AEWA Status
1	Grey-headed Kingfisher	Halcyon leucocephala	3	Alcedinidae	Carnivore	LC	Yes
2	African Pigmy Kingfisher	Ispidina picta	5	Alcedinidae	Insectivore (arthropods)	LC	N/A
3	White face Whistling Ducks	Dendrocygna viduata	188	Anatidae	grannivore/herbivore	LC	N/A
4	African Pigmy Goose	Nettapus auritus	2	Anatidae	Herbivore/Insectivore	LC	Yes
5	Fulvous Whistling Duck	Dendrocygna bicolor	4	Anatidae	Omnivore	LC	Yes
6	Knob Billed Duck	Sarkidiornis melanotos	18	Anatidae	Omnivore	LC	Yes

S/N	Species	Scientific Name	No	Family	Feeding Guilds	IUCN Status	AEWA Status
7	Black Crown Night heron	Nycticorax nycticorax	4	Ardeidae	Carnivore	LC	Yes

8	Black Headed Heron	Ardea melanocephala	10	Ardeidae	Carnivore	LC	Yes
9	Intermediate Egret	Ardea intermedia	2	Ardeidae	Insectivore	LC	Yes
10	Little Egret	Egretta garzetta	10	Ardeidae	Insectivore	LC	Yes
11	Grey Heron	Ardea cinerea	87	Ardeidae	Omnivore	LC	Yes
12	Cattle Egret	Bubulcus ibis	16	Ardeidae	Insectivore	LC	Yes
13	Spur winged Lapwing	Vanellus spinosus	64	Charadriidae	Insectivore	LC	Yes
14	Three Banded Plover	Charadrius tricollaris	9	Charadriidae	Insectivore	LC	Yes
15	Long Tail Comorant	Phalacrocorax carbo	31	Phalacrocoracidae	Omnivore	LC	Yes
16	Black Winged Stilt	Himantopus himantopus	3	Recurvirostridae	Insectivore/Crustaceans	LC	Yes
17	Little Stint	Calidris minuta	1	Scolopacidae	Invertebrates	LC	Yes
18	Common Sandpiper	Actitis hypoleucos	6	Scolopacidae	Insectivore	LC	Yes
19	Hamerkop	Scopus umbretta	11	Scopidae	Carnivore	LC	N/A

DISCUSSION

The main goal of this study was to use abundance and diversity estimates of avian species to determine the state of wellbeing of the reclaimed habitats and artificial wetlands of the post-mined area of Maiganga. The rationale being that places rich in avifaunal diversity would be rich in other forms of biodiversity (Orme *et al*., 2005). It is therefore expected that a bird species-rich post-mined area will most likely support other biological diversity as the reclamation progresses.

The consensus of experts is of the view that the successes of reclamation cannot be measured and limited to vegetation cover (reforestation) but should take into consideration, other aspects and components of biological diversity such as birds, other small vertebrates and macro-invertebrates (Oruonye *et al*., 2016). This view emphasizes the need to stretch appraisal of reclamation successes to the attainment of an ecologically functional community where plants interact freely with various populations of animals in a complex web of interactions. In the light of this we used birds to underscore the ecological integrity of the reclaimed land area and artificial wetlands. Birds were considered the first choice in keeping with the notion that birds are among the best indicators of environmental health due to their high sensitivity to environmental change (Gregory *et al*., 2003).

So far the outcome of our study is quite insightful and very impressive as the results shows a relatively higher diversity than results from surveys conducted elsewhere in Gombe State and similar wetland landscapes in the North East region and Nigeria (See Adang, *et al*., 2015; Ringim *et al*., 2018; Nsor *et al*., 2018).

Based on the scope of this study and the amount of time (12) days spent in the field; it is worthy of note that Maiganga appears to be among the most species' rich and avian diversity hot-spots in Gombe State. This claim was authenticated by comparing the results with data from the on-going NiBAP (Nigeria Bird Atlas Project); a member of the continent-wide project - the African Bird Atlas Project (ABAP).

The NiBAP project currently holds records of 5538 individuals of 323 bird species in 139 atlased pentads; derived from a five year long periodic survey that commenced on 16-05-2016 to 30-07-2021 (http://www.birdmap.africa/coverage/country/Nigeria). The on-going NiBAP aims to chronicle the extant distribution and diversity of avian species in the 36 states of Nigeria.

On a national scale, the avifauna of Nigeria comprises a total of 975 species of which four are endemic to Nigeria (Borrow and Demey, 2014; Bird-Life International, 2022). Twenty six of the almost 1000 bird species that occur in Nigeria are globally threatened (Bird-Life International 2022). Nigeria ranks 22nd among avifaunal rich countries and holds approximately 10 % of the global extant avian diversity (Bird-Life International, 2022).

Although bird diversity and abundance does not necessarily differ primarily as a result of land area, but rather on the ecological uniqueness of the landscape (i.e. the vegetation structure and composition); we however, attempt to compare the composition of avian species in Maiganga reclaimed area with the state, regional and national relative to land area. This approach is aimed at appraising the avifaunal richness of the study area as an integral component of the avifaunal richness of Gombe State and Nigeria. Based on this perspective, Maiganga currently host about 36% of the state wide record of 323 species of birds across 139 of the planned 255 pentads for the entire Gombe state (NiBAP 2016-2021 data). Similarly the study area plays host to about 11.4% of the total avian diversity in Nigeria. This is quantitatively significant when we consider the fact that Maiganga community is just 48.16 km^2 relative to the 18,768 km^2 of Gombe and 923,768 km^2 of the land area of Nigeria.

Studies have shown that avian diversity tends to increase proportionately with habitat heterogeneity (Nsor *et al.*, 2021). More-so, the structure of the vegetation is often the most proximate factor that determines habitat selection and species abundance in any given area (Adam *et al*, 2015). At Maiganga, the once extensive savannah grassland is now heterogeneous, with the creation of artificial wetland, reforested woodlots, interspersed by fragments of remnant original flora. This re-engineered and reclaimed landscape is also dominated at the fringes by some rocky outcrops surrounded by farmlands of predominantly maize, guinea corn and millet (Oruonye *et al.*, 2016). This is perhaps why more species where recorded in the study area relative to other similar areas in Gombe.

Apart from the diversity and relative abundance of species, the presence of various feeding guilds is an attestation that the reclamation effort seems to be ecologically viable. The benefit of birds to the local communities is multi-dimensional considering how significant some birds are in providing ecosystem services such as pest-control (Tela *et al.*, 2021) dispersal and pollination (Lamido *et al* 2021); and maintenance of ecological networks (Nsor, 2015). These ecosystem services are invaluable considering how beneficial they are to crop productivity and human wellbeing. For instance Tela *et al* (2021) demonstrated how farmlands located close to the Ngel Nyaki Forest Reserve in Taraba State enjoyed better yield than those farther away, due to recruitment of insect eating birds from the adjoining forest.

Wetland Viability and Status

Thus far, 19 water birds of the 147 species that occur in Nigeria (BirdLife International 2022) have been recorded in the artificial wetland of Maiganga (Table 2); interestingly 16 of these species are among the 255 species listed under the African-Eurasian Water-bird Agreement (AEWA) (Table 2). The agreements core objective is the conservation of African-Eurasian Migratory Water-birds and their habitats. These birds are ecologically dependent on wetlands for at least part of their annual cycle. All AEWA species cross international boundaries during their migrations and require good quality habitat for breeding as well as a network of suitable sites like Maiganga and other allied habitats to support their annual journeys. International cooperation across their entire migratory range is therefore essential for the conservation and management of migratory water-bird populations and the habitats crucial for their survival. Although Nigeria has 11 Ramsar sites of global importance (Ezealor, 2002), habitats like Maiganga are essential in the overall wellbeing of migratory species as continuous shrinkage of major wetlands including major Ramser sites may push these species of Palearctic migrants to sub-optimal sites within their migratory routes. The abundance records of the 19 species of water-dwelling birds and diversity of birds from other guilds in Maiganga is a proof of the ecological benefits and transformation of the landscape which was once contiguous dry savannah reminiscent of the semi-arid region of the North East (Benjamin *et al* 2016).

Maiganga is unarguably a priority habitat for water birds, Palearctic migrants and visitors. So far several vagrants, Palearctic, intra-tropical and intra-African migrants have been recorded (Appendix 2). The composition of avian species cutting across different feeding guilds and trophic levels is an indication of habitat richness and environmental wellbeing. More so, the presence of nests (plate 1a) and breeding populations of various species of land and water birds (e.g. hamercop, red cheeked cordon bleu, and red-rump swallow) is a strong indicator of habitat suitability and consolidates the assertion that the study area has potential to support more birds and other vertebrate species as the reclamation and wetland development progresses.

Conservation and ecological implication of the study

The ecological integrity of the burgeoning wetland and reclaimed land area of Maiganga is evident in the diversity of feeding guilds recorded in this study. Consequently, several inter-species interactions would be formed and maintained by bird species from the different feeding guilds such as flesh-eating (carnivores), insect–dependent (insectivores), and plant-dependent birds such as frugivores, nectarivores, granivores and omnivores (Table 1). The existence of these guilds is proof that the reclaimed habitat has the basic resources to support avian species. Moreover, the availability of resources underpins ecological robustness and the persistence of potential interactions (predatorship, herbivory, pollination and dispersal) that maintains community stability. In this study, insect eating birds, comprising 28 out of 42 families were the most abundant, making insects perhaps the most abundant food resource for omnivores and insectivorous birds in the study area. Furthermore, the presence of 12 families of granivores and 10 of omnivores (Table 1); strengthens the perception of a functional ecosystem with the availability of alternative food resources for bird species that seasonally switch their diets. The agro-ecological implication of the high number of insectivores in the study area is in the potential benefit this may have for farmers, if harnessed as a sustainable bio-control measure to eradicate insect pest and other macro-invertebrates on agricultural fields adjoining the study area (Tela et al., 2021). Bio-control measures if applied by farmers could reduce the level of dependence on pesticides and more specifically insecticides, thereby regulating the build-up of agro-chemical pollutants in soil and water (Wuana and Felix, 2011; Ogidi 2015; Babangida *et al* 2017).

CONCLUSION

The record of a near threatened bird species, the Pallid Harrier, the CITES listed Senegal Parrot, and 16 species of water birds of the AEWA priority list, supports the assertion that the study area is an ecologically functional wetland worthy of conservation. We have hopefully demonstrated by assessing the assemblage of birds in Maiganga that there is hope for the modified landscape to support more diversity apart from avifauna. Most importantly, the results show that the reclaimed and engineered Maiganga landscape is environmentally friendly for birds and has the potential to become one of the most crucial habitats for avian conservation in Gombe state.

Recommendations

1. Conduct periodic surveys (January to December), to capture the complete abundance and diversity of avian species in the study area.
2. Identify micro-habitats crucial to the survival and persistence of species in Maiganga.
3. Conduct a comparative eco-toxicological assessment to determine the amount of toxins in the blood samples of resident bird species relative to similar species in other wetlands.
4. Establish conservation and bird clubs in primary, secondary and among out of school youths in Maiganga to enlighten them on the ecological importance of birds.
5. Further efforts should focus on estimating abundance of other taxa to determine their current population status.

Appendix 1.Taxonomic Distribution and abundance of Avian Species at Maiganga Coal Mine. (Values in table are counts**)**

S/n	Family	Genera	Species	Individuals
1	Accipitridae	4	8	18
2	Acrocephalidae	2	3	10
3	Alaudidae	2	3	20
4	Alcedinidae	2	2	8
5	Anatidae	3	4	212
6	Apodidae	2	2	34
7	Ardeidae	4	6	95
8	Bucerotidae	2	2	35
9	Caprimulgidae	1	1	1
10	Charadriidae	2	2	73
11	Cisticolidae	4	4	10
12	Columbidae	6	8	113
13	Coraciidae	1	1	10
14	Corvidae	1	1	24
15	Cuculidae	1	1	21
16	Dicruridae	1	2	8
17	Emberizidae	1	2	80
18	Estrildidae	4	4	114
19	Falconidae	1	6	9
20	Fringillidae	1	2	23
21	Hirundiniidae	6	7	178
22	Laniidae	1	1	51
23	Lybiidae	2	2	20
24	Malaconotidae	2	3	18
25	Meropidae	1	2	260
26	Muscicapidae	3	3	82
27	Nectariniidae	3	4	71
28	Odontophoridae	1	1	3
29	Passeridae	2	2	25
30	Phalacrocoracidae	1	1	31
31	Phasianidae	2	2	7
32	Phylloscopidae	1	1	4
33	Ploceidae	4	4	19
34	Psittacidae	1	1	7
35	Pycnonotidae	1	1	7
36	Recurvirostridae	1	1	3
37	Scolopacidae	2	2	7
38	Scopidae	1	1	11
39	Sturnidae	1	3	96
40	Sylviidae	1	1	2
41	Turdidae	1	1	7
42	Viduidae	1	3	30

Appendix 2. Checklist, Abundance and Distribution Status of Avian Species at Maiganga Coal Mine.

(Values in table are counts, LC = Least Concern; NT = Near Threatened)

SN	Species	Scientific Name	No	Family	Feeding Guilds	Distribution Status	Consv Status
1	Abyssinian roller	Coracias abyssinicus	10	Coraciidae	Insectivore/Carnivore	Partially Migratory	LC
2	African Collared Dove	Streptopelia rosegrisea	6	Columbidae	Frugivore	Resident	LC
3	African Grey Hornbill	Lophoceros nasatus	10	Bucerotidae	Insectivore/Carnivore	Resident	LC
4	African Hobby	Falco cuvierii	1	Falconidae	Carnivore	Resident	LC
5	African Mourning Dove	Streptopelia decipiens	4	Columbidae	Frugivore/Granivore	Endemic Resident	LC
6	African Palm Swift	Cypsiurus parvus	2	Apodidae	Insectivore (airborne)	Resident	LC
7	African Pigmy Goose	Nettapus auritus	2	Anatidae	Herbivore/Insectivore	Resident	LC
8	African Pigmy Kingfisher	Ispidina picta	5	Alcedinidae	Insectivore (arthropods)	Intra-Afr.Migr/En.Res	LC

9	African Thrush	Turdus pelios	7	Turdidae	Insectivore/Frugivore/Granivore	Resident	LC
10	Barn Swallow	Hirundo rustica	16	Hirundiniidae	Insectivore	Common Resident	LC
11	Bearded Barbet	Lybius dubius	13	Lybiidae	Frugivore	Resident	LC
12	Beautiful Sunbird	Cinnyris pulchellus	2	Nectriniidae	Insectivore/Nectrinivore	Resident	LC
13	Black Billed Wood Dove	Turtur abyssinicus	4	Columbidae	Frugivore/Granivore/Herbivore	Resident	LC
14	Black Crown Night heron	Nycticorax nycticorax	4	Ardeidae	Carnivore	Vag/Res/Migratory(Northermost Range)	LC
15	Black Crowned Sparrow lark	Eremopterix nigriceps	3	Alaudidae	Granivore/Insectivore	Resident	LC
16	Black Crowned Tchagra	Tchagra senegalus	15	Malaconotidae	Insectivore	Resident	LC
17	Black Faced Canary	Crithagra capistrata	2	Fringillidae	Granivore/Insectivore	ResidentLC	
18	Black Headed Heron	Ardea melanocephala	10	Ardeidae	Carnivore	Resident, Moves during rains	LC
19	Black Kite	Milvus migrans	5	Accipitridae	Carnivore	Migratory	LC
20	Black Winged Stilt	Himantopus himantopus	3	Recurvirostridae	Insectivore/Crustaceans	Migratory &Short range Vag in warmer	LC
21	Bronze Mannikin	Spermetes cucullata	9	Estrildidae	Granivore	Resident	LC
22	Bruice's Fruit Pigeon	Treron waalia	2	Columbidae	Frugivore	Resident	LC
23	Bush Petronia	Gymnoris dentata	1	Passeridae	Insectivore	Resident	LC
24	Cattle Egret	Bubulcus ibis	16	Ardeidae	Insectivore	Migratory	LC
25	Chestnut Backed Sparrow Lark	Eremopterix leucotis	3	Alaudidae	Insectivore/Granivore	Resident	LC
26	Chestnut Bellied Starling	Lamprotornis pulcher	8	Sturnidae	Insectivore/Frugivore	Common Resident	LC
27	Chestnut Crowned Sparrow Weaver	Plocepasser superciliosus	2	Ploceidae	Granivore	Endemic Resident	LC
28	Cinnamon Breasted Rock Bunting	Emberiza tahapisi	64	Emberizidae	Granivore	Partially Migratory	LC
29	Cliff Chat	Thamnolaea cinnamomeiventris	40	Muscicapidae	Insectivore	Endemic Resident	LC
30	Common Bulbul	Pycnonotus barbatus	7	Pycnonotidae	Omnivore	Resident	LC
31	Common House Martin	Delichon urbicum	4	Hirundiniidae	Insectivore	Migratory	LC
32	Common Quail	Coturnix coturnix	3	Phasianidae	Omnivore	Migratory	LC
33	Common Sandpiper	Actitis hypoleucos	6	Scolopacidae	Insectivore	Palearctic visitor	LC
34	Common White throat	Corruca communis	2	Sylviidae	Omnivore	Palearctic migrant	LC
35	Crested Lark	Galerida cristata	14	Alaudidae	Granivore/Insectivore	Vagrant/Resident	LC
36	Dark Chanting Goshawk	Melierax metabates	1	Accipitridae	Carnivore	Resident	LC
37	Double Spur Francolin	Pternistis bicalcaratus	4	Phasianidae	Omnivore	Resident LC	
38	Ethiopian swallow	Hirundo aethiopica	31	Hirundiniidae	Insectivore	Endemic Resident/Intra African Migrant	LC
39	Eurasian Hobby	Falco subbuteo	1	Falconidae	Carnivore	Migratory	LC
40	Eurasian Marsh Harrier	Circus aeruginosus	3	Accipitridae	Carnivore	Migratory	LC
41	European Reed Warbler	Acrocephalus scirpaceus	3	Acrocephalidae	Insectivore	Migratory	LC
42	Exclamatory Whydah	Virdua interjecta	2	Viduidae	Granivore	Endemic Resident	LC
43	Familiar Chat	Oenanthe familiaris	2	Muscicapidae	Insectivore	Resident	LC
44	Fanti Saw-wing	Psalidoprocne obscura	3	Hirundiniidae	Insectivore	Endemic Resident/Intra African Migrant	LC
45	Fox Kestrel	Falco alopex	2	Falconidae	Carnivore	Resident	LC
46	Fulvous Whistling Duck	Dendrocygna bicolor	4	Anatidae	Omnivore	Resident	LC
47	Fork-Tailed Drongo	Dicrurus adsimilis	3	Dicruridaek,	Insectivore	Resident	LC
48	Gosling Bunting	Emberiza goslingi	16	Emberizidae	Granivore/Insectivore	Resident/Partial Migrant	LC
49	Great Egret	Ardea alba	53	Ardeidae	Carnivore	Resident, Palearctic visitor/Intra. Af mig/Va	LC
50	Green Winged Pytilia	Pytilia melba	1	Estrildidae	Granivore	Endemic Resident	LC
51	Grey-Backed Camaroptera	Camaroptera brevicaudata	1	Cisticolidae	Insectivore	Endemic Resident	LC
52	Grey Heron	Ardea cinerea	87	Ardeidae	Omnivore	Resident	LC
53	Grey-headed Kingfisher	Halcyon leucocephala	3	Alcedinidae	Carnivore	Resident/Intra-tropical Migrant	LC
54	Hamerkop	Scopus umbretta	11	Scopidae	Carnivore	Resident	LC
55	Hen Harrier	Circus cyaneus	1	Accipitridae	Carnivore	Migratory	LC
56	Icterine Warbler	Hippolaise icterina	2	Acrocephalidae	Insectivore	Migratory	LC
57	Intermediate Egret	Ardea intermedia	2	Ardeidae	Insectivore	Resident	LC
58	Knob Billed Duck	Sarkidiornis melanotos	18	Anatidae	Omnivore	Resident, disperses in wet season	LC
59	Lanner Falcon	Falco biarmicus	1	Falconidae	Carnivore	Resident	LC
60	Laughing Dove	Spilopelia senegalensis	43	Columbidae	Frugivore	Resident	LC
61	Lesser Kestrel	Falco naumanni	1	Falconidae	Carnivore	Migratory	LC
62	Little Egret	Egretta garzetta	10	Ardeidae	Insectivore	Migratory	LC
63	Little Stint	Calidris minuta	1	Scolopacidae	Invertebrates	Seasonal Vagrant	LC
64	Little Swift	Apus affinis	5	Apodidae	Insectivores	Migratory	LC
65	Lizard Buzzard	Kaupifalco monogrammicus	3	Accipitridae	Carnivore	Resident	LC
66	Long Tail Comorant	Phalacrocorax carbo	31	Phalacrocoracidae	Omnivore	Resident	LC
67	African Marsh Harrier	Circus ranivorus	1	Accipitridae	Carnivore	Resident	LC
68	Long Tailed Glossy Starling	Lamprotornis caudatusm	56	Sturnidae	Omnivore	Resident	LC
69	Melodious Warbler	Hippolaise polyglotta	5	Acrocephalidae	Omnivore	Migratory	LC
70	Montagus Harrier	Circus pygargus	1	Accipitridae	Carnivore	Migratory	LC
71	Mosque Swallow	Cecropsis senegalensis	7	Hirundiniidae	Insectivore	Resident	LC
72	Namaqua Dove	Oena capensis	10	Columbidae	Granivore	Resident	LC

73	Northern Ant Eater Chat	Myrmecocichla aethiops	40	Muscicapidae	Insectivore	Resident	LC
74	Northern Carmine Beeeater	Merops nubicus	97	Meropidae	Insectivore	Resident/ Partial migrant	LC
75	Northern Grey Headed Sparrow	Passer grisseus	24	Passeridae	Granivore	Resident	LC
76	Northern Red Bishop	Euplectes franciscanus	12	Ploceidae	Grannivore/Insectivore	Resident/ local movements	LC
77	Pallied Harrier	Circus macrorus	3	Accipitridae	Carnivore	Migratory	NT
78	Peregrine Falcon	Falco peregrinus	3	Falconidae	Carnivore	Resident	LC
79	Piapiac	Ptiliostomus afer	24	Corvidae	Omnivore	Resident	LC
80	Pigmy Sunbird	Hedydipna platura	15	Nectariniidae	Nectrivore/Insectivore	Resident	LC
81	Pin Tailed Whydah	Virdua macroura	1	Viduidae	Insectivore	Resident	LC
82	Preus Clift Swallow	Petrochelidon preussi	104	Hirundiniidae	Insectivore	Resident	LC
83	Purple Glossy Starling	Lamprotornis purpureus	32	Sturnidae	Omnivore	Resident	LC
84	Red Billed Fire Finch	Lagonosticta senegala	5	Estrildidae	Granivore	Resident	LC
85	Red Billed Hornbill	Torkus erythrorhynchus	25	Bucerotidae	Omnivore	Resident	LC
86	Red Cheeked Cordon Bleu	Uraeginthus bengalus	99	Estrildidae	Granivore	Resident	LC
87	Red Rumped Swallow	Cecropsis daurica	13	Hirundiniidae	Insectivore	Resident, Intra-tropical Mig, Palearctic Vis	LC
88	Scarlet Chested Sunbird	Chalcomitra senegalensis	46	Nectariniidae	Insectivore/ Nectrinivore	Resident	LC
89	Senegal Coucal	Centropus senegalensis	21	Cuculidae	Insectivore	Resident	LC
90	Senegal Eremomela	Eremomela pusilla	6	Cisticolidae	Insectivore	Resident	LC
91	Senegal Parrot	Poicephalus senegalus	7	Psittacidae	Frugivore	Intra-African Migrant/Endemic Resident	CITES Apdx 2
92	Singing Cisticola	Cisticola cantans	1	Cisticolidae	Insectivore	Resident	LC
93	Speckled Fronted Weaver	Sporopipes frontalis	1	Ploceidae	Granivore	Resident	LC
94	Speckled Pigeon	Columba guinea	23	Columbidae	Vegetables/Granivore	Resident	LC
95	Spur winged Lapwing	Vanellus spinosus	64	Charadriidae	Insectivore	Migratory	LC
96	Square Tailed Drongo	Dicrurus ludwigii	5	Dicruridae	Insectivores	Resident	LC
97	Standard Winged Nightjar	Caprimulgus longipennis	1	Caprimulgidae	Insectivore	Resident	LC
98	Stone Patridge	Ptilopachus petrosus	3	Odontophoridae	Granivore	Resident	LC
99	Tawny Flanked Prinia	Prinia subflava	2	Cisticolidae	Insectivore	Resident	LC
100	Three Banded Plover	Charadrius tricollaris	9	Charadriidae	Insectivore	Resident	LC
101	Variable Sunbird	Cinnyris venustus	8	Nectariniidae	Insectivore/Nectrinivore	Resident	LC
102	Village Indigobird	Virdua chalybeata	27	Viduidae	Granivore	Resident	LC
103	Village Weaver	Ploceus cucullatus	4	Ploceidae	Granivore	Resident	LC
104	Vinaceous Dove	Streptopelia vinacea	21	Columbidae	Herbivore/Granivore	Resident	LC
105	White face Whistling Ducks	Dendrocygna viduata	188	Anatidae	grannivore/herbivore	Resident	LC AEWA
106	White Rumped Seedeater	Crithagra leucopygia	21	Fringillidae	Granivore	Resident	LC
107	White Throated Bee eaters	Merops bullockoides	163	Meropidae	Insectivore	Resident	LC
108	Willow Warbler	Phylloscopus trochilus	4	Phylloscopidae	Insectivore	Migratory	LC
109	Yellow Billed Shrike	Corvinella corvina	51	Laniidae	Insectivore/Carnivore	Resident	LC
110	Yellow Crown Gonolek	Laniarus barbarus	3	Malaconotidae	Insectivore	Resident	LC
111	Yellow Fronted Tinker Bird	Pogoniulus chrysoconus	7	Lybiidae	Insectivore/Frugivore	Resident	LC

REFERENCES

Adang, K. L., Nsor, C. A. & Terla, M (2015) Checklist of bird species at the Dadin Kowa Dam, Gombe, Gombe State Nigeria. Global Advanced Research Journal of Agricultural Science (ISSN: 2315-5094) Vol. 4(5) (Journal Article).

Adam B, Mustapha, A., Hasan E., Nicklas J., Mats, N.,Lars, W., and Per, M. (2015). Influences of Forest type amd habitat structure on bird assemblage of oak (Quercus spp.) and pine (Pinus spp.) stands in southwestern Turkey. Forest Ecology and Management. (336), 137-147.

Babangida, H., Hassan, A.F., Hassan, M.A.K and Ibrahim, U. (2017). Determination of Heavy Metals Concentration in Irrigated Soils in Gombe State, Nigeria. Asian Journal of Science and Technology. 8(12): 7047-7054.

Benjamin M., Aliyuda, K. and Amin Dawa, C.C. (2016). Impact of Coal Mining on the Environment in Maiganga Community of Akko Local Government, Gombe State, Nigeria. A paper presented at the 57th Annual Conference of the Association of Nigerian Geographers (ANG) held at University of Lagos, Nigeria, April 10–15 2016

Bhangare R, Tiwari M, Ajmal P, Sahu S, Pandit G. (2014). Distribution of natural radioactivity in coal and combustion residues of thermal power plants. Journal of Radioanalytical and Nuclear Chemistry. 300 (1): 17–22

Bibby, C. J., Burgess, N. D., Hill, D. A., and Mustoe, S. H. (2001). Bird Census Techniques. Academic Press, London. 302 pp.

BirdLife International (2022). Country profile: Nigeria. Available from http://www.birdlife.org/datazone/country/Nigeria. Checked 2022-03-18

Borrow, N., and Demey, R. (2001). A Guide to the Birds of Western Africa. Princeton University Press. Pp. 392 – 401

Butler S., ed (2010). Macquarie Concise Dictionary (5th ed.). Sydney Australia: Macquarie Dictionary Publihers Ltd. ISBN 978-1-876429-85-0.

Ezealor, A. (2002). Critical sites for biodiversity conservation in Nigeria: Nigerian Conservation Foundation; Pp 673-682

Gregory, R. , Noble, D., Field, R., Marchant, J., Raven, M., and Gibbons, D. W. (2003). Using birds as indicators of biodiversity. Ornis Hungarica, 12(13), 11-24.

Keddy, P. A. (2010). Wetland Ecology Principles and Conservation (2nd Edition). Cambridge University Press, Cambridge, UK. 497 pp

Koko M.T, Khandaker M.U, Amin Y.M, Abdullah W.H.B (2016). Quantification and Radiological Risk Estimation Due to the Presence of Natural Radionuclides in Maiganga Coal, Nigeria. PLoS ONE 11(6): e0158100. doi:10.1371/journal.pone.0158100

Maestre, F. T., Castillo-Monroy, A. P., Bowker, M. A., and Ochoa-Hueso, R. (2012). Plant species richness and ecosystem multifunctionality in global drylands. Sc., 335(6065), 214-218.

Mann, C. F., and Cheke, R. A. (2001). Sunbirds: A guide to the sunbirds, flowerpeckers, spiderhunters and sugarbirds of the world. Christopher Helm, A&C Black. First Edition , Pp 56- 122.

Nsor C. A. (2015). Sunbird pollination and the fate of strong contributors to a mutualistic network in a West African Montane Forest. Doctoral Thesis. University of Canterbury Repository. UC. Library. http://hdl.handle.net/10092/11636 Pp. 51-72

Nsor, C.A; Aliyu, B. Zhigla, D; Dauda, E and Cleophas, B.A. (2018). Making the best of a human modified habitat; an assessment of avian distribution and Diversity in Federal College of Education (Technical) Gombe, Gombe State-Nigeria. International Journal of Environment, Agriculture and Biotechnology (IJEAB). ISSN: 2456-1878, DOI: 10:22161/ijeab.

Nsor C. A, Hazel M. Chapman, William Godsoe, Amina Haruna Aliyu (2021) Floral Resources of key Afromontane Tree Species Predict Sunbird Distribution and Abundance in Ngel Nyaki Forest, Taraba State-Nigeria. Greener Journal of Biological Sciences. Vol. 11(2), pp. 81-92, 2021. ISSN: 2276-7762 http://gjournals.org/GJBS.

Official Page of the Ramser Convention. Retrieved 2011-09-25

Ogidi, A.O. (2015). Comparative Assessment of Heavy Metals in Fluted Pumpkin (Telfaria occidentalis), Water Hyacinth (Eichhornia crassipes), Water and Soil from River Benue. (M.Sc Thesis) Department of Chemistry, University of Agriculture, Makurdi, Benue state, Nigeria. 1-115pp

Onsachi, J.M., Dibal, H. U, Daku, S.S. (2016) The Maiganga Coal Mine Drainage and Its Effects on Water Quality, North Eastern Nigeria. International Journal of Emerging Trends in Science and Technology Vol.3 (7) Pages 4324-4333

Orme, C.D.L., Davies, R. G., Burgess, M., Eigenbrod, F., Pickup, N., Olson, V. A., Ridgely, R. S. (2005). Global hotspots of species richness are not congruent with endemism or threat. Nat., 436(7053), 1016-1019.

Oruonye, E.D. Iliya, M., and Ahmed, Y.M. (2016). Sustainable Mining Practices in Nigeria: A case study of Maiganga Coal Mining in Gombe State. International Journal of Plant and Soil Science. 11(5), 1-9.

Pearce, J., and Ferrier, S. (2001). The practical value of modelling relative abundance of species for regional conservation planning: a case study. Biol. Conserv, 98(1), 33-43.

Pringle, R. M., Doak, D. F., Brody, A. K., Jocqué, R., and Palmer, T. M. (2010). Spatial pattern enhances ecosystem functioning in an African savanna. PLoS biol., 8(5), e1000377.

Ramser (2019). Ramser Sites Information System. Home: https://rsis.ramsar.org

Ringim, A.S., Magigije, F.J John, J.R. (2018). Diversity and Density of Avifauna in Areas with Different Protection Status: A Case Study in Hadejia-Nguru Wetlands, North-eastern Nigeria. International Journal of Ecology and Environmental Sciences 44 (2): 117-125.

Tela, M., Cresswell., W, and Chapman, H. (2021) Pest-removal services provided by birds on subsistence farms in south-eastern Nigeria. PloS ONE. 16(8): e0255638. https://doi.org/10.1371/journal.pone.0255638

Wuana, R.A. and Felix, E.O. (2011). Heavy metals in contaminated soils; a review of sources, chemistry, risks and best available strategy for remediation. International Scholarly Research Network. ISRN, Ecology 2011, 20pp.

TOXICOLOGICAL EFFECTS OF SPENT ENGINE OIL ON MAIZE (*Zea mays* L.) AND SOIL PHYSICAL AND CHEMICAL PROPERTIES IN ABRAKA, DELTA STATE, NIGERIA

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ABSTRACT

The study evaluated the toxicological effects of spent engine oil on the soils of Site 2 of Delta State University, Abraka, with the aim of assessing the effects on the soil physical and chemical parameters and their impacts on germination of maize seeds. Soil samples were collected with bucket auger from site 2 and subjected to six levels of Spent Engine Oil (SEO) treatments (0, 20, 40, 60, 80 and 100 ml). Spent engine oil was collected from mechanical workshops in Campus 1 in Abraka. The bulked soil samples were taken to Botany Laboratory, Delta State University, Abraka where they were analysed to determine the effect of spent engine oil on the physical and the chemical properties. The findings of the study showed that application of spent engine oil had deleterious effect on physical and chemical properties of soil. The application of spent engine oil increased bulk density, reduced total porosity, moisture retention capacity of soil and water transmission. Similarly, available phosphorus as well as exchangeable cations (P, K^{2+}, Mg) were generally depressed due to spent engine oil application. Bulk density of spent engine oil treated soil was significantly ($p<0.05$) higher than the control. The result further showed that gravimetric moisture content (GMC), total porosity and hydraulic conductivity of control were significantly ($p<0.05$) higher than the values from SEO-treated soil. The pH was generally higher and increased with increase in SEO levels. The percent organic carbon (%OC) across the treatments was significantly ($P<0.05$) higher than the control. The percentage germination characteristics of seeds reduced from 0-ml SEO (100%) to 80-ml and 100-ml (0%). The study has shown that spent engine oil has negative effects on soils and germination properties of maize hence recommended appropriate disposal to prevent soil degradation and consequent food insecurity.

Keywords: Spent engine oil, soil properties, maize

INTRODUCTION

Spent Engine Oil (SEO), which is chemically referred to as used mineral–based crank case oil, is simply described as the brown to black, oily liquid removed from the engine of a motor vehicle. The disposal of spent engine oil into gutters, water drains, open vacant plots and farms is a common practice by roadside motor mechanics. This SEO is usually obtained after servicing and subsequently draining from automobile and generator engines and much of this oil is poured into the soil. There are relatively large amounts of hydrocarbons in the used oil, including the highly toxic noncyclic aromatic hydrocarbons. Most heavy metals such as V, Pb, Al, Ni and Fe, which were below detection in unused lubricating oil and give high values (ppm) in used oil. These heavy metals may be retained in soils in the form of oxides, hydroxides, carbonates, exchangeable cations, and/or bound to organic matter in the soil (Anoleifo *et al*., 2016). Nevertheless, this is dependent on the local environmental conditions and on the kind of soil constituents present in the soil-water system. In Abraka, various types of activities like transportation and automobile shops produce large amount of SEO. This SEO from various sources are deposited on the soil surfaces. It has dark brown to black colour and it is harmful to the soil environment because it contains a mixture of different chemicals including low to high molecular weight compounds, lubricants, heavy metals, additives and decomposition products which have been found to be harmful to the soil, crop plants and human health (Agbogidi *et al*., 2006; Duffus, 2012).

The increase in the number of vehicles in Nigeria has necessitated a higher production and use of spent engine oil and hence generation of large quantities, at the time of servicing the vehicles. Spent engine oil is considered as ordinary waste by majority of the workers of the automobile mechanic workshops, who dispose this oil by dumping on surface soil. This practice of disposal is a continuous exercise. Pollution from spent engine oil is one of the environmental problems in Nigeria and is more widespread than crude oil pollution (Agbogidi *et al*., 2009; Odjegba and Sadiq, 2012). Change in soil properties occurs in the physical, chemical and microbiological properties of soils contaminated with SEO, thus affecting the plants.

The presence of SEO in soil, increases bulk density, decreases water holding capacity and aeration propensity (Ezenwa *et al*, 2020). Spent engine oil reduced nitrogen, phosphorus, potassium, magnesium, calcium, sodium and increased levels of heavy metals in soils contaminated with spent oil (Nwite and Alu, 2015). These conditions generally cause unsatisfactory seed germination, growth and yield in soil contaminated with spent engine oil.
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In Site 2 of the Delta State University Abraka, some farmers or residents grow vegetables, maize and other crops around the environment. The aim of the study was to evaluate the toxicological effects of SEO on the soil properties of Delta State University, Abraka, Site 2 and its effect on the germination of maize. This study is a baseline study as no documented research has been done in this direction in the study area.

MATERIALS AND METHODS

Study Area

The study was carried out in Abraka, Delta State. Abraka is located in Ethiope East Local Government Area of Delta State and is situated between latitude 5° 45’ and 5° 5’ N and longitude 6° and 6° 15’E in an agglomeration of several communities that are aligned linearly along the New and Old Sapele-Agbor highway. The Abraka area is a typical coastal plain terrain, monotonously lowland and flat with a gentle slope towards the Ethiope River. The climate is equatorial, hot (23 to 37°C) and humid (relative humidity, 50 to 70%).
There is a dry season from about November to February and a wet season that begins in March, peaks in July and October. Six years (2000 to 2005) annual mean rainfall measured at the Delta State University weather station is 3317.8mm. Vegetation is rainforest, most of which has been decimated and replaced with farmlands and secondary forest (Efe and Aruegodor, 2003).

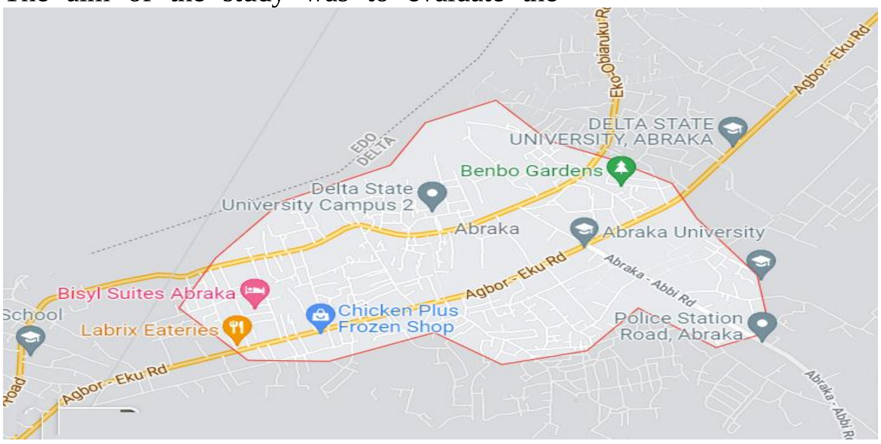

Fig. 1: Map of Delta State University, Site 2, Abraka, Delta State
Source: Google Search engine

Top soil samples were collected with the aid of bucket auger from Campes II, Delta State University Abraka. Spent engine oil was collected from mechanical workshops along Campus 1, Delta State University Abraka. The soil samples were taken to Botany Laboratory, Delta State University, Abraka where they were analysed to determine the effect of SEO the physical and the chemical property of Campus 2 soil. The physical and chemical properties of the soil sample were determined before and after treating soil with SEO. The volumes of

SEO used were (in mL) 20, 40, 60, 80 and 100. Spent engine oil was worked into the soil (0.5kg) contained in the nursery bags. The soil samples were properly mixed with the SEO to ensure contamination before analyses. The physical parameters determined included Bulk density (BD), gravimetric moisture content (GMC), total porosity (TP) and hydraulic conductivity of control (HCC), while the chemical properties included the percent organic carbon (% OC), phosphorus (P), Exchangeable cations of K, Mg, Na and Ca.

The pH of the soil was determined at ambient temperature using glass electrode pH and conductivity meter (Hannia, Italy) in 1:1 water to soil ratio. Nitrogen was determined by the micro Kjedahl method. Phosphorus was determined by the Murphy and Riley (1962) method. The ignition method of Akinsanmi (1975) was used to determine the organic matter content while the dry weight was used to determine the moisture content. Germination characteristics measured were Days to germination (DTG), Rate of germination (ROG) and % germination. Data collected were subjected to analysis of variance (ANOVA) and the significant means were separated with Duncan's Multiple Range Tests using SAS (2005).

RESULTS AND DISCUSSION

The properties of soil before contamination and concentration of nutrients in oil are presented in Table 1. The textural class is sandy loam. The soil physical and chemical properties affected by oil are presented in Tables 2 and 3 respectively. The pH value was 5.2 and this was rated as strongly acidic (USDA SCS, 1974). Organic carbon (OC) and total nitrogen (N) recorded low values. Available phosphorus was high. Exchangeable calcium (Ca) and magnesium (Mg) dominated the exchange complex of soil. Heavy metals concentration in spent engine oil (Table 1) indicated that the values of Zn, Pb, Cu and Cd were within normal safe range in soils.

Table 1: Physical and chemical Properties of the soil sample before contamination

Soil Properties	**Values**
Sand (gkg-1)	69.0
Silt (gkg-1)	11.0
Clay (gkg-1)	20.0
Textural Class	Sandy Loamy
pH	5.0
Organic Carbon (%)	0.46
Nitrogen (%)	0.04
Phosphorus (mgkg-1)	58.20
Calcium (cmolkg-1)	5.60
Magnesium (cmolkg-1)	4.00
Potassium (cmolkg-1)	0.16
Sodium (cmolkg-1)	0.16
Zinc (mgkg-1)	19.30
Lead (mgkg-1)	39.75
Copper (mgkg-1)	16.85
Cadmium (mgkg-1)	10.56
Organic carbon (%)	0.13
Nitrogen (%)	0.06
Available phosphorus (mgkg-)	0.02

Germination studies indicated that SEO significantly affected the germination characteristics of maize in terms of days to germination (DTG), rate of germination (ROG) and germination percentage (%germination) (Table 4). While it took 5 days for maize seeds sown in control (0-ml) and 20-ml of soils contaminated with oil to germinate, 6 days and 7 days were required by maize seeds sown in 40-ml and 60-ml of oil to germinate, respectively. Maize seeds sown in soil polluted with 80-ml and 100-ml of SEO did not germinate. In the same vein, the rate of germination was significantly reduced with increasing concentration of spent oil in the soil. All the seeds (4) sown in the control 0-ml and 20-ml contaminated soil germinated while 3 and 2 seeds out of the 4 sown in soils contaminated with 40- and 60-ml germinated respectively. Seeds grown in 80-ml and 100-ml of oil did not sprout. The percentage germination characteristics of seeds followed the trend 0-ml (100%), 20-ml (100%), 40-ml (75%), 60-ml (50%), and 80-ml and 100-ml (0%). The observed significant reduction in the germination of maize seeds with increasing oil level could be attributed to adulterated soil properties which reduced soil aeration, embryo viability and activity. Similar findings have been reported on *Gambaya albida* (Agbogidi and Ejemete, 2005), *Annona muricata* (Agbogidi and Ofuoku, 2005), on maize (Agbogidi *et al*., 2006) and on *Dacryodes edulis* (Ezenwa *et al*. 2020; Ilyas *et al*., 2021).

Table 2: Effect of spent engine oil on soil physical properties

Treatment	BD (gcm^{-3})	GMC (%)	TP (%)	HC ($cmhr^{-1}$)	PS
0-ml (control)	1.50d	47.98a	43.67a	3.99a	2.70a
20-ml	1.65d	14.47b	37.67b	2.90b	2.64a
40-ml	1.71c	13.52b	35.00c	2.66c	2.62b
60-ml	1.74c	13.45c	34.00d	2.55c	2.60b
80-ml	1.78b	13.14c	32.67e	1.49d	2.58c
100-ml	1.80a	12.55d	32.33e	1.24e	2.56c

Means with the different superscripts are significantly different at ($P<0.05$) using the Duncan's Multiple Range Tests

Key: BD – Bulk density; GMC –Gravimetric moisture content; TP-Total Porosity; HC - Hydraulic conductivity; PS – Particle size

Table 3. Effect of spent engine oil on soil chemical properties.

Treatment	**pH(H_2O)**	**OC (%)**	**N (%)**	**P ($mgkg^1$)**	**K**	**Mg ($Cmolkg^1$)**
0-ml (control)	5.20d	0.44d	0.11c	61.30a	0.21a	4.00a
20-ml	5.51c	2.50c	0.14b	46.50b	0.14b	3.60b
40-ml	5.54c	2.63b	0.18a	40.40c	0.14b	3.20c
60-ml	5.58b	2.65b	0.18a	40.20e	0.12c	2.80c
80-ml	5.60a	2.68a	0.14b	39.70d	0.12c	2.80c
100-ml	5.62a	2.83a	0.10c	27.50e	0.07d	2.40d

Means with the different superscripts are significantly different at ($P<0.05$) using the Duncan's Multiple Range Tests

Table 4: Effects of spent engine oil on the germination characteristics of maize in site 2, DELSU, Abraka

Oil Level	Days to germination	Rate of germination	% Germination
0-ml (control)	5c	4a	100.00a
20-ml	5c	4a	100.00a
40-ml	6b	3b	75.00b
60-ml	7a	2c	50.00c
80-ml	0c	0d	0.00d
100-ml	0d	0d	0.00d

Means with the different superscripts are significantly different at (P<0.05) using the Duncan's Multiple Range Tests

Table 5: Heavy metal contents of soils contaminated with spent engine oil in Abraka, Delta State, Nigeria.

Treatment	Zn	Pd	Fe	Mn	Cd
0-ml (control)	40.5d	2.30d	19.60d	63.40d	10.16d
20-ml	41.6d	2.46c	20.12d	65.41c	10.20c
40-ml	43.6c	2.80b	21.62c	66.70b	11.61b
60-ml	43.9c	3.45b	23.44b	68.14b	11.81b
80-ml	44.8b	4.61a	24.50a	69.94a	12.60a
100-ml	46.0a	5.60a	25.00a	71.00a	13.00a

Means with the different superscripts are significantly different at (P<0.05) using the Duncan's Multiple Range Tests.

Soil pollution with SEO affected the physical and chemical properties of the soil. Oil pollution of soil led to build up of essential and non-essential elements in soil and the eventual translocation into plant tissues as in the case of N and organic carbon, while P, K and Mg levels were significantly reduced with increasing SEO levels (Table 5).

The results showed that bulk density of SEO-treated soil was significantly (p<0.05) higher than the control. The bulk density of spent engine oil treated soil generally increased with increase in levels of spent engine. The result further showed that gravimetric moisture content (GMC), total porosity and hydraulic conductivity of control were significantly (p<0.05) higher than SEO-treated soils. Gravimetric moisture content generally decreased across the treatments with 100-ml SEO being the least (Table 2). Oil in soil has been reported to cause depression in soil physical and chemical properties, resulting in poor performance of crop plants (Agbogidi *et al*., 2006). The presence of high level of heavy metals when compared with the control (Table 5) including zinc, lead, Iron, manganese, cadmium have been reported to be dangerous to soil and its organisms (Agbogidi *et al*., 2007). Particle size decreased in increasing oil level, the pH increased with oil level while the cation decreased with oil levels in the soil. All these values are still within values for fertile soil although care has to be taken to avoid build up with time.

CONCLUSION

The results of this study have shown that application of spent engine oil has deleterious effect on physical and chemical properties of soil and hence poor growth of plants, including maize. These alterations could cause delayed germination of plants as well as their performances. Heavy metals uptake by crops poses danger to human health since human beings depend on crops for food. It is recommended that indiscriminate disposal of spent engine oil to open vacant land, farmlands and roadsides should be discouraged for proper environmental conservation and sustainable development.

REFERENCES

Agbogidi, O. M. and Ofuoku, A.U. (2005). Response of sour sop (*Annona muricata* Linn.) to crude oil levels. *Journal of Sustainable Tropical Agricultural Research* 16: 98-102. Nigeria.

Agbogidi, O. M., Eruotor, P. G., Akparobi, S. O. and Nnaji, G. U. (2017). Evaluation of crude oil contaminated soil on the mineral nutrient elements of maize (*Zea mays L*.). J. Agron., **6**(1): 188-193.

Agbogidi, O.M. and Ejemete, O.R. (2005). An assessment of the effects of crude oil pollution on soil properties, germination and growth of *Gambaya albida* (L.). *Uniswa Research Journal of Agriculture, Science and Technology* 8 (2): 148-155. Nigeria.

Agbogidi, O.M. and Eshegbeyi, O.F. (2006). Performance of *Dacryodes edulis* (Don. G. Lam H.J.) seeds and seedlings in a crude oil contaminated soil. *Journal of Sustainable Forestry* 22 (3/4): 1-14. Nigeria.

Anolifo, G.O., Ikhajiagbe, B., Okonoghua, B.O. and Diafe, F.V. (2016). Eco-taxanomic distribution of plant species around motor mechanic workshops in Asaba and Benin City: identification of oil tolerant plant species. African Journal of Biotechnology, **5**(19), 1757-1762

Duffus, J. H. (2012). Heavy metals "a meaningless term" (IUPAC Technical Report). *Pure. Appl. Chem*. **74** (2):793-80.

Efe, S. I. and Aruegodore, P. (2003). Aspect of microclimates in Nigerian Rural Environment: The Abraka Experience. *Nigeria Journal of Research and Production*, **2** (3): 48-57.

Ezenwa N. J., Adieze I. E.. and Aririatu L. N. (2020). Effects of used engine oil polluted-soil on seeds' germination and seedlings' growth characteristics of some tropical crops. *International Journal of Environment, Agriculture and Biotechnology* (IJEAB). *J. Appl. Sci. Environ. Manage.* **21** (3) 421-428

Ilyas S, Sabo A. and Gbenga F. A. (2021). Assessment of metal accumulation in plant and soil at egg on community mining site, Nasarawa, *Nigeria. Journal of Research in Forestry, Wildlife & Environment* **13**(3). 93-102.

Nwite, J. N. and Alu, M. O. (2015). Effect of different levels of spent engine oil on soil porperties, grain yield of maize and its heavy metal uptake in Abakaliki, Southeastern Nigeria. *Journal of Soil Science and Environmental Management.* (4), pp. 44-51,

Odjegba, V. J. and Sadiq, A. O (2012). Effects of spent engine oil on the growth parameters, chlorophyll and protein levels of *Amaranthus hybridus* L. *The Environmentalist* **22** (1): 23-28.

Okon, J. E. and Mbong, E. O (2013). The effect of nutrient amendments of spent engine oil polluted soil on some growth parameter of okra (*Abelmoschus esculentus*). *Bull. Env. Pharmacol. Life Sci.*, **2** (5): 75-78.

SAS (2005). SAS User's guide. Statistics version 5. SAS Institute Inc. Raleigh, USA.

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ASSESSMENT OF PHYSICOCHEMICAL CHARACTERISTICS OF SURFACE WATER AND SEDIMENT WITH BENTHIC MACROINVERTEBRATE COMMUNITIES AROUND SELECTED FLOW STATIONS; OTUMARA, SAGHARA, AND ESCRAVOS, DELTA STATE

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ABSTRACT

Impurities in any aquatic ecosystem can disrupt physical and chemical properties and balance of the biota. Recent studies have shown the impacts of processed and produced effluents released from crude oil flow stations on terrestrial and aquatic environs, leading to ecosystem deterioration and species displacement. In the Niger Delta region, these activities are common, and the potentials of such acts on the ecosystem need to be studied. The study aims to assess the physical and chemical characteristics of water and sediment in relation to benthic macroinvertebrate communities of water bodies around selected flow stations. This study was conducted at three stations: Otumara, Saghara creeks, and Escravos River, designated as Stations 1, 2, and 3 respectively, in Delta State, Nigeria. The parameters were assessed in water and sediment samples collected monthly between August 2016 to July 2017. In-situ measurements were recorded for water and ambient temperatures, total dissolved solids, conductivity, and pH. Water, while sediment samples were analysed ex-situ in the laboratory. Data were descriptively and inferentially analyzed using Statistical Package for Social Sciences (SPSS 16.0). Faunal diversity indices were computed with Palaeontology statistics (PAST) software version 3.0. Most of the physicochemical parameters in the surface water were not significant ($p>0.05$) across the studied stations. However, Electrical conductivity concentrations were significantly higher at $p<0.01$ in stations 2 and 3 than in station 1. The physicochemical parameters of the water analyzed were above the Federal Ministry of Environment of Nigeria 2003 and World Health Organization 2008 set standards. Most of the physicochemical parameters in sediments were significantly at $p<0.05$ across the studied 3 stations. Electrical conductivity was significantly higher at $p<0.01$ in stations 2 and 3 respectively. The physicochemical parameters of the sediment analyzed were above WHO standards. A total of 12 macrobenthic invertebrate species [Otumara (4), Saghara (5), and Escravo (3)] were enumerated. The relative percentage composition of Benthic macroinvertebrates obtained in the studied stations, indicated Gastropoda as the dominant group; Tympanatomus radula (20.00%) station 1, (31.90%) station 2 and (15.79%) station 3, Tympanatomus fuscatus (11.21%) station 2 and (10.00%) station 3] and Neritina glabrata (10.00%) station 1. Overall, 83.11% of macrobenthic invertebrate species in the study areas were Gastropoda, followed by the Oligochaeta. Gastropods were dominant probably because they are tolerant to pollution, The study revealed ecosystem impacts from industrial activities, on the community structure of species. Proper treatment of industrial effluents before discharging into the aquatic ecosystem around the flow stations is highly encouraged!

Keywords: Gastropods, Aquatic Pollution, Flow stations, Benthic community, Macroinvertebrate.

INTRODUCTION

It is undisputed that industrialization brings assets; science now says that uncontrolled industrial practices have resulted in increased levels of harmful or toxic substances in rivers, lakes, coastal waters, and soils, other environmental consequences of uncontrolled industrial practice are deforestation, overpopulation, noise, and air pollution, accumulation of hazardous wastes (Anani and Olumukoro, 2017).

One of the natural resources endowed by the Nation Nigeria is oil and gas. These natural resources have been long exploited because of the benefits human derived from it. However, overexploitations have left the country in a state of depleted pollution because of mismanagement. This has also brought threat to biodiversities and the ecosystem at large (Nduka and Orisakwe, 2009; Enuneku *et al.*, 2021).

Organic and inorganic pollutants including heavy metals from industrial activities and oil exploration, find themselves in surrounding water bodies (Bay *et al.*, 2003; Anani and Olomukoro, 2018). Also, oil activities impact adversely on the aquatic environment, with allied severe socioeconomic effects (Liu and Wirtz, 2005).

The presence of impurities in the pristine aquatic body changes its worth and frequently causes severe pressure on water biota. Numerous works have revealed a positive relationship between contaminations from petroleum wastes on the health of water biotas (Otukunefor and Obiukwu, 2005). Waste comprising lubricant when released into an aquatic ecosystem can result in dissolved oxygen (DO) reduction because of the alteration of carbon-based materials into in-organic complexes, displacement of aquatic organisms through a reduction in crustaceans with no carapace (amphipod) population that is vital in the structure of the food chain and eutrophication (Anani *et al.*, 2020). Toxic pollutants like heavy metals have been reported to bioaccumulate in living animals without being perceived (Ihenyen 2002; Anani *et al.*, 2020). This makes them a source of concern.

Significant substrates for heavy metals are in assembly with the sediments of any water surroundings (Horowitz, 1985; Deely *et al.*, 1992; Anani *et al.*, 2020). The level at which aquatic bodies resist heavy metal toxic waste is commonly reliant on the volume of suspended sediment in the aquatic environment. Suspended sediment in the aquatic column mainly clay, acts as mops in absorbing metals straight from the thawed resolves and build-up metal pollution in that zone (Cauwet, 1987; Forstner, 1989; Anani and Olomukoro, 2021). Heavy metal contents in waters may differ amongst the aquatic level and sediments bed. Though, the difference in concentration of physicochemical constituents relies on the concentration from developments functioning around the areas.

Macrobenthic organisms have been widely used to assess the pollution status of any aquatic environment this is because they play an important role in the surface water monitoring, cycling of wastes from organic matter, sediment-oxygen reflux, mineralization, and the churning of the sediment (Rosenberg and Resh, 1993; Nystrom *et al.*, 1996; Carlisle *et al.*, 2007; George *et al.*, 2009; Sharma and Chowdhary, 2011; Ishaq and Khan, 2013; Olomukoro and Anani, 2019).

It is based on the above that it turns out to be essential to evaluate the water quality, and pollution status (Peerzada *et. al.*, 1990; Olomukoro and Anani, 2019). The aim of the study is to the assess physicochemical characteristics of water and sediment with benthic macroinvertebrate communities of selected water bodies around the flow station Delta State oil exploration environment (Otumara, Saghara, and Escravos).

MATERIALS AND METHODS

Geographical locations

Three sampling stations were chosen for their proximity to human activities that could potentially affect water quality and biodiversity. Station 1 (Escravous): Escravous field lies on latitude (5° 36' 00.4"N) and longitude (5° 12' 24.9"), Station 2 (Otumara): Otumara field lies on latitude (5° 39' 12. 3"N) and longitude (5° 08' 41.2"), and Station 3 (Saghara): Saghara field lies on latitude (5° 37' 23.2"N) and longitude (5° 10' 31.9") Figure 1.

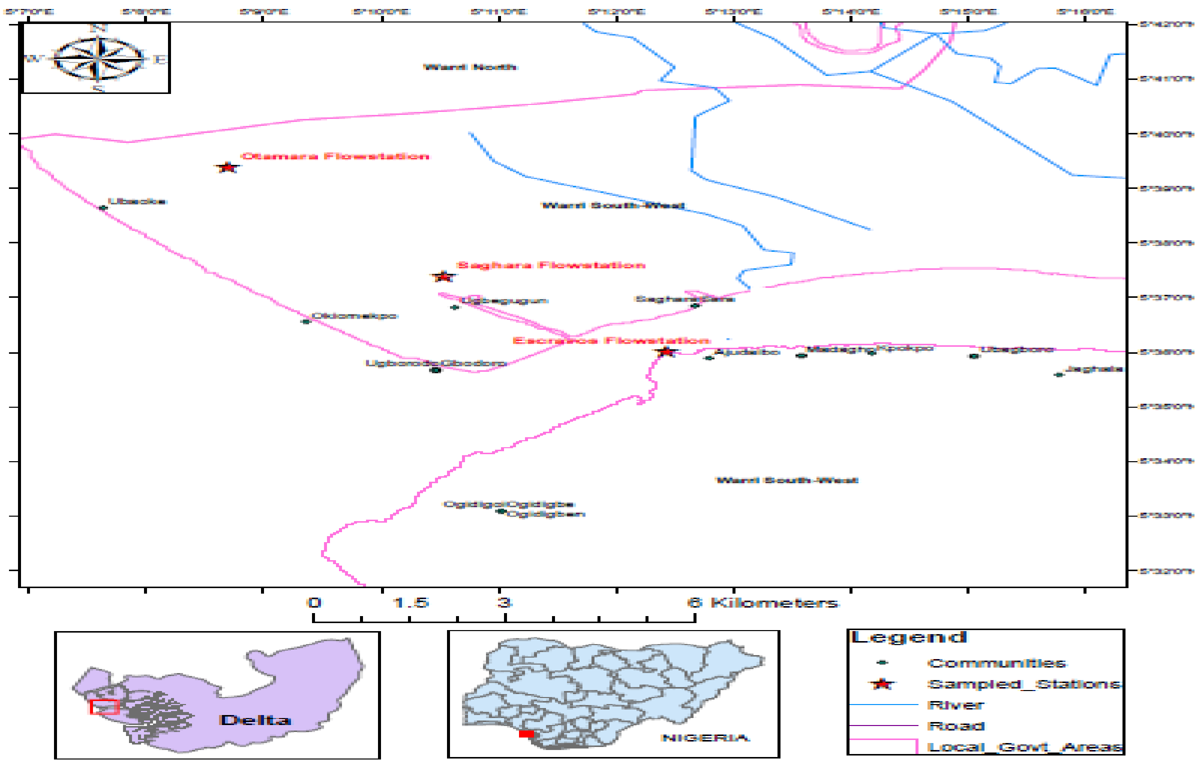

Fig. 1: Map of Nigeria, showing the study area (Delta State) and sampling stations

Climate

The climatic factors are basically dry season which starts from November-March each year, and wet season which commences from April-October every year This region has clear characteristics of a tropical rainforest. According to Akpokodje, (2001), the annual precipitation is between 2000 and 4000 mm in the inland and the coast respectively.

Geological terrain

The study area (Otumara, Saghara, and Escravos) is part of the geologic sequence of the Quarternary and Tertiary formations of the Niger Delta consisting of three main geological formations – the Benin formation (the topmost unit), the Agbada, and the basal unit, the Akata formations. Lithological units of the study area are generally composed of sands, silty sands, and clays.

Vegetation

The vegetation comprises predominantly rubber (*Hevea brasiliensis*), plantain trees (*Musa* sp.), Oil palm trees (*Elaeis guinensis*), and Nipa palm (*Nypa fruticans*). The dominant species of the Salt Marsh ecosystem include *Paspalum vaginatum, Acrostichum aureum,* and *Avicennia germinans.* Phoenix swamp had *Phoenix reclinata, Avicennia germinans, Elaeis guineensis*; Mangrove swamp, *Rhizophora racemosa, Rhizophora harrisonii,* and *Rhizophora mangle*, and the Freshwater swamp – *Fleroya ledermanii, Alstonia boonei, Anthocleista djalonensis.*

Human activities

The human activities in these stations are fishing, farming, trading, and local dredging. They have about 20 active dredged wells and some have been abandoned.

Sampling Periodicity and sampling periodicity

Once every month, samples of water, sediment and macroinvertebrates were taken from August 2016 to August 2017 at each station.

Field activities

In situ measurements were taken for Air and water temperature, pH, conductivity, and total dissolved with an Extech meter probes (Extsik ii) D 600 made in China monthly at the field during the sampling regime. The Winkler method as proposed by Anani and Olomukoro (2021) was used dissolved for oxygen and BOD_5 (Biological Dissolved Oxygen). Samples of sediment were also abstracted with a Grab sampler and stored in an icebox under a closed temperature of 4 ℃ for prior transfer for laboratory analysis.

Laboratory activities (determination of the physicochemical characteristics of surface water and Sediment)

In the surface water, the APHA (2005) method was used to determine the dissolved oxygen (DO) using titrimetric analysis, Turbidity by using a spectrophotometer model 12ID, Total Dissolved Solid by using evaporated to dryness in a boiling water bath, sodium, potassium, calcium, and magnesium by using a Flame Photometer and then Ca and Mg either by Atomic Absorption Spectrophotometer (Radojevic and Baskin, 1999). The methods of Radojevic and Baskin (1999) and Anani and Olomukoro (2021) were used to determine the heavy metals (Fe, Cu, Zn, Cd, Cr, Pb, and Ni using Atomic Absorption Spectrophotometer.

The pH of the sediment was determined using a conductivity meter (APHA, 2005). The determination of the exchangeable anionic bases (sodium, potassium, calcium, and magnesium) was done using the method of Unican 929 Atomic Absorption Spectrometry (APHA, 2005). The determination of the heavy metals (Fe, Cu, Zn, Cd, Cr, Pb, and Ni) was carried out using the Unican 929 Atomic Absorption Spectrometry (APHA, 2005).

Macrobenthic Invertebrates

The modified methods by Armitage (1978) and Lenat *et al*., (1981) earlier described by Victor and Ogbeibu (1985) and Olomukoro and Ezemonye (2007) were used in collecting macrobenthic invertebrates from the bankroot biotope of each station. It is an efficient sampling method for large vagile organisms. The sorted animals were preserved in 5% formalin for late examination. The specimens were identified under the hand lens, dissecting microscope, and the compound microscope (100-400X) depending on the size, with the aid of relevant descriptions and illustrations provided for identification (Olomukoro and Anani, 2019). The identified macrobenthic invertebrates were counted in a counting chamber under the dissecting microscope and all specimens were microphotographed.

Statistical Analysis

Data were analyzed using Statistical Package for Social Sciences (SPSS 16.0) to measure central tendency and dispersion, and inter-station comparisons were carried out to test for significant differences in the physicochemical conditions and the faunal abundance using parametric analysis of variance (ANOVA). The significance value was set at $P<0.05$. Duncan's multiple range (DMR) test was performed to determine the location of significant differences.

Diversity Indices

The basic diversity indices such as Dominance, Shannon (H), Simpson (D), Evenness (H/S), Menhinick, Margalef, and Equitability (J) were employed using Palaeontology statistics (PAST) software version 3.0.

RESULTS

Physicochemical Characterization of surface water (SW) in Otumara (OUT); station 1, Saghara (SAGH); station 2 and Escravos (ESC); station 3.

Table 1 shows the physicochemical parameters of surface water in Otumara (station 1), Saghara (station 2), and Escravos (station 3) fields. Values were represented in mean and standard deviation (SD) and compared with the Nigerian Federal Ministry of Environment (FMEvn) and World Health Organization (WHO) standard limits for surface water.

Hydrogen ion concentration (pH)

The highest pH was in stations 2 and 3 (7.24) while the lowest was observed in station 1 (6.77). There was no significant difference ($P>0.05$) between the mean hydrogen ion concentration in the three stations. The pH range across each station are Otumura (6.75-7.28), Saghara (6.98-7.78), and Escravous (4.40-7.09). There were variations in the pH characteristics in the studied stations.

Water temperature (°C)

The mean temperature was highest (29.09˚C) in station 3 and lowest in station 1 (28.80˚C). There was no significant difference ($P>0.05$) between the mean temperature in the studied stations. The water temperature range across each station are Otumura (25.70-32.80˚C), Saghara (26.20-33.30˚C), and Escravous (28.20-31.30˚C). There was slight uniformity in the water temperature characteristics in the studied stations.

Electrical Conductivity (EC) µs/cm

The mean electrical conductivity concentration was highest (17793 µs/cm) in station 3. There was a significant difference ($P<0.05$) between the mean electrical conductivity concentration in the study stations. *A posterior* Duncan multiple range test further revealed that station 1 was significantly higher than stations 2 and 3 at $p < 0.05$ and stations 2 and 3 were significantly higher than station 1 at $p < 0.01$ respectively. The EC range across each station are Otumura (3039.00-18730.0 µs/cm), Saghara (0.00-2960.00 µs/cm) and Escravous (10709.00-280800.00 µs/cm). There were clear variations in the Ec characteristics in the studied stations.

Salinity (g/l)

The mean value of salinity was highest in station 3 (14.96 g/l) and was lowest in station 1 (4.43 g/l). There was no significant difference ($P>0.05$) between the mean salinity in the studied stations. The salinity range across each station are Otumura (1.37-8.47 g/l), Saghara (4.06-14.84 g/l), and Escravous (12.53-19.41 g/l). There were clear variations in the salinity characteristics in the studied stations.

Colour (Pt. Co)

The mean values of color were highest in station 2 (13.86 Pt. Co) and were lowest in station 1 (10.55 Pt. Co). There was no significant difference ($P>0.05$) between the mean salinity in the studied stations. The color range across each station are Otumura (8.90-18.50 Pt. Co), Saghara (5.80-20.50 Pt. Co), and Escravous (5.20-21.50 Pt. Co). There were slight variations in the color characteristics in the studied stations.

Turbidity (NTU)

The mean turbidity was highest (15.10 NTU) in station 3 and lowest in station 2 (9.27 NTU). There was no significant difference ($P>0.05$) in the turbidity across the study stations. The turbidity range across each station are Otumura (6.80-14.50 NTU), Saghara (3.50-12.50 NTU), and Escravous (10.20-22.00 NTU). There were slight variations in the turbidity characteristics in the studied stations.

Total Suspended Solid (TSS) mg/l

The mean TSS was highest (13.06 mg/l) in station 2 and lowest in station 3 (12.54 mg/l). There was significant difference ($P<0.05$) in the TSS in the study stations. The TSS range across each station are Otumura (9.30-18.30 mg/l), Saghara (9.00-19.30 mg/l) and Escravous (10.00-15.30 mg/l). There were slight variations in the TSS characteristics in the studied stations.

Total Dissolved Solid (TDS) mg/l

The mean values of TDS were highest (9725.08mg/l) in station 3 and lowest (5121.83) in station 1 There was no significant difference ($P>0.05$) between the mean TDS in the study stations. The TDS range across each station are Otumura (1523.00-9927.00 mg/l), Saghara (4393.00-1486.00 mg/l) and Escravous (5280.00-15112.00 mg/l). There were variations in the TDS characteristics in the studied stations.

Dissolved Oxygen (DO) mg/l

The mean values of dissolved oxygen were highest (6.48 mg/l) in station 3 and lowest in station 1 (6.02mg/l). There was no significant difference ($P>0.05$) in the mean dissolved oxygen in the study stations. The DO range across each station are Otumura (4.60-7.00 mg/l), Saghara (4.40-7.26 mg/l), and Escravous (5.27-7.92 mg/l). There were slight variations in the DO characteristics in the studied stations.

Biological Oxygen Demand (BOD_5) mg/l

The mean biological oxygen demand was highest (3.51 mg/l) in station 3 and lowest in station 1 (2.34 mg/l). There was no significant difference ($P>0.05$) in the mean BOD_5 across the study station. The BOD_5 range across each station are Otumura (1.30-3.00 mg/l), Saghara (1.50-5.0 mg/l) and Escravous (1.85-5.08 mg/l). There were slight variations in the BOD_5 characteristics in the studied stations.

Table 1: The summary of the physicochemical characteristics of water from three stations (Otumara, Saghara, and Escravos)

Parameters	Units	Station 1	Station 2	Station 3	P-Value		
		Mean ± SD	Mean ± SD	Mean ± SD		FMEnvN (2003) limits	WHO (2008) limits
pH		6.97±0.05	7.24±0.08	7.24±0.08	P>0.05	6-9	6-8
		(6.75-7.28)	(6.90-7.78)	(4.40-7.09)			
Water temperature	(°C)	28.80±0.89	29.01±0.72	29.09±0.28	P>0.05	<40	NS
		(25.70-32.80)	(26.20-33.30)	(28.20-31.30)			
Electrical Conductivity	(µS/cm)	9810.00±2245.05[b]	14310.58±2898.04[a]	17793.00±13853.83[a]	P>0.05	3.0	NS
		(3039.00-18730.00)	(0.00-29600.00)	(10709.00-28080.00)			
Salinity	(g/l)	4.43±1.01	7.37±1.11	14.96±0.59	P<0.05	NS	NS
		(1.37-8.47)	(4.06-14.84)	(12.53-19.41)			
Colour	(Pt.Co)	12.54±0.90	13.86±1.30	10.55±1.23	P>0.05	15	NS
		(8.90-18.50)	(5.80-20.50)	(5.20-21.50)			
Turbidity	(NTU)	9.38±0.75	9.27±0.74	15.10±1.30	P<0.05	5.0	5.0
		(6.80-14.50)	(3.50-12.50)	(10.20-22.00)			
TSS	(mg/l)	13.06±1.01	12.65±0.82	12.54±0.47	P>0.05	10	1000
		(9.30-18.30)	(9.00-18.30)	(10.00-15.30)			
TDS	(mg/l)	5121.83±1209.38	8235.92±1223.62	9725.08±1029.63	P>0.05	2000	NS
		(1523.00-9927.00)	(4393.00-14800.00)	(5280.0-15112.00)			
DO	(mg/l)	6.02±0.31	6.23±0.33	6.48±0.25	P>0.05	NS	NS
		(4.60-7.00)	(4.40-7.28)	(5.27-7.92)			
BOD_5	(mg/l)	2.34±0.16	3.07±0.28	3.51±0.30	P>0.05	3.0	NS
		(1.30-3.00)	(1.50-5.00)	(1.85-5.08)			

p<0.05 – Significant difference; p>0.05 – No significant difference; Superscript [a] means significant at <0.01 and Superscript[b] means not significant. at >0.01. FMEnvN stands for

Physicochemical Characteristics of Sediment (SD) in Otumara; station 1, Saghara; station 2 and Escravos; station 3

A summary of the results of the physicochemical characteristics of the sediment from waters around Otumara (Station 1), Saghara (station 2), and Escravos (station 3) are presented in Table 2. The mean, standard error, minimum and maximum values for each parameter analyzed at the three stations are also given. The values were represented in mean and standard deviation (SD) and compared with the Nigerian Federal Ministry of Environment (FMEvn) and World Health Organization (WHO) standard limits for surface water.

Hydrogen ion concentration (pH)

The mean hydrogen ion concentration was highest (5.71) in station 3 and lowest in station 2 (5.21). There was no statistical difference (P>0.05) between the mean hydrogen ion concentration in the study stations. The range in values of pH obtained in this study is Otumura (4.20-6.88), Saghara (4.26-6.40), and Escravous (4.40-7.09). There were slight variations in the values across the stations.

Electrical Conductivity (EC) µs/cm

The mean electrical conductivity concentration was highest (11907 µs/cm) in station 2 and lowest in station 1 (6058.33 µs/cm). There was a statistical difference (P<0.05) between the mean conductivity concentration in the study station. *A posterior* Duncan multiple range tests further revealed that station 1 was not significantly different from stations 2 and 3 which were significantly different (P<0.01). The range in values of EC obtained in this study are Otumura (2030.00-1035.00 µs/cm), Saghara (4700.00-16200.00 µs/cm), and Escravous (2940.00-2114.00 µs/cm). There were clear variations of the values across the stations.

Sodium

The mean for sodium was highest (8.18 meg/100g) in stations 2 and lowest (7.91 meg/100g) in stations 1 and 3. There was no significant difference (P>0.05) between the mean for sodium in the study stations. The range in values of sodium obtained in this study is Otumura (4.16-10.45 meg/100g), Saghara (5.04-10.74 meg/100g), and Escravous (4.16-10.45 meg/100g). There was slight uniformity in variations of the values across the stations.

Potassium

The mean potassium was highest (4.52 meg/100g) in stations 1 and 3 while the lowest (4.08 meg/100g) was in station 2. There was no significant difference (P>0.05) between the mean potassium in the study stations. The range in values of potassium obtained in this study is Otumura (1.17-8.82 meg/100g), Saghara (0.71-7.55 meg/100g), and Escravous (1.17-8.82 meg/100g). There were slight variations in the values across the stations.

Calcium

The mean calcium was highest (72.00 meg/100g) in station 2 and lowest in both stations 1 and 3 (10.67 meg/100g). There was a significant difference (P<0.05) between the mean calcium concentration in the study station. The range in values of calcium obtained in this study is Otumura (7.48-12.40 meg/100g), Saghara (8.61-16.40 meg/100g), and Escravous (7.48-12.40 meg/100g). There were slight variations in the values across the stations.

Magnesium

The mean magnesium was highest (8.81 meg/100g) in station 2 and lowest in stations 1 and 2 (7.82 meg/100g). There was no significant difference (P>0.05) between the mean magnesium conductivity concentration in the studied stations. The range in values of magnesium obtained in this study is Otumura (5.14-10.70 meg/100g), Saghara (6.17-14.70 meg/100g), and Escravous (5.14-10.70 meg/100g). There were slight variations in the values across the stations.

Iron

The mean iron was highest (195.74 mg/kg) in station 3 and lowest in station 2 (166.40 mg/kg). There was no significant difference (P>0.05) between the mean iron in the study station. The range in values of iron obtained in this study is Otumura (125.40-211.60 mg/kg), Saghara (133.00-210.00 mg/kg), and Escravous (125.40-285.20 mg/kg). There were slight variations in the values across the stations.

Copper

The mean copper was highest (15.99 mg/kg) in station 2 and lowest in station 3 (15.52 mg/kg). There was no significant difference (P>0.05) between the mean copper in the study stations. The range in values of copper obtained in this study is Otumura (2.41-48 mg/kg), Saghara (2.28-30.50 mg/kg), and Escravous (2.41-48.00 mg/kg). There were slight variations in the values across the stations.

Zinc

The mean zinc was highest (13.46 mg/kg) in station 1 and lowest (12.62 mg/kg) in station 3. There was no significant difference (P>0.05) between mean zinc in the study stations. The range in values of zinc obtained in this study is Otumura (3.34-30.30 mg/kg), Saghara (3.68-16.90 mg/kg), and Escravous (3.34-30.30 mg/kg). There were slight variations in the values across the stations.

Table 2: A summary of the physicochemical characteristics of sediment from three stations (Otumara, Saghara, and Escravous)

Parameters	Units	Station 1 Mean ± SD	Station 2 Mean ± SD	Station 3 Mean ± SD	P-Value	WHO (2004)/FMEnvN (2003)
pH		5.40±0.26 (4.20-6.88)	5.21±0.17 (4.26-6.40)	5.71±0.22 (4.40-7.09)	P>0.05	6.5-8.5
Electrical Conductivity	(µS/cm)	6058.33±847.26[b] (2030.00-10350.00)	11907.50±110.69[a] (4700.00-16200.00)	10223.33±1575.75[a] (2940.00-21140.00)	P<0.05	100
Sodium	(meg/100g)	7.91±0.59 (4.16-10.45)	8.19±0.57 (5.04-10.74)	7.91±0.59 (4.16-10.45)	P>0.05	NS
Potassium	(meg/100g)	4.52±0.69 (1.17-8.82)	4.08±0.62 (0.71-7.55)	4.52±0.69 (1.17-8.82)	P>0.05	NS
Calcium	(meg/100g)	10.67±0.41 (7.48-12.40)	11.72±0.82 (8.61-16.40)	10.67±0.41 (7.48-12.40)	P>0.05	NS
Magnesium	(meg/100g)	7.82±0.50 (5.14-10.70)	8.81±0.77 (6.17-14.90)	7.52±0.50 (5.14-10.70)	P>0.05	70
Iron	(mg/kg)	175.74±9.23 (125.40-211.60)	166.40±9.43 (133.00-210.00)	195.74±13.49 (125.40-285.20)	P>0.05	NS
Copper	(mg/kg)	15.60±5.01 (2.41-48.00)	15.99±3.16 (2.28-30.50)	15.52±4.94 (2.41-48.00)	P>0.05	0.030
Zinc	(mg/kg)	13.46±2.80 (3.34-30.30)	11.39±1.46 (3.68-16.90)	12.62±2.44 (3.34-30.30)	P>0.05	0.030

p<0.05 – Significant difference; p>0.05 – No significant difference; Superscript [a] means significant at <0.01 and Superscript[b] means not significant at >0.01. NS means not specified. FMEnvN means; Nigeria Federal Ministry of Environment and WHO means; World Health Organization.

The macrobenthic invertebrates' community of Otumara, Saghara, and Escravos rivers

The overall species composition, distribution, and abundance of macro-invertebrates collected during the study period are presented in Table 3.

A total of 35 macrobenthic invertebrate species [Otumara (11), Saghara (12), and Escravos (12)], comprising 111 individuals [Otumara (27), Saghara (40), and Escravos (48)] were obtained in this study (Table 3 and Figure 2).

Table 4 shows the relative percentage composition of macrobenthic invertebrates obtained in the studied stations. The dominant groups are the Gastropoda [*Neritina glabrata* (22.50%) station 2], Coleoptera [*Dyticus marginalis* (22.22%) station 1] Oligochaeta [*Nadium Osborni* (18.52%) station 1, *Nadium sp* (18.18%), 3 and *Medium breviseta* (13.04%) station 3 and *Eiseniella sp* (11.11%) station 1] . This made a total of 94.46% of the percentage occurrence of the species in the studied stations.

The sub-dominant and the common groups in terms of percentage occurrence are: Decapoda [*Callinectus marginatus* (10.00%) station 2, *Callinectus amnicola* (9.09%) station 3, 7.50% station 2 and 7.41% station 1], Emphemoptera [Baetis tricadatus (7.00) station 2] and Hemiptera [*Pelocoris femoratus* (7.45%) station 1. The other species made up the rare groups with values less than 1 (<1).

Table 3: Composition and abundance of macroinvertebrates in Otumara, Saghara, and Escravos flow stations

Species composition	Otumara (Station 1)	Saghara (Station 2)	Escravos (Station 3)
ANNELIDA	0	0	0
Oligochaeta	0	0	0
Eiseniella sp	3	2	4
Enchytraeus sp	1	4	1
Nadium breviseta	2	4	6
Nadium osborni	5	3	8
Nadium sp	0	0	8
Chaetogaster sp	0	4	0
Polychaeta	0	0	0
Nais communis	2	1	4
Nais simplex	1	0	0
Nereis sp	1	1	1
EPHEMEROPTERA	0	0	0
Baetis tricaudotus	0	3	2
HEMIPTERA	0	0	0
Pelocoris femoratus	2	0	1
COLEOPTERA	0	0	0
Amphiopops gibbos	0	2	0
Dyticus marginalis	6	0	0
DECAPODA	0	0	0
Callinectes marginatus	0	4	3
Callinectes Amnicola	2	3	4
GASTROPODA	0	0	0
Neritina glabrata	2	9	2
Number of species	11	12	12
Number of individuals	27	40	44

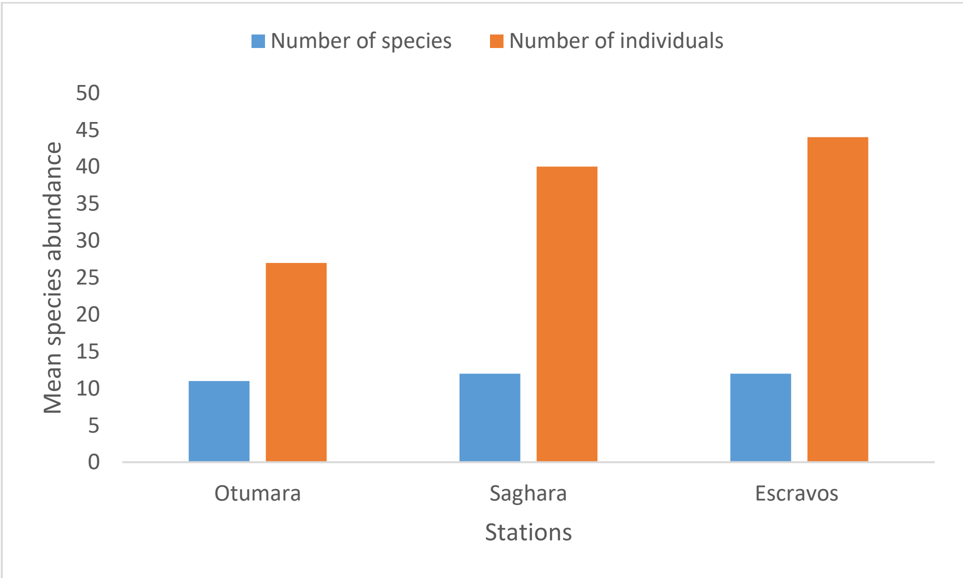

Fig. 2: Species composition and abundance of individuals

Table 4: Relative percentage composition of macrobenthic invertebrates in the studied stations

Species composition	Otumara	% occurrence	Saghara	% occurrence	Escravos	% occurrence
ANNELIDA	0	0.00	0	0.00	0	0.00
Oligochaeta	0	0.00	0	0.00	0	0.00
Eiseniella sp	3	11.11	2	5.00	4	9.09
Enchytraeus sp	1	3.70	4	10.00	1	2.27
Nadium breviseta	2	7.41	4	10.00	6	13.64
Nadium osborni	5	18.52	3	7.50	8	18.18
Nadium sp	0	0.00	0	0.00	8	18.18
Chaetogaster sp	0	0.00	4	10.00	0	0.00
Polychaeta	0	0.00	0	0.00	0	0.00
Nais communis	2	7.41	1	2.50	4	9.09
Nais simplex	1	3.70	0	0.00	0	0.00
Nereis sp	1	3.70	1	2.50	1	2.27
EPHEMEROPTERA	0	0.00	0	0.00	0	0.00
Baetis tricaudotus	0	0.00	3	7.50	2	4.55
HEMIPTERA	0	0.00	0	0.00	0	0.00
Pelocoris femoratus	2	7.41	0	0.00	1	2.27
COLEOPTERA	0	0.00	0	0.00	0	0.00
Amphiopops gibbos	0	0.00	2	5.00	0	0.00
Dyticus marginalis	6	22.22	0	0.00	0	0.00
DECAPODA	0	0.00	0	0.00	0	0.00
Callinectes marginatus	0	0.00	4	10.00	3	6.82
Callinectes Amnicola	2	7.41	3	7.50	4	9.09
GASTROPODA	0	0.00	0	0.00	0	0.00
Neritina glabrata	2	7.41	9	22.50	2	4.55
Total	27	100.00	40	100.00	44	100.00

Species indices of Otumara, Saghara and Escravos rivers

Diversity index of Otumara, Saghara and Escravos rivers

The diversity index of Otumara, Saghara, and Escravos rivers varied significantly amongst the study stations. Margalef index had the highest diversity (3.03) at Otumara and the lowest (2.91) at Escravos. Shanon-Weiner index had the highest diversity (2.32) at Saghara and the lowest (2.22) at Otumara. The Simpson index had the highest diversity (0.89) at Saghara and the lowest (0.87) at Otumara (Table 5).

Table 5: Overall diversity and richness of the macro-invertebrate community of studied stations

	Otumara	Saghara	Escravos
Number of species	11	12	12
Number of individuals	27	40	44
Dominance_D	0.13	0.11	0.12
Simpson_1-D	0.87	0.89	0.88
Shannon_H	2.22	2.32	2.27
Evenness_e^H/S	0.84	0.85	0.80
Margalef	3.03	2.98	2.91
Equitability_J	0.93	0.94	0.91

Richness/Dominance Index of Otumara, Saghara, and Escravos rivers

The species richness of the studied rivers was significantly higher at Otumara (0.13) with 11 species and 27 individuals. The lowest species richness was observed at Saghara (0.11) with 12 species and 40 individuals (Table 5).

Evenness and Equitability Index of Otumara, Saghara, and Escravos rivers

The evenness and equitability index were fairly low in Escravous (0.30 and 0.91) respectively. But higher at Saghara and Otumara (0.85 and 0.93) respectively (Table 5).

DISCUSSION

The physicochemical characteristics

The findings from the results of the physicochemical characteristics revealed that the concentrations of most of the parameters in the surface water varied across the studied stations. The parameters were far above the set limits (FMEnvN, 2003 and WHO, 2008) for tropical waters especially electrical conductivity (EC) and total dissolved solids (TDS) in Escravous and Saghara. This may be attributed to high industrial petrochemical complexes and Agricultural discharges into the rivers. Similar studies have been reported by Trocine *et al.* (1993), He *et al.* (2005), Shrestha and Kazama (2007), Anani and Olomukoro (2017), Olomukoro and Anani (2019), Anani *et* *al.* (2020), and Anani and Olomukoro (2021) in different water bodies.

The findings from the pH characteristics obtained from the studied rivers revealed high acidity to a neutral state. The consequence of this is that most aquatic animals such as benthic macroinvertebrates will likely not thrive better at this low level of pH level. Similar findings have also been observed in the works of Martin *et al.* (1998) in Lativain waters; Izonfuo and Bariweni (2001) in Epie Creek, Niger Delta, and Dirisu and Olomukoro (2015) in Agbede wetland, Sothern Nigeria. But contrary in terms of irregular variations with the findings obtained by Ikhile and Olorode, (2012) in Ose-Ossiomo River and Anani *et al.*, (2020) in Ossiomo River.

The findings from the results of the temperature characteristics obtained are typical of tropical water bodies. There were slight variations across the stations. The observed temperatures were higher during the dry season months. Similar findings have also been reported by Akpan, (2000), Olomukoro and Egborge, (2004), Dirisu and Olomukoro (2015), and Anani *et al.* (2020) in some Nigeria inland waters. Irregularity of temperature may affect the rate or degree of metabolic activities and development of water biota and also cause the organisms to disperse from their natural ecological niche.

High electrical conductivity values were obtained in various stations. The values obtained cannot be compared to what was obtained in related rivers by Aisien *et al.* (2010) - 8.01 and 10.62 µs/cm, in Ethiope River and by Imoobe and Oboh (2003) - 10.14 and 13.19us/cm, in River Jamieson. The higher values of Electrical conductivity in all the stations could be attributed to high organic load from anthropogenic activities along the study stretch, especially in the rainy season. Similar findings have also been reported by Ajibade *et al.* (2008) in the kanji dam and Idodo-Umeh (2002) in the water bodies of Areba Olomoro, Isoko, and Anani *et al.* (2020) in Ossiomo River. However, the values obtained in this study suggest complete estuarine, characterized by the very high conductivity levels.

The findings from the salinity characteristics, revealed high saline contents differ from the tropical freshwater environment but, ascribed values similar to a typical estuarine ecosystem environment (McLusky and Elliot, 1981).

The turbidity characteristics obtained were very high. These values are similar to the values obtained by Ogbeibu and Ezeunara (2002) - (45 and 1670 NTU) in Ikpoba River, Edo, Aisien, *et al.* (2010) (3.70 and 25 NTU) in River Ethiope, Delta State, but contrary to the values (1.16 and 5.81 NTU) obtained by Omo-Irabor and Olabaniyi (2007) in River Ethiope watershed, Delta state because of its low values. Higher turbidity values were observed during the rainy season compared to the dry season as a result of erosion from the bank of the river via runoffs. The high values obtained showed that the rivers might have had some suspended particles which might impede enough light penetration into them. This might also have negative impacts on the biota therein.

The TSS values obtained here were low. The results were dissimilar to what was obtained by Ajibade, (2004) - 766.60-1498.60 mg/l, in Asa River (Kwara state), Osibanjo *et al.* (2011) - 370 and 290 mg/l for Rivers Ona and Alaro in Ibadan respectively. The low values obtained here might be a result of the self-purification ability of the rivers. However, low or high TSS in any river water could also act as a vector of nutrients such as phosphorus and toxic compounds such as pesticides and herbicides from the land surface to the water body Kronvang *et al.* (2003), leading to the proliferation of toxic phytoplankton in rivers. This will invariably affect the population of benthic macroinvertebrates.

The total dissolved solids (TDS) obtained were far greater than the slated value (2000 mg/l) as slated by FMEnvN, (2003) standard. The high values observed here, were dissimilar to what was obtained by Ajibade, (2004) which showed high TDS values (704.60-1799.80 mg/l) in Asa River (Kwara state), and with the values obtained by Osibanjo *et al.* (2011) who reported 120 and 40 mg/l for Rivers Ona and Alaro in Ibadan respectively. Alabaster and Lloyd (1980) reported that excessive concentration of total solids might be harmful to aquatic life.

The findings from dissolved oxygen results obtained were quite higher than the slated limits and with the values obtained by Radojevic and Bashkin (1999) but in some cases irregular. The values can be compared with what was obtained in Luubara creek (4.0-7.5 mg/l) by Deekae et al. (2010). But slightly above the values obtained in Ikpoba River (3.71mg/l) by Ogbeibu and Ezeunara, (2002) and within the values obtained by Hart and Zabbey (2005) in Woji creek (1.6-10.1mg/l). High DO values were recorded during the rainy season. The low DO value obtained during the dry season is a consequence of low precipitation. Ikongbeh *et al.* (2013) also recorded high oxygen concentrations in the rainy season for Lake Akata. These irregulars DO values obtained in these rivers, indicated a poor water system.

The results of the BOD_5 characteristics obtained in this study fall within the allowable range set by FMEnvN, (2003). A BOD_5 level beyond 4 mg/l has been indicated to cause serious environmental pollution (Radojevic and Bashkin, 1999). The values obtained in the studied rivers are quite higher compared with the value (4 mg/l). However, Clerk, (1986) reported a BOD_5 range of 2-4 mg/l, Ogbeibu, and Ezeunara, (2002) reported a BOD_5 of 0.10 and 1.90 mg/l in Ikpoba River, and Aisien *et al.* (2010) obtained a BOD_5 of 3.8 and 76.75 mg/l in Ethiope River. The findings revealed variations in the BOD_5 values which may be due to the variance of industrial activities influencing the various stations.

Sediment studies

The findings indicated that the sediment quality concentrations fluctuated across the stations. These values were placed alongside the World Health Organisation (WHO, 2003) limit for discharge into sediment and the Nigeria Federal Environmental Protection Agency (FMEnvN, 2003). Most of the parameters were slightly higher than the recommended regulatory limits for river sediment, especially from Escravos.

The pH of the sediment showed low to high values (4.20-7.09) which indicates a typical acidic ecosystem. The findings of this study are similar to the works of Iwegbue *et al.* (2007) who reported the values of 4.57-7.30 in the sediment of Ase River, Niger Delta, Nigeria, Davies, and Tawari (2010) who reported the values of 4.45-5.80 in the sediment of trans-Okpoka Creek, upper bonny Estuary, Nigeria, and Ogbeibu *et al.* (2014) who reported 4.80-5.50 in Benin River, Delta regions of Nigeria. A high pH value can regulate the entire chemical characteristic of any river and in turn affect the biota distribution and occurrence.

The high concentrations of electrical conductivity values recorded were very high. This is in line with the findings obtained by Davies and Tawari (2010) who reported 4080-4577.78 µS/cm in the sediment of trans-Okpoka Creek, upper bonny Estuary but dissimilar with what was obtained (99.00-1215.00 µS/cm) by Ogbeibu *et al.* (2014) in Benin River. The high EC obtained can be a result of the discharge of ionic compounds into the rivers via industrial outputs.

High alkali earth metals were recorded in the Saghara and Escravos. This conforms to the findings obtained by Ogbeibu *et al.* (2014). The results of this high base contents in the rivers can increase the high pH of the river which is considered to be more worrisome because of the probable ecological risk they pose to the lives

The high concentration of iron obtained is as compared with the findings (28.1-33.7mg/kg) for Orogodo River sediments obtained by Puyate *et al.* (2007), 31.19-8.34 mg/kg in the sediments of river Ngada obtained by Akan *et al.* (2010) and 1.88-12.73 mg/kg of Benin River obtained by Ogbeibu *et al.* (2014). But lower when compared with values (867.8-7195.0 mg/kg) in the Benin River obtained by Ogbeibu, (2011). These variations were designated to the nature of the industrial activities carried out within the river. Iron has been reported to occur at higher concentrations in Nigerian soil/sediment (Adefemi *et al.*, 2007; Ogbeibu *et al.*, 2014; Anani and Olomukoro, 2017).

The concentration of copper obtained, surpassed the slated limits. Puyate *et al.* (2007) and Ogbeibu (2011) documented higher values in the sediments of the Orogodo River and Benin River respectively. High levels of copper have been associated with anemia, liver and kidney damage, and stomach and intestinal irritation (Priju and Narayana, 2007).

The findings obtained for zinc differ from what was obtained by Ihenyen (2001), Ogbeibu (2011), and Ogbeibu *et al.* (2014) in the sediment of a similar river they examined. The values of Zn also surpassed the slated limits set by the regulatory bodies. This might be due to the high pollution from effluent that has high zinc content.

Macrobenthic Invertebrates

The community structure explains the qualitative nature of the macrobenthic fauna associated with the bottom sediment of the Otumara, Saghara, and Escravos rivers. The macrobenthic invertebrates in the sediment of the studied rivers seemed to be unique in their community structure.

The findings from the results of the macrobenthic community revealed an overall total of 35 macroinvertebrates species comprising 111 individuals which were recorded within the sampling regime. The species observed were far higher than the 9 species recorded by Ezekiel *et al.* (2011), the 30 species reported by Hart and Zabbey (2005), and the 30 species recorded by Ansa (2005). However, far lesser than the 51 species reported by Hart (1994) in mangrove swamps in Port Harcourt, the 84 species reported from Ibiekuma River by Edokpayi and Osimen (2001) and the 122 species (Lagos Lagoon) and 414 species (Seamounts on the Northwest Chatham Rise) reported by Onyenekan, (1987) and Rowden *et al.* (2002) respectively.

The species in this present study was dominated by the Gastropoda. The dominance of Gastropoda in this ecosystem indicated that the ecosystem is polluted. Gastropods are very well known to be well tolerant to pollutants and often used to detect the pollution status of any river water (Olomukoro and Anani, 2019). The presence of the diverse species indicates their tolerance level as well as their dominance in the ecosystem. This study agrees with the report of George *et al.* (2010), Hart and Zabbey (2005), Edokpayi and Osimen (2001), and Ezekiel *et al.* (2011). The composition of benthic macroinvertebrates in this study area was closely related to the findings by Hart (1994) and Ansa (2005) in the Andoni flats and Eagle Island (both in the Niger Delta) respectively and the findings reported by Ezekiel *et al.* (2011) in the Sombreiro River. The differences in species composition and abundance in this study may be linked to several ecosystem factors such as diverse habitat locations, sampling regime study, and the fitness or health of the water (Dance and Hynes, 1980).

The results of the species diversity indices (Simpson index) indicated a very low diversity of macrobenthic invertebrates in all the studied stations. Low species diversity was also reported by Zabi and Leloeuff (1993) in populations found in Senegambia (Senegal, Gambia, and Casamance) Rivers. This might be an indication that species in the ecosystem are very low, a consequence of environmental stress by passive industrial pollution (Efitre *et al.*, 2001; Olomukoro and Victor, 2001; Furey, 2006; Olomukoro and Ezemonye, 2007; Olomukoro and Ovioje, 2015; Olomukoro and Anani, 2019).

CONCLUSION

The findings from the surface water revealed that most of the parameters were far above the set limits (Nigeria Federal Ministry of Environmental and World Health Organization) for tropical waters especially electrical conductivity (EC) and total dissolved solids (TDS) in Escravous and Saghara. This may be attributed to high industrial petrochemical complexes and Agricultural discharges into the rivers.

The findings from the sediment indicated that the sediment quality concentrations fluctuated across the stations. Most of the parameters were slightly higher than the recommended regulatory limits for river sediment, especially from Escravos. The source of pollution was traced from runoff from the cities, discharge of improperly treated waste effluents, sewage sludge, and the use of pesticides for agricultural and industrial purposes.

The findings from the macrobenthic community revealed that the ecosystem was highly perturbed, which led to low diversity, occurrence, and distribution of benthic invertebrates across the rivers. However, the community was dominated by Gastropods>Coleoptera>Decapoda>Empheroptera. The dominance of these organisms was based on their levels of tolerance to pollution.

REFERENCES

Adefemi, O. S. Asaolu, S. S. and Olaofe, O. (2007). Assessment of the physicochemical status of water samples from major dams in Ekiti State, Nigeria. *Pakistan Journal of Nutrition* **6** (6): 657 - 659.

Aisien, E. T. Gbegbaje-Das,1. E. and Aisien, F. A. (2010). Water quality assessment of River Ethiope in the Niger Delta Coast of Nigeria. *Electronic Journal of Environmental Agricultural and Food Chemistry* **9** (11): 1739-1745.

Ajibade, L. T. (2004). Assessment of water quality near River Asa, Ilorin, Nigeria. *The Environmentalist* **24** (1): 11-18. https://doi.org/10.1023/B:ENVR.0000 046342. 65791.07.

Akpokodje, E.G. (2001). Introduction to Engineering Geology. Pam Unique Publishing Co. Ltd., Port Harcourt. pp. 180-181.

American Public Health Association (APHA) (2005). Standard Methods for the Examination of Water and Wastewater. 21st ed. American Public Health Association, Washington DC, 120pp.

Anani, O. A. and Olomukoro, J. O. (2017). The Evaluation of heavy metal load in benthic sediment using some pollution indices in Ossiomo River, Benin City, Nigeria. *Funai Journal of Science and Technology* **3** (2): 103-119.

Anani, O. A. and Olomukoro, J. O (2021). Probabilistic risk assessment and water quality index of a tropical delta river. *PeerJ* **9**(2):e12487. https://doi.org/10.7717/peerj.12487.

Anani, O. A. Olomukoro, J. O and Ezenwa, I. M. (2020). Limnological evaluation in terms of water quality of Ossiomo River, Southern Nigeria. *International Journal of Conservation Science* **11** (2): 571-588.

Anani, O. A. and Olomukoro, J. O. (2018). Trace metal residues in a tropical Watercourse sediment in Nigeria: Health risk implications. *IOP Conference Series: Earth and Environmental Science* 210: 012005.

Anani, O. A. Olomukoro, J. O. And Enuneku, A. A. (2020). Geospatial mapping, environmetrics and indexing approach for a tropical River sediment in Southern Nigeria. *Pakistan Journal Science and Industrial Research Series A: Physical Science* **63A** (3): 176-187.

Ansa, E. J. (2005). Studies of the benthic macrofauna of the Andoni River flats in the Niger Delta area of Nigeria. Ph.D. Thesis, University of Port Harcourt, Port Harcourt, Nigeria. pp. 242.

Armitage, P. D. (1978). Downstream changes in the composition, numbers and biomass of bottom fauna in The Tees below Cow Green Reservoir and in unregulated Maize Beck, in the first years after impoundment. *Hydrobiology* **58**:145-146.

Bay, F., Fäh, D., Malagnini, L., and Giardini, D. (2003). Spectral Shear-Wave Ground Motion Scaling in Switzerland. BSSA 93(1):414–429.

Carlisle, D. M. Meador, M. R. Moulton, S. R. Ruhl, P. M. (2007). Estimation and application of indicator values for common macro invertebrates. *Ecological Indictors* **7**:22-33.

Cauwet, G. (1987). Influence of sedimentological features on the distribution of trace metals in marine sediments. *Marine chemistry* 22: 221-234.

Dance, K. W. and Hynes, H. R. N. (1980). Some effects of agricultural land use on stream insect communities. *Environmental Pollution* **22** (Series A): 14 – 28.

Deekae, S. N. Abowei, J. F. N. and Chinda, A.C. (2010). Some physico-chemical parameters of Luubara Creek, Ogoni Land. Niger Delta, Nigeria. *Research Journal of Environment and Earth Science* **2**(4): 199-207.

Deely, J. M. Tunnicliff, J. C. Orange, C. J. and Edgerley, W. H. L. (1992). Heavy Metals in Surface Sediments of Waiwhetu Stream, Lower Hutt, New Zealand, New Zealand. *Journal of Marine and Freshwater Research* 26: 417-427.

Dirisu, A. R. and Olomukoro, J. O. (2015). Investigation of Water Quality of two Rivers in Agbede – Wetlands in Southern Nigeria. *Global NEST Journal* **17** (3): 451-462.

Edokpayi, C. A. and Osimen, E. C. (2001). Hydrobiological studies on Ibiekuma River at Ekpoma, Southern Nigeria, after impoundment: The faunal characteristics. *AJST Science and Engineering Series* **2** (1): 72 – 81.

Efitre, J. Chapmaan, J. L. and Makanga, B. (2001). The inshore benthic macroinvertebrates of Lake Nabugabo, Uganda: seasonal and spatial patterns. *African Zoology* **36** (2):205-216.

Enuneku, A. Anani, O. A. Job, O. Kubeyinje, B. F. Ogbomida, E. T. Asemota, C. O. Okpara, B. Imoobe, T. Ezemonye, L. I. Adetunji, C. O. Hefft, D. O. (2021). Mapping soil susceptibility to Crude oil Pollution in the Region of Delta. South-South Nigeria: A proportional Study of Evironmetrics, Health, Ecological Risks, and Geospatial Evaluation. *Scientific African* e01012. https://doi.org/10.1016/j.sciaf.2021.e01012.

Ezekiel, E. N, Hart, A. I. and Abowei, J. F. N. (2011). Benthic Macro-Fauna Composition and Abundance in Sombreiro River, Niger Delta, Nigeria. *Research Journal of Applied Science* *and Engineering Technology* 3 (4): 257 – 263.

FEPA/(FMEnv), (2003). Guidelines and standards for environmental pollution control in Nigeria. Federal Environmental Protection Agency. pp. 238.

Forstner, U. (1989). Contaminated sediments: lectures on environmental aspects of particle-associated chemicals in aquatic systems. Berlin, Heidelberg, New York, Springer-Verlag. pp. 157.

Furey, C. P. Nordin, N. R. and Mazmuder, A. (2006). Littoral benthic macroinvertebrates under contrasting drawdown in a reservior and a natural lake. *Journal of Nature America Benthological Society* **25** (1):19-33.

George, A. D. I. Abowei, J. F. N. and Daka E. R. (2009). Benthic macroinvertebrate fauna and physico-chemical parameters in Okpoka creek sediments Niger Delta, Nigeria. *International Journal of Animal and Veterinary Advancement* 1 (2):59-65.

Hart, A. I. and Zabbey, N. (2005). Physic-chemistry and benthic fauna of Woji creek in the Lower Niger Delta, Nigeria. *Environmental Ecology* **23** (2): 361-368.

He, Z. L. Yang, X. E. Stoffella, P. J. (2005). Trace elements in agro ecosystems and impacts on the environment. *Journal of Trace Elements in Medicine and Biology* **19**: 125–140.

Horowitz, A. J. (1985). A Primer on Trace Element-sediment. Chemistry, U.S. Geological Survey water supply paper 2277. pp 6.7.

Idodo-Umeh, G. (2002). Assessment of water bodies in Olomoro, Isoko South Delta State, Nigeria using physical, chemical and biological indices. Unpublished Ph.D Dissertation. Dept. Fisheries. University of Benin, Benin City. pp. 378.

Ihenyen, A. E. (2001). Heavy metals in sediments of the Benin River estuary and its environs, western Niger Delta, Nigeria. *Environmental Science* 6: 551-559.

Ihenyen, A. E. and Aghimien, A. E. (2002). A study of trace heavy metal levels in Warri Soils and Vegetables, Southern Nigeria. *African Journal of Environmental Pollution and Health*. 1 (1): 72-82.

Ikhile, C. I. and Olorode, D. O. (2012). Climate Change and Water Balance in the Osse-Ossiomo Sub-Basin of S.W. Nigeria. *Port Harcourt Journal of Social Sciences* 3: 98-109.

Ikongbeh, O. A. Ogbe, F. G. and Solomon, S. G. (2013). Length-Weight Relationship and Condition Factor of *Auchenoglanis occidentalis* (VALENCIENNES, 1775) from Lake Akata, Benue State, Nigeria. *IOSR Journal of Agriculture and Veterinary Science* **3**(6):11-17.

Imoobe, T. O. T. and Oboh, I. P. (2003). Physical and Chemical Hydrology of River Jamieson, Delta State, Nigeria. *Benin Science Digest* 1, 105-119.

Ishaq, F. and Khan, A. (2013). Seasonal limnological variation and macrobenthic diversity in river Yamuna at Kalsi, Dehrandun of Uttarakhand. *Asian Journal of Plant Science and Research* **3** (2):133-144.

Izonfuo, L. W. A. and Bariweni, A. P. (2001). The effect of urban runoff water and human activities on some physico-chemical parameters of the Epie Creek in the Niger Delta. *Journal of Applied Science and Environmental Management* **5** (1): 47-55.

Kronvang, B. Laubel, A. Larsen, S. E. and Friberg, N. (2003). Pesticides and heavy metals in Danish streambed sediment. *Hydrobiologia* **494** (1–3): 93–101.

Lenat, D. R. (1998). Water quality assessment of streams using Qualitative collection methods for benthic macro invertebrates. *Journal of North American Benthological Society* 7: 222-233.

Liu, X. and Wirtz, K. W. (2005). Sequential negotiation in multiagent systems for oil spill response decision-making. *Marine Pollution Bulletin* 50: 469–474.

Martin, J. C. Hoggart, C. and Matissa, A. (1998). Improvement priorities for sewage treatment in Latvian small and medium sized towns. *Water Science Technology* **37** (8): 137-144.

McLusky, D. S. pp. and Elliott, M. (1981). The Feeding and Survival Strategies of Estuarine Molluscs. In: Jones, N.V. and Wolff, W.J., Eds., Feeding and Survival Strategies of Estuarine Organisms, Plenum Press, New York, 109-122.

http://dx.doi.org/10.1007/978-1-4613-3318-0_9.

Nduka, J. K. and Orisakwe, O. E. (2009). Effect of effluents from Warri refinery petrochemical company WRPC on water and soil qualities of contiguous host and impacted on communities of Delta State, Nigeria. *Open Environmental Pollution Toxicological Journal* 1:11-17.

Nystrom, P. Bronmark, C. and Graneli, W. (1996). Patterns in benthic food webs: a role of Omnivorous crayfish. *Freshwater Biology* 16: 631-646.

Ogbeibu, A. E. (2011). Oil spill tracking and characterization – A case study of oil pollution in the Ethiope - Benin River, Niger Delta, Nigeria. IAIA Conference, Puebla, Mexico.

Ogbeibu, A. E. and Ezeunara, P. U. (2002). Ecological impact of brewery effluent on the Ikpoba River, using the fish communities as bio-indicators. *Journal of Aquatic Sciences* 17 (1): 35 – 44.

Ogbeibu, A. E. Omoigberale, M. O. Ezenwa, I. M. Eziza, J. O. and Igwe, J. O. (2014). Using Pollution Load Index and Geoaccumulation Index for the Assessment of Heavy Metal Pollution and Sediment Quality of the Benin River, Nigeria. *Natural Environment* 2 (1):1 - 9.

Olomukoro, J. O. and Anani, O. A. (2019). Evaluation of aquatic macro-invertebrate populations: a model for emergent bio-monitoring guide for quantifying uncleanness of some Rivers in Northern Central Nigeria. *Nigerian Journal of Technological Research* l14 (2), 54-62.

Olomukoro, J. O. and Oviojie, E. O. (2015). Diversity and Distribution of Benthic Macroinvertebrate Fauna of Obazuwa Lake in Benin City. Nigeria. *Journal of Biology Agriculture and Healthcare* 5: 1.

Olomukoro, J. O., and Egborge, A. B. M. (2004). Hydrobiological Studies on Warri River Nigeria, Part II: Seasonal trend in the physico–chemical Limnology. Tropical Freshwater Biology. 12 (13): 9–23.

Olomukoro, J. O. and Ezemonye, L. I. N. (2007). Assessment of the macro-invertebrate fauna of rivers in southern Nigeria. *African Zoology*. 42: 1.

Olomukoro, J. O. and Victor, R. (2001). The distributional relationship between the macrobenthic invertebrate fauna and Particulate Organic matter in a small tropical stream. *Tropical Journal of Environment, Science and Health* **2**(1): 58-64.

Omo-Irabor, O. O. and Olobanyi, S. B. (2007). Investigation of the hydrological quality of Ethiope River watershed, Southern Nigeria. *Journal of Applied Science and Environmental Management* **11** (2): 13-19.

Onyenekan, J. A. (1987). Benthic macrofaunal communities of Lagos lagoon, Nigeria. *Nigeria Journal of Science* 10: 45 – 51.

Osibanjo, O. Daso, A. P. and Gbadebo, A. M (2011). The impact of industries on surface water quality of River Ona and River Alaro in Oluyole Industrial Estate, Ibadan, Nigeria. *African Journal of Biotechnology* **10** (4): 696-702, 24. https://doi.org/10.5897/AJB10.1065.

Otukunefor, T. V. and Obiukwu, C. (2005). "Impact of Refinery Effluent on the Physiochemical Properties of a Water Body in the Niger Delta". *Applied Ecology and Environmental Research* **3** (1): 61-72.

Peerzada, N. Mcmorrow, L. Skiliros, S. Guinea, M. and Ryan, P. (1990). Distribution of heavy metals in Gove harbour, Northern territory, Australia. *Science of the Total Environment* 92:1-12.

Priju, C. P. and Narayana, A. C. (2007). Heavy and Trace Metals in Vembanad Lake Sediments. *International Journal of Environmental Research* **1** (4): 280 - 289.

Puyate, Y. T. Rim-Rukeh, A. and Awatefe, J. K. (2007). Metal pollution assessment and article size distribution of bottom sediment of Orogodo River, Agbor, Delta State. Nigeria. *Journal of applied sciences research* **3** (12): 2056-2061.

Radojevic, M. and Bashkin, V. N. (1999). Practical environmental analysis. Royal school of chemistry, Thomas Graham house, science park Cambridge, UK. pp. 645.

Rowden, A. A. O'Shea, S. and Clarke, M. R. (2002). Benthic biodiversity of sea mounts on the northwest Chatham Rise. *Marine Biodiversity Biosecurity Report* **2** (1) 21.

Sharma, K. K. and Chowdhary, S. (2011). Macro invertebrate assemblages as biological indicators of pollution in central Himalayan, river Jawi (J and K). *International Journal of Biodiversity and Conservation* **3** (5):167-174.

Shrestha, S. and Kazama, F. (2007). Assessment of surface water quality using multivariate statistical techniques: A case study of the Fuji river basin, Japan. *Environmental. Modelling Software* **22** (4): 464-475.

Trocine, R. P. Trefry, J. H. Windsor, J. G. Surma, J. M. (1993). Toxic substances survey for the Indian River Lagoon system. Florida Institute of Technology. *Marine and Environmental Chemistry Laboratories*.

Victor, R, and Dickson, D. T. (1985). Macrobenthic invertebrates of a perturbed stream in Southern Nigeria. *Environmental Pollution*. 38 (A): 99 – 107.

WHO, (2004). Guidelines for Drinking Water Quality. 3rd Edn. World Health Organization, ISBN: 92- 4-154638-7. 516.

WHO, (2008). Guidelines for Drinking Water Quality, 3rd ed. Vol 1. Incorporating the first and Second Addenda, WHO, Geneva. ISBN 978 92 4 154761 1.

Zabi, G .S. F. and Leloeuff, P. (1993). Benthic Fauna in Margino - littoral system of West Africa, a review. Part 2. Fauna and Biotopes. *Review on Hydrobiology Tropics* 26: 19 – 51.

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OLFACTORY RESPONSE OF *MEGALUROTHRIPS SJOSTEDTI* TRYBOM TO HEADSPACE VOLATILES OF RESISTANT AND SUSCEPTIBLE COWPEA CULTIVARS

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ABSTRACT

Cowpea is a vital plant protein in African's diet. Megalurothrips sjostedti, is an insect pest of cowpea, which causes severe yield loss to the crop during its flowering stage. The behavioral response of an insect to plant volatiles has important implications related to its attraction to that plant. Headspace volatiles of some crops have been harnessed to develop attractants and repellants as safe alternatives for pest control but have been scarcely documented in cowpea insect pest management. Therefore, headspace Volatiles of cowpea cultivars were investigated for their attractant and repellant properties on M. sjostedti. Olfactory bioassay was carried out to determine the response of M. sjostedti (n=60) to clean air and headspace volatiles from five resistant cowpea cultivars: Moussa Local, Sewe, TVu1509, Sanzibanili, IT90K-277-2 and two susceptible cultivars: Ife brown and Vita7 at their flowering stage, was investigated in the laboratory with a Y-tube olfactometer. Choices of M. sjostedti (% response) were determined and data were analysed using descriptive and Chi-square statistics. Attraction of M. sjostedti to headspace volatiles of cowpea cultivars relative to clean air was significantly higher in all the cultivars, ranging from 93.3 % in Vita7 ($\chi2$=45.07) to 76.0 % in Sewe ($\chi2$=17.07). However, the relative attraction of M. sjostedti to the four resistant cultivars and the susceptible cultivar Ife brown showed that thrips were significantly more attracted to Ife brown (63.3 %) than Moussa Local (36.7 %) with a Chi-square value of $\chi2$=4.27 and significantly more attracted to IT90K-277-2 (63. 7%) than Ife brown (36.7%), with a Chi-square value of $\chi2$ =4.27. Megalurothrips sjostedti was attracted equally to both resistant and susceptible cowpea cultivars but preferred odours emanating from Ife brown (susceptible) and IT90K-277-2 (moderately resistant) cultivars. Volatiles from these cultivars could be harnessed to develop attractants for the management of Megalurothips sjostedti.

Keywords: *Attraction, Megalurothrips sjostedti, olfactory bioassay, volatiles, Ife brown.*

INTRODUCTION

Cowpea,*Vigna unguiculata* (L.) Walpers (Fabale s: Fabaceae), is a leguminous crop grown in the arid and semi-arid agro-ecologies. In Nigeria, it is a staple food crop mostly cultivated by small scale farmers in the dry savannah region, for its edible seeds. Analysis of cowpea production over the last two decades showed that increase in yield is seen when there is an increase in cultivated land area rather than improved yield per hectare, therefore resulting in cowpea demand deficit of 500,000 tonnes (NBDA, 2019). The incidence of insect pest attacks is a re-occurring phenomenon causing reduced yield in cowpea production. Different insects attack the crop at every stage of growth. Among the important pests attacking cowpea on the field are aphids. *Aphis craccivora* sucks plant juice from the leaves and stem of young cowpea plant, they also transmit the cowpea mosaic virus which can cause yield loss of 13 – 87 % (Bashir et al., 2002; Togola et al., 2017). The pod borer *Maruca vitrata* (Fab.) bores into the pods and eat the seeds, the buds, flowers, and leaves, or web them together (Msm*et al*., 2016; Ogunwolu, 1990). The pod sucking bug complex: *Clavigrallato mentosicollis* Stal., *Anoplocnemis curvipes* Fabricus, *Rhiptortus dentipes* Fabricus, *Nezeraviridula* Linnaeus, *Mirperus jaculus* Thunberg, *Asparvia armigera* Fabricius; they suck juice from the cowpea in the pods, causing the pods to shrivel and inducing premature drying and abscission of the pods (Dabire-Binso*et al*., 2010; Mansaray *et al*., 2020; Soyelu and Akingbohungbe, 2007).

Cowpea flower bud thrips, *Megalurothrips sjostedti* Trybom is the first pest of flowering cowpea (Alabi *et al*., 2003). They are cryptic insects that hide inside enclosed flowers of cowpea, causing abnormal pod and seed formation and yield losses between 20 – 100% (Nabirye *et al*., 2003; Sani, 2017). *M. sjostedti* occurs every growing season but are most abundant during the dry season, at the later stage of cowpea development. They pierce on plant tissues with their mouth part and suck on the juices, which results in the premature dropping of flowers (Adati *et al*., 2007; Gianessi, 2013). According to (Salifu, 1992), three to five adults per raceme on cowpeas was sufficient to cause economic injury. Both adult and nymphal stages of *M. sjostedti* feed on cowpea flower juice (Sani, 2017). Plants respond to herbivore attack through induced, direct, or indirect defenses. In direct defense, organic chemicals produced by the plant directly target the herbivore (Lou and Baldwin, 2003), whereas in indirect defense the chemicals increase herbivore mortality through the recruitment of natural enemies (Kessler and Baldwin, 2001).

Most control strategies against insect pests involve some sort of change to their behavior (Foster and Harris, 1997; Gould, 1991), whether it is through chemical (i.e., volatiles and non-volatile compounds, feeding deterrents), visual, or auditory signals. Many plant species emit volatiles to defend themselves by producing info-chemicals or toxins that act directly against herbivores or indirectly by producing chemicals, which attract herbivores' natural enemies (Pare and Tumlinson, 1999). Methyl salicylate is a phenolic organic compound that serves in plant defenses against pathogens and herbivores (Park *et al*., 2007; Vlot*et al*., 2008). Methyl salicylate can also attract natural enemies before herbivore outbreaks. Early attraction of natural enemies into an agro-ecosystem is believed to be an important attribute contributing to effective biological control of herbivores (Z. Khan *et al*., 2008; Tamiru and Khan, 2017).

Floral volatiles give characteristic odour and flavor to each plant (Surburg *et al*., 1993). They consist of complex mixtures of acyclic, aromatic, and heterocyclic compounds and they may be classified broadly as: aromatics, terpenes, nitrogen, and sulphur containing compounds.

Volatile compounds mediate many interactions between organisms, including plant response to pathogen infection or pest infestations (Eigenbrode *et al*., 2002; Shulaev *et al*., 1997), plant-parasitoid signaling in response to herbivory and plant-pollinator communication during flowering (Turlings*et al*., 1990). As pollinator attractants, volatiles are important cues that help insects locate flowers and signal the presence of food or mates (Knudsen *et al*., 1993). Plants synthesize and emit a large variety of volatile organic compounds with terpenoids, fatty acids and derivatives as the dominant classes. Plant odour specificity is achieved by a characteristic ratio of the constituent chemical compounds, which are generally distributed among the plant species (Visser, 1986). Floral volatiles act as attractants for species-specific pollinators. However, the volatiles emitted from the vegetative parts, especially those released after herbivory, protect plants by deterring herbivores and/ or attracting the enemies of herbivores (Pichersky and Gershenzon, 2002). To make use of volatile organic compounds in a biological control programme, it is necessary to know how the herbivores pest and its natural enemies respond to the volatiles released by a specific plant species or cultivar.

Most of the floral fragrance compounds are terpenoids, simple aromatics, amines, and hydrocarbons. The most common floral fragrance compounds are monoterpenes (Vickery and Vickery, 1981; Williams and Whi, 1983). In the study carried out by Ager (2001), he identified major volatiles in cowpea flower were under the groups: monoterpenes, sesquiterpenes, norisoprenoids, aromatics, aliphatic compounds, and other miscellaneous compounds.

Concerted efforts are made to develop varieties of cowpea that are resistant to insect pests, to minimize the need for chemical control. Some cowpea with resistance to flower thrips has been identified; a land race Sanzisabinli from Ghana (Omo-Ikerodah *et al*., 2009) and TVu1509 from Obafemi Awolowo University, Ile - Ife. In a screening study carried out by (Alabi *et al*., 2003, 2011) some level of resistance to thrips was also observed in some of the cultivars evaluated such as IT90k-277-2, KVx 404-8-1, Sewe, Moussa Local and Sanzisabinli. To achieve a more realistic increase in cowpea production, integrated pest management has been proposed (Adati *et al*., 2007). It involves a combination of two or more compatible pest control measures that is economical and environmentally safe. The potentials of plant volatiles to control insect pests have been demonstrated by several authors (Khan *et al*., 2008; Parker *et al*., 2013; Parolin *et al*., 2012). The volatiles emitted by the plants may be used in management of pests through several approaches such as mass trapping, synergistic effect of plant volatiles in pheromone traps, plant volatiles as attractants of natural enemies of pests, 'push-pull' strategy. In this study, headspace Volatiles of cowpea cultivars were investigated for their attractant and repellant properties on *M. sjostedti*.

MATERIALS AND METHODS

Experimental site

Insect Chemical Ecology Laboratory, Department of Crop Protection and Environmental Biology, University of Ibadan.

Plant materials

Seeds of Ife brown, TVu1509, Vita7 and IT90K-227-2 were obtained from the Genetic Resources Center, IITA Ibadan, while Moussa Local, Sewe and Sanzibanili were obtained from IITA Benin Republic. The seeds were sown in 5 kg pots at two seeds/pot and were thinned to one plant per pot. | Cowpea cultivars were sown at two weeks interval to prevent cross pollination. Plants were grown in the screen house at a temperature of 29±6ºC and relative humidity of 72 ±5%. Only cowpea plants that have started flowering, with a minimum of one open flower was used for the study.

Rearing of *Megalurothrips sjostedti*

Initial population of *Megalurothrips sjostedti* was collected from cowpea plants on the demonstration plot at IITA Ibadan. Thrips were reared in 10 cm by 16 cm ventilated plastic jars covered with thrips proof mesh. Two pods of *Vigna unguiculata* ssp *sesquipedalis* commonly referred to as Yardlong beans averagely measuring 45 cm long was put into the rearing jars to serve as feed as well as substrate for the insects to lay eggs. Petals of infested cowpea flower were carefully severed to expose thrips. An aspirator was used to pick 300 insects into each of the rearing jars. After 48 hours, the insects had laid eggs on the bean pods. Pods with eggs were removed into an empty jar and replaced with fresh pods. Fresh pods were re-introduced into the jars containing the initial insect population every 48 hours to ensure a continuous supply of new adults. Dry and decaying pods were removed from the other jars and replaced with fresh pods until the eggs developed through the larvae stages to become adults. The culture was maintained in the Entomology laboratory, IITA Ibadan at a temperature of 25 ±1 ºC; relative humidity 70 ±5 % and 12 light – 12 hours darkness photoperiod.

Olfactometer choice assay

Olfactory response of adult female *M. sjostedti*, to odours from seven flowering cowpea cultivars were evaluated using a Y-tube olfactometer (internal diameter: 0.5 cm, stem length: 4 cm, arm length: 5.5 cm) at a temperature of 27 ± 1 °C and 40–50% relative humidity as described by Diabate (Diabate *et al*., 2019a).

The Y-tube was positioned on a white board placed at an angle of 25° to the horizontal plane (Koschier *et al*., 2017), within a cardboard box (50 cm × 48 cm × 33 cm). The box was slightly opened at the top to allow for a white florescent light for illuminating the bioassay arena to eliminate light bias. The entire arena was lined with white paper to prevent any visual cues interrupting the olfactory response of thrips to the odours from the cowpea plants. Adult female thrips were isolated and starved for one hour before commencing bioassay.

The shoot of cowpea plant was covered with an oven bag to ward off odours emanating from the soil from interacting with those from the plants and held tightly with Teflon tape around the stem just above the soil. Two teflon tubes carried filtered compressed air from the Volatile Assay Systems (VAS) field pump into the bagged cowpea head space, which is the first odour source, and into an empty but tied oven bag, which is the second odour source, serving as the control. The two odour sources were connected to the right and left arm of the olfactometer, respectively. The flow of odour was allowed to run for 20 minutes before the insects were introduced to the tail of the Y tube. Individual adult female *Megalurothrips sjostedti* was released at the inlet of the Y- tube olfactometer and was observed for 3 min. If the insect failed to choose within 3 min, it was considered non-responsive and when the insect reached the far end of either arm of the olfactometer, it was recorded as a choice. To avoid any bias, the Y-tube was alternated, and the plant materials were connected to the opposite arm after five insects had been tested, while plant materials were replaced after twenty insects had been tested. A total of sixty insects were tested per cultivar.

Y-tube was washed with clean water and ethanol after testing for each cultivar and left to dry overnight. A different oven bag was used for each of the seven cultivars. Assay was conducted for (a) the reproductive stage of each cultivar tested against clean air b) the reproductive stage of selected resistant and susceptible cultivars, tested against each other.

Data collection and analysis

Data were collected on the choice of the insects and the time taken by the insects to move through the stem of the Y-tube, the time taken at the junction before it makes a choice and the time it takes the insect to move to the end of the chosen arm of the olfactometer. Choice data collected were analysed with Chi-square (χ^2) test to evaluate the preferences of *Megalurothrips sjostedti* amongst different cowpea cultivars, while time data was analysed with T-test.

RESULTS

Olfactory response of female *Megalurothrips sjostedti to* headspace volatiles of flowering cowpea cultivars

Adult female *M. sjostedti* showed similar response to all the seven cultivars by choosing their headspace volatile over clean air. The percentage number of thrips that chose the different arms of the olfactometer out of sixty insects that were tested per cultivar is presented in Figure1. The susceptible cultivars, Vita7 and Ife brown had the highest number of thrips choosing them over clean air. Vita 7 had 93% of sixty thrips and Ife brown had 85% of sixty thrips being tested. The resistant cultivar Sewe, had the lowest number of thrips choosing it, with 76.7% of sixty thrips tested. All the cowpea varieties attracted more insect compared to the clean air in the following decreasing order: Vita7 < Ife brown < IT90K-227-2 < TVu1509 <Sanzibanili< Moussa Local <Sewe. Observed differences in the number of *M. sjostedti* that chose either of the two arms of the olfactometer were all statistically significant at $p < 0.01$ (Table1). This is reflected in the statistics; Vita7: $\chi^2 = 45.07$, $P < 0.01$, Ife brown: $\chi^2 = 29.4$, $P < 0.01$, IT90K-227-2: $\chi^2 = 29.4$, $p < 0.01$, TVu1509: $\chi^2 = 24.07$, $P < 0.01$, Sanzibanili: $\chi^2 = 24.07$, $P < 0.01$, Moussa Local: $\chi^2 = 19.27$, $P < 0.01$, Sewe: $\chi^2 = 17.07.4$, $P < 0.01$.

Time taken for thrips to respond to headspace volatile from resistant and susceptible cowpea cultivars

The time taken by *M. sjostedti*to move through the stem, the junction, and the end of the chosen arm of the Y-tube olfactometer while choosing between headspace volatiles from cowpea cultivars and clean air is presented on Table 2. At the stem, the mean time the insects spent before moving to Sanzibanili, a resistant cultivar was 26.24 seconds with the standard deviation of 20.14, and it was higher than the time they spent at the stem before moving to clean air, which was 7.45 seconds with a standard deviation of 2.52. The observed difference was significant at $p < 0.05$. At the junction and arm of the Y-tube olfactometer, there was no significant difference in the time of response by *M. sjostedti* to both Sanzibanili and clean air (P>0.05).

The mean time taken for thrips to respond to either Ife brown (susceptible cultivar) or clean air was significantly different from each other ($p < 0.05$), only at the junction of the Y-tube olfactometer. *M. sjostetdi* spent 9.51 seconds at the junction before moving in the direction of Ife brown while it spent 33.77 seconds before moving in the direction of clean air. The differences in the response time of thrips to the other cowpea cultivars (Sewe, Moussa Local, Vita 7, TVu1509, IT90K-227-2,) relative to clean air was not significant ($p > 0.05$) at the stem, junction, and arm of the Y-tube olfactometer. There was also no specific trend observed in the time of response moving to clean air, which was 7.45 seconds with a standard deviation of 2.52. The observed difference was significant at $p < 0.05$. At the junction and arm of the Y-tube olfactometer, there was no significant difference in the time of response by *M. sjostedti* to both Sanzibanili and clean air (P>0.05).

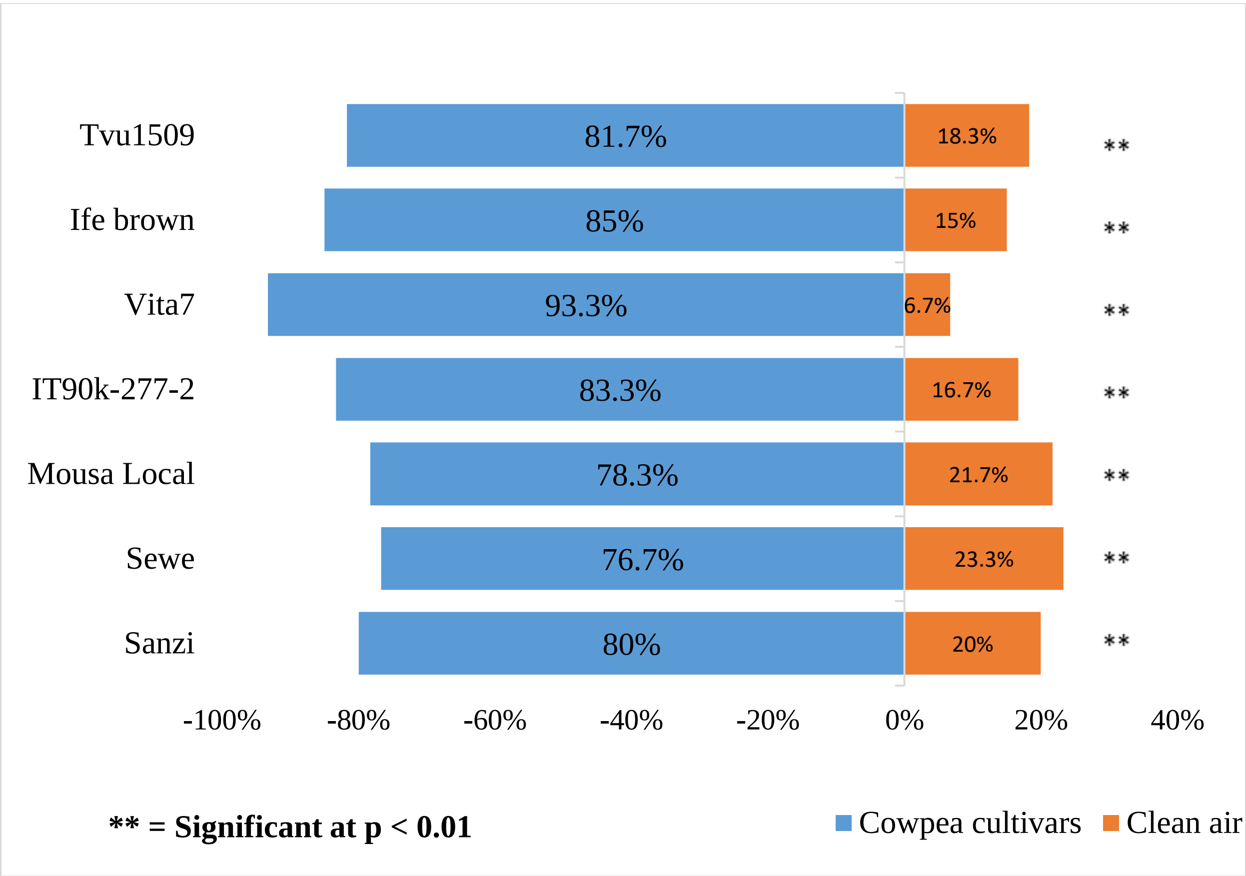

Figure1: Percentage response of female *M. sjostedti* to head space volatiles from seven cowpea cultivars

Table 1: Response of *Megalurothrips sjostedti* to head space volatiles from seven cowpea varieties

Cowpea Cultivars	X^2	Prob. Value	Significance
Sanzi vs Blank	24.07	9.31E-07	p < 0.01
Sewe vs Blank	17.07	3.61E-05	p < 0.01
Moussa Local vs Blank	19.27	1.14E-05	p < 0.01
IT90K-227-2 vs Blank	29.40	5.89E-08	p < 0.01
Vita 7 vs Blank	45.07	1.9E-11	p < 0.01
Ife Brown vs Blank	29.40	5.89E-08	P < 0.01
TVu1509 vs Blank	24.07	9.31E-07	p < 0.01

Table2: Time taken for *M. sjostedti*to move through the Y-tube olfactometer in response to cowpea cultivars or clean air

Y- Tube	Choices (cultivar/clean air)	Time (seconds)	Std.Dev.	t-cal	p-value	Significance
Stem	Sanzibanili	26.24	20.14	2.769	0.009	$p < 0.05$
	Clean Air	7.45	2.52			
Junction	Sanzibanili	6.18	9.04	1.204	0.236	$p > 0.05$
	Clean Air	2.50	1.80			
Arm	Sanzibanili	10.31	10.64	1.790	0.082	$p > 0.05$
	Clean Air	3.81	3.38			
Stem	Moussa-Local	27.48	30.02	1.232	0.223	$p > 0.05$
	Clean Air	16.88	13.98			
Junction	Moussa-Local	4.46	4.87	0.185	0.884	$p > 0.05$
	Clean Air	4.15	7.23			
Arm	Moussa-Local	9.66	8.05	1.762	0.083	$p > 0.05$
	Clean Air	5.64	2.98			
Stem	Vita7	26.81	20.61	1.944	0.057	$p > 0.05$
	Clean Air	14.46	8.07			
Junction	Vita7	10.37	15.16	1.485	0.143	$p > 0.05$
	Clean Air	19.95	32.64			
Arm	Vita7	8.05	11.08	1.297	0.369	$p > 0.05$
	Clean Air	11.19	6.08			
Stem	TVu1509	14.02	15.67	1.171	0.246	$p > 0.05$
	Clean Air	20.75	23.28			
Junction	TVu1509	6.72	9.78	0.993	0.325	$p > 0.05$
	Clean Air	3.76	1.81			
Arm	TVu1509	7.87	11.42	0.447	0.657	$p > 0.05$
	Clean Air	6.27	6.47			
Stem	Sewe	31.81	28.66	1.441	0.155	$p > 0.05$
	Clean Air	47.24	51.46			
Junction	Sewe	10.24	15.68	1.124	0.266	$p > 0.05$
	Clean Air	15.64	15.94			
Arm	Sewe	5.53	6.81	0.571	0.571	$p > 0.05$
	Clean Air	4.46	2.87			
Stem	IT90K-227-2	27.28	20.30	1.136	0.261	$p > 0.05$
	Clean Air	19.07	16.97			
Junction	IT90K-227-2	7.63	10.64	0.303	0.763	$p > 0.05$
	Clean Air	6.52	4.95			
Arm	IT90K-227-2	5.78	5.07	1.414	0.163	$p > 0.05$
	Clean Air	3.36	1.25			
Stem	Ife Brown	33.48	30.36	1.821	0.074	$p > 0.05$
	Clear Air	14.52	15.73			
Junction	Ife Brown	9.51	16.71	2.995	0.004	$p < 0.05$
	Clear Air	33.77	43.52			
Arm	Ife Brown	9.08	13.68	0.418	0.678	$p > 0.05$
	Clear Air	11.16	14.31			

Comparison of olfactory response of female *Megalurothrips sjostedti* to cowpea headspace volatiles from a susceptible and some resistant cultivars of flowering cowpea

The percentage response of *M. sjostedti* to odour from four resistant cowpea cultivars (IT90K-227-2, Moussa Local, TVu1509, Sewe) relative to Ife brown, a susceptible cowpea cultivar is presented in Figure 2. Cowpea cultivar IT90K-227-2 had the highest thrips attraction of 63.7% of sixty thrips tested, closely followed by Ife brown, which had 63.3% of sixty thrips tested. Moussa Local had the lowest percentage of thrips (36.7%) attracted to it. TVu1509 had 50% of sixty thrips tested relative to Ife brown. There was no definite trend observed in the percentage number of thrips response to the cowpea cultivars.

The differences in the percentage number of thrips attracted to five cowpea cultivars as presented on Table 3, showed that the response of thrips to Moussa Local relative to Ife brown was significant (Moussa Local: $\chi 2 = 4.27$, $P < 0.05$). Also, the response of thrips to IT90K-227-2 relative to Ife brown was significant (IT90k-227-2: $\chi 2 = 4.27$, $P < 0.05$). A neutral response was observed between TVu1509 vs Ife brown ($\chi 2 = 0$, $P = 1$) while the difference observed between Sewe vs Ife brown was not significant ($\chi 2 = 1.67$, $P > 0.05$).

Time taken for *M. sjostedti* to respond to headspace volatile from four resistant cultivar relative to a susceptible cultivar

The response time of *M. sjostedti* through the stem, junction, and arm of the Y- tube olfactometer was compared between each of the four resistant cultivars (Sewe, Moussa Local, TVu1509, and Sanzibanili) and Ife brown. The results presented in Table 4 showed that there was no significant difference ($p > 0.05$) in the response time of thrips at the stem, junction, and arm to all the cowpea cultivars. There was no definite trend observed in the time of response of thrips to all the cultivars.

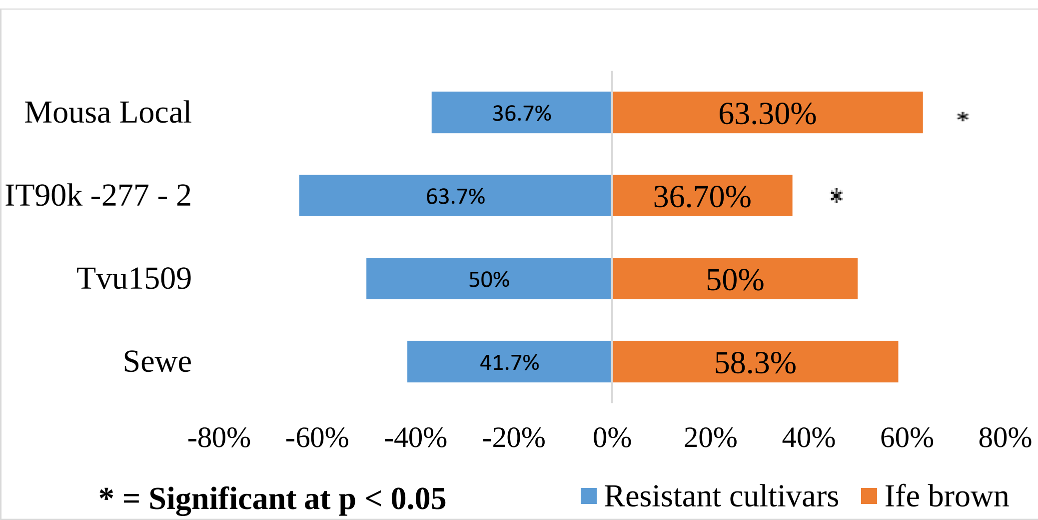

Figure 2: Response of female *M. sjostedti*to headspace volatiles from a susceptible cultivar and four resistant cultivars of cowpea

Table 3: Response of *Megalurothrips sjostedti* to headspace volatiles from a susceptible cultivar and four resistant cultivars

Cowpea Cultivars	Chi Test Stat	Prob. Value	Significance
Ife brown vs Sewe	1.67	0.196706	$p > 0.05$
Ife brown vs TVu1509	0	1	$P > 0.05$
Ife brown vs IT90K-227-2	4.27	0.038867	$p < 0.05$
Ife brown vs Moussa Local	4.27	0.038867	$p < 0.05$

Table 4: Time taken for *M. sjostedti* to move through the Y-tube olfactometer in response to four resistant cowpea cultivars and a susceptible cultivar

Y- Tube	Choices (resistant cultivar/Ife brown)	Time (seconds)	Std.Dev.	t-cal	p-value	Significance
Stem	Ife Brown	14.20	13.79	1.356	0.180	$P > 0.05$
	Sewe	9.77	10.32			
Junction	Ife Brown	8.66	12.80	1.465	0.151	$P > 0.05$
	Sewe	4.81	3.67			
Arm	Ife Brown	3.70	3.20	1.918	0.060	$P > 0.05$
	Sewe	2.38	1.48			
Stem	TVu1509	11.98	12.41	0.154	0.878	$P > 0.05$
	Ife Brown	11.45	14.60			
Junction	TVu1509	10.22	16.06	1.383	0.173	$P > 0.05$
	Ife Brown	5.58	8.96			
Arm	TVu1509	5.47	9.017	0.929	0.357	$P > 0.05$
	Ife Brown	3.62	6.16			
Stem	IT90k-227-2	14.19	14.93	1.911	0.061	$P > 0.05$
	Ife Brown	7.96	3.96			
Junction	IT90k-227-2	12.43	26.63	1.006	0.318	$P > 0.05$
	Ife Brown	6.47	10.07			
Arm	IT90k-227-2	3.16	3.64	0.188	0.855	$P > 0.05$
	Ife Brown	2.97	3.89			
Stem	Moussa local	12.97	13.63	0.742	0.462	$P > 0.05$
	Ife Brown	21.69	50.05			
Junction	Moussa local	4.36	5.08	1.515	0.136	$P > 0.05$
	Ife Brown	10.34	16.73			
Arm	Moussa local	2.50	3.99	0.808	0.423	$P > 0.05$
	Ife Brown	3.81	6.45			
Stem	Sanzibanili	8.40	7.34	0.202	0.843	$P > 0.05$
	Ife Brown	9.04	5.77			
Junction	Sanzibanili	10.18	18.60	1.043	0.314	$P > 0.05$
	Ife Brown	25.18	34.52			
Arm	Sanzibanili	1.51	.58	1.450	0.168	$P > 0.05$
	Ife Brown	4.68	5.70			

DISCUSSION

Insect's behaviour is generally a response to several factors operating in their environment. Some of these behaviours include activities such as locomotion, mating, communicating, grooming, reproduction, feeding, and host selection among others. Insect chemical ecology as partly determined by volatile organic compounds, given off by plants plays a major role in insect host finding. Several researches highlight the role of antennal olfactory receptors for plant volatiles, which enables orientation and movement towards the host plant from a distance (Conchou*et al*., 2019; Visser, 1986).

Olfactory bioassay with living cowpea plants

This study hypothesizes that headspace volatiles from resistant and susceptible cowpea cultivars are different, and the difference is a factor in their attractiveness to cowpea flower thrips *Megalurothrips sjostedti*. Cowpea cultivars~~s~~ in this study, both resistant and susceptible, were strongly attractive to *M. sjostedti*. The scenario here suggests that in the absence of alternative host plants which are known to enhance the pest status of *M. sjostedti*(Tamo*et al*., 1993), all the cowpea varieties are similarly predisposed to thrips infestation. Therefore, a sole cowpea crop without any form of control measure will always be an attraction for thrips. The emphasis on sole cowpea crop is supported by the report by (Ekesi*et al*., 1998) which stated that the olfactory attractiveness of cowpea to *M. sjostedti* decreased when it was intercropped with maize. However, whether the population of thrips on the field corresponds to the level of damage to crop would depend on the resistant status as well as the mechanism of resistance in operation in the cowpea cultivars. This line of thought agrees with the report of (Feng *et al*., 2017) which stated that after an insect has been attracted to a plant, the physical and chemical properties of a plant is important in determining its suitability for oviposition. The suitability of the host crop for the success of the insect is determined by chemoreceptors located on the tarsi, mouthparts, or ovipositors of the insects.

In a comparison between the susceptible Ife-brown and five other resistant varieties, the finding shows that the attractiveness of cowpea headspace volatiles to thrips differs with cowpea varieties. This agrees with the report of (Diabate *et al*., 2019b) that apart from phenological stage of cowpea and sex of thrips, behavior of thrips towards cowpea volatile also differs with the variety of cowpea. Since all the cowpea cultivars were attractive to *M. sjostedti* relative to clean air but showed preference for Ife brown and IT90K-277-2, there is probably some variation in the components of the headspace volatiles emitted by the cultivars. The observed difference in attractiveness of the cowpea varieties reflected preference in favour of the susceptible Ife brown cultivar and moderately resistant IT90K-277-2 cultivar. This suggests that the resistant status of cowpea cultivar does not translate to the olfactory repulsion of the crop to *M sjostedti*. A study on thrips *Frankliniella occidentallis* showed that it responds positively to all volatiles of its host plant (Ekesi*et al*., 1998). However, certain compounds are essential in the recognition of host plant volatiles by insects and their absence affect the behavioural response of the insect (Bruce and Pickett, 2011). Studies have shown the preference of female *M.sjostedti* for floral volatiles (Ngakou*et al*., 2008; Niassy *et al*., 2016). Since this study was carried out with female *M. sjostedti*, it is possible that high quality and quantity of floral volatile was produced by the preferred cultivars. volatile compounds from cowpea leaves such as (E)-2-Hexenal (Diabate *et al*., 2019b)have been reported to reduces the attractiveness of the cowpea flower to female *M. sjostedti.* This may interfere with host detection by affecting the attractant volatile compounds, binding proteins, or blocking olfactory receptors, thus interrupting the signal flow to the glomeruli of the insect. This scenario was not observed during this study but could give direction to further studies into the volatile organic compounds present in the cowpea cultivars studied.

CONCLUSION

Megalurothrips sjostedti was attracted equally to both resistant and susceptible cowpea cultivars but preferred odours emanating from Ife brown (susceptible) and IT90K-277-2 (moderately resistant) cultivars. Volatiles from these cultivars could be harnessed to develop attractants for the management of *Megalurothipssjostedti.*

Acknowledgement

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REFERENCES

Adati, T., Tamo, M., Yusuf, S. R., Downham, M. C. A., Singh, B., & Hammond, W. (2007). Integrated pest management for cowpea–cereal cropping systems in the West African savannah. *International Journal of Tropical Insect Science*, *27*, 123–137. https://doi.org/10.1017/S1742758407883172

Alabi, O., Odebiyi, J. A., &Jackai, L. (2003). Field evaluation of cowpea cultivars (Vigna unguiculata [L.] Walp.) for resistance to flower bud thrips (*Megalurothripssjostedti*Trybom) (Thysanoptera: Thripidae). *International Journal of Pest Management*, *49*, 287–291. https://doi.org/10.1080/0967087031000123706

Alabi, O., Odebiyi, J. A., Tamo, M., &Omoloye, A. (2011). The roles of plant secondary metabolites from cowpea floral structures in resistance to the flower bud thrips. *J. Agril. Sci. Tech.*, 262–269.

Bashir, M., Ahmad, Z., & Ghafoor, A. (2002). Cowpea aphid-borne mosaic potyvirus: A review. *International Journal of Pest Management*, *48*(2), 155–168. https://doi.org/10.1080/09670870110118722

Bruce, T. J. A., & Pickett, J. A. (2011). Perception of plant volatile blends by herbivorous insects - Finding the right mix. In *Phytochemistry* (Vol. 72, Issue 13, pp. 1605–1611). Phytochemistry. https://doi.org/10.1016/j.phytochem.2011.04.011

Conchou, L., Lucas, P., Meslin, C., Proffit, M., Staudt, M., & Renou, M. (2019). Insect odorscapes: From plant volatiles to natural olfactory scenes. In *Frontiers in Physiology* (Vol. 10, Issue JUL, p. 972). Frontiers Media S.A. https://doi.org/10.3389/fphys.2019.00972

Dabire-Binso, C. L., Ba, N. M., Sanon, A., Drabo, I., & Bi, K. F. (2010). Resistance mechanism to the pod-sucking bug Clavigrallatomentosicollis (Hemiptera: Coreidae) in the cowpea IT86D-716 variety. *International Journal of Tropical Insect Science*, *30*(4), 192–199. https://doi.org/10.1017/S1742758410000354

Diabate, S., Deletre, E., Murungi, L. K., Fiaboe, K. K. M., Subramanian, S., Wesonga, J., & Martin, T. (2019a). Behavioural responses of bean flower thrips (*Megalurothripssjostedti*) to vegetative and floral volatiles from different cowpea cultivars. *Chemoecology*, *29*(2), 73–88. https://doi.org/10.1007/s00049-019-00278-0

Diabate, S., Deletre, E., Murungi, L. K., Fiaboe, K. K. M., Subramanian, S., Wesonga, J., & Martin, T. (2019b). Behavioural responses of bean flower thrips (*Megalurothripssjostedti*) to vegetative and floral volatiles from different cowpea cultivars. *Chemoecology*, *29*(2), 73–88. https://doi.org/10.1007/s00049-019-00278-0

Eigenbrode, S. D., Ding, H., Shiel, P., & Berger, P. H. (2002). Volatiles from potato plants infected with potato leafroll virus attract and arrest the virus vector, Myzuspersicae (Homoptera: Aphididae). *Proceedings of the Royal Society B: Biological Sciences*, *269*(1490), 455–460. https://doi.org/10.1098/rspb.2001.1909

Ekesi, S., Maniania, N. K., Onu, I., & Löhr, B. (1998). Pathogenicity of entomopathogenic fungi (Hyphomycetes) to the legume flower thrips, *Megalurothrips sjostedti* (Trybom)(Thysan., Thripidae). *Journal of Applied Entomology*, *122*(9–10), 629–634. https://doi.org/10.1111/j.1439-0418.1998.tb01557.x

Feng, B., Qian, K., & Du, Y. J. (2017). Floral volatiles from vignaunguiculata are olfactory and gustatory stimulants for oviposition by the bean pod borer moth marucavitrata. *Insects*, *8*(2). https://doi.org/10.3390/insects8020060

Foster, S., & Harris, M. (1997). Behavioural manipulation methods for pest-management. *Annual Review of Entomology*, *42*, 123–146. https://doi.org/10.1146/annurev.ento.42.1.123

Gianessi, L. (2013). *IPM Proves Most Effective in Controlling Insect Pests of Cowpea in Africa*. *99*, 20005.

Gould, F. (1991). Arthropod behavior and the efficacy of plant protectants. *Annual Review of Entomology*, *36*(1), 305–330. https://doi.org/10.1146/annurev.en.36.010191.001513

Kessler, A., & Baldwin, I. T. (2001). Defensive function of herbivore-induced plant volatile emissions in nature. *Science*, *291*(5511), 2141–2144. https://doi.org/10.1126/science.291.5511.2141

Khan, Z., James, D., Midega, C., & Pickett, J. (2008). Chemical ecology and conservation biological control. *Biological Control*, *45*, 210–224. https://doi.org/10.1016/j.biocontrol.2007.11.009

Knudsen, J. T., Tollsten, L., & Bergström, L. G. (1993). Floral scents-a checklist of volatile compounds isolated by head-space techniques. In *Phytochemistry* (Vol. 33, Issue 2, pp. 253–280). Pergamon. https://doi.org/10.1016/0031-9422(93)85502-I

Koschier, E. H., Nielsen, M. C., Spangl, B., Davidson, M. M., &Teulon, D. A. J. (2017). The effect of background plant odours on the behavioural responses of Frankliniellaoccidentalis to attractive or repellent compounds in a Y-tube olfactometer. *EntomologiaExperimentalis et Applicata*, *163*(2), 160–169. https://doi.org/10.1111/eea.12566

Lou, Y., & Baldwin, I. T. (2003). Manducasexta recognition and resistance among allopolyploid Nicotiana host plants. *Proceedings of the National Academy of Sciences of the United States of America*, *100*(24), 14581–14586. https://doi.org/10.1073/pnas.2135348100

Mansaray, A., Mark, Y. K., Moseray, M. T., Kamara, A. Y., & Conteh, A. R. (2020). *Effect of cowpea cultivar , planting date and application of insecticide in the management of cowpea insect pests in South Eastern Sierra Leone*. *12*(June), 39–45. https://doi.org/10.5897/JEN2019.0233

Msm, L., Sreekanth, M., Adinarayana, M., Reni, Y., Rao, Y., & Narayana, E. (2016). Incidence, bionomics and management of spotted pod borer [Marucavitrata (Geyer)] in major pulse crops in India-A review. *Agricultural Reviews*, *37*. https://doi.org/10.18805/ar.v37i1.9260

Nabirye, J., Nampala, P., Kyamanywa, S., Ogenga-Latigo, M. W., Wilson, H., &Adipala, E. (2003). Determination of damage-yield loss relationships and economic injury levels of flower thrips on cowpea in eastern Uganda. *Crop Protection*, *22*(7), 911–915. https://doi.org/10.1016/S0261-2194(03)00086-3

NBDA. (2019). *PBR Cowpea 'll bridge demand deficit of 500, 000 tonnes — NBDA*. https://www.vanguardngr.com/2019/12/pbr-cowpea-ll-bridge-demand-deficit-of-500-000-tonnes-nbda/

Ngakou, A., Tamò, M., Parh, I. A., Nwaga, D., Ntonifor, N. N., Korie, S., &Nebane, C. L. N. (2008). Management of cowpea flower thrips, *Megalurothrips sjostedti* (Thysanoptera, Thripidae), in Cameroon. *Crop Protection*, *27*(3–5), 481–488. https://doi.org/10.1016/j.cropro.2007.08.002

Niassy, S., Ekesi, S., Maniania, N., Orindi, B., Moritz, G., de kogel, W., & Subramanian, S. (2016). Active aggregation among sexes in bean flower thrips (*Megalurothripssjostedti*) on cowpea (Vigna unguiculata). *EntomologiaExperimentalis et Applicata*, *158*, 17–24. https://doi.org/10.1111/eea.12383

Ogunwolu, E. O. (1990). Damage to cowpea by the legume pod borer, Marucatestulalis Geyer, as influenced by infestation density in Nigeria. *Tropical Pest Management*, *36*(2), 138–140. https://doi.org/10.1080/09670879009371457

Omo-Ikerodah, E., Fatokun, C., &Fawole, I. (2009). Genetic analysis of resistance to flower bud thrips (*Megalurothripssjostedti*) in cowpea (Vigna unguiculata [L.] Walp.). *Euphytica*, *165*, 145–154. https://doi.org/10.1007/s10681-008-9776-4

Pare, P. W., & Tumlinson, J. H. (1999). Update on plant-insect interactions plant volatiles as a defense against insect herbivores. *Plant Physiology*, *121*(October), 325–331. https://doi.org/10.1104/pp.121.2.325

Park, S. W., Kaimoyo, E., Kumar, D., Mosher, S., & Klessig, D. F. (2007). Methyl salicylate is a critical mobile signal for plant systemic acquired resistance. *Science*, *318*(5847), 113–116. https://doi.org/10.1126/science.1147113

Parker, E. J., E., W., C., G., &RodriguezSao, C. (2013). Companion Planting and Insect Pest Control. In *Weed and Pest Control - Conventional and New Challenges*. InTech. https://doi.org/10.5772/55044

Parolin, P., Bresch, cécile, Desneux, N., Brun, R., Bout, A., Boll, R., & Poncet, C. (2012). Secondary plants used in biological control: A review. *International Journal of Pest Management - Int J Pest Management*, *58*. https://doi.org/10.1080/09670874.2012.659229

Pichersky, E., &Gershenzon, J. (2002). The formation and function of plant volatiles: Perfumes for pollinator attraction and defense. In *Current Opinion in Plant Biology* (Vol. 5, Issue 3, pp. 237–243). Elsevier Ltd. https://doi.org/10.1016/S1369-5266(02)00251-0

Salifu, A. B. (1992). Some aspects of the biology of the bean flower thrips*Megalurothrips sjostedti* (Trybom) (Thysanoptera: Thripidae) with reference to economic injury levels on cowpea (Vigna unguiculata (L.) Walp). *Revue de ZoologieAfricaine*, *106*(5), 451–459.

Sani, I. (2017). *Biology and Management of Legume Flower Thrips (Megalurothripssjostedti) (Thysanoptera: Thripidae), a Major Insect Pest of Cowpea: A Review*.

Shulaev, V., Silverman, P., & Raskin, I. (1997). Airborne signalling by methyl salicylate in plant pathogen resistance. *Nature*, *385*(6618), 718–721. https://doi.org/10.1038/385718a0

Soyelu, O. L., &Akingbohungbe, A. E. (2007). Comparative assessment of feeding damage by pod-sucking bugs (Heteroptera: Coreoidea) associated with cowpea, Vigna unguiculata ssp. unguiculata in Nigeria. *Bulletin of Entomological Research*, *97*(1), 1–7. https://doi.org/DOI: 10.1017/S0007485307004695

Surburg, H., Guentert, M., & Harder, H. (1993). *Volatile Compounds from Flowers* (pp. 168–186). https://doi.org/10.1021/bk-1993-0525.ch013

Tamiru, A., & Khan, Z. R. (2017). *Volatile Semiochemical Mediated Plant Defense in Cereals : A Novel Strategy for Crop Protection*. https://doi.org/10.3390/agronomy7030058

Tamo, M., Baumgärtner, J., Delucchi, V., & Herren, H. (1993). Assessment of key factors responsible for the pest status of the bean flower thrips*Megalurothrips sjostedti* (Thysanoptera: Thripidae) in West Africa. *Bulletin of Entomological Research*, *83*, 251–258. https://doi.org/10.1017/S000748530003474X

Togola, A., Boukar, O., Belko, N., Chamarthi, S., Fatokun, C., Tamo, M., &Oigiangbe, N. (2017). Host plant resistance to insect pests of cowpea (Vigna unguiculata L. Walp.): achievements and future prospects. *Euphytica*, *213*. https://doi.org/10.1007/s10681-017-2030-1

Turlings, T. C. J., Tumlinson, J. H., & Lewis, W. J. (1990). Exploitation of herbivore-induced plant odors by host-seeking parasitic wasps. *Science*, *250*(4985), 1251–1253. https://doi.org/10.1126/science.250.4985.1251

Vickery, M. L., & Vickery, B. (1981). Secondary plant metabolism. *Secondary Plant Metabolism.*

Visser, J. H. (1986). Host Odor Perception in Phytophagous Insects. *Annual Review of Entomology*, *31*(1), 121–144. https://doi.org/10.1146/annurev.en.31.010186.001005

Vlot, A. C., Klessig, D. F., & Park, S. W. (2008). Systemic acquired resistance: the elusive signal(s). In *Current Opinion in Plant Biology* (Vol. 11, Issue 4, pp. 436–442). CurrOpin Plant Biol. https://doi.org/10.1016/j.pbi.2008.05.003

Williams, N., & Whi, W. (1983). Orchid Floral Fragrances and Male Euglossine Bees: Methods and Advances in the Last Sesquidecade. *Biological Bulletin*, *164*. https://doi.org/10.2307/1541248

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EXPLORING DECADAL CHANGES IN LAKE CHAD ECOSYSTEMS WITH SATELLITE REMOTE SENSING

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ABSTRACT

Lake Chad is a shallow endorheic basin located in the Sahel region. The Lake and its basin are known to provide ecosystem services to an estimated forty–five million inhabitants living in Nigeria, Cameroon, Niger, and the Chad Republic. Mapping the spatial heterogeneity of ecosystem services of Lake Chad requires a large volume of information. Satellite remote sensing has the potential for cost-effective monitoring of ecosystem services from a global to a local scale. This study explores the use of remote sensing data within the Google Earth Engine (GEE) platform for time series decadal analysis of ecosystem changes in Lake Chad using dry season Landsat images from 1990 to 2020. Four major ecosystems were assessed based on the World Wild Life Fund ecosystem classifications and need assessments for 2018 (namely: Water, Reed islands, Inundated/ irrigated land, and Archipelagos). Results of the analysis show that the lake water size reduced from 10703.03 to 2779.41km^2 (46.06%–11.96%), and the Archipelagos increased by 43%. The Reed's ecosystem of the lake was reduced by 11.05% while the inundated/ irrigation ecosystem increased from 25.45% to 43.14% within the study period.

Keywords: *Lake Chad, Ecosystem, Changes, Remote Sensing*

INTRODUCTION

Though the formal development of the concept of 'ecosystem services' is relatively recent (dating from the middle 1960s and beginning of the 1970s), recognition of the provisioning services of ecosystems is as early as the first man (Townsend *et al*., 2018; Sherbinin *et al*., 2007). Land use and other ecosystem changes have been argued to persist because most of the benefits they provide are not traded in economic markets and have no price tags (Kampeng and Zhishi, 2003). Beautiful as the arguments seem, there remain some constraints. One is the definition of the services provided by each ecosystem and approaches to their valuation (Constanza, 2008; Wallace, 2007; Fisher *et al*., 2009; Swetnam *et al*., 2010) while another is the recognition of the spatiotemporal dependencies of these ecosystems service productions and their flow (Swetnam *et al.*, 2010). Because of the spatially diverse nature of service generation and flow, ecosystem service mapping for management and planning objectives are difficult (Swetnam *et al*., 2010). Consequently, efforts are progressively made at understanding and defining the concepts of ecosystems and their related terms, capturing and mapping the dynamics of its parts, and identifying its drivers and interconnectedness with other components for optimal and sustainable production.

Ecosystem services refer to goods and services provided, either directly or indirectly by ecological systems for the benefit of humankind and are linked with biophysical processes and ecological functions, both of which are influenced by biological diversity (Daily *et al*., 1997). In 2005, the Millennium Ecosystem Assessment (MEA), categorized these services into four namely: Provisioning services, supporting services (agriculture, flood and erosion control, nutrient cycling, soil formation, photosynthesis, etc.), regulating services (carbon sequestration, climate regulation, pest regulation, pollination, water purification, etc) and cultural services (recreation, tourism, religion and cultural activities, aesthetic values, etc).

In Africa, watersheds, wetlands and lakes, forests and vegetation are highly productive biodiversity hotspots, providing ecosystem services and livelihoods (Kafumbata *et al*., 2014; Ola and Benjamin, 2019) and cultural services (recreation, tourism, religion and cultural activities, aesthetic values, etc.). Lake Chad has primarily been seen and characterised as a water source for the teaming population/ surrounding inhabitants and was once a virile and highly diverse ecosystem that supports a host of biological diversities. While ecological studies of the Lake Chad area may be difficult now due to the security occasioned by insurgency, the characterization of Lake Chad into different ecosystems and understanding of its dynamism is achievable with aid of time-series satellite remote sensing.

Remote Sensing offers a veritable and cheaper way of conducting spatial explicit ecosystem characterization. The availabilities of satellite remote sensing data confer an enormous advantage in the studies of ecosystem characterisation. This study, therefore, aims to characterise Lake Chad into the different ecosystems and determine the changes within the ecosystems using decadal satellite remote sensing images with other ancillary data.

The Study Area

Lake Chad (Fig. 1) is a large shallow, endorheic/closed (no water outflow), freshwater body in the Sahelian zone of West–Central Africa. It lies within latitudes 12°10'N and 14°30'N and longitudes 13°E and 15°30'E. Being a transboundary freshwater lake, it supports a large number (at least forty-five million inhabitants by providing fresh water for consumption and pastoral and agricultural lands, means of livelihood and support for their various socio-economic activities (Buma *et al*., 2018). The lake is situated on an altitudinal plateau, estimated to be, 282m above sea level (Birkett, 2000) and has a depth that varies within a range of 1.50m and 10.50m (FAO, 2009). The climate in the southern part of the lake is semi-arid while that of the northern part is arid. The annual maximum temperature of the basin ranges between 35°C and 40°C, while the area is characterized by a short-wet season (about 550 mm and 250 mm per annum in the south and north respectively), that occurs between May and August and a long period of the dry season occurring between October and April (Birkett, 2000).

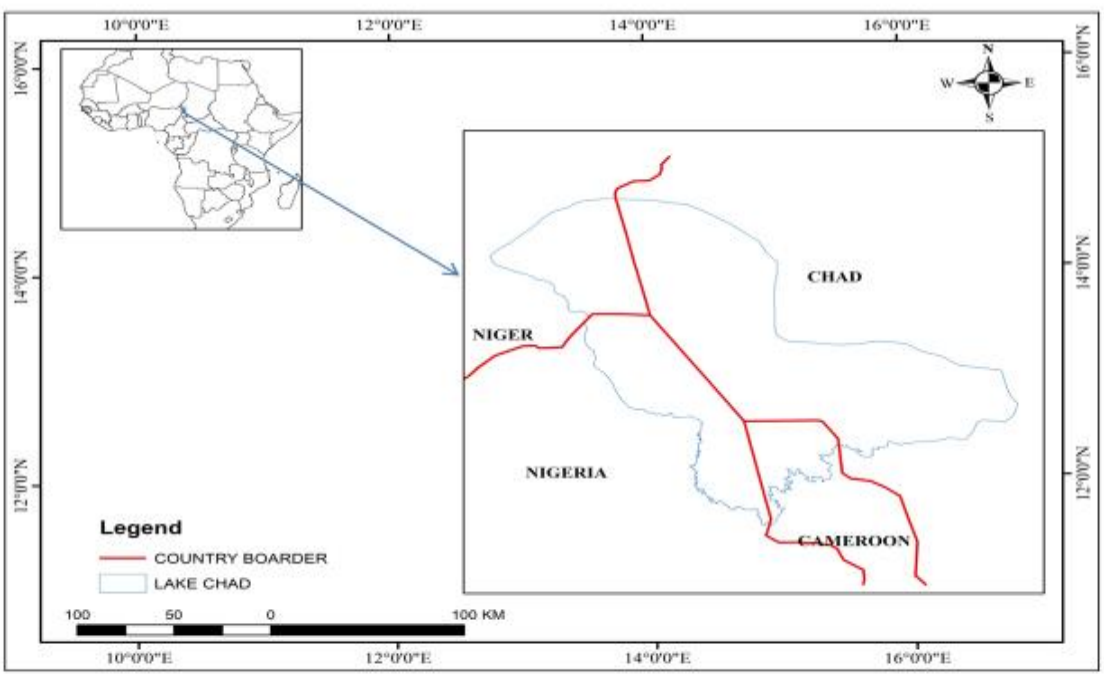

Figure 1: Map of the Study Area

The Lake's annual recharge is estimated at a maximum of 50km^3, comprising river supply and rainfall (Evans and Mohieldeen, 2002). Approximately ninety per cent (90%) of the river supply comes from the Chari/Logone River systems which have their origin in the Adamawa highlands in Cameroon and the Central African Republic and the remaining ten per cent (10%) is supplied by local precipitation, the El Beid and Komadougou–Yobe Rivers.

Data acquisition

We adopted the Benech et al, 1983 and World Wild Life classification (WWF, 2020) for the characterization of Lake Chad into five major ecosystems namely; Water, Reeds, Archipelago inundated/irrigated land and Tree crops. Training data for the supervised class was generated using time series high-resolution images in Google Earth Pro. To have a reliable, consistent and robust approach for capturing ecosystem dynamics that will produce accurate information for the end-users, a statistically robust transparent approach is necessary for generating training data sets for both ecosystem characterization and validation (Olofsson et.al (2013). We, therefore, followed the protocols proposed by Olofsson et.al (2013 & 2014) and Food Agriculture of the United Nations (FAO,2016) for generating data sets for ecosystems characterization of the study area and its dynamic changes. A total of 360 training data were randomly generated for the Lake Chad ecosystem characterization. The training data sets were then divided into 70% for classification and 30% for validation with the aid of Java script in Google Earth Engine (GEE).

RESULTS AND DISCUSSION

In its natural state, the Lake ecosystem is an excellent indicator of climate change and also can rapidly change due to anthropogenic impacts on the water budget. Similarly in an ecosystem like lake Chad, water reaches equilibrium when evaporation equals the inflows from rain and streams. These inflows are associated with rainfall from the basin and the water bodies from the basins are highly sensitive to anthropogenic changes and climate variability. The Lake Chad water ecosystem decreased from 25.7% (in the year 2000) to 17.5% in the year 2020. The gradual reduction of the Lake Chad freshwater ecosystem has been attributed to climate change (Lemoalle., 2004). However, the impact of anthropogenic changes on the Lake Chad ecosystem as opined by Lemoalle (2004) has never been fully studied.

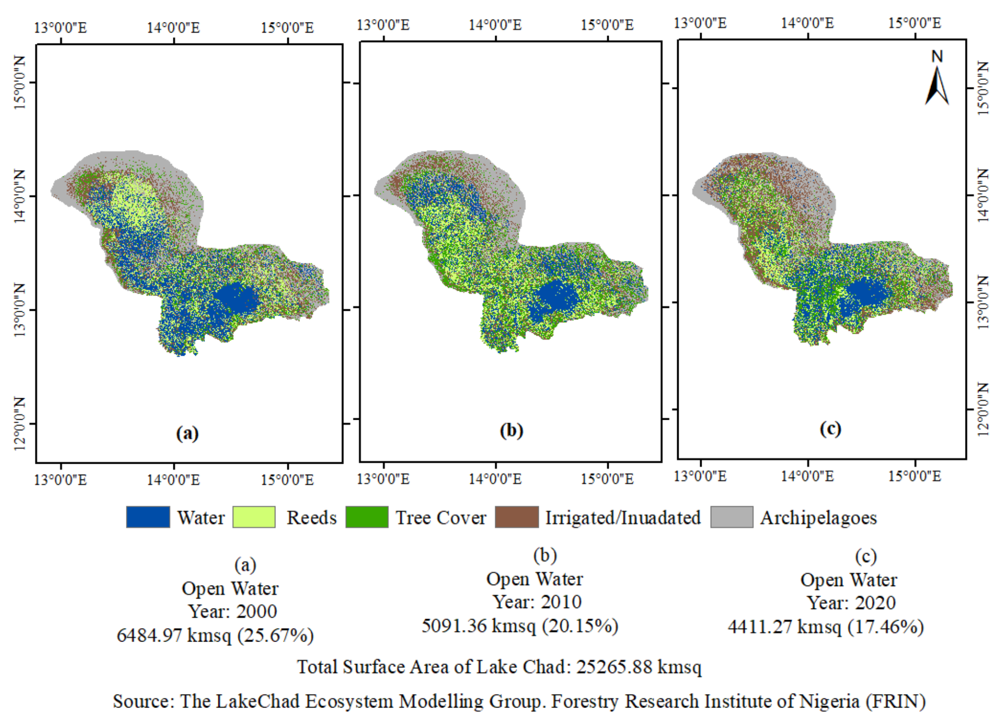

Figure 2: Classified Images of Lake Chad Showing changes within the five ecosystems.

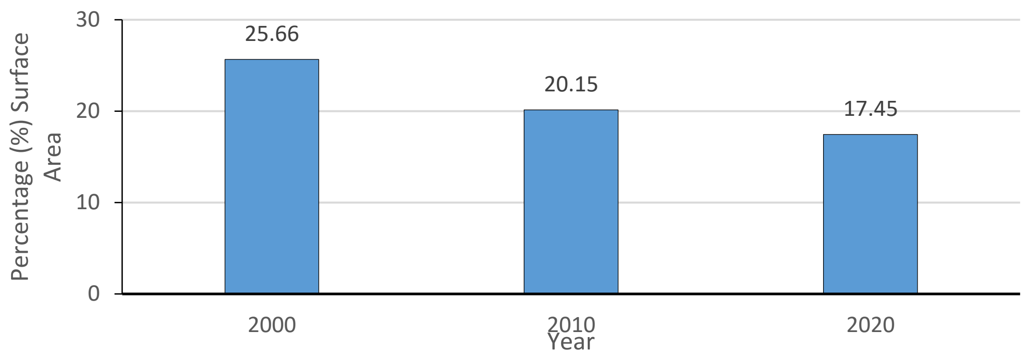

Figure 3: Percentage Surface Area of the Water Ecosystem from Year 2000 – 2020

The gradual reduction of the Lake Chad freshwater ecosystem has been attributed to climate change (Lemoalle, 2004). However, the impact of anthropogenic changes on the Lake Chad ecosystem as opined by Lemoalle (2004) has never been fully studied.

Aside from the water ecosystem which provides ecosystem services like fishing, irrigation, water for animal husbandry, etc. The reeds island is a swampy ecosystem comprising *Phragmites spp*, *Cyperus papyrus* and *Typha australis*. These water plant species often form dense thickets or floating mats within the lake. Major ecosystem services provided by Reed's ecosystem is the use of *Cyperus papyrus* (papyrus) by the local inhabitants as raw material for canoe making. The reeds island ecosystem decreased to 14.96% (the year 2020) from the initial 16.49% base year 2000). This decrease in the reeds ecosystem is a result of the conversion into irrigated/ inundated ecosystem owing to the gradual decrease in water and deposits of silts and fine sand from the desert.

Results from time-series satellite data analysis showed an increase in irrigated/ inundated ecosystems from 16.41% (the year 2000) to 23.76% (the year 2020). This is a result of receding water and the deposits of silts which add nutrients to the soil. Intensive agriculture production is observed across the years. The gradual increase in irrigated land resulted from the drying of Lake Chad. Thus, there is an increase in irrigated land for agricultural production at the expense of water for fishing, reeds Island and other activities.

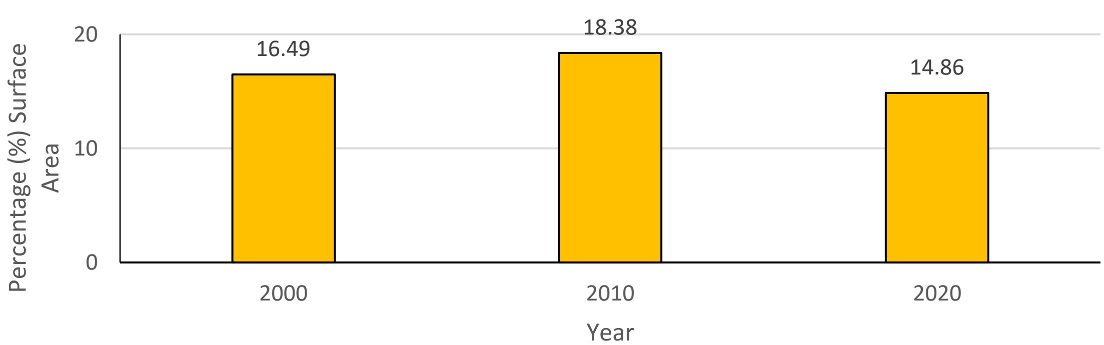

Figure 4: Percentage Surface Area of the Reeds Island Ecosystem from Year 2000 – 2020

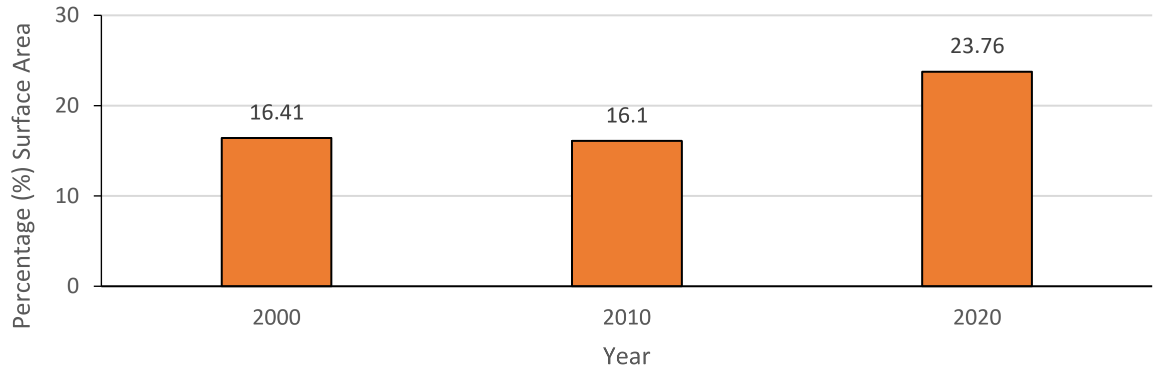

Figure 5: Percentage Surface Area of the Irrigated/Inundated Ecosystem from Year 2000 – 2020

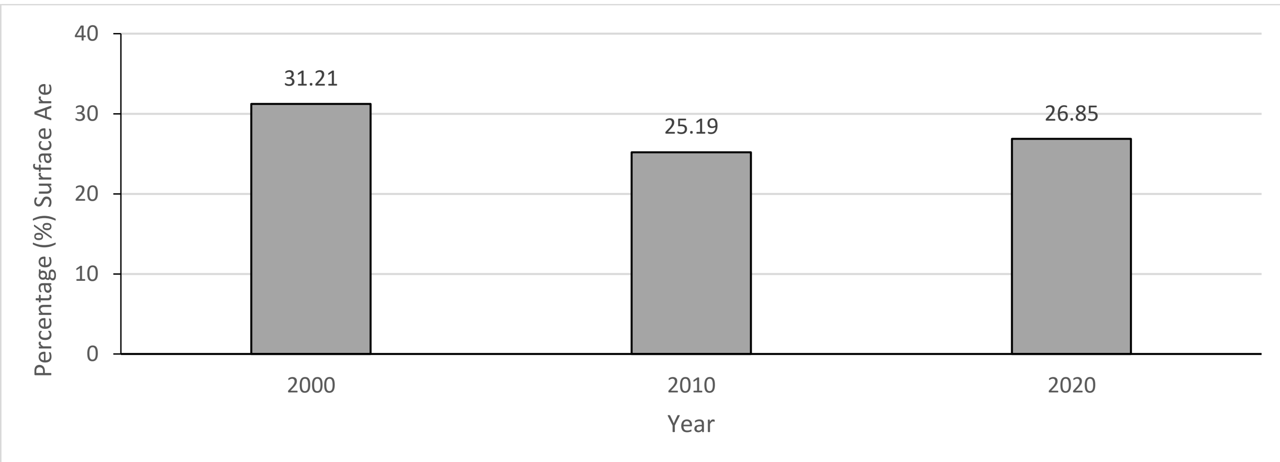

Figure 6: Percentage Surface Area of the Archipelago Ecosystem from Year 2000 – 2020

Small Islands/ archipelagos are formed by the moving dunes and the deposits of silts from receding water at the end of raining season. These small islands/ archipelagos are often inhabited and also utilized as a base for fishing.

Characteristic *tree species of the Lake Chad ecosystem* include Acacia spp, *Balanites aegyptiaca Tamarindus indica*, *Ziziphus spp* and *Adansonia digitata*. These tree species are agroforestry crops and contribute to the economic well-being of the inhabitants

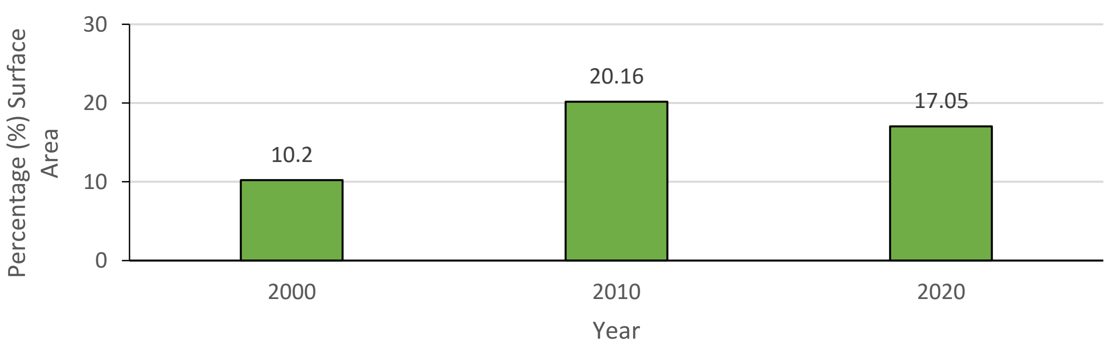

Figure 7: Percentage Surface Area of the Tree Cover from Year 2000 – 2020.

CONCLUSION

In 1994 the summit of the Lake Chad Basin Commission (LCBC) Heads of states mandated the Commission to ‘‘ensure the economic security of the freshwater ecosystem resources through the sustenance of biodiversity and aquatic resources and to ensure equitable use of the resources for the service of the needs of the population of the basin thereby reducing the poverty level through the development of feasibility studies’’(Lemoalle., et all.2012). 26 years after the mandate by the Heads of States of the Lake Chad Commission, the Lake Chad freshwater ecosystem has been dwindling.

Lake Chad water ecosystem has reduced in size from Ten thousand and Seventy-three (10703 km^2) to Two Thousand, Seven Hundred and Seventy-Nine (2779.41km^2) Square Kilometers within twenty years. The receding water has gradually distorted the ecosystem balance in Lake Chad, thus causing economic hardship to over forty–five million inhabitants of Lake Chad living in Nigeria, Cameroon, Niger, and the Chad republic. Several studies had posited the influence of climate change on the receding Lake.

The major factors attributed to climate change are drought and desertification, however, no study has considered the anthropogenic impacts on the ecosystem imbalance along the basin tributaries. The basin tributaries contribute substantial water inflow into the Lake. Ecosystem imbalance along the tributaries can therefore impact negatively the Lake. Assessment of the impact of man-made changes to land use along the basin tributaries and the commitment to restore the degradation along the basin tributaries may be the beginning of restoring Lake Chad to its former state.

REFERENCES

Birkett, C.M. (2000). “Synergistic remote sensing of Lake Chad: Variability of Basin inundation.” *Remote Sens. Envrion.* 72:2178–236.

Buma. W. G., Lee. S. and Seo, J.Y. (2018). “Recent surface water extent of Lake Chad from multispectral sensors and GRACE.” *Sensors* 18:1–24. Doi:10.3390/s18072082.

Coe, M.T. and Foley, J.A. (2001). “Human and natural impacts on the water resources of the Lake Chad basin.” *J. Geophys. Res. Atmos.* 106(D4): 3349–3356.

Constanza, R., d’Arge. R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O’Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., and van den Belt, M. (1997). The value of the world’s ecosystem services and natural capital. *Nature,* 387:253–260.

Costanza, R. (2008). Ecosystem services: multiple classification systems are needed. *Biological conservation,* 141(2):350–352.

Evans, M. and Mohieldeen, Y. (2002). Environmental change and livelihood strategies: The case of Lake Chad. *Geography,* 87(1):3–13.

FAO (2009). Adaptive Water Management in the Lake Chad Basin: Addressing current challenges and adapting to future needs. Food and Agriculture Organization (FAO) Water Seminar. In: Proceedings: World Water Week, Stockholm, 16–22 August, 2009, pp.10–19.

FAO (2016). Map Accuracy Assessment and Area Estimation. A Practical Guide. National forest monitoring assessment working paper No.46/E.

Fisher, B., Turner, R.K. and Morling, P. (2009). Defining and classifying ecosystem services for decision making. *Ecological Economics,* 68:643–653.

Kafumbata, D., Jamu, D. and Chiotha, S. (2014). Riparian ecosystem resilience and livelihood strategies under test: lessons from Lake Chilwa in Malawi and other lakes in Africa. *Phil. Trans. R. Soc. B.* 369:20130052. http://dx.doi.org/10.1098/rstb.2013.0052

Kampeng, L. and Zhishi, W. (2003). The value of the ecosystem services and method. *J. Geo. Sci.* 13(3):339–347

Koca, D., Smith, B. and Sykes, M.T. (2006). Modelling regional climate change effects on potential natural ecosystems in Sweden. *Climate change,* 78:381–406. Doi:10.1007/s10584–005–9030–1.

Lemoalle, J., Bader, J.C. and Leblanc, M. (2008). “The variability of Lake Chad: hydrological modelling and ecosystem services.” In: Proceedings of the 13th World Water Congress, Global Changes and Water Resources, International Water Resources Association, 01–04 September 2008, Montpellier, France, pp.1–15.

Millennium Ecosystem Assessment (MEA) (2005). *Ecosystems and human well – being: synthesis*. Island Press, Washington, D.C.

Nwilo, P.C., Umar, A.A., Adepoju, M.O. and Okolie, C.J. (2019). “Spatio –temporal assessment of changing land surface temperature and depleting water in the Lake Chad Area.” *South African Journal of Geomatics*, 8(2):144–159. Doi:http://dx.doi.org/10.4314/sajg.v8i2.3

Olofsson P, Foody GM., Stehman SV., Woodcock Curtis (2013). Making better use of accuracy data in land change studies: Estimating accuracy and area and quantifying uncertainty using stratified estimation. Remote Sensing of Environment 129 (2013) 122–131.

Olofsson P, Foody GM., Martin H., Stehman SV., Woodcock C E., Wulder M A. (2014). Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment 148 (2014) 42–57.

Ola, O. and Benjamin, E. (2019). Preserving biodiversity and ecosystem services in West African forest, watersheds and wetlands: A review of incentives. *Forests*, 10. Doi:10.3390/f10060479.

Onamuti, O.Y., Okogbue, E.C. and Orimoloye, I.R. (2017). “Remote sensing appraisal of Lake Chad shrinkage connotes severe impacts on green economics and socio–economics of the catchment area.” *R. Soc. Open Sci.* 4:171120. http://dx.doi.org/10.1098/rs0s.171120.

Ridder, B. (2008). Questioning the ecosystem services argument for biodiversity conservation. *Biodivers Conserv*, 17:781–790.

Sherbinin, A., Carr, D., Cassels, S. and Jiang, L. (2007). Population and environment. *Annu. Rev. Environ. Resour.* 32: 345–373. Doi:10.1146/annurev.energy.32.041306.100243.

Svizzero, S. (2017). Persistent controversies about the Neolithic revolution. *J. His. Arch & Anthropol. Sci.*, 1(2): 53–61. Doi:10.15406/jhaas.2017.01.00013.

Swetnam, R.D., Fisher, B., Mbilinyi, B.P., Munishi, P.K.T., Willock, S., Ricketts, T., Mwakalila, S., Balmford, A., Burgess, N.D., Marshall, A.R. and Lewis, S.L. (2010). Mapping socio –economic scenarios of land cover change: A GIS method to enable ecosystem service modelling. *J. Environ. Managem.*, doi:10.1016/j.jenvman.2010.09.007.

Townsend, M., Davies, K., Hanley, N., Hewitt, J.E., Lundquist, C.J. and Lohrer, A.M. (2018). “The challenge of implementing the marine ecosystem concept”. *Front. Mar. Sci.* https://doi.org/10.3389/fmars.2018.00359.

Wallace, K.J. (2007). Classification of ecosystem services: problems and solutions. *Biological Conservation*, 139(3–4):235–246.

World Meteorological Organization (2015). Lake Chad–HYCOS: A component of the World Hydrological Cycle Observing System (WHYCOS). October, https://library.wmo.int/?lvl=notice_display&id=20506#.XxqctGko80M

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ECOLOGICAL CONCEPTUALIZATION OF LIFE AND LIVING ENTITY FROM GROWTH MODELS OF CELLULAR AND NON-CELLULAR MATTERS

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ABSTRACT

Current paradigm in science is that every existent is matter or antimatter classified as living or non-living entity but only cellular matter are considered to have life and to be living entities. Critical observation indicated that cellular matter like zygote and non-cellular matter like Universe do grow to form specialized self-organized parts and systems. This research was aimed at re-investigating the concepts of life and living entity by pioneering a method of studying cellular and non-cellular matters from ecological perspective. Volumes and mass of 45 stands of samples of Amaranthus esculentus of varying ages (3 - 23 days old) and Clarias gariepinus (3 - 52 weeks old) were measured; secondary data were obtained on sex, age, height and weight of 537 males and 743 females of Homo sapiens (0 - 80 years old). Data on average length and weight of human foetus (8 - 43 weeks old) were obtained from a Baby centre while data on Universe were obtained from Wikipedia and from the works of Kohut. Simulative Expansion (Growth), Generalised Einstein Mass-energy Equivalence and other Models were used to analyse the data. Quantitative and qualitative characteristics of cellular and non-cellular matters were determined. Quantitative characteristics: masses, volumes and densities were increasing with time (age); growth rates (expansion velocities), internal environment volumetric acceleration per unit mass, acceleration due to gravity, Hubble constant are decreasing with age; the qualitative characteristics indicate evolutionary structural and functional developmental stages with age through natural automation. These implied that the growths are governed by similar law(s) in nature. ***Findings*** *include a Biorelativity Principle stating that Life is only derivable from life while living and non-living states are interchangeably latent relative to specific environmental factors; Inherent fundamental characteristics of life are information, mass-energy and spacetime relative to every living entity with levels of consciousness; cellular and non-cellular matters are living entities with boundaries forming their internal environments derived from pre-existing external environments; it is postulated from evolutional perspective that every boundary-forming entity must have been derived through chains of pre-existing boundary-forming entities down to a boundless pre-existing entity which is the only non-derived life and the highest level of organization of life termed Omnibio. This research is a paradigm shift from the current concepts of life and living entity. Replication of this research by other scientists is recommended.*

Key words: *Life, Living Entity, Boundary–forming Entity, Biorelativity principle, Omnibio, cellular matter, non-cellular matter.*

INTRODUCTION

The current paradigm in science is that every existent is matter or antimatter which is characterised by mass-energy and spacetime and are classified into living and non-living. The criteria used for classifying matter into living entities were based on cellular forms of life since 1830s to date in cell theory (Gupta and Jangir, 2010). However, this theory answers the question of what plants and animals are made up, but did not provide adequate explanation on why cellular forms of matter are considered living entities. A cell such as zygote grows to form several specialized and self-organized parts and systems (Tortora and Derrickso, 2012) by deriving resources from its external environment into its internal environment to grow. Also, the universe as a whole emerges from a zero volume in the big bang theory and has evolved to form order and specialized self-organized parts and systems. The universe is still growing, that is expanding in size for over 13.798 ± 0.037 billion years (Wilkinson Microwave Anisotropy Probe [WMAP], 2011). Cell theory lies in the realm of biology which is a science studying nature from animate perspective while big bang theory is in the realm of cosmology and astrophysics which are fields of science studying nature from inanimate perspective. Ecology on the other hand is a science studying nature from both inanimate (abiotic) and animate (biotic) perspectives with levels of integrations, therefore, it is a discipline that could reconcile the limitations in these two theories.

This research seeks to develop a method of comparing the common qualitative and quantitative characteristics of cellular and non-cellular forms of matter through the use of growth models for possibly conceptualizing a living entity from broader ecological perspective to encompass both cellular and non-cellular forms of matter. This is a basic research seeking to address the limitations of over a century old theories thus deepening the understanding of the concept of life and a living entity in nature through the following research questions: (i) Could the mechanism of expansion of the universe as a non-cellular form of matter and relative higher level of integration be understood from growth of relative lower levels of integrations of cellular forms of matter? (ii) How could generalized characteristics of cellular and non-cellular forms of matter be deduced relative to their living and non-living states? (iii) How could the most fundamental characteristics of cellular forms of matter as living entities be applied in conceptualizing life in non-cellular forms of matter? (iv) If the concept of living entity encompasses non-cellular forms of matter, what could probably be their origin from evolutionary perspective? (v) What could be the new possible levels of integrations to be used in organizing cellular and non-cellular forms of life? The objectives are (i) To determine the quantitative and qualitative characteristics of cellular forms of matter using growth models for plant, animal and human beings as relative lower levels of integrations; (ii) To determine the quantitative and qualitative characteristics of non-cellular form of matter using growth models for the universe as relative higher level of integration; (iii) To compare and contrast between the determined characteristics for possible extension of concept of a living entity beyond cellular forms of matter and to answer the research questions.

MATERIALS AND METHODS

Description of Sites

The research was carried out in the Department of Biological Sciences Laboratory (DBSL) of Abubakar Tafawa Balewa University; Abubakar Tafawa Balewa University Teaching Hospital (ATBUTH); A Primary Health Care (PHC) Centre and three farms; all in Bauchi Local Government Area – Nigeria.

Data Collection and Sample Size

Amaranthus esculentus were grown on a farm. Samples of varying ages (3 – 23 days old) at different developmental stages were uprooted around 6:30 am and collected into a plastic container covered and transported to the DBSL. A total of 45 individual stands' biometric indices (volume, mass, total height, shoot height, root height and stem diameter) were measured and number of leaves were counted. *Clarias gariepinus* were bred and reared in two Private farms. A total of 60 individual samples of different ages ranging from 3weeks to 52 weeks old were collected and their biometric indices (Volume, mass and total length) were measured on site at the farms. Other qualitative characteristics such as sex, types of fins developed were observed and recorded. *Homo sapiens* records from few hours old to over 80 years old from 2017 to 2019 were accessed from ATBUTH and supplementary data of infants from few hours old to 5 years old were obtained from PHC for same period. The records obtained covered sex, age, height and weight for 537 males and 743 females. Sets of data on human foetus aged from 8 weeks to 43 weeks for average length and weight were obtained from Babycenter (2019). Data on Universe were obtained from Wikipedia (2019) and from the works of Kohut (2010).

Thought experiment

Thought experiment of a photon moving through a complete circular path was used to derive a generalised Einstein's mass-energy equivalence model (Einstein, 1905) with a quantised speed of light and cosmic-quantum constant:

$$E_n = mC_n^2 2\pi \qquad \text{…….. Eqn. 1}$$

Where E_n = energy at energy level n; m = mass; C_n = quantised speed of light in vacuum at different energy level n; 2π = cosmic-quantum constant = 44/7; n = quantum number for $C_n = C^n$ where $1 \leq n \leq \infty$.

Analysis of Data

Data collected were analysed using Microsoft Excel (2007 Version) using Simulative Expansion Model (SEM) based on the expanding universe model of Friedman-Lemaitre-Robertson-Walker (FLRW) solution to Einstein Field Equations (Weinberg, 1989) was used for comparison:

$V_e{}^2 / r^2 = 8\pi GD/3 = H_o{}^2$ ……. Eqn. 2

where V_e = the growth rate/expansion velocity; r = the volumetric radius of the growing/ expanding entity; G = Newton universal gravitational constant/acceleration of volumetric expansion per unit mass within the internal spacetime of the growing or expanding entity; D = the density of the growing/expanding entity; H_o = Hubble's constant/ inverse age constant of the growing or expanding entity; $8\pi/3$ = Constant = 176/21.

Foetal Volume was determined according to the model of Meban (1983); Human body surface area was determined according to the model of Gehan and George (1970); Human body Volume for male and female of any age was determined according to the model of Sendroy and Collision (1966). Models derived in the course of this research were also used.

RESULTS AND DISCUSSIONS

Research question 1: Could the mechanism of expansion of the universe as a non-cellular form of matter and relative higher level of integration be understood from growth of relative lower levels of integrations of cellular forms of matter?

The results from graphs elucidated in Figure 1 illustrate common trends of Quantitative Characteristics among cellular and non-cellular matters: it depicts mass–age and volume–age graphs for cellular matters: *A. esculentus*, *C. gariepinus*, embryo of *H. sapiens*, male *H. sapiens*, female *H. sapiens* and non-cellular matter: the universe. The trends in all the naturally growing cellular and non-cellular entities showed increase in mass and volume with age (time).

According to Krebs (1978), the mechanisms of higher level of integration could be better understood by studying the lower levels of integrations constituting it. Cellular growth of plant, animal and human and non-cellular growth (expansion) of the universe are physically an increase in size (space) of an entity relative to time. The whole universe could not be observed wholly as a single entity, however, some entities within the universe such as the *A. esculentus* (plant), *C. gariepinus* (animal) and *H. sapiens* (Human beings) could be observed wholly. Some common physical characteristics and mechanism or processes between the wholly observable entity (WOE) and partially observable entity (POE) could be generalized.

The volume and Mass have time dependent increment for Cellular and non-cellular Matters (Figure1). This is evidence that there is regular inflow of material/energy from the external environments of the entities into their respective internal environments. Subsequently, applying the general principle of equilibrium implies that, there is inflow (such as nutrition in cellular matter) and outflow (such as excretion in cellular matter) but the rate of inflow is greater than the outflow, making the balance to favour the increase (growth) with time. An equivalent mechanism such as inflow through probably a white hole and outflow through probably a black hole should definitely exist in the non-cellular matter (Universe) for it to be increasing in size (growing) as well. The cumulative increase in the mass and volumes of the cellular and non-cellular entities through varying mechanisms has led to observable structural formations and self-organizing systems in both cellular and non-cellular forms of maters. Turing (1952) applied cosmological model in studying chemical basis (mechanism) of morphogenesis in human embryo conversely, the application of growth (expansion) model in this study revealed trends in other quantitative characteristics (Figs 2 – 7) comparatively depicting a commonality of similar growth patterns among the cellular and non-cellular matters in nature.

The mass–volume graphs for cellular matters: *A. esculentus*, *C. gariepinus*, embryo of *H. sapiens*, male *H. sapiens*, female *H. sapiens* and non-cellular matter (the universe) are shown in Figure 2. The trends in all the naturally growing cellular and non-cellular entities elucidated that there is strong positive correlation between mass and volume.

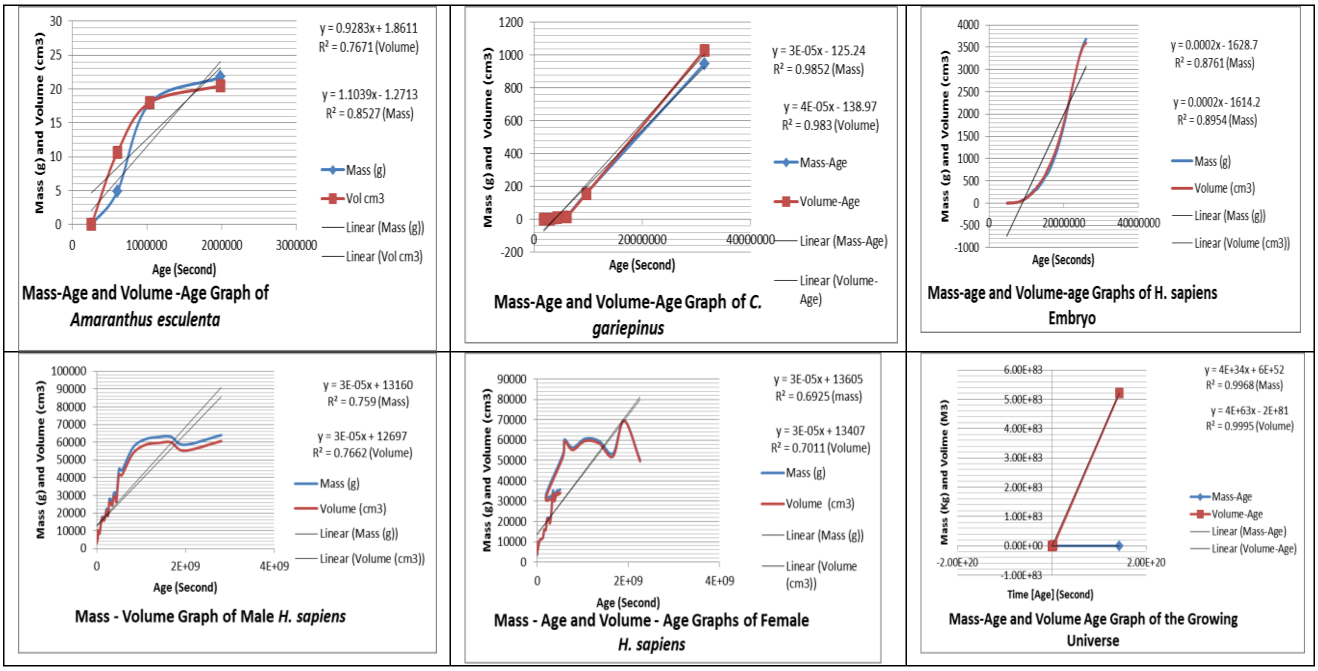

Figure 1: Comparative mass–age and volume-age characteristics of cellular and non-cellular matters as naturally growing entities.

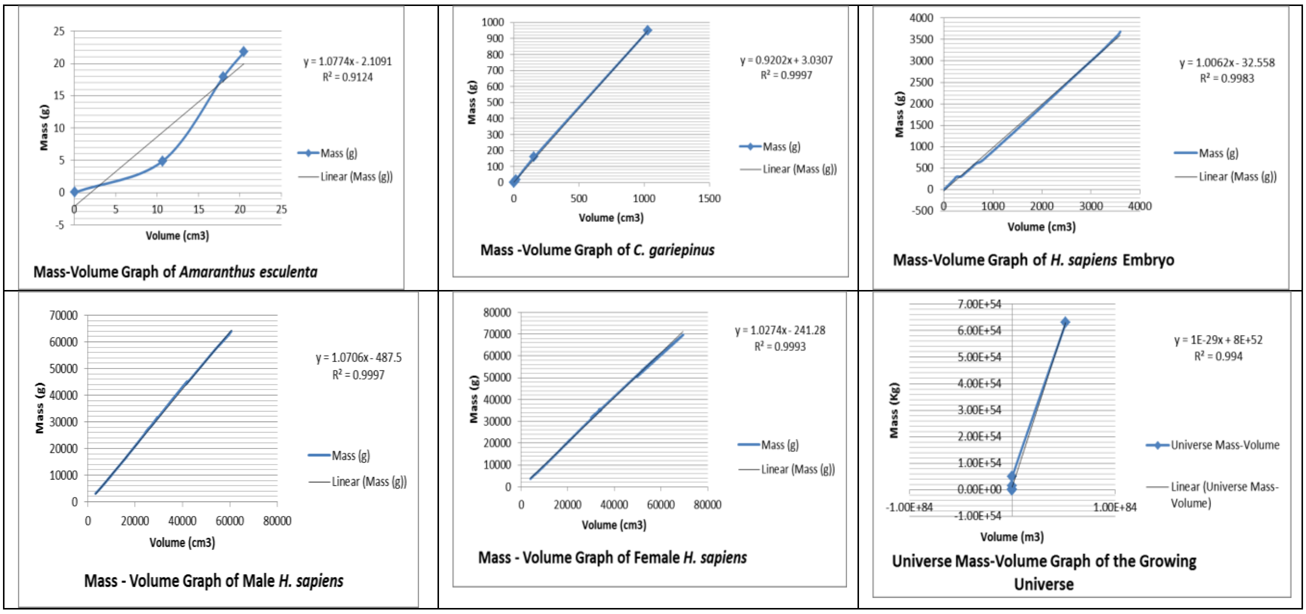

Figure 2: Comparative mass-volume characteristics of cellular and non-cellular matters as naturally growing entities.

Figure 3 is Density–age graphs for cellular matters: *A. esculentus*, *C. gariepinus*, embryo of *H. sapiens*, male and female *H. sapiens* and non-cellular matter: the universe. The trends in all the naturally growing cellular and non-cellular entities elucidated that there is weak positive correlation between density and increasing age (time) while the densities elucidated a general increase with age.

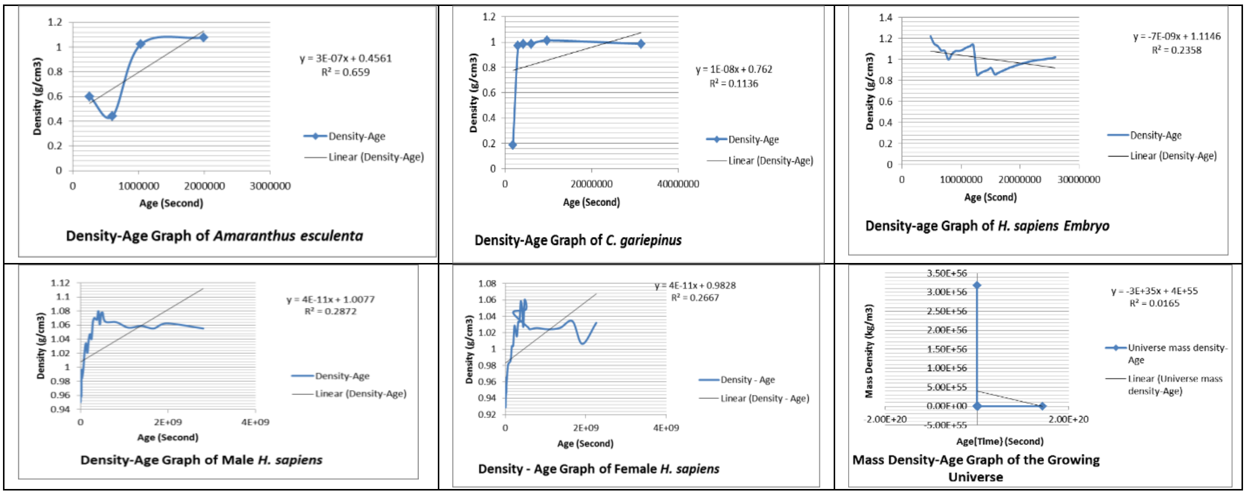

Figure3: Comparative density–age characteristics of cellular and non-cellular matters as naturally growing entities**.**

Figure 4 is expansion (growth) Velocity–Distance (spherical radius) graphs for cellular matters: *A. esculentus*, *C. gariepinus*, embryo of *H. sapiens*, male and female *H. sapiens* and non-cellular matter: the universe. The trends in all the naturally growing cellular and non-cellular entities elucidated that there is weak correlation between expansion (growth) velocity and distance (spherical radius) except for embryo of *H. sapiens* with a strong correlation. Expansion velocity decreases with increasing distance (spherical radius) in all the entities

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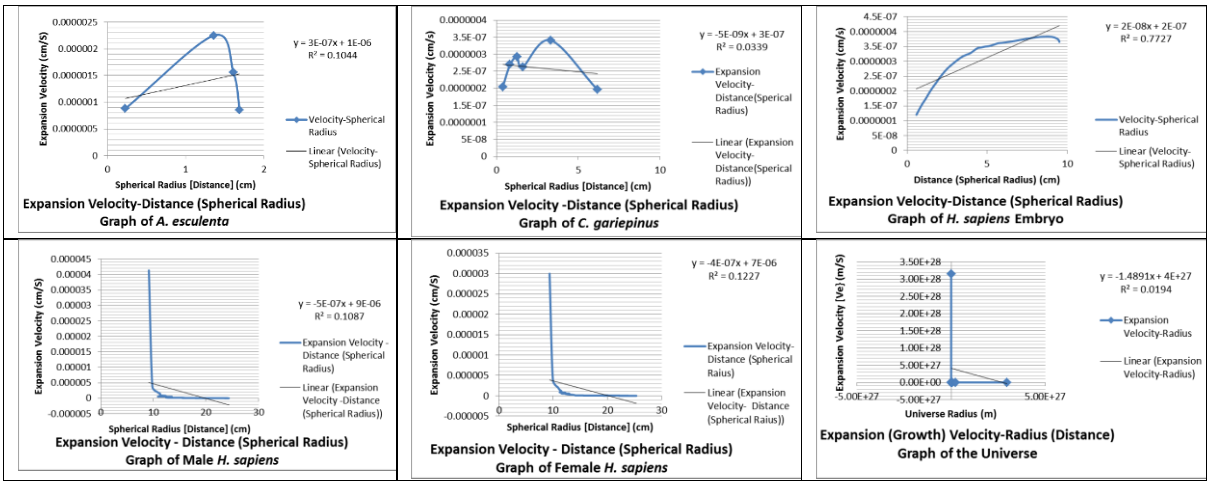

Figure 4: Comparative expansion (growth) velocity–distance (spherical radius) characteristics of cellular and non-cellular matters as naturally growing entities.

Figure 5 is Internal Environment Volumetric Acceleration [Bio-Newton Relative Constant] (G_o) – Age graphs for cellular matters: *A. esculentus*, *C. gariepinus*, embryo of *H. sapiens*, male and female *H. sapiens* and non-cellular matter: the universe. The trends in all the naturally growing cellular and non-cellular entities elucidated that G_o is decreasing with increasing age in general.

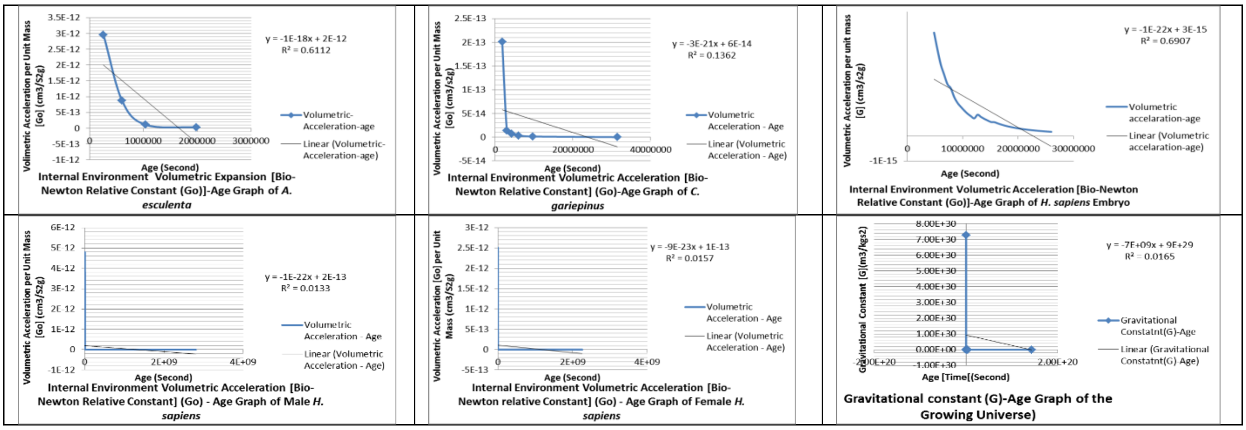

Figure5: Comparative internal environment volumetric acceleration [bio-newton relative constant] (Go)–age characteristics of cellular and non-cellular matters as naturally growing entities

Figure 6 is acceleration due to Internal Environment Volumetric Acceleration [Gravity] (g) - Age graphs for cellular matters: *A. esculentus*, *C. gariepinus*, embryo of *H. sapiens*, male and female *H. sapiens* and non-cellular matter: the universe. The trends in all the naturally growing cellular and non-cellular entities elucidated that g is decreasing with increasing age in general.

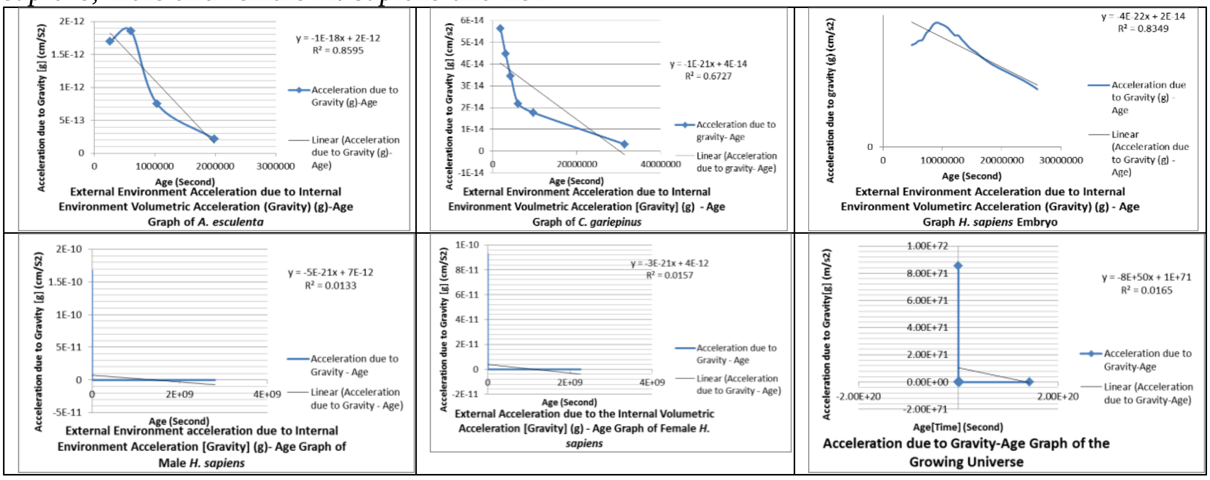

Figure6: Comparative acceleration due to internal environment volumetric acceleration [gravity] (g)-age graph of cellular and non-cellular matters as naturally growing entities.

Figure 7 is Bio-Hubble Relative Constant [H_o]-Age graphs for cellular matters: *A. esculentus*, *C. gariepinus*, embryo of *H. sapiens*, male and female *H. sapiens* and Hubble Relative Constant [H_o] – Age for non-cellular matter: the universe. The trends in all the naturally growing cellular and non-cellular entities elucidated that H_o is decreasing with increasing age in general.

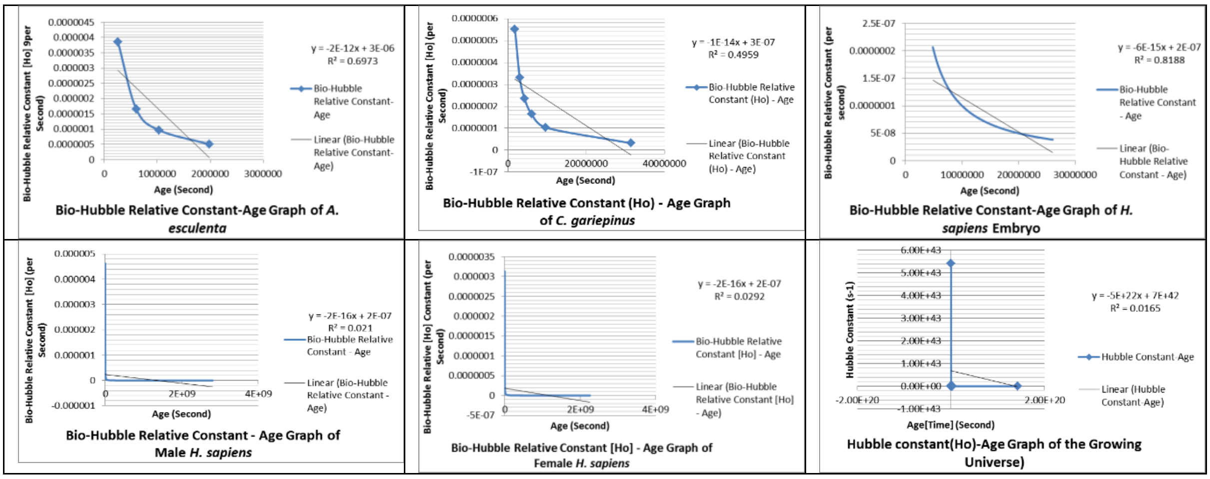

Figure7: Comparative Bio-Hubble relative constant [H_o]-age characteristics of cellular and Hubble Relative Constant [H_o] – Age for non-cellular matters as naturally growing entities.

Qualitative Characteristics among cellular and non-cellular matters

All the cellular forms of matter (*A. esculentus*, *C. gariepinus*, *H. sapiens*) and the non-cellular matter (Universe) elucidated similar qualitative characteristics throughout the five compared developmental stages though at different range of time (Table 1): the emergence of cellular and non-cellular matters from zero volume as a qualitative characteristic could be observed that *A. esculentus* developed from dormant embryo in its seed; *C. gariepinus* and *H. sapiens* developed from zygotes; hence, none of the cellular entities emerged from Absolute Zero Volume. This implied that the cellular matters (WOE) developed from pre-existing environment before developing their respective boundaries giving them distinct entity characteristics by separating their respective internal environments from their external environments. Therefore, the zero volume in the universe (POE) could be understood in similar trend. This simply means that the existence of what cause the universe was in a pre-existing environment prior to formation of the boundary of the internal environment of the universe as non-cellular matter (POE).

Generalized Implication of Zero (0) in Physical Mathematical models could be understood as a change of state of an entity which the model is describing rather than depicting absolute nothingness. For instance, the zero volume/mass relative to the time just before the birth of *H. sapiens;* The zero volume/masse relative to the time just before hatching of *C. gariepinus*; the zero volume/mass relative to the time just before the germination of *A. amaranthus* all were apparent zero volumes/mass relative to time implying that they were in a different state (environment) relative to the new environment they are, hence, these phenomena are extended as a general principle thus "*All the constituents of the universe and beyond the universe, that is, multiverse inclusive, emerged from external environment; hence, there is no entity without mass-energy and spacetime characteristics.*"

Research question2: How could generalized characteristics of cellular and non-cellular forms of matter be deduced relative to their living and non-living states?

Prior to the formation of the respective boundaries separating the internal environments of cellular and non-cellular forms of matter from their respective pre-existing environments, they were in their non-living states but with inherent potential living characteristics while relative to the boundary formations giving them distinct entity, they are in their living states. However, the pre-existing external environments from which the cellular matters were derived (in this case, the parents) were in their living states. This leads to formulation of a Biorelativistic principle which states that ***life is only derivable from life while living and non-living states are interchangeably latent relative to specific environmental factors***. This generalization is extrapolated to include the non-cellular matter such as the universe. This implies that the environment from which the universe is derived is also in its living state while the universe as a non-cellular entity was though in its non-living state but with inherent potential life, prior to its formation of boundary that gave it a distinct internal environment from its external environment; conversely, is now in its living state after its boundary is formed similar to the cellular entities (plant, animal and human) that were in their respective non-living states prior to their formation of boundaries that gave each its distinct internal environment from a living parent which is the external environment from which each was derived before, being in their respective living states after the formation of their respective boundaries.

Table 1: Comparative Descriptive (Qualitative) Characteristics of the growing Cellular and non-cellular Matters in Stages

Stage	****Amaranthus esculentus***	**Clarias gariepinus*	****Homo sapiens***	**Universe****
I	**Emergence from apparent zero volume.** Embryonic development and germination in the soil and emergence (0 sec to 2 days)	**Emergence from apparent zero volume.** Formation of zygote; mitotic cell division; morphogenesis; embryonic development in the egg and hatching out (0 sec to 24 hours).	**Emergence from apparent zero volume.** Formation of zygote; mitotic cell division; morphogenesis; embryonic to foetal development in the uterus and birth (0 sec to 43 weeks or 9 months).	**Emergence from zero volume.** During this time, the energy density of massless and near-massless relativistic components such as photons and neutrinos, which move at or close to the speed of light, dominates both matter density and dark energy [From inflation (~ 10^{-32} sec) ~ 47 ka],
II	Post germination stage. Photosynthesis commenced and very few (2) leaves, stem and roots developed (3 – 6 days)	Laval and fry Stages. Absorption of yolk sac and intake of matter from the external environment into the internal environment (0 sec - <4 weeks).	Infant and childhood stages, several anatomic and psychological developments (0 second to 9 years).	During this time, the energy density of matter dominates both radiation density and dark energy, resulting in a decelerated metric expansion of space (47 ka ~ 9.8 Ga).
III	Vegetative growth stage. More leaves, branching stem and longer roots and more root hairs. (7 – 24 days)	Fingerling to post fingerling stage. Development of fins (4 – 8 weeks)	Puberty stage, maturation of reproductive organs and system; further psychological developments and further increase in size (10 years to 19 years)	Matter density falls below dark energy density (vacuum energy), and expansion of space begins to accelerate. This time happens to correspond roughly to the time of the formation of the Solar System and the evolutionary history of cellular matter (>9.8 Ga).
IV	Reproductive growth stage. Flowering stages/ seed production. Larger leaf surface area, thicker and longer stem (24 – 28 days)	Juvenile stage. Maturation of reproductive organs sets in (9 weeks - < 6 months)	Adulthood (20 years to 40 years)	The time between the first formation of Population III stars until the cessation of star formation, leaving all stars in the form of degenerate remnants (150 Ma ~ 100 Ga).
V	Adult stage and degenerating to death stage (>28 days)	Adult stage and subsequently growing to death (> 6 months)	Old age sets in and subsequently death transforming its internal environment and boundary into the external environment (>40 years).	The Stelliferous Era will end as stars eventually die and fewer are born to replace them, leading to a darkening universe. Various theories suggest a number of subsequent possibilities. Assuming proton decay, matter may eventually evaporate into a Dark Era (heat death). Alternatively the universe may collapse in a Big Crunch. Alternative suggestions include a false vacuum catastrophe or a Big Rip as possible ends to the universe (>100 Ga).

Keys:*Embryonic developmental stages were inclusive in the description; ** Wikipedia (2019) from https://en.wikipedia.org/w/index.php?title=Chronology_of_the_universe&oldid=925183261; ka = kilo annum; Ma = Mega annum; Ga = Giga annum

The current paradigm in science is based on criteria for classifying matter into living entities is restrictive to cellular forms of matters as a physicochemical self-organising system with specific characteristics which are movement, reproduction, nutrition, irritability, growth, excretion, respiration, death, competition and adaptation. Whereas, fundamental observations revealed that cell functions and structures depend on the genetic information carried by the genes on the chromosomes (Vasudevan *et al.*, 2011) and traits, though inherent, are expressed based on genetic (internal environment) and epigenetic (external environment) factors. The ability of the DNA to store, replicate and transmit information (Abercrombie *et al.*, 1990) is what makes cellular forms of matter exhibit their characteristics for them to be considered as living entities peculiar to a specific external environment. Every entity at cosmic or quantum scale has registerable bits of information according to Landauer's principle (Landauer, 1988). The interactions with spacetime and mass-energy makes the partial entities to exhibit at least one or all partial entity's characteristics summarized as Competability (C), Adaptability (A), Self-multiplicability (S), Transporsability (T), Derivability (D), Acto-rectability (A), Transfigurability (T) and Exchangeability (E) (CAST DATE). Therefore, the criteria for classifying matter into a living entity may be broadened and generalized to include cellular and non-cellular matter as "CAST DATE" (Table 2).

Table 2: Generalized Characteristics of a Boundary Forming Living entity (To exhibit at least one of the "CAST DATE" Characteristics)

Generalized criteria for both Cellular and non-cellular matter	Explanation	Equivalent Criteria for Cellular Matter
Competability	Any resource within the internal environment of a boundary forming living entity is a denial to its external environment. The competition among the boundary forming entities is based on the principle of opportunity cost.	Competition
Adaptability	This is the ability of the entity to maintain equilibrium of the internal environment with the external environment in order to continuously sustain its living state.	Adaptation, homeostasis
Self-multiplicability	This is natural automatic quantitative and qualitative increment with time in its internal environment, structurally and functionally. It includes self-organization and differentiation.	Growth, development
Transposability	This is the ability to change position wholly or partially in form of vibration, rotational, translational, randomly or relatively.	Movement
Derivability	This is the ability to Selfless-multiply resulting to another form derived from self (internal environment) and/or to be derivable from another self (external environment).	Reproduction
Acto-reactability	This is the ability to act and be reacted upon or to react due to being acted upon.	Irritability
Transfigurability	This is the ability of the entity to change partly or wholly losing its internal environment to the external environment.	Death
Exchangeability	This is an interactive ability of the internal environment of the boundary forming entities with the external environment in the form of absorption, conduction, contraction, excretion and so forth	Nutrition, Respiration, Excretion

Research question3: How could the most fundamental characteristics of cellular forms of matter as living entities be applied in conceptualizing life in non-cellular forms of matter?

The most fundamental characteristic of the cellular or non-cellular matter as a derived life prior to its living state is the information inherent in it mass-energy which enables it to form its internal environment as a distinct entity by interacting (communicating) with the external environment intelligibly to express its quantitative and qualitative characteristics (traits). With mass-energy equivalence principle ($E = mc^2$) according to Einstein (1905) and generalised in this work as $E_n = mC_n^2 2\pi$, the mass is a condensed energy peculiar to the spacetime dimension of the entity, therefore, (i) Information (ii) mass-energy and (iii) spacetime are the inherent fundamental characteristics of life in cellular and non-cellular forms of matter. It is the energy that gives the boundary forming living entity the ability to exhibit any of the generalized characteristics (Table 2). The fundamental characteristics of every living entity (information, mass-energy and spacetime) confer consciousness to it, therefore, making it an intelligent and subjective being to certain degree – every entity has potential consciousness. Consciousness is the state of knowing or being aware of, that is being informed of oneself (internal environment) and/or other entities (external environment). Information is carried in and by energy that can be transmitted and decoded visually (light energy)/in audio form (sound energy)/ as feelings in form of impulses (electrical/heat/chemical energy). All these forms of energy are characterised by speeds, waves and frequencies within spacetime with mass-energy. The intrinsic nature of these characteristics generates quantifiable ranges of values which are specific to the sensitivity (protocols) of each entity to communicate (transmit - encode and/or receive - decode) in order for an entity to be aware of the constituent information. Information is potential intelligence. Also, intelligence is function of memory (accumulated information with time) in form of records of past experiences through spacetime dynamics and the retrieval mechanism of part or whole of the record which is partly an exhibition of acto-reactability broadened characteristics of a living entity.

Research question 4: If the concept of living entity encompasses non-cellular forms of matter, what could probably be their origin from evolutionary perspective?

The cellular and non-cellular matters are living entities with boundaries forming their internal environments derived from pre-existing external environments. if traced back through time, every boundary-forming entity must have been derived through chains of pre-existing boundary-forming entities down to a boundless pre-existing environment such boundless entity would only be the non-derived life with no distinct external or internal environment but characterized by the three fundamental characteristics: information, mass-energy and spacetime in its singularity from which the inherent characteristics of life in boundary forming cellular and non-cellular forms of matter were derived from.

Johannsen (2005) asserts that organisms (cellular forms of matter) first appear with information, that is, information has been in existence since the beginning of evolution which is linked to meaning. Therefore, meaning is produced by evolution as part of the organisms (cellular forms of matter) that are created in the process of evolution. This is partly relative to the internal environment and partly by allowing external information to enter the organisms from the external environment for further processing. The organisms depend on the information that comes from the external environment but with varying senses which began from evolution with life as biological biggest mystery. However, it could be argued that the evolution of information as an intrinsic property of life for both cellular and non-cellular forms of matter started from the boundless entity and not from the cellular forms of matter. Johannsen (2005) considered catching of information as the first and Loevenstein (2003) argued that the most fundamental level of life is photosynthesis. On the contrary, this might be restrictive to cellular forms of matter but the fundamental level of life could be more general to consider the non-cellular entity that initially self-differentiate and subsequently self-integrating at various levels – aggregating progressively – and through evolution to cellular forms of matter.

Therefore, the boundless entity with no distinct internal and external environment is a living non-cellular entity and the origin from which all life forms (cellular and non-cellular) evolved. The boundless entity is termed *Omnibio*.

Research question 5: What could be the new possible levels of integrations to be used in organizing cellular and non-cellular forms of life?

The composite levels of integration to organize cellular and non-cellular forms of life including boundless and boundary forming entities is suggested in Table 3. There are two major spheres in organisation of life: infinitiosphere or omnisphere and finitiosphere or partiosphere. The highest level being *Omnibio* entity in omnisphere or infinitiosphere while other six composite levels broadly in finitiosphere from cosmic entities in cosmosphere to the lowest level of organisation: infra-particles in infrosphere.

Table 3: Levels of Integration to organize Cellular and Non-cellular Forms of Life to include Boundless and Boundary Forming Entities

Levels of integration of organization of Life in descending composite order	Explanation	Spheres
Omnibio Entity	The highest level of organization of life. The boundless environment with no distinct internal and external environment; characterized by information, mass-energy and spacetime in its singularity from which the inherent characteristics of life in boundary forming cellular and non-cellular forms of matter were derived through simultaneous and instantaneous self- differentiation and self-integration abilities resulting in the continuous formations of any boundary forming entity.	Infinitiosphere or omnisphere
Cosmic entities	This include, in descending order: multiverse, universe, galaxies, solar systems.	Cosmosphere
Ecosystemic Entities	Planetary bodies like satellites, planets and stars; community and population entities.	Ecosphere
Organismic Entities	System-organ entities, organ entities and Tissue entities	Organosphere
Multi-particulate Entities	Nuclear, atomic, elemental, molecular, organelic and unicellular entities	Polosphere
Particulate Entities	Electronic, protonic and neutronic entities	monosphere
Infra-particulate Entities	Charges, neutrino, quarks, Higs bosons, photons, gravitons and photonic mass series (generally including all fermions and bosons)	Infrosphere

The infinitiosphere or omnisphere is infinite relative to the partial being in finitiosphere or partiosphere of every partial entity but is finite relative to the wholesomeness of *Omnibio* entity itself. The infinitiosphere or omnisphere is the sphere of Omnibio entity. Every partial entity is dependent on an external environment to be derived from and grows and develops through interaction between its internal environment and external environment. On the other hand, the wholesome entity is self-dependent on its environment which is non-derivative from any environment. According to the fundamental law of kinematics which states that object will continue to be in motion or state of rest unless acted upon by internal or external force. As for the boundless entity (*Omnibio*) without distinct internal or external environment, what informed it of its first motion? The inherent fundamental characteristics of life (information, spacetime and mass-energy) confer intelligence to it with consciousness and subjectivity. The numerous laws of nature and their applicability to certain domains leading to various mechanisms functionally and structurally are justifications for the subjectivity of *Omnibio* as an entity while the orderliness that evolved in processes among the partial entities in the universe and multiverse sustainably justifies the intelligence of the *Omnibio*.

The word Nature is coined from the Latin word: *naturalis* which means "process", the *Omnibio* being the highest level of organisation of life and non-cellular living entity is ultimately the originator of all the processes and intrinsically the process, hence the Nature. Therefore, all partial entities in finitiosphere evolved and are progressively sustained by ultimately a subjective process (Nature). *Omnibio* is a boundless entity without distinct internal and external environment; therefore, it is constantly in its living state.

The energy in the boundless entity gives it the ability of simultaneous and instantaneous self-differentiability and self-integratability bringing about changes in the equilibrium of energy flow (creating gradients) within the omnisphere resulting in the continuous formations of any boundary forming entity. The derived $E_n = mC_n^2 2\pi$ for $C_n = C^n$ where $1 \leq n \leq \infty$ where E_n = energy in energy level; m = mass; C = speed of light in vacuum; 2π = cosmic-quantum constant = 44/7; n is quantum number in every energy level and is only raising the numeric value of speed of light C without affecting the dimension of C^2. The model is a generalised cosmic-quantum mass-energy equivalence of Einstein's model of $E=mc^2$.

To appreciate the singularity of spacetime at C_∞ to all spheres, an example of astronomical distance of Sun-Earth is considered. A light year or lightyear (ly) is a unit of measurement of length as the distance light travels in a vacuum in one Julian year, that is 365.25 days (31.5576 million seconds) as defined by International Astronomical Union (IAU), it is 9,460,730,472,580.8 km (9.4607E15m) (Seidelmann, 1992 in IAU, 2020). It takes 8.3 minutes for light to travel from sun to earth which is a distances of 1.58E-5 ly (about 150 million km). Now, at speed of light C (C_1 = 299792458 m/s), the photons we received on earth informs us of the condition of the sun 8.3 minutes ago and to communicate back to the sun from earth it will take another 8.3 minutes. Simply put, coming from the sun to earth was our past and it took 8.3 minutes and going back to sun from earth would be our future and it will equally take 8.3 minutes while our present is instantaneous relative to our position on earth. In a nutshell, a distance of about 300 million km to and fro between sun and earth is covered in 16.6 minutes at the speed of light C; hence, we are conscious of our past and future to occur through our present in 16.6 minutes. At higher speed of light C_n ($C_{1.3539}$ = 3E11 m/s) the whole of the events of the past and future of 16.6 minutes can occur instantaneously as our present in a second. Therefore, this leads to the formulation of a *Biorelativity principle of consciousness* which states that *the consciousness as a barrier of time relative to the past, present and future events at a lower speed of lower energy level is an instantaneous event at certain higher speed of higher energy level while at C_∞ in omnisphere, Omnibio is constantly in an instantaneous consciousness of every event in all spheres.*

Conclusions

Based on the findings of this research all the cellular matters (*A. esculentus*, *C. gariepinus*, *H. sapiens*) and non-cellular matter (the Universe) exhibit similar trends in their quantitative and qualitative characteristics implying that these characteristics could be generalized whereby, all would be considered as living entities of different forms with the highest level of organisation of life being *Omnibio*. Biorelativity principle states that *Life is only derivable from life while living and non-living states are interchangeably latent relative to specific environmental factors*. The inherent fundamental characteristics of life are information, mass-energy and space-time relative to every entity and broaden characteristics of a living entity are CAST DATE: Competability (C), Adaptability (A), Self-multiplicability (S), Transporsability (T), Derivability (D), Acto-rectability (A), Transfigurability (T) and Exchangeability (E).

Recommendations

The research findings are potential shift in current paradigm in respect to the concept of life and living entity laying foundation for a new theory which could complement the theory of everything, therefore, should be re-examined by other scientists and the methods should be replicated for constructive criticism.

REFERENCES

Abercrombie, M., Hickman, M., Johnson, M. L. and Thain, M. (1990). The New Penguin Dictionary of Biology (8th Ed.). Penguin Group, London, England.

Babycenter (2019). Growth-Chart Fetal Length and Weight, Week by Week. Rtreived on 16th September, 2019 from https://www.babycenter.com

Einstein, A. (1905). "Zur elektrodynamik bewegter Korper," Annalen der Physik **322**(10):891 – 921

Gehan, E. A. and George, S. L. (1970). Estimation of Human Body Surface Area from Height and weight. Cancer chemotherapy Report Part 1, **54**(4): 225 – 235

Gupta, M. L. and Jangir, M. L. (2010) Cell Biology: Fundamentals and Applications. Student edition, Jodhpur. Pp 729.

International Astronomical Union (2020). Measuring the Universe: The IAU and Astronomical Units retrieved 10 April, 2020 from http://www.iau.org/public/them

Johannsen, W. (2005). On Semantic Information in Nature. *Information*, **6**:411 – 431 DOI: 10.3390/info6030411. Reyreived from http://www.mdpi.com/journal/information

Krebs, C. J. (1978). Ecology: The experimental analysis of distribution and abundance (2nd edition), Harper and Row Publisher, New York. Pp539.

Kohut, P. (2010). Mathematical modelling of the Universe. *The General Science Journal* Issued January 27, 2010 Retrieved on 14th November, 2019 from gsjournal.net/Science-Journals/Research%20papers/View/3124

Landauer, R. (1988). Dissipation and noise immunity in computation and communication. *Nature*, **335** (6193): 779 – 784.

Loevenstein, W. (2003). Physics in Mind. Basic Books., New York, NY, USA

Meban, C. (1983). The Surface Area and Volume of human fetus, *Journal of Anatomy* **137**(2): 271 – 278

Seidelmann P. K. (Ed) (1992). Explanatory supplement to the Astronomical Almanac, University Science Books.

Sendroy, J. JR., and Collison, H. A. (1966). Determination of human body volume from height and weight. *Journal of Applied Physiology*,**21**(1):167 – 172

Tortora, G. J. and Derrickso, B. (2012). Principles of Anatomy and Physiology (13th Ed.). John Wiley & Sons, Inc., USA. Pp.1222.

Turing, A. M. (1952). The Chemical Basis of Morphogensis. Philosophoical Transaction of the Royal Society of London, Series B, Biological Sciences, **237**(641):37 – 72

Vasudevan, D. M., Sreekumari, S. and Vaidyanathan, K. (2011). Textbook of Biochemistry for Medical Students (6th ed.). Jaypee Brothers Medical Publishers (P) Ltd, New Delhi. Pp. 657

Weinberg, S. (1989). The Cosmological Constant Problem. Reviews of Modern Physics, **61**(1):1-23. Retrieved March 13, 2014 from: ftp://ftp.phy.pku.edu.cn/pub/Boooks/

Wikipedia (2019). Chronology of the universe. Retrieved November 6, 2019 from https://en.wikipedia.org/w/index.php?title=Chronology_of_the_universe&oldid=925183261 Pp27

Wilkinson Microwave Anisotropy Probe (2011) Cosmology: The Study of the Universe. Pp50. Retrieved March 13, 2014 from: http://map.gsfc.nasa.gov./universe/WMAP_universes.pdf

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IMPROVING MASS PROPAGATION OF *NAUCLEA DIDERRICHII* (DE WILD.) MERR. USING SINGLE NODE CUTTINGS AND APPROPRIATE GROWTH PROMOTANTS

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ABSTRACT

Nauclea diderrichii (De Wild.) Merr is a sun loving species, found in tropical rainforest of West Africa and used for heavy construction, railway sleepers, and veneers, round timbers and transmission poles. Investigation was carried out to develop protocol for in vitro propagation of Nauclea diderrichii (De Wild.) Merr using nodal cuttings. Single node cuttings (explants) were obtained from one-year-old seedlings and inoculated on Murashige and Skoog (MS) and Woody Plant Medium (WPM) without modification. The cuttings were treated with MS and WPM supplemented with Indole-3-butyric acid (IBA) at 1.0 mg/L; Kinetin (KIN) ranging from 1.0–5.0 mg/L and Benzylaminopurine (BAP) from 1.0– 5.0 mg/L and control (no treatment) for four weeks. Regenerated plantlets were sub-cultured on the same initial combinations of MS and WPM basal media. Unmodified WPM had highest mean shoot length, (2.34 cm), mean number of shoots/node (2.67) and root initiation. With modified MS media, the best result was obtained from 1.0 mg/L IBA+2.0 mg/L BAP with highest mean shoot length, 2.99 cm, mean number of nodes 2.40 with no root initiation. Woody Plant Medium is the best growth medium for shoot and root initiation for in vitro propagation of N. dideriichii.

Keywords: *In vitro propagation, nodal cuttings, Mass propagation, Micropropagation, Nauclea diderrichii, Opepe.*

INTRODUCTION

Tissue culture, also known as micropropagation is a collection of methods that are used to grow different types of plant tissue *in vitro*, in a sterile and controlled environment (Hartmann *et al*. 1991). Due to the totipotency potential of plant cells, these cells provide the genetic information and cellular machinery necessary to generate an entire organism (Thorpe, 1981). Over the years, tissue culture techniques have become very significant in the agricultural sector. According to Hall (1999), plant tissue culture has progressed from the confines of small laboratories into broad-scale techniques which is being employed by the agricultural industry. This technique is being used for mass multiplication of genetically identical plants (Raven *et al*. 1999, Sebastina *et al*. 2005, Ravi *et al*. 2014).

Nauclea diderrichii belongs to the family Rubiaceae naturally found in subtropical or tropical moist lowland forest habitat (Keay, 1989). According to the *International Union for Conservation of Nature* (IUCN) red list of threatened species, *N. diderrichii* is vulnerable to extinction (African Regional Workshop, 1998). It is heavily exploited for its good quality timber. Although, natural regeneration of the species occurs in large canopy gaps, the species is usually outcompeted by other pioneer species after clear-felling. Forest trees including *N. diderrichii* have traditionally yielded a great variety of useful products such as fodders, food and fibers, typical of many African forests in recent times. *Nauclea diderrichii* has been used as an agroforestry plantation species in Nigeria where it is preserved in its natural environment alongside arable crops and other tree crops. According to CABI (2000), there has been establishment of plantations or trials of *N. diderrichii* in Cameroon, Côte d'Ivoire and Liberia. It is a high quality timber species used for heavy construction, railway sleepers, furniture, and veneers and as round timbers. It has also been found to be a very suitable species for transmission poles.

This study provides reliable information on *in vitro* propagation for mass production of genetically identical germplasm of *N. diderrichii* which can be a vital and useful method for production of viable seedlings in plantation establishment. Therefore, the study aimed at evaluating alternative propagation method, through tissue culture and the development of appropriate protocol and growth media for *in vitro* regeneration of *N. diderrichii*.

MATERIALS AND METHODS

The research was carried out at the tissue culture laboratory of the National Centre for Genetic Resources and Biotechnology (NACGRAB), Moor Plantation (7°22′N and 3°50′E), Ibadan, Nigeria. Uniformly growing, healthy and disease-free one year old seedlings of *N. diderrichii* were sourced from the Nursery department, Forestry Research Institute of Nigeria (FRIN), Jericho quarters, Ibadan, Oyo State. These seedlings were transferred to the laboratory and nodal cuttings incised at about 0.8 – 1.0 cm using a sterilized surgical blade and were immediately transferred into 250 mL beaker containing distilled water to prevent dehydration prior to culturing. The explants were washed in detergent and rinsed thoroughly using distilled water to remove any residual lather from the detergent. The washed explants were taken to the transfer hood for disinfection. To disinfect, the explants were soaked in 70% ethanol with 2-3 drops of Tween 20 added to the cuttings, with swirling at intervals, for 5 minutes and decanted, followed by addition of 10% of Sodium hypochlorite (NaOCl) for 30 minutes. The cuttings were rinsed thoroughly using sterile distilled water so as to remove the associated microbial load. Three hundred and sixty explants were used for the study. The experimental design was a 2 x 11 factorial in a completely randomized design with ten replicates. Factor A is growth media at 2 levels and factor B is treatment combination at 11 levels.

Preparation of growth media

Unmodified Murashige and Skoog, MS (1962) basal medium and Lloyd and Mccown (1981) Woody Plant basal medium; were supplemented with varying levels of growth hormones: 1.0 mg/L IBA, combined with 1.0 – 5.0 mg/L BAP and; 1.0 mg/L IBA and 1.0 – 5.0 BAP for regeneration and shoot proliferation. The MS and WPM media modification are shown below:

MS + 1.0 IBA + 1.0 BAP	WPM + 1.0 IBA + 1.0 BAP
MS + 1.0 IBA + 2.0 BAP	WPM + 1.0 IBA + 2.0 BAP
MS + 1.0 IBA + 3.0 BAP	WPM + 1.0 IBA + 3.0 BAP
MS + 1.0 IBA + 4.0 BAP	WPM + 1.0 IBA + 4.0 BAP
MS + 1.0 IBA + 5.0 BAP	WPM+ 1.0 IBA + 5.0 BAP
MS + 1.0 IBA + 1.0 KIN	WPM + 1.0 IBA + 1.0 KIN
MS + 1.0 IBA + 2.0 KIN	WPM + 1.0 IBA + 2.0 KIN
MS + 1.0 IBA + 3.0 KIN	WPM + 1.0 IBA + 3.0 KIN
MS + 1.0 IBA + 4.0 KIN	WPM + 1.0 IBA + 4.0 KIN
MS + 1.0 IBA + 5.0 KIN	WPM + 1.0 IBA + 5.0 KIN
MS only (no supplement)	WPM only (no supplement)

One litre of each growth medium was prepared with 50 mL of stock solution I, 5 mL of stock solution II and vitamin; and 2 mL of stock solution III. The pH was adjusted to 5.7 after which 7.0 g of the gelling agent (dehydrated agar) was added. The media were autoclaved at 120℃ under pressure of 1.2 kg.cm^{-2} for fifteen minutes. The media were allowed to cool to 40-50ºC before dispensing into test-tubes at which had been sterilized in a dry oven (Gallenkamp hotbox oven, Gallenkamp, U.K.) at 200℃ for one hour. Each sterilised cutting was introduced into each test tube containing 5 ml of each treatment combination.

Data collection and analysis

Cuttings were monitored daily for 4 weeks. Data were collected on shoot length, number of shoots and number of leaves. At the end of the experiment, ANOVA and descriptive statistics were used to analyze the data generated. A follow up test for ANOVA was carried out using Duncan Multiple Range Test.

RESULTS

Nauclea diderrichii was successfully propagated *in vitro* using single node cuttings inoculated on pure MS and WPM basal media; and a combination of MS and WPM supplemented with IBA at 1.0mg/l, BAP and KIN from 1.0 – 5.0 mg/l.

Effects of growth hormones and media on shoot length

Explants cultured in unmodified WPM had mean shoot length of 2.34 cm followed by explants in 1.0 IBA+2.0 KIN treatment with 2.13 cm while 1.0 IBA + 1.0 KIN treatment explants recorded the lowest mean shoot length of 0.33 cm (Figure 1).

Highest shoot length of 2.99 cm was recorded in explants cultured on MS and 1.0 IBA + 2.0 BAP treatment while plantlets with 0.62 cm shoot length of was observed in 1.0 IBA + 3.0 BAP treatment. Table 1 shows the analysis of variance on growth variables of *N. diderrichii* plantlets over the study period. There was a significant increase in shoot length throughout the assessment period ($p \leq 0.05$). Significant differences ($p<0.05$) were observed among the growth regulators or treatments, and across the weeks. The interaction between growth regulators across the weeks also had a significant effect on the shoot length. Fig. 1 illustrates the shoot length of *N. diderrichii* under the two-culture media across the treatments.

Effects of growth hormones and media on the number of shoots per node

The explants cultured in unmodified WPM medium recorded the highest mean value of 2.67 followed by treatment 1.0 IBA + 4.0 BAP with mean value 1.77 while the lowest mean of 0.40 was observed in 1.0 IBA + 1.0 KIN treatment. Explants cultured in MS and 1.0 IBA + 2.0 BAP treatment had 2.40 mean number of shoots per node, followed by treatment 1.0 IBA + 3.0 BAP with the lowest number of shoots per node, 0.57. Analysis of variance on mean number of shoots per node revealed that at $p<0.05$, the treatments were significantly different. However, there was no significant difference across the weeks (Table 1). Fig. 2 illustrates the number of shoots per node using two culture media across the treatments.

Effects of growth hormones and media on the number of leaves per explant

Plantlets grown on unmodified WPM had the highest mean value of 5.30 for the number of leaves per explant, followed by 3.53 leaves in 1.0 IBA + 4.0 BAP treatment and the lowest mean number of leaves (0.40) was obtained from explant treated with 1.0 IBA + 1.0 KIN. Using MS medium, the highest number of leaves (4.63) was obtained from 0.1 IBA + 2.0 BAP treatment and the lowest number of leaves (0.33) was recorded in 1.0 IBA + 3.0 BAP treatment.

Table 1: Analysis of variance of growth parameters of *N. diderrichii* explants

Growth variables	df	MS	F	P-level
Shoot length (cm)				
Treatments	5	19.2911*	104.2764*	0.0000*
Weeks	5	1.4937*	8.0740*	0.0000*
Treatment x Weeks	25	0.1973	1.0665 ^{ns}	0.3886*
Error	144	0.1850		
Root length (cm)				
Treatments	5	0.7094*	5.8708*	0.0000*
Weeks	5	0.0031	0.0258 ^{ns}	0.9997
Treatment x Weeks	25	0.0031	0.0258 ^{ns}	1.0000
Error	144	0.1208		
Number of shoots per nodes				
Treatments	5	20.7733*	12.2997*	0.0000*
Weeks	5	0.2133	0.1253	0.9865
Treatment x Weeks	25	0.2267	0.1331	1.0000
Error	144	1.7028		
Number of Leaves per explant				
Treatments	5	91.9833*	13.9608*	0.000*
Weeks	5	1.4633	0.2221	0.9525
Treatment x Weeks	25	0.2767	0.0420	1.0000
Error	144	6.5889		
Number of Multiple Shoots				
Treatments	5	0.8400*	3.0545*	0.1189*
Weeks	5	0.3600	1.3091	0.2634
Treatment x Weeks	25	0.2640	0.9600	0.5239
Error	144	0.2750		

*Significant at $\alpha = 0.05$ ns- Not significant

The result of the analysis of variance for the mean number of leaves revealed that at 5% probability level, there were significant differences among the treatments. However, the interaction effect was not significantly different (Table 1).

Effects of growth hormones and media on multiple shoots

Explants cultured in WPM combined with 1.0 IBA+4.0 BAP treatment, had the highest number of multiple shoots, followed by unmodified WPM. There was a significant difference ($p<0.05$) among the treatments and the interaction effect between treatments and across the weeks was not significant. In MS medium, explants treated with 1.0 IBA + 2.0 BAP had the highest number of multiple shoots followed by 1.0 IBA + 3.0 BAP treatment.

Table 1: Analysis of variance of growth variables of *N. diderrichii* explants

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Shoot length (cm)				
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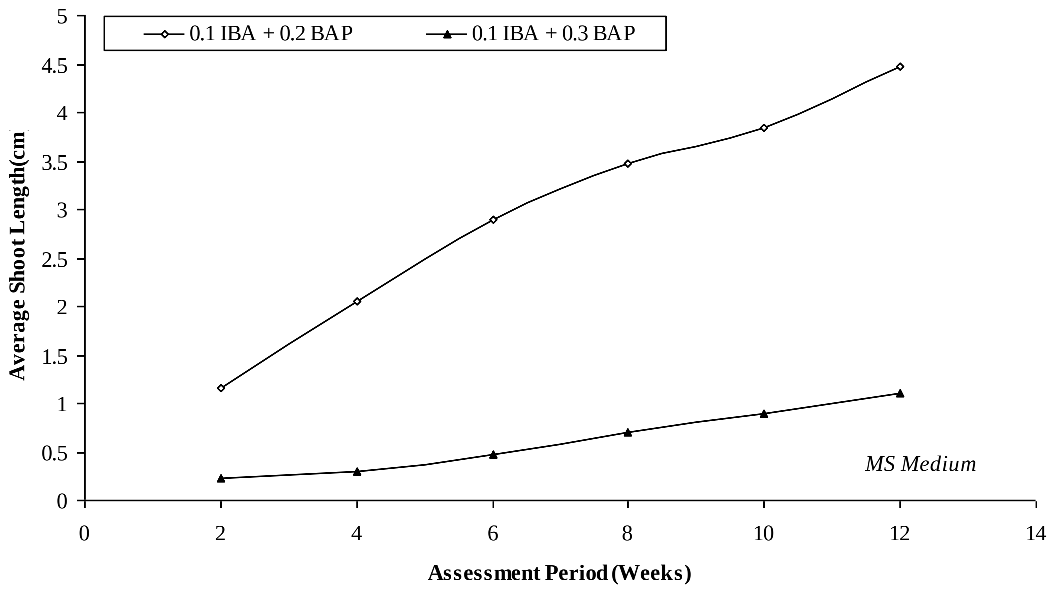
Root length (cm)				
Treatments	5	0.7094*	5.8708*	0.0000*
Weeks	5	0.0031	0.0258ns	0.9997
Treatment x Weeks	25	0.0031	0.0258 ns	1.0000
Error	144	0.1208		
Number of shoots per nodes				
Treatments	5	20.7733*	12.2997*	0.0000*
Weeks	5	0.2133	0.1253	0.9865
Treatment x Weeks	25	0.2267	0.1331	1.0000
Error	144	1.7028		
Number of Leaves per explant				
Treatments	5	91.9833*	3.9608*	0.000*
Weeks	5	1.4633	0.2221	0.9525
Treatment x Weeks	25	0.2767	0.0420	1.0000
Error	144	6.5889		
Number of Multiple Shoots				
Treatments	5	0.8400*	3.0545*	0.1189*
Weeks	5	0.3600	1.3091	0.2634
Treatment x Weeks	25	0.2640	0.9600	0.5239
Error	144	0.2750		

*Significant at α = 0.05 ns- Not significant



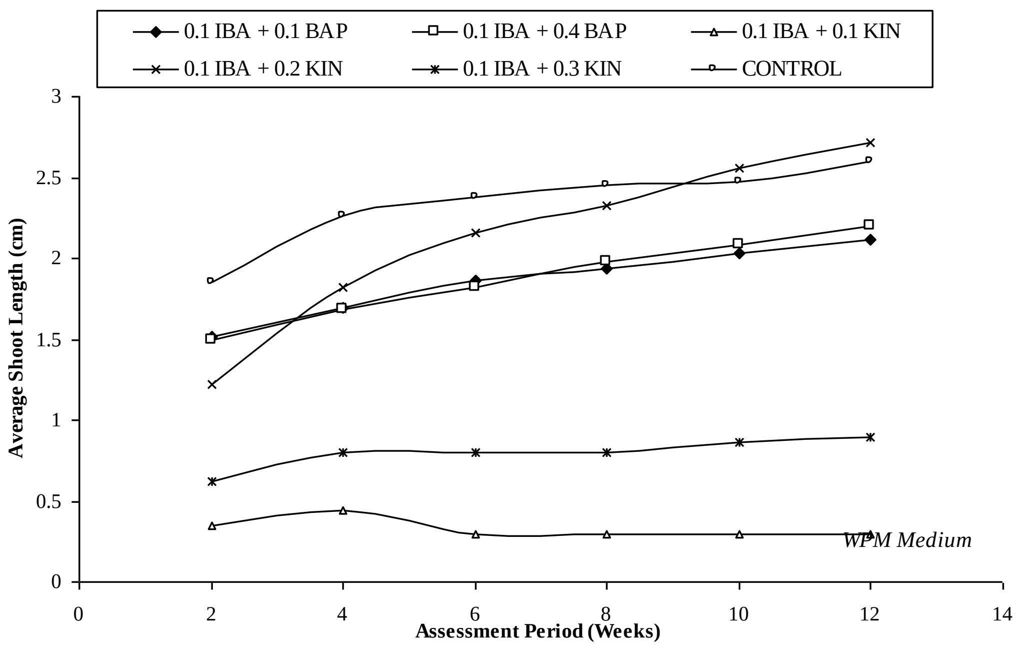
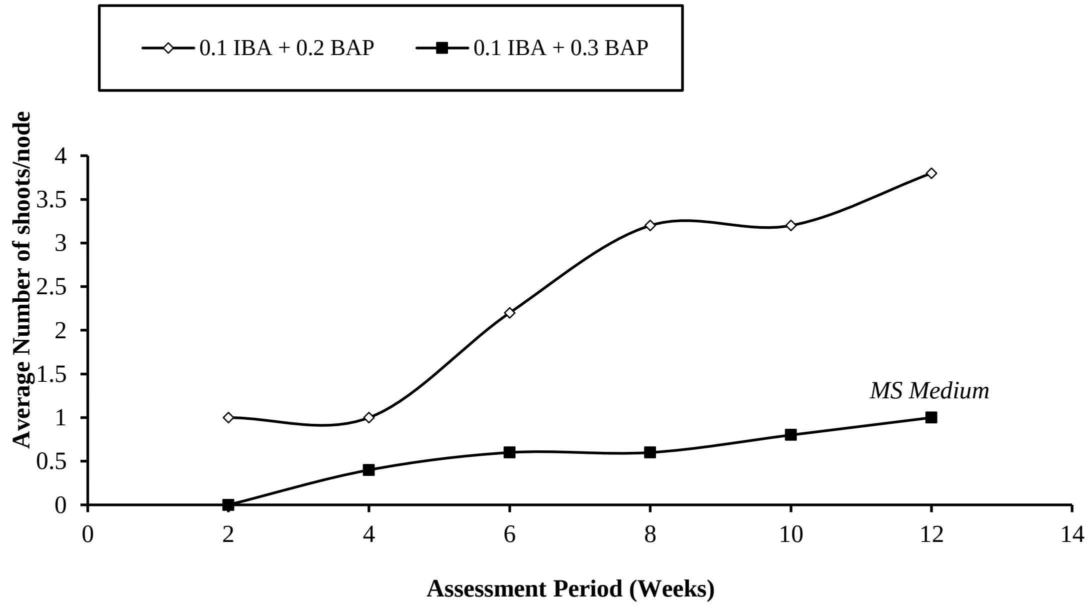


Fig.1: Average shoot length of *Nauclea diderrichii* under two media (MS and WPM) and varying treatments across the assessment period.



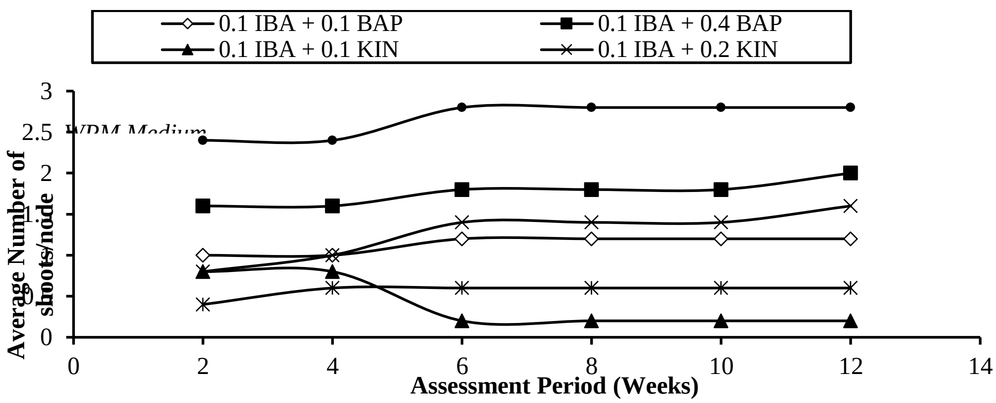


Fig.2: Average number of shoots/ node of *Nauclea diderrichii* under two media (MS and WPM) and varying treatments across the assessment period.

DISCUSSION

Plant tissue culture, as a technique, has contributed significantly to the mass multiplication and improvement of both agricultural and tree crops. The use of WPM and MS enhanced the growth of shoot length in *N. diderrichii* plantlets. There are biological processes that allows the manipulation of *in vitro* morphogenesis and investigations on various physiological, biochemical and molecular aspect of plant hormones. Available knowledge and information about these biological processes will help address the issues of *in vitro* recalcitrance or *in vitro* plant growth and development. The satisfactory performance of BAP at 2.0 mg/L for the propagation of nodal cuttings in *N. diderrichii* is in conformity with the findings of Sebastina *et al*. (2005) who reported germination of embryos in *Phyllanthus emblica* and *Hevea brasiliensis* using the growth hormones; and Ravi *et al*. (2014) who observed that 1.5 mgL^{-1} BAP was most suitable for shoot multiplication of *Terminalia arjuna*. These findings supported the reports on enhanced shoot multiplication by addition of auxin along with cytokinin. Akinyele *et al.* (2020), observed that the use of IBA at 1.5 mgL^{-1} concentration enhanced rooting and callus formation in *H. barteri* cuttings although few *H. barteri* cuttings also formed callus and roots with no treatment application. In this study, the optimal shoot length was observed on WPM media without growth regulator followed by treatment with Kinetin. This is in agreement with the findings of Tetyana and Van Staden (2001) who recommended the use of kinetin for shoot initiation and proliferation for *in vitro* culture of *Cussonia paniculata*. MS supplement with various concentrations of kinetin shows an increase in shoot length at high cytokinin/auxin ratio (Fig. 1) and this was in conformity with Hartmann *et al.* (1997) who reported that a high auxin/cytokinin ratio favors shoot formation. The number of shoot increases as the concentration of BAP increases in MS medium (Fig. 2). This is supported by Hartmann *et al.* (1997) who reported that the increase in cytokinin level shows a corresponding increase in the number of shoots per explants of shoot inoculation of eastern redbud *Cercis canadensis*. Manikandan *et al.* (2017) observed that BAP at 1.5 mg/L induced optimum shoot proliferation in *Dalbergia latifolia* while IBA at 3.0 mg/L concentration was optimum for root induction from the shoots of the same species while Kiondo *et al*. (2014) reported the best shoot initiation for *D. melanoxylon* on Murashige and Skoog (MS) medium using 2.0 mg/L BAP and 1.0 mg/L NAA and optimum root initiation on MS medium combined with 1.0 mg/L NAA. While Usman and Akinyele (2015) reported that auxin treatments have the potential of ensuring sprouting and rooting of *Massu.8o55 laria acuminata*.

However, Gostin (2008) observed that a medium concentration of BAP induced growth rate of *Salvia officinalis* cultivated *in vitro,* with the resulted plantlets having normal aspect while Ravi *et al*. (2014) obtained the best *in vitro* rooting in *Terminalia arjuna* using 0.1 mg/L^{-1} IBA. Khalafalla and Daffalla (2008) also reported that only medium containing IBA at 1.0 mg L^{-1} concentration induced 25% rooting in *Acacia Senegal* while production of leaves, shoots and leaves length were better when compared with media having a lower or higher amount of BAP. This is contrary to the findings in this study as both the lower and medium concentrations induced growth. Many works have been done on the propagation of various species (Baker 1992; Englemann 1997; Anegbeh, *et al*. 2007; Akin-Idowu *et al*. 2008; Abdullahi & Akinyele 2013; Akinyele & Maradesa 2013, Onefeli & Akinyele 2014; Usman & Akinyele 2015). Datta *et al*. (1982) described *in vitro* propagation of the valuable tropical timber *Dalbergia sisso* (one of the rosewoods). Cheema (1989) successfully carried out somatic embryogenesis and plant regeneration of *Populus ciliata* using cell suspensions derived from a 40-year-old specimen of the species. According to Sasson and Costarini (1989), plant tissue culture have recently become the means of achieving large clonal propagation, germplasm transfer, germplasm conservation, genetic improvement as well as propagation of recalcitrant woody species. Also, Pierik (1987) opined that *in vitro* propagation in forestry has the advantages of saving time, space and resources for wood species and conservation of disease-free plants, while *in vitro* storage has been showed to be useful and necessary in clonal forestry. It may also have applications in solving problems associated with recalcitrant seed storage (Englemann, 1997). The principal threat to indigenous high valued tree species such as *N. diderrichii* comes from the increase in the human population, urbanization enhancement and rapid deforestation from demand for agricultural land (Anegbeh *et al*, 2007). When overexploitation, destructive harvesting and poor management lead to the depletion of these resources, no new market, cottage industry or land tenure system will be able to change the circumstances. This requires that the forest resources be sustainably maintained and secured. Taking cognizance of the importance of *N. diderrichii* species and to ensure its continuous production, there is a need for regular and mass production using a method that will ensure the production of genetically identical species to the parent plant in a short period of time. Thus, to encourage commercial cultivation, micro-propagation of *N. diderrichii* using tissue culture is required. This will not only enhance mass propagation and reduce the gestation period of this indigenous tree species, but it also provides a large number of plantlets for further researches on the species.

CONCLUSION

The successful application of biotechnology including its commercialization would depend on several factors. There must be an adequate research base with a free flow of ideas and technical information. Development of a protocol for *in vitro* propagation of *N. diderrichii* has provided the technical information needed for mass production of seedlings of this species. With sufficient scientific and biotechnological base in terms of infrastructure and manpower, it is possible to transform the latent potential of clonal forestry into realistic productivity output in developing countries by the provision of sufficient planting materials for plantation establishment. Since micro-propagation has an important role in the rapid multiplication of elite genotypes (clones, families, etc) of tree species which is particularly true in tropical and sub-tropical countries where many species have only recently been domesticated, high growth rates are possible and the demand for wood is very high. Micro-propagation can readily fit into tree improvement programs even where the trees planted in the forest are seedlings or cuttings.

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REFERENCES

Abdullahi, I.N. and Akinyele, A.O. (2013). Shoot Proliferation Using Cotyledonary Nodes of locally Conserved *Parkia biglobosa* (Jacq.) Benth Seeds. *International Research Journal of Plant Science.* 4(10):302 - 309.

African Regional Workshop (1998). *Nauclea diderrichii*. *The IUCN Red List of Threatened Species* 1998: e.T33058A9746387. https://dx.doi.org/10.2305/IUCN.UK.1998.RLTS.T33058A9746387.en. Downloaded on 10 February 2020.

Akinyele, A. O., Onefeli, A. O. and Ige O. C. (2020). Macropropagation of *Hildegardia barteri* (Mast.) Kosterm using Stem Cuttings and growth promotants. In: Ogunsanwo O.Y., Adewole N. A.., Oni, P.I., Idumah, F. (Eds.). Forestry Development in Nigeria: Fifty years of Intervention and Advocacy. Proceedings of the 42nd annual conference of the Forestry Association of Nigeria. Exotic Dezines Ltd. ISBN: 978-978-310-496-5. Pp 456-464.

Akinyele, A.O. and Maradesa, B.O. (2013) Propagation of *Tetrapleura tetraptera* (Schum & Thonn) Taub. Using tissue culture. *Forest and Forest Products Journal*. Vol 6:1-8.

Akin-Idowu, P.E., Ibitoye, D.O., Akinyemi, S.O.S. and Ademoyegun, O.T. (2008) Tissue Culture as a Plant Production Technique for Horticultural Crops. In: Horticultural Society of Nigeria; Proceedings of the 26th Annual Conference of the Horticultural Society of Nigeria, held at Adamawa State University, Mubi, Nigeria. Oct 26- 30th, 2008. 71-76pp.

Anegbeh, P.O., Tchoundjeu, Z., Simons, A.J. and Roy-Macauley, H. (2007) Domestication of *Allanblackia floribunda*. Vegetative Propagation by Leafy Stem Cuttings in The Niger Delta Region of Nigeria. www.worldagroforestrycentre.org.

Baker, F.W. (1992) Rapid Propagation of Fast-growing Woody Species. CAB International for Committee on the application of Science to Agriculture; Forestry and Agriculture (CASAFA).

Redwood Press Ltd. Melkasham, UK. Pp.125.

CABI (2000) Global Forestry Compendium. CD-ROM. CABI

Cheema, G.S. (1989) Somatic Embryogenesis and Plant Regeneration from Cell Suspensions and Tissue Cultures of Mature Himalayan poplar (*Populus ciliata*). Plant Cell Reports**,** 8; 124-127.

Datta, S.K., Datta, K. and Pramanik, T. (1982) *In Vitro* Clonal Multiplication of Mature Trees of *Dalbergia Sissoo* Roxb. Plant Cell Tissue and Organ Culture 2; www.springerlink.com.

Englemann, F. (1997) *In Vitro* Conservation Methods. Biotechnology in Agric. J. A. Callow, B. V. FordLloyd and H. J. Newburg. Eds. Walling Ford, UK CAB International. Series.19; 119-161.

Gostin, I. (2008) Effects of different plant hormones on *Silvia officinalis* cultivated *in vitro*. International Journal of Botany 4 (4): 430-436pp.

Hall, R.D. (1999) Plant Cell Culture Protocols. (New Jersey: Humana Press Inc.) 421pp.

Hartmann, H.T., Kester, D.E., Davies, F.T. Jr and Geneve, R.L. (1997) Plant Propagation.
Principles and Practices (6th edition). Prentice Hall International, Inc., USA. 770pp.

Khalafalla, M.M. and Daffalla, H.M. (2008) In Vitro Micropropagation and Micrografting of
Gum Arabic Tree *Acacia senegal* (L.) Wild]. International Journal of Sustainable Crop Production. 3(1):19-27

Keay, R.W.J. (1989) Trees of Nigeria. 2nd Edition, Clarendon Press Oxford. 176pp.

Kiondo, F., Feyissa, T., Ndakidemi, P.A., Seth, M. and Lema, K. (2014) Micropropagation of
Dalbergia melanoxylon Guill. & Perr.: A threatened tree species. American Journal of Research Communication. Vol. 2(12): 43-52

Lloyd, G. and Mccown, L.B. (1981) Commercially- feasible micropropagation of mountain laurel, *Kalmia latifolia*, by use of shoot tip-tissue. Comb Proc International Plant Prop Soc 30: 557pp.

Manikandan, I.G., Bhuvaneswari, R.T., Ramya, M.A. and Ramasubbu, R. (2017) In vitro Propagation and Mass multiplication of *Dalbergia latifolia* Roxb: A Vulnerable Tree Species from Eastern Ghats, Tamil Nadu, India. International Journal of Botany Studies. Vol. 2(6)52-57.

Murashige, T. and Skoog, F. (1962) A revised medium for rapid growth and bioassay with Tobacco tissue cultures. Physio. Plant. 15: 473 – 479.

Novel Africa Initiative (2007) Allanblackia and Biodiversity. What is Allanblackia? Retrieved June 15, 2008, from http:/www./
allanblackiaandbiodiversity_novel africainitiative 6.htm

Onefeli, A. O. and Akinyele, A. O. (2014). Macropropagation of *Dennettia tripetala* Baker f. *South-east European forestry Journal* 5 (2): 135 - 144.

Pierik, R.L.M. (1987) *In vitro* Culture of Higher Plants as Tool in the Propagation of ornamental plants. Retrieved7March, 2006fromhttp.//www.actahort.org/books/226/226-1, htm.

Raven, P.H., Evert, R.F. and Eichorn, S.E. (1999) Biology of Plants, 6th edition. (New York: W.H. Freeman and Company). 562pp.

Ravi, M., Ramanjaneyulu, P. and Vijaya, B.R.A. (2014) Micropropagation of *Terminalia arjuna*
Roxb., from Nursery Plant Material. International Journal of Emerging Trends in Science and Technology. Page 997-1005

Sasson, A. and Costarini, V. (1989) Plant Biotechnology for Developing Countries. Proceeding of an intl. Symposium organized by CTA and FAO 26-30 June 1989. Luxembourg: Pp 329.

Sebastina, R., Karamthanan, P.V. and Mathew, M.M. (2005) Somatic embryogenesis and plant
regeneration in *Phyllanthus emblica* L. Plant Cell Biotechnology and Molecular Biology.6(3&4): 155-58.

Tetyana, P. and Van Staden, J. (2001) Micropropagation of *Cussonia paniculata*- a medicinal
plant with horticultural potentials. South African Journal of Botany 67(2): 367-370.

Thorpe, T.A. (1981) Plant Tissue Culture: Methods and Applications in Agriculture. (New York Academic Press), 393pp.

Usman, I. A. and Akinyele, A. O. (2015). Effects of Growth Media and Hormones on the Sprouting and Rooting Ability of *Massularia acuminata* (G. Don) Bullock ex Hoyl. *Journal of Research in Forestry, Wildlife and Environment. Volu*me 7(2) pp138-146.

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LOCAL SITES OF SPECIAL SPECIES INTEREST: IMPERATIVE CONSERVATION FRAMEWORK FOR COMMUNITY FOREST AND TABOO SPECIES IN DELTA STATE, NIGERIA

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ABSTRACT

Habitat fragmentation and increased edge effects constitute sources of biodiversity leakages from protected areas to free community forest with higher level of threats. Fortunately, communities that taboo biodiversity often create safe landing for sustained viable population. This study was conducted to conceptualize these communities as local sites of special species interest (LSSSI) for possible adoption as Sites of Special Scientific Interest (SSSI) to enhance conservation targets in Delta State, Nigeria. Data were gathered from Ugono-Orogun, Umute-Nsukwa, Ugili Amai-Olloh Ossisa and Emu-Uno communities that taboo various species of Primates and Reptiles by survey at sighting regime of 2, 4 and 6ha per beat at two days interval for two weeks in a-3 x 2 x 5 factorial experimental design. Square root transformation was carried out on collected data before analysis of variance (ANOVA) was conducted and significant means separated at 5% level of significance using the Duncan multiple range test. Fineness/coarseness of forest corridors and edges, availability of propagules alongside a subjective habitat matrix score for 7 key attributes likely to further forest fragments along with soil samples were analyzed for CEC, exchangeable cations and Ca-Mg ratio. Results showed that Umute-Nsukwa and Ugili-Ossisa sites had high conservation values of endemic species (>1) while others were medium (=1). The Ugono-Orogun and Ugili-Amai sites have high conservation size value (>300ha) compared to others with medium values (3-300ha) and high habitat diversity but with higher protection from fire (4) and exotic invasive species (4) in the habitat matrix. Mean population sighted was higher in habitat corridors than edges except in 2ha-habitat sighting regime at Umute-Nsukwa. Propagule availability was Ugili Amai-Olloh Ossisa (18.5kg/ha) > Ugono-Orogun (16.8kg/ha) > Umute-Nsukwa (15.2kg/ha) > Emu Uno (10.8kg/ha). These underpinned the choice of conservation habitats as Umute-Nsukwa > Ugili-Ossisa > Ugono-Orogu > Emu-Uno for the protection of the IUCN Red List Vulnerable White-throated guenon (Cercopithecus erythrogaster) and threatened West Africa dwarf crocodile (Osteollaemus tetraspis) in the lowland rainforest ecological zone of Delta State as Local Sites of Special Scientific Interest (LSSSI).

Keywords*: Sites of special scientific interest, Local sites of special species interest, Habitat fragmentation, Taboo species, Corridors and Edges*

INTRODUCTION

Sites of special scientific interest represent strategic tool for the conservation of remnant forest ecosystem patches among increasing ecosystem degradation. The earlier legislation and gazette of forest estates with different needs to constitute forest reserves was particularly carried out in the colonial and military administrations across Nigeria. These forest reserves which were constituted, managed and sustained for specific purposes were located in different ecological zones have served as sources of forest minor produce, ecological and environmental shields until gradual deforestation and de-reservation crept in to undermine the various objective of sustainable forest management (Dike, 2002; Akansanmi,2006; World Bank, 2018). Unfortunately, there have been lots significant anthropogenic activities in the last three decades with severe incursions on reserved forest estates. It has become alarming that while there have been no new constituted forest reserves for over three decades in Nigeria, the existing few are either degraded, deforested or awaiting de-reservation.

Onochie (1994) documented the distribution of forest reserves in the six geopolitical zones of approximately 99,991.92km^2 with the south-south, south-west, north-east and south-east representing 15.61%, 16.69%, 6.55% and 1.63% respectively. These reserves were created by central government and handed over to the then local authorities in the regions for regulations and management. But the creation of states from the regional government led to loss of reserves to development for infrastructures, agriculture, poor management owning to boundary disputes and inconsistent forest regulatory framework that had no bearing with suitable scientific policies. Consequently, protected habitats for the survival of wildlife and biological diversities were lost and accounted for migration of endemic species in the various ecological zones to seemingly safer regions for survival. Oni (2006) showed that Nigeria was endowed with 24 species of mammals, 23 species of primates, 839 bird species among others.

The survival of migrating species, especially terrestrial species have been reported to anchor on the receipt of individual community forests that have been designated as either evil forest or tabooed sacred forest in local areas (Eburu, 2018). Viable populations of bio-diversity have been reported in these community forests and have been relied upon as pragmatic formwork for the realization of in-situ conservation in documented climes (Millennium Ecosystem Assessment, 2005). In addition, there are other communities that strictly taboo different wild life species. There are forest areas, often relatively intact, that are referred to “evil forest” and restrictions are enforced to maintain “sanctity of the spirit” and thereby avoid de-reservation by “mortal men”. Documentation of these have been absolutely oral, even though these proliferate the numerous ecological zones of the tropical forest area as tradition often hold sway in the face of modern religion.

Traditional ecological knowledge therefore creates a driving platform for the integration of local sites of special scientific interest into existing conservation portfolio. Although traditional ecological knowledge has been relatively exploited in land-use practices for high agricultural production as in shifting cultivation, seed storage, local soil mineralization and mulching techniques, its engagement n conservation barely contradicts in negative sense vulnerability as the risk communities are faced due to transformation by extractive uses (Margules and Pressey, 2000). The intensive use of forest trees species especially the roots, barks and trunks by direct extraction and collection for fifty medicinal purposes has been reported as a major source of biodiversity loss leakage that breed both threat as well as extinction in Nigeria ecosystem due to habitat loss (Umar *et al*, 2013; Odugbemi *et al*, 2017).

The Nigeria National Biodiversity Strategy and Action Plan (NBSAP, 2001) listed approximately seventeen groups of wildlife species in which significant population changes occurred over the last ten decades. Population decline among the Primates (Monkeys and Apes) were notably adduced to hunting for bushmeat and international trade while that of Crocodiles (Crocodylidae) was attributed to overharvesting. The purported lost benefits were basically tied to tourism, genetic diversity and skins which to large extents constitute sources of economic revenue to the nation. Yet, the critical issues of habitat defense for the conservation by reduction of deforestation and engagement of alternative products of forest origin to minimize pressure on the habitat was only linked to protected reserves and national parks that are quite few and poorly linked within individual ecological zones. Article 8 (a) of the Convention on Biological Diversity relies on the Precautionary principle that the absence of full scientific certainty should not be used as a reason for postponing measures to avoid or minimize observable threats of significant reduction or loss of biological diversity.

SPWA (2010) reported that Delta State, in the Niger-Delta region, provides habitat to six (6) endemic wildlife species on the IUCN Red List among which are the vulnerable White-throated guenon (*Cercopithecus erythrogaster*) and threatened West Africa dwarf crocodile (*Osteollaemus tetraspis*) even though significant population has been lost due to intense hunting pressure, crude oil and gas exploration activities, The cultural taboo of some communities along the ecological zones has largely contributed to sustenance of viable populations. Consequently, habitat protection for the conservation of these wildlife species cannot be overemphasized in the course of proposing *in-situ* conservation portfolios, especially in developing climes where forest resources are key sustainable livelihood options. It is against this backdrop that relatively intact habitat corridors and edges of forest fragments in selected communities with known population of tabooed White-throated monkey and West African dwarf crocodile were studied as notable formwork for the design of conservation portfolios and habitat restoration to further enhance possible inclusion in the National Biodiversity Strategy Action Plan.

MATERIALS AND METHODS

Description of study areas

The study was conducted in Umute-Nsukwa, Ugili Amai-Olloh Ossisa, Emu-Uno and Ugono-Orogun communities in the lowland rainforest ecological zone of Delta State in the Niger Delta region of Nigeria. Umute-Nsukwa is in Aniocha South LGA on Lat. 6^o 7´N and Long. 6^o 29´E. It encloses a long stretch of water habitat that runs towards the boundary with Nsukwa, with standing forest connections at Nsukwa junction along the Kwale-Warri Road. The stream forest transverses the heavy traffic road that has high crown cover which permit aboreal movement White-throated monkey population. The sacred forest around this transverse road accounts for approximately 6-10ha of intact indigenous forest tree species. The Umute-Nsukwa community forest is bounded in the eastern axis by Isheagwu forest reserve and south by the Olloh-Ossisa grass-plain vegetation. Major species tabooed in this community is vulnerable White-throated guenon (*Cercopithecus erythrogaster)* which is protected, even though the population constitutes a significant level of pest to agricultural fields especially *Zea mays* (maize) and Cassava.

Ugilli-Osissa community is located in Ndokwa West LGA on Lat. 5^o 46´ N and Long. 6^o 24´ E. The Ugili Amai-Olloh Ossisa community shares boundary on the west and east by Nsukwa and Isheagwu respectively. Existing vegetation is denser along the Isheagwu boundary and sparse at Nsukwa axis. It narrows off in Olloh-Ossisa with significant grass-plain in Ugili-Amai, dotted with different patches of *Daniella oliveri*, *Khaya senegalensis*, and *Lophira alata* tree species that serve as habitat for the IUCN Red List Vulnerable White-throated guenon (*Cercopithecus erythrogaster*) and several migratory bird species as nesting ground.

Emu-Uno community is situated between Lat. 5^o 38´ - 4^o 2´N and long. 6^o 13 - 6^o 25´E in Ndokwa West LGA. The vegetation is highly degraded by agriculture with a lot of secondary forest and agroforestry practices especially Hevea species. But the tabooed IUCN threatened West African dwarf Crocodile (*Osteolaemus tetraspis*) enjoy the habitat along marshy and protected areas of the community.

Ugono-Orogun is a mixed habitat grassland with relatively intact vegetation in Ughelli North LGA on lat. 5^o 31´N and long. 6^o 48´E. Crude oil exploration is the major bane to tabooed Iguana/alligator reptile population although a significant number of adjoining communities that also taboo has contributed to the conservation.

Data collection

Thirty (30) local persons in each community were employed to conduct the survey at the rate of 10persons per sighting regime and beat at two days interval for two weeks. Number of each tabooed species per team per ha in different beats were taken every other day for two weeks and expressed in percentages.

Focus group interviews were conducted for 15 persons in each community to assess seven (7) key anthropogenic-habitat framework attributes capable of affecting forest fragmentation for conservation portfolios using factor scores (1-4). Mean of each attribute was taken and the final total score per community was adjudged accordingly as the relative conservation value as well as protection from habitat degradation potential.

Available propagules and soil samples from 0-15cm depth were studied by collection from strategically located points within 1ha plot size in the corridors and edges of fragmented habitats in each community areas under study. Soil samples were analyzed for cation exchange capacity CEC, essential exchangeable cations of Ca, Mg and Mg-Ca ratios respectively.

Data analysis

The numbers of sighted taboo species of interest per sighting regime of 2, 4 and 6ha in two different habitat fragments per community were expressed as percentages of total species in a-3 x 2 x 5 factorial design experiment. Square root transformation was carried out by taking the square root of each observation before the analysis of variance (ANOVA) was conducted and significant means were separated using the Duncan multiple range test at 0.05 probability level of significance.

RESULTS

The status of communities for proposed conservation activities were ranked for existing forest remnant (Table 1). Umute-Nsukwa had the highest habitat diversity of 4 while Emu-Uno the least (1). The Ugili-Ossisa and Ugono-Orogun had the same habitat diversity of two (2). Estimated size was largest at Ugono-Orogun and least at Emu-Uno of 315ha and 10.5ha respectively. Umute-Nsukwa had 28ha.

The forest types ranged from mixed forest at Umute-Nsukwa, Ugili-Ossisa and Ugono-Orogun respectively. Emu-Uno was agroforestry in nature. Endemic wildlife species with the addition of tabooed species was 3 in Umute-Nsukwa and 2 at Ugili-Ossisa.

The Umute-Nsukwa community has a relatively pristine forest while Ugili-Ossisa and Ugono-Orogun have modified. The Emu-Uno is degraded with agriculture. Ugili-Ossisa and Ugono-Orogun have an occurring grass-plain that is regular in shape even though intercepted by anthropogenic activities at different points along the different ecological zones of the State.

Table 1: Ranking of relative values of existing forest remnants for community conservation

	Communities			
Criteria	**Umute-Nsukwa**	**Emu-Uno**	**Ugili-Ossisa**	**Ugono-Orogun**
Habitat diversity	4	1	2	2
Estimated size (Ha)	28.00	10.50	305	315
Matrix type	Mixed-forest	Agro-forest	Mixed-forest	Mixed-forest
Endemic species	3	1	2	1
Disturbance	Relatively pristine	Degraded	Modified	Modified
Slope	Intermediate	Irregular	Regular	Regular

Effect of forest fragments of distribution of tabooed species

The effect of different forest fragments on the mean distribution of different tabooed species is shown (Table 2). There were significant differences in the means of sighted tabooed species within and among the forest edges and corridors of the habitat fragments in different communities at different sighting regimes ($p > 0.05$). The highest mean (44.40) at 6.0ha sighting regime was significantly different along forest fragments and sighting regime in Umute-Nsukwa.

In Emu-Uno, there were significant differences among the sighting regime and within forest fragments. The forest corridor at 4ha sighting regime recorded the highest mean of 33.30 while the least mean (9.99) was recorded in the forest edge at 2ha sighting regime.

There was however no significant difference between the mean of sighted tabooed species in the forest corridors at 2ha and 6ha sighting regimes in Ugili-Ossisa. The highest mean of 35.0 was recorded in the forest corridor at 4ha sighting regime while the least of 10.00 was along the forest edge habitat fragment.

The 6ha sighting regime recorded the highest mean (38.08) along the corridor in Ugono-Orogun. There was no significant difference between the mean of sighted tabooed species in the forest edges at 2ha and 4ha sighting regimes with the least means of 14.28 respectively.

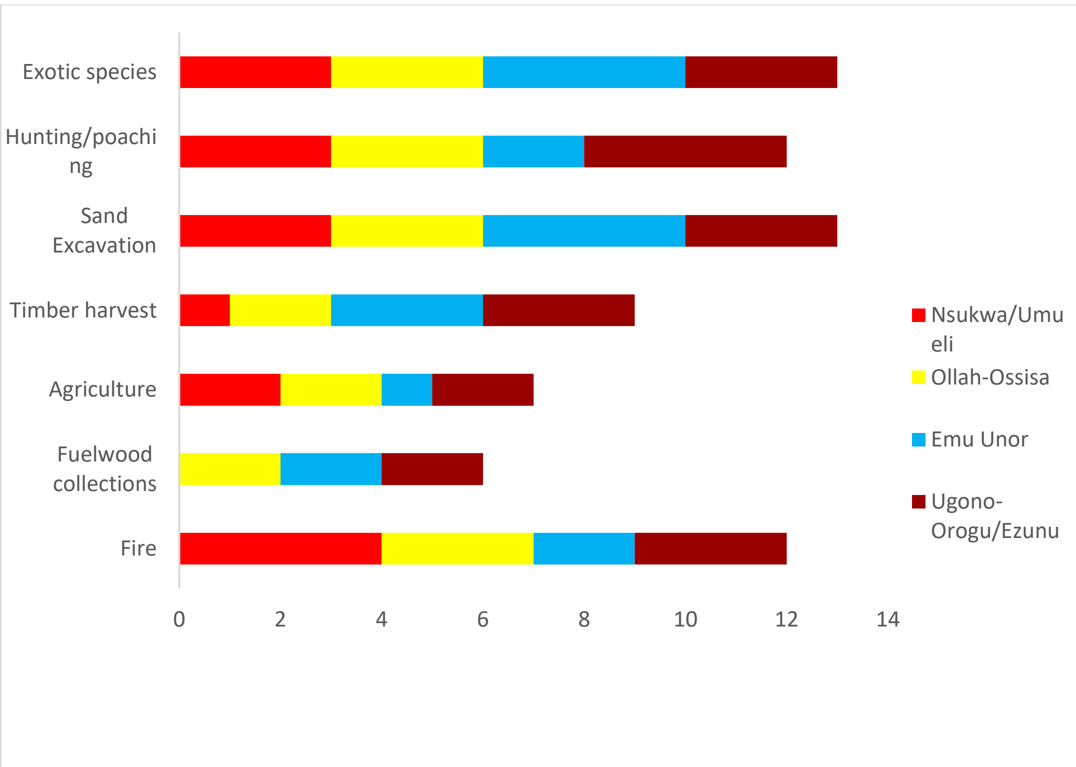
Table 2: Effect of habitat corridors and edges on distribution of tabooed species

Sighting Regime (ha)	Habitat Fragment	Umute-Nsukwa	Emu-Uno	Ugili-Ossisa	Ugono-Orogun
2.00	Edge	11.10[d]	9.99[e]	10.00[d]	14.28[d]
	Corridor	4.44[e]	13.32[d]	20.00[b]	19.04[c]
4.00	Edge	17.76[c]	19.98[c]	15.00[c]	14.28[d]
	Corridor	39.96[b]	33.30[a]	35.00 [a]	23.80[b]
6.00	Corridor	44.40[a]	23.31[b]	20.00[b]	38.08[a]

Means in the same column with the same superscript are not significantly different ($p > 0.05$)

Matrix of habitat and anthropogenic activities on conservation

The threats of anthropogenic activities in the communities are as depicted in Figure 1. It was Umute-Nsukwa > Ugili-Ossisa = Ugono-Orogun > Emu-Uno for fire. With respect to hunting and poaching for wildlife it was Ugono-Orogun > Ugili-Ossisa = Umute-Nsukwa = Emu Uno. Agriculture was Umute-Nsukwa = Ugili-Ossisa > Ugono-Orogun > Emu Uno while fuel-wood collection was Ugili-Ossisa = Emu Uno = Ugono-Orogun.



Evaluation of forest soil-habitat restoration potential

The forest soil habitat matrix for the various communities is shown (Table 3). The highest and least cation exchange capacity (CEC) of 18.30meq/100g soil and 5.25meq/100g soil at the forest edges was recorded in Ugono-Orogun and Umute-Nsukwa respectively. The forest corridors in Ugono-Orogun and Emu-Uno had CEC of 20.40 and 12.11meq/100gsoil respectively.

The highest and least Ca along forest edge habitat was recorded in Ugono-Orogun (13.50) and Umute-Nsukwa (2.43) while it was Ugili-Ossisa (16.52) and Emu-Uno (8.77) respectively at the corridors. Magnesium recorded the highest value along the forest edges at Umute-Nsukwa (1.83) and least (1.14) at Emu-Uno. The forest corridors had the highest Mg (2.83) at Ugono-Orogun and least (0.93) at Emu-Uno.

The Ca-Mg ratio along forest edges of communities was widest (10.23) and narrowest (1.33) at Ugono-Orogun and Umute-Nsukwa respectively. The available propagules were least (10.8kg/ha) and highest (18.50kg/ha) at Emu-Uno and Ugili-Ossisa respectively.

Table 3: Forest soil habitat matrix for restoration of degraded communities

Community	Habitat Fragment	CEC (Meq/100g soil)	Exc. Cations Ca^{2+}	Mg^{2+}	Ca/Mg ratio	Propagules available (Kg/ha)
Umute-Nsukwa	Edge	5.25	2.43	1.83	1.33	15.20
	Corridor	13.10	10.12	2.40	4.23	
Ugili-Ossisa	Edge	14.60	10.14	1.67	6.07	18.50
	Corridor	18.33	16.52	1.33	12.42	
Emu-Uno	Edge	11.20	5.63	1.14	4.94	10.80
	Corridor	12.11	8.77	0.93	9.43	
Ugono-Orogun	Edge	18.30	13.50	1.32	10.23	16.83
	Corridor	20.40	15.31	2.83	5.41	

DISCUSSIONS

Generally, the highest mean population of tabooed species in the various communities was sighted in the third sighting regime of 6ha. But in Ugili-Ossisa, there was no significant difference between the population of tabooed species sighted at first and third sighting regimes. This may probably be due to the existing grass-plain vegetation that is more homogenous with dotted trees species which allowed wider movement of species. Yet, this observation was also tied only to the corridor fragments. The populations of sighted species at the forest edge habitat fragments were generally low in all the communities. Perhaps as a result of the degradation often associated with forest edges due to deforestation (Putz *et al*, 2000).

Within each community habitat fragment, the corridors showed wider value except in Ugono-Orogun where it was reversed. Whereas between the two habitat fragments in each community, all forest corridors showed higher CEC and exchangeable cations as well as wider Ca-Mg ratio except in Ugono-Orogun. The higher CEC in corridors may not be unconnected with the richer nutrient capacities and compositions due to more remnant forest tree vegetation than in the edges of the same habitat in various communities. This is because forest litters represent potential sources of soil nutrient enrichment in forest ecosystem (McDonald, 2003) particularly for restoration of degraded habitat fragments. Forest litters at the edges of fragmented habitats provide nutrient for interaction with wildlife wastes for initiation of natural forest successions in less disturbed forests.

Furthermore, the nutrient retention capacities as expressed by the CEC and Ca/Mg ratio suggested the type of habitat grains in the different forest fragments. Higher nutrient retention capacity could typify luxuriant forest structure and fine-grained habitat patches compared to a more degraded coarse-grained fragments that loss nutrient both to the environment and internally due to downward leakages as a result of narrow Ca/Mg ratio. This finding is line with Asadu and Akamigbo (1990) that reported a correlation between soil nutrient retention and exchangeable cations in degraded forest ecosystems.

Although the forest edges showed lower values, the usual nutrient compensations form boundary corridors often serve as leeway for transfer of energy resources from medians especially by remnant wildlife population for restoration and regeneration activities. Consequently, the corridors in each fragmented habitat may have contributed to greater proportion of available propagules estimated in the different communities in view of restoration and succession. Ugili-Ossisa habitat with notably over two habitats had the highest propagules compared to the least in Emu-Uno probably as a result of heavy degradation and deforestation which has modified to accommodate agroforestry practices to the detriment of the root rhizosphere region (Dupuch and Fortin, 2013). Hence, the coarse-grained habitat in Emu-Uno represented the least with conservation potential among the communities proposed for selection as sites of special interest.

CONCLUSION

The four communities showed potential as conservation portfolios for White-throated monkey and dwarf crocodile with Umute-Nsukwa as the best for these tabooed and IUCN threatened species in Delta State. The various habitat fragments in the communities however revealed that Emu-Uno had the least characteristics to sustain viable population but with highest available propagules for habitat restoration and forest succession. The choice of conservation location within community is critical the survival of existing taboo species. The corridors demonstrated the most enriched and suitable habitat fragment for the possible erection of conservation portfolios in the respective communities. Consequently, all the communities have notable sites for conservation and should be adopted as Local sites of special scientific interests in the State for wider protection of biodiversity in Nigeria.

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REFERENCES

Akansanmi, F.A. (2006). Challenges of Forest production for economic development. Proceedings of the 31st Annual Conference of the Forest Association of Nigeria, Held in Makurdi, Benue State, Nigeria, 20-25th November, 2006.

Asadu, C.I.A. and Akamigbo, F.O.R. (1990). Soil Map of the World: 1:5 million Contributions of organic matter and clay fractions to cation exchange capacity of soils in South eastern Nigeria. Samaru Journal of Agricultural Research, 7: 17-23

Dike, M.C. (2002). Composition distribution and volumes of vascular plants in Nigerian strict Nature Resort. *Journal of Sustainable Agriculture and Environment*, 4(1): 139-145.

Dupuch, A. and Fortin, D. (2013). The extent of edge effects increases during post-harvesting forest succession. *Biological Conservation*, **162**, 9-16.

McDonald, M.A. (2003). The role of corridors in biodiversity conservation in production of landscapes: A Literature Review. *Tasforests*, 41-52.

Millenium Ecosystem Assessment (2005). *Ecosystem and human wellbeing: Synthesis*. Washington DC. Island Press

Odugbemi, T.O, Akinsulire, O.R., Aibinu, I. E. and Fabeku, P.O. (2017). Medicinal plants useful for malaria therapy in Okeigbo, Ondo State, Southwest Nigeria. *Afr. J. Trad. CAM* 4.2: 191-198

Oni, T.O. (2006). "Constraints to sustainable forest management in the south-western Nigeria". In: *The Proceedings of 31st Annual Conference of the Forestry Association of Nigeria (FAN) Held at Makurdi*, 20th-25th November. Pp. 295-302.

Onochie, C.F.A. (1984). What is wrong with Nigerian Forestry? In: Okoro, O.O and J.A. Fuwape (eds). *Conservation and Optimization of forest resources*. Proceedings of the 14th Annual Conference of the Forestry Association of Nigeria held in Port Harcourt, December 3-8,1984.

DIVERSITY OF FRUIT TREE SPECIES IN SITE II, DELTA STATE UNIVERSITY, ABRAKA, NIGERIA

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ABSTRACT

This study was carried out with a view of documenting the fruit tree species diversity in the site II of Delta State University, Abraka in May, 2021. Sampling for fruits diversity was carried out through direct observation within the study area. Photographs were taken to aid identification. Accurate taxonomic references were employed in the process of identification of the specimens collected. Percentage distribution of the fruit tree species and families encountered were documented. From the results of the study area surveyed, a total number of 20 fruit tree species belonging to 13 families were enumerated. The distribution of the fruits based on frequency of occurrence in the visible head count of fruit trees showed that the Indian almond fruit tree species (Terminalia catappa) is most dominant with approximately 90%, followed by the coconut species (Cocos nucifera) and oil palm fruit specie (Elaeis guineensis) with approximately 50%, banana (Musa acuminata), mango (Mangifera indica) and orange (Citrus sinensis) with approximately 30%, pawpaw (Carica papaya), Guava (Psidium guajava), and Lime (Citrus aurantiifolia) with approximately 15%. Others recorded very low species with 5% occurrence, respectively. The study showed that fruits are diverse in the premises of site II of Delta State University, Abraka. The species are important in the ecosystem function and services; hence activities which could lead to their depletion should be controlled.

Keywords: *Diversity, fruit tree species, Abraka, Delta State*

INTRODUCTION

Fruit, the fleshy or dry ripened ovary of a flowering plant, enclosing the seed or seeds. Thus, apricots, bananas, and grapes, as well as bean pods, corn grains, tomatoes, cucumbers, and (in their shells) acorns and almonds, are all technically fruits. Fruit crop production is thus of particular economic importance. In 2007, a total of about 500 millions of fruit crops (exclusive of melon) were produced in the world on approximately 47 million ha.

Fruits are very important components of the diet. Fruits are, in general, low in calories and fat but high in vitamins, minerals and dietary fibre (Turcotte, 2010). Fruits are generally considered to be high in dietary fibre, vitamin C and other certain vitamins. Fruits also contain various phytochemicals, which are required for proper long-term cellular health and disease prevention. Regular consumption of fruits is associated with reduced risks of cancer, cardiovascular disease (especially coronary heart disease), stroke, Alzheimer disease, cataracts, and some of the functional declines associated with aging (WHO, 2003). Vegetables are sources of many nutrients, especially potassium, folate, the antioxidant vitamins A and E, and dietary fibre. These nutrients support body function in many ways, which makes vegetables important components of a healthy diet. For example, potassium helps to maintain healthy blood pressure, folate (folic acid) helps with red blood cell production, vitamin A enhances immune function, and vitamin E protects cells from free radicals. Though vegetables are an excellent food source of vitamins A/beta-carotene and E, fruits offer more substantial amounts of other antioxidant nutrients like vitamin C. Vitamin C helps heal cuts and wounds and keeps teeth and gums healthy. It also aids in iron absorption, protects the body's cells from oxidative damage due to free radicals, and enhances immune system function (Turcotte, 2010; Agbogidi, 2019).

Fruits and vegetables play a significant role in human nutrition, especially as sources of vitamins C (ascorbic acid), A, thiamine (B1), niacin (B3), pyridoxine (B6), folacin (also known as folic acid or folate) (B9), E], minerals, and dietary fibre (Wargovich, 2000).Diets rich in fruits and vegetables have been shown to be correlated with positive health outcomes, including decreased cardiovascular disease risk, lowered risk for certain cancers (Temple and Gladwin, 2003), and lower body mass index (Charlton *et al*., 2014). A recent WHO/FAO expert consultation report on diet, nutrition and prevention of chronic diseases, sets population nutrient goals and recommends intake of a minimum of 400 g of fruits and vegetables (excluding potatoes and other starchy tubers) per day for the prevention of chronic diseases such as heart diseases, cancer, diabetes and obesity. The report states that there is convincing evidence that fruits and vegetables decrease the risk for obesity, and evidence that they probably decrease the risk of diabetes. Further, there is convincing evidence that fruit and vegetables lower the risk for Cardiovascular diseases (CVD), and also prevent and alleviate several micronutrient deficiencies, especially in less developed countries (WHO 2003). Overall, it is estimated that up to 2.7 million lives could potentially be saved each year if consumption of fruits and vegetables is sufficiently increased. Nutrition plays a very important role in the well-being of an adolescent. Nutritional needs during adolescence are increased because of the increased growth rate and changes in body composition associated with puberty (Spear, 2002; Jenkins and Horner, 2005). The dramatic increase in energy and nutrient requirements coincides with other factors that may affect adolescents' food choices and nutrient intake and thus, nutritional status. These factors, including the quest for independence and acceptance by peers, increased mobility, greater time spent at school and/or work activities, and preoccupation with self-image, contribute to the erratic and unhealthy eating behaviours that are common during adolescence (Spear, 2002).

Sound nutrition can play a role in the prevention of several chronic diseases, including obesity, coronary heart disease, certain types of cancer, stroke, and type 2 diabetes (WHO, 2003). To help prevent diet-related chronic diseases, it is proposed that healthy eating behaviours should be established in childhood and maintained during adolescence (Spear, 2002). The objective of this study is to document the diversity of fruit tree species in site II, Delta State University, Abraka with a view to encouraging their conservation, cultivation and consumption.

MATERIALS AND METHODS

The study was carried out in site II, Delta State University, Abraka, Nigeria. Abraka is a favourite destination for domestic and international tourism. It attracts numerous domestic and international tourists. Abraka's Rivotel is famous for its natural flowing spring water, and has recreational facilities for outdoor activities like canoeing, fishing, swimming, barbecue. Abraka has a tropical wet and dry season, with a lengthy wet season and relatively constant temperatures throughout the course of the year. Abraka's wet season runs from March through October, though August has somewhat of a lull in precipitation. This lull nearly divides the wet season into two different wet seasons. The remaining months form the city's dry season. Like a good portion of West Africa, Abraka experiences the harmattan between the months of November and February.

Abraka is located within latitudes 5°45`` and 5°50``N of the equator and longitude 6° and 6°15``E of the Greenwich meridian (Figure. 1). It has a tropical type of climate with mean temperature of 30°C and annual rainfall amount of 3,098 mm, and monthly rainfall amount ranging from 25.8 mm in December to 628.9 mm in September (Efe and Aruegodor, 2003).

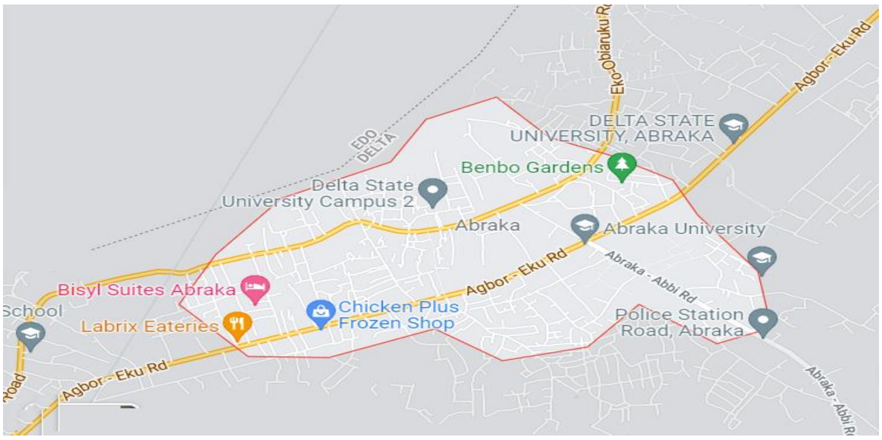

Figure 1: Map of Delta State University, Site 2, Abraka, Delta State
Source: Google Search engine

The study used random sampling design to conduct an inventory on the fruit tree species within site II campus of the University. Sampling was done along different paths, streets, walkways, residential areas, forested areas within the premises of site II, Delta State University, Abraka. The inventory was carried out by first mapping out locations accordingly to aid the research process. The sampling was conducted daily for a period of 1 week so as to cover the mapped out locations, sampling was majorly carried out in the morning so as to enable the researcher carry out sampling effectively before sunrise.

During the study, fruit bearing trees within the mapped out study areas were inventoried and recorded. Their details were entered into a field notebook and then samples of the fruit trees encountered were collected through documentation and photographs taken in order to authenticate their scientific names. Accurate taxonomic references were employed in the process of identification of the specimens collected. The number of fruit tress encountered were documented, the number of their occurrences also documented as well as their families.

The identification of fruit species was carried out using photographs of fruits trees. Identified fruit species were grouped into common names, botanical names and families and presented in Tables and Charts.

The species occurrence documented during the study were subjected to statistical analysis using the percentage (%) of occurrence by dividing the total number of a species by the total number of all species multiplied by a hundred.

Percentage (%) occurrence =

$$\frac{\text{number of a species}}{\text{Total number of all species}} \times 100$$

RESULTS AND DISCUSSION

The results of diversity of fruit species growing within site II premises of Delta State University, Abraka, Delta State are presented in Table 1. A total of 20 fruit tree species belonging to 13 families were encountered and recorded. The distribution of the fruit species based on frequency of occurrence in the visible head count of fruit trees showed that the Indian almond tree species *(Terminalia catappa)* is most dominant with approximately 90%, followed by coconut species (*Cocos nucifera*), and Oil palm fruit (*Elaeis guineensis*) with approximately 50%, Banana (*Musa acuminata*), Mango (*Mangifera indica*), Orange (*Citrus sinensis*) with approximately 30%, Pawpaw (*Carica papaya*), Guava (*Psidium guajava*), Lime (*Citrus aurantiifolia*) with approximately 15%, others including maize, okra and tomatoes recorded very low species with 5% occurrence, respectively (Figure 2).

Fruits are rich in fibre which is very essential for the smooth movement of the digestive system. There are some fruits that give body energy as they contain carbohydrates which is the main source of energy. Carbohydrate in fruits, are mainly sugar which actually breaks down easily and provides a quick source of energy. Fruits contain at least 90 to 95 percent water which is also an important nutrient. Basically, fruit benefits a healthy lifestyle by giving us carbohydrate, fibre and micro-nutrients which aid our bodies to function properly. Fruits give more energy than sugar or sweet as they contain natural glucose and fructose. It is advisable to grow more fruit trees around our environment to give us free access to enjoying nature at low cost. The frequency occurrence of fruit species in site II, DELSU, Abraka is presented in Figure 2.

Table 1: The fruit tree species enumerated in site II, Delta State University, Abraka.

Family	Botanical names	Common names
Anacardiaceae	*Mangifera indica*	Mango
	Anacardium occidentale	Cashew
Arecaceae	*Cocos nucifera*	Coconut
	Phoenix dactylifera	Date palm
	Elaeis guineensis	Oil palm
Caricaceae	*Carica papaya*	Pawpaw
Combretaceae	*Terminalia catappa*	Indian almond
Convolvulaceae	*Ipomoea batata*	Sweet potato
Cucurbitaceae	*Citrullus colocynthis*	Bitter apple
Malvaceae	*Abelmoschus esculentus*	Okra
	Theobroma cacao	Cocoa
Moraceae	*Ficus carica*	Fig
Musaceae	*Musa acuminata*	Banana
Myrtaceae	*Psidium guajava*	Guava
Poaceae	*Zea mays*	Corn
Rutaceae	*Citrus sinensis*	Orange
	Citrus aurantiifolia	Lime
	Citrus hystrix	Kaffir lime
Solanaceae	*Capsicum annum*	Pepper
	Solanum lycopersicum	Tomato

Field survey (2021)

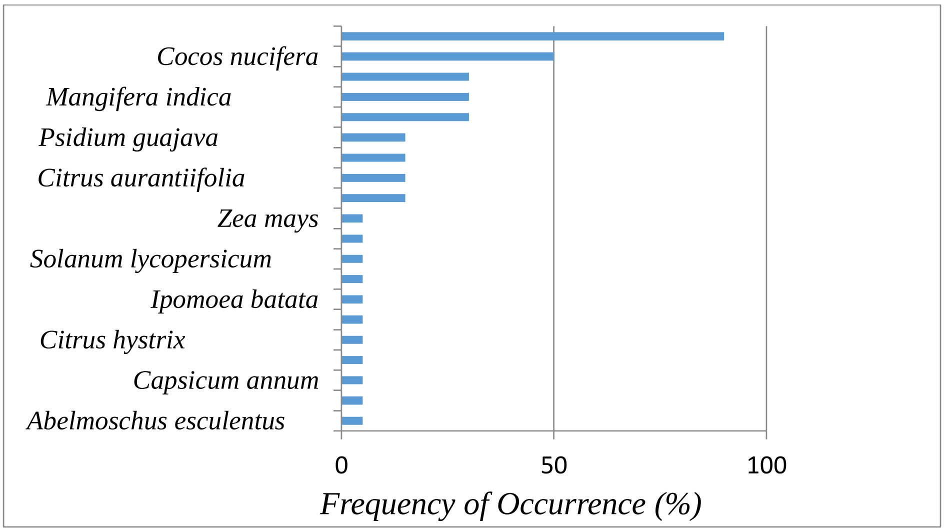

Figure 2: Frequency occurrence of fruit species in site 2, DELSU, Abraka

In general, fruit trees thrive best in well-drained soil with a sandy, loamy texture. If there's too much clay, or too many rocks, it can be difficult for a fruit tree to flourish. Soils that are lacking in nutrients also make it challenging for fruit trees to produce tasty, juicy fruit. Fruit trees also need lots of fertilizer, all year long. It helps them to yield more fruit. In fact, it is a good idea to add fertilizer to fruit tree containers on a monthly basis, unless you opt for a slow-release fertilizer. In this instance, new fertilizer is added at least every three months.

The almond fruit (*Terminalia catappa*) which is the most frequent occurring fruit species in the study area, plays an important role in controlling the economy of a huge nation like India. As much as the contributions to your life, they also stays and provides shade through-out our lifetime. They contribute every inch of their life, to become more useful to us. From giving a highly nutritious edible seed, providing landscape, construction and furniture materials, fibre, coir, medicinal contents, oils, tonics, beverage ingredients, and all the way to making even dye, facewash, masticatories, sweeteners, edible flowers, thickeners, stimulants, diversify habitats outside their roles in carbon sequestration (Agbogidi, 2019; Agbogidi *et al.*, 2022).

CONCLUSION

These fruits tree species should be conserved and more planted. The fruits should be included in our daily diets for a healthy living. Also, they should be cultivated and sustainably used to perpetuate their species.

REFERENCE

Agbogidi, O. M. (2019). Ecosystem services and management for better life. 80th in the series of inaugural lectures of the Delta State University, Abraka, Nigeria delivered on the 10th October 2019. 96p.

Agbogidi, O. M., Enujeke, C. E., Odume, C. S., Agbogidi, O.M. and Odibo, O. J. (2022). Ethnobotanical uses of plants by the Ijaw people in Patani, Delta State, Nigeria. *World Journal of Pharmaceutical and Life Sciences*, **8** (1): 60-67

Charlton, K., Kowal, P., Sorano, M., Williams, S., and Banks, E. (2014). Fruit and vegetable intake and body mass index in a large sample of middle-aged Australian men and women. *Nutrients*. 6 (6): 2305-2319.

Efe, S. I. and Aruegodore, P. (2003). Aspect of microclimates in Nigerian Rural Environment: The Abraka Experience. *Nigeria Journal of Research and Production*, **2** (3): 48-57.

International Agency for Research on Cancer (2003). IARC Handbooks of Cancer Prevention. Vol 8: Fruits and Vegetables. Lyon, IARC Press.

Jenkins, S. and Horner, S. (2005). Barriers that influence eating behaviors in adolescents. *Journal of Pediatric Nursing.* 20:258.

Spear, B.A. (2002). Adolescent growth and development. *Journal of American Dietetic Association* 102: 523-530.

Temple, N.J. and Gladwin, K.K. (2003). Fruit, vegetables and the prevention of cancer: research challenges. *Nutrition.* 19: 467-470.

Turcotte, M. (2010). Nutrition facts on fruits and vegetables. United States Department of Agriculture. 2011.Mushrooms classified under "Other vegetables‖. Retrieved June 2, 2011 from http:// www. choosemyplate.gov/food groups/vegetables. Html U.S. Department of Agriculture. 2005. Dietary Guidelines for Americans, Center for Nutrition Policy and Promotion.

W.H.O (2003). Diet, nutrition and the prevention of chronic diseases. Report of a Joint FAO/WHO Expert Consultation. Geneva, (WHO Technical ReportSeries, No.916).

Wargovich, M. (2000). Anticancer properties of fruits and vegetables. *Horticultural Science*. 3 (5):573-575.

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INFLUENCE OF AGRICULTURAL EXPANSION ON FOREST DEGRADATION AND DEFORESTATION IN OYO STATE, NIGERIA

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ABSTRACT

Despite the crucial importance of forests, large expanse of forest areas in the tropics are converted to agricultural lands every year. We assessed the influence of agricultural expansion on deforestation and degradation in Oyo state, using remote sensing and Geographic Information Systems (GIS) technique. The extent of change of seven forest reserves in Oyo state between 1984 and 2020 was determined. Landsat 5 TM 1984, Landsat 7 ETM+ 2000, Landsat 8 OLI/TC 2013 and Landsat 8 OLI/TC 2020 satellite images were analysed using ArcGIS version 10.3. After the processing and classification of imageries, a total of six (6) land-use and land-cover classes were distinguished, viz: forest, plantation, farmland, bare land, and built-up area and water bodies. The study revealed that of about 330,441 ha of Oyo State's forest reserves, only about 18% is presently covered by natural forest, resulting in the loss of over 29,000 ha of forested area in 1984 and 2020. The study also revealed that the most damage was done to Ijaiye forest reserve, in which about one-fourth (25%) of the total land area has been converted to farmland. Between 1984 and 2020, the forested areas in forest reserves in Oyo state have reduced by about 35%, while agricultural land has increased by an outrageous 12%. The study recommends that all degraded parts of the reserve be restored and rehabilitated without further delay. Strict measures should be placed on protecting the reserves from intruders, and joint forest management should be considered in partnership with the boundary communities to ensure a reasonable conservation effort.

***Keywords**: Deforestation, Degradation, Remote Sensing and GIS, Satellite images, Land-use and Land-cover, Agricultural land.*

INTRODUCTION

Forests contribute significantly to the delivery of measurable and immeasurable goods and services that benefits man in the form of provision (e.g. food), regulation (e.g. climate control), support (e.g. nutrient cycling) and cultural (e.g. recreation). Regardless of the crucial importance of forests, each year, large expanse of forested lands are converted to non-forestry land use, especially agriculture (FAO, 2015).

Forest degradation and deforestation are two similar but different terms. Degradation is defined by FAO (2015) as "the reduction of the capacity of a forest to provide goods and services", while deforestation is generally regarded as the reduction in forested areas by converting forest land to other land uses. Forest degradation and deforestation affect structure, composition and diversity, carbon stocks, functionality and ecosystem processes (Gao *et al*., 2020). Since trees are generally seen as obstacles to most developmental projects and land uses other than forestry, deforestation and degradation have become significant challenges facing forests today.

Nigeria had a population of approximately 140 million in 2006, and the estimated population by the National Population Commission for 2016 was about 193 million at an annual population growth rate of 3.2% (National Bureau of Statistics (NBS), 2017). These facts and figures imply that more resources would be needed for humankind's survival, which would pressure natural resources, especially forest resources. By implication, more forests would be converted to agricultural lands, more trees would be cut down for construction works, and more poachers would be around protected areas to kill animals, especially in countries where forest laws and policies are obsolete. According to Akpan-Ebe (2017), overexploitation, agricultural expansion, urbanization, illegal logging, cash crop farming, encroachment, and infrastructural development has damaged almost 60% of the original forest reserve area. This is also corroborated by a report from the World Bank (2018) that the forest estate in Nigeria was about 19% of its landmass in 1990 but has drastically reduced to about 9% in 2018. This fact has also been stressed by Eboh and Ujah (2003) and Alamu and Agbeja (2011).

Mere visual analysis cannot tell how much forest has been lost in any location over the years. Foresters in developing countries have mainly depended on inventory to estimate the amount of forest lost over the years. Unfortunately, inventory activities are primarily frustrated by the lack of funds to conduct repeated inventory exercises. One of the options available for researchers to assess forest loss now is the use of Geographic Information System (GIS) and remote sensing technique. GIS is basically designed to manipulate spatial information. Therefore, satellite remote sensing and GIS have been deemed practical tools in detecting changes in land activities and land cover (Ehlers *et al*., 1990).

Literature (Adedeji *et al*., 2015; Soneye *et al*., 2017; Babatunde *et al*., 2020; Phillips and Ceesay, 2020) have shown that anthropogenic factors especially farming activities, are the major drivers of deforestation and degradation in Oyo state. However, there is a dearth of information on the extent of these activities and their threats to the protected areas in Oyo state. Therefore, there is a need to provide relevant information and evaluate changes to these protected areas to support subsequent management plans.

MATERIALS AND METHODS

Study area

Oyo State is one of the states in the southwestern part of Nigeria, with Ibadan as its capital. It is bounded in the north by Kwara State, in the east by Osun State, in the south by Ogun State, and in the west partly by Ogun State and partly by the Republic of Benin. It is situated between latitudes 7°8'30"N and 9°8'30"N and longitudes 2°29'30"E and 4°32'30"E and has a landmass of about 26,500 km^2 (NBS, 2010).

Table 1: Distribution of the forest reserves in the study

S/N	Forest reserve	Domicile area	Size (ha)
1	Onigambari	Oluyole	13747.68
2	Olasehinde	Iseyin	15980.04
3	Ijaiye	Akinyele	24564.15
4	Lanlate	Ibarapa East	10515.87
5	Igangan	Ibarapa North	39125.52
6	Olokemeji	Ibarapa East	5022.45
7	Osho	Ido	3600.00

Source: Jaiyesimi (2012); Alo (2017); Hastrup *et al*. (2020)

Satellite data

Path and rows of 191 and 054, 055 were used in this study. Acquisition dates of the multi-temporal satellite data of different sensors Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+), and Operational Land Imager (OLI/TC) scenes employed in the change detection process fall within the same season. All sensors have a spatial resolution of 30m with a projection type of transverse Mercator. All images acquired were of same season which falls between October and December in other to maintain consistency throughout the classification process.

Image analysis

The image classification was done using Isocluster unsupervised classification. It was used to classify the land-use types using false colour composite; the image was then reclassified into five classes suited for the study.

Trend analysis

$$Change\ in\ LULC = L_2 - L_1 \ldots\ldots(1)$$

Where; L_2= final year and L_1= initial year

Land-use classification

The land-use types in the study are are categorized into five, comprising water, built-up farmlands and forest as presented and described in Table 2.

Table 2: Description of the different land-use in the study

LULC	Description
Forest	This comprises the natural forest vegetation of the area and secondary forest and other vegetation association such as shrubs.
Plantation	This comprises areas dominated by tree stands (indigenous or exotic) in the study area raised artificially.
Farmland/bare surface	This includes lands for permanent crops, pastures, and heterogeneous agricultural areas. It also includes areas with bare ground surface and rock.
Built-up	Areas loosely covered by houses, roads and other buildings.
Water	Areas with natural or artificial, permanent or temporal water whether flowing or static.

RESULTS

In Onigambari forest reserve, plantation accounted for 12.81% in 1984, 9.71% in 2000, 21.62% in 2013 and 17.38% in 2020. However, there was an increase in farmland between 1984 and 2000 but a reduction between 2013 and 2020. The trend analysis showed that water bodies reduced by 7.63% between 1984 and 2000, 0.71% between 2000 and 2013 and 3.67% between 2013 and 2020. However, built-up areas reduced (-13.78%) between 2000 and 2013 as opposed to a +12.57% increase between 1984 and 2000 (Table 3).

In Olaseinde forest reserve, forests accounted for much of land cover in 2013 and 2020, which was a gain from what was observed in 1984 and 2002. Plantation increased by 1.36% and 5.70% between 1984-2000 and 2013-2020. Farmland/bare surface reduced throughout the period with the most negligible reduction (-2.50%) in 1984-2000 and the highest reduction rate (-7.62%) in 2013-2020. Built-up increased throughout the analysis, while water bodies only increased by 8.84% in 1894-2000 (Table 4).

In Ijaiye forest reserve, forest covered about 48.30% in 1984, 36.85% in 2000, 41.31% in 2013 and 40.56% in 2020. There was an increase in plantation (28.32%) in 1984-2000 and a reduction (-19.64%) in 2000-2013, and a further increase (27.18%) in 2013-2020. Bare land only increased in 2000-2013 as against increase in other periods (1984-2000 and 2000-2013), while farmland decreased by -0.33% in 2000-2013 (Table 5).

In Lanlate forest reserve, plantation accounted for the most significant percentage of land cover in 2013, while forested areas accounted for the most significant percentage in 2020. Plantation increased by 1.36% and 5.70% between 1984-2000 and 2013-2020. Bare surface increased by 11.30% in 2013-2020 as against -5.38% and 26.70% recorded in 1984-2000 and 2000-2013, respectively. However, farmland reduced by 3.46% in 2000-2013 and increased by 1.98% and 2.91% in 1984-2000and 2013-2020, respectively (Table 6).

In the Igangan forest reserve, bare land accounted for the most significant land cover throughout the analysis. Forest cover was 13.76% in 1984 and increased to 25.14% and 31.58% in 2000 and 2013, respectively. It, however, reduced to 17.19% in 2020. Plantation increased by -5.71% in 1984-2000 and increased by 7.31% and

12.97% in 2000-2013 and 2013-2020, respectively. Farmland, however, increased by 0.78% in 1984-2000, decreased by 0.23% in 2000-2013 and decreased by -0-01% in 2013-2020 (Table 7).

In Olokemeji forest reserve, forest covered about 21.89% in 1984, 14.93% in 2000, 46.54% in 2013 and 20.03% in 2020. There was an increase in plantation (8.44%) in 1984-2000 and a reduction (-3.89%) in 2000-2013, and a further increase (14.29%) in 2013-2020. Bare land only decreased in 2000-2013 as against increase in other periods (1984-2000 and 2013-2020). Farmland decreased by -0.56% and -2.47% in 1984-2000 and 2013-2020, respectively. However, water bodies decreased (-3.57%) between 1984-2000, increased by 1.59% in 2000-2013 and further reduced by 4.24% in 2013-2020 (Table 8).

In Osho forest reserve, forest accounted for 37.89% in 1984, 41.89% in 2000, 30.85% in 2013 and decreased to 10.03% in 2020. Plantation and bare surface recorded about 5.69% and 46.04%, respectively, in 1984. However, in 2020, plantations increased to 46.86 while bare surface decreased to 35.59%. Farmland increased by 1.21% and 5.13% between 1984-2002 and 2002-2013, respectively (Table 9).

Table 3: Land use and land cover changes in Onigambari Forest Reserve from 1984 to 2020

Year	**1984**		**2000**		**2013**		**2020**	
LULC	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%
Forest	6591.24	47.94	6266.79	45.58	5481.90	39.88	7034.13	51.17
Plantation	1760.49	12.81	1334.70	9.71	2972.70	21.62	2388.96	17.38
Farmland/Bare land	2729.07	19.85	2800.44	20.37	3938.22	28.65	1803.87	13.12
Built-up	515.61	3.75	2243.43	16.32	349.65	2.54	2019.87	14.69
Water	2151.27	15.65	1102.32	8.02	1005.21	7.31	500.85	3.64
Total	13747.68	100.00	13747.68	100.00	13747.68	100.00	13747.68	100.00

Table 4: Land use and land cover changes in Olasehinde Forest Reserve from 1984 to 2020

Year	**1984**		**2000**		**2013**		**2020**	
LULC	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%
Forest	7770.78	48.63	6164.10	38.57	8263.17	51.71	8016.93	50.17
Plantation	2267.91	14.19	2484.54	15.55	2217.96	13.88	3128.49	19.58
Farmland/Bare land	4786.74	29.95	4386.87	27.45	3961.53	24.79	2744.01	17.17
Built-up	448.11	2.80	825.66	5.17	854.37	5.35	1512.36	9.46
Water	706.50	4.42	2118.87	13.26	683.01	4.27	578.25	3.62
Total	15980.04	100.00	15980.04	100.00	15980.04	100.00	15980.04	100.00

Table 5: Land use and land cover changes in Ijaiye Forest Reserve from 1984 to 2020

Year	**1984**		**2000**		**2013**		**2020**	
LULC	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%
Forest	11864.16	48.30	9054.36	36.86	10146.51	41.31	9962.01	40.56
Plantation	1674.00	6.81	8630.55	35.13	3805.83	15.49	10483.38	42.68
Bare land	10334.79	42.07	5797.80	23.60	9611.28	39.13	3091.68	12.59
Farmland	691.20	2.81	1081.44	4.40	1000.53	4.07	1027.08	4.18
Total	24564.15	100.00	24564.15	100.00	24564.15	100.00	24564.15	100.00

Table 6: Land use and land cover changes in Lanlate Forest Reserve from 1984 to 2020

Year	**1984**		**2000**		**2013**		**2020**	
LULC	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%

Forest	3544.47	33.71	3128.49	29.75	2930.58	27.87	5344.11	50.82
Plantation	1899.36	18.06	2673.36	25.42	6042.87	57.46	2135.07	20.30
Bare land	4496.58	42.76	3930.48	37.38	1122.39	10.67	2310.66	21.97
Farmland	575.46	5.47	783.54	7.45	420.03	3.99	726.03	6.90
Total	10515.87	100.00	10515.87	100.00	10515.87	100.00	10515.87	100.00

Table 7: Land use and land cover changes in Igangan Forest Reserve from 1984 to 2020

Year	**1984**		**2000**		**2013**		**2020**	
LULC	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%
Forest	5383.53	13.76	9835.74	25.14	12354.21	31.58	6726.51	17.19
Plantation	9469.44	24.20	7235.28	18.49	10094.58	25.80	15169.68	38.77
Bare land	22753.89	58.16	20231.37	51.71	14944.23	38.20	15501.96	39.62
Farmland	1518.66	3.88	1823.13	4.66	1732.50	4.43	1727.37	4.41
Total	39125.52	100.00	39125.52	100.00	39125.52	100.00	39125.52	100.00

Table 8: Land use and land cover changes in Olokemeji Forest Reserve from 1984 to 2020

Year	**1984**		**2000**		**2013**		**2020**	
LULC	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%
Forest	1099.53	21.89	749.61	14.93	2337.48	46.54	1005.75	20.03
Plantation	1003.32	19.98	1432.89	28.53	1237.32	24.64	1952.82	38.88
Bare land	2141.28	42.63	2269.26	45.18	622.17	12.39	1575.45	31.37
Farmland	230.85	4.60	202.68	4.04	377.73	7.52	253.71	5.05
Water	547.47	10.90	368.01	7.33	447.75	8.91	234.72	4.67
Total	5022.45	100.00	5022.45	100.00	5022.45	100.00	5022.45	100.00

Table 9: Land use and land cover changes in Osho Forest Reserve from 1984 to 2020

Year	**1984**		**2000**		**2013**		**2020**	
LULC	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%
Forest	1244.25	37.89	1375.74	41.89	1013.31	30.85	329.49	10.03
Plantation	187.11	5.69	215.55	6.56	746.91	22.74	1539	46.86
Bare land	1511.91	46.04	1312.38	39.96	975.06	29.69	1168.65	35.59
Farmland	340.38	10.38	379.98	11.59	548.37	16.72	246.51	7.52
Total	3283.65	100.00	3283.65	100.00	3283.65	100.00	3283.65	100.00

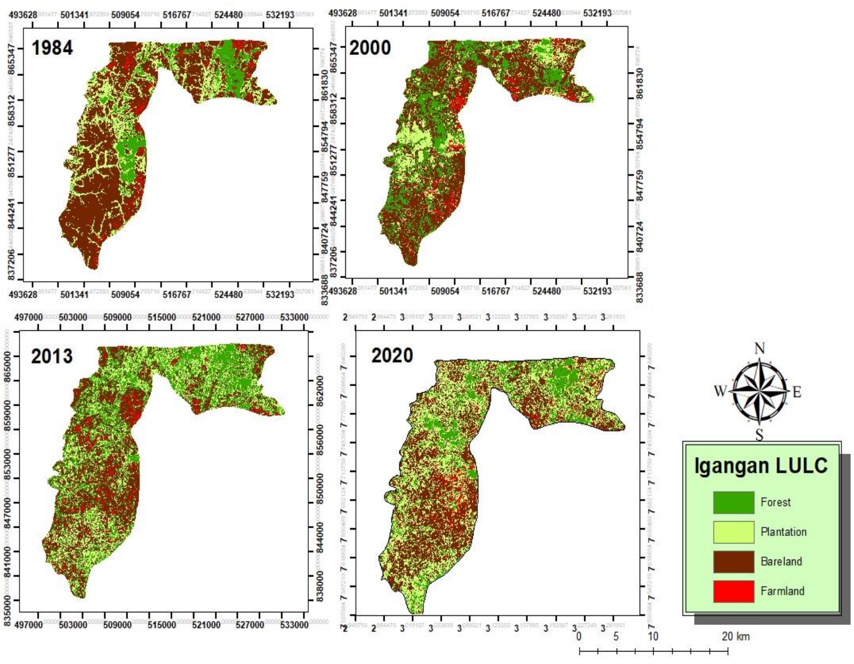

Figure 1: LULC change in Igangan Forest Reserve between 1984 and 2020

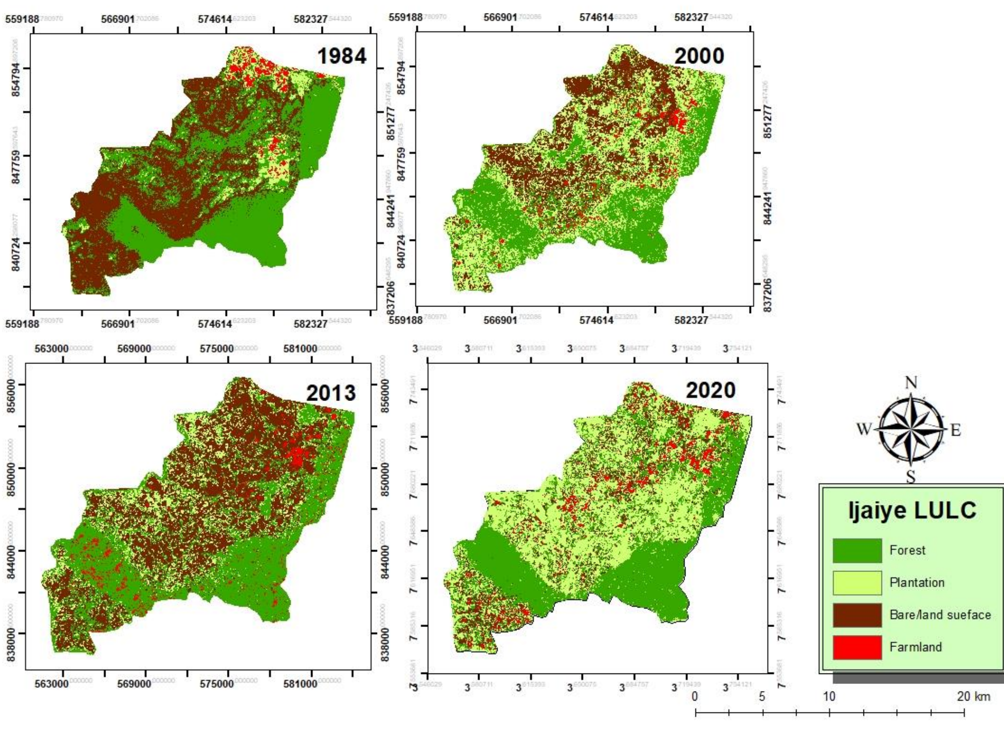

Figure 2: LULC change in Ijaiye Forest Reserve between 1984 and 2020

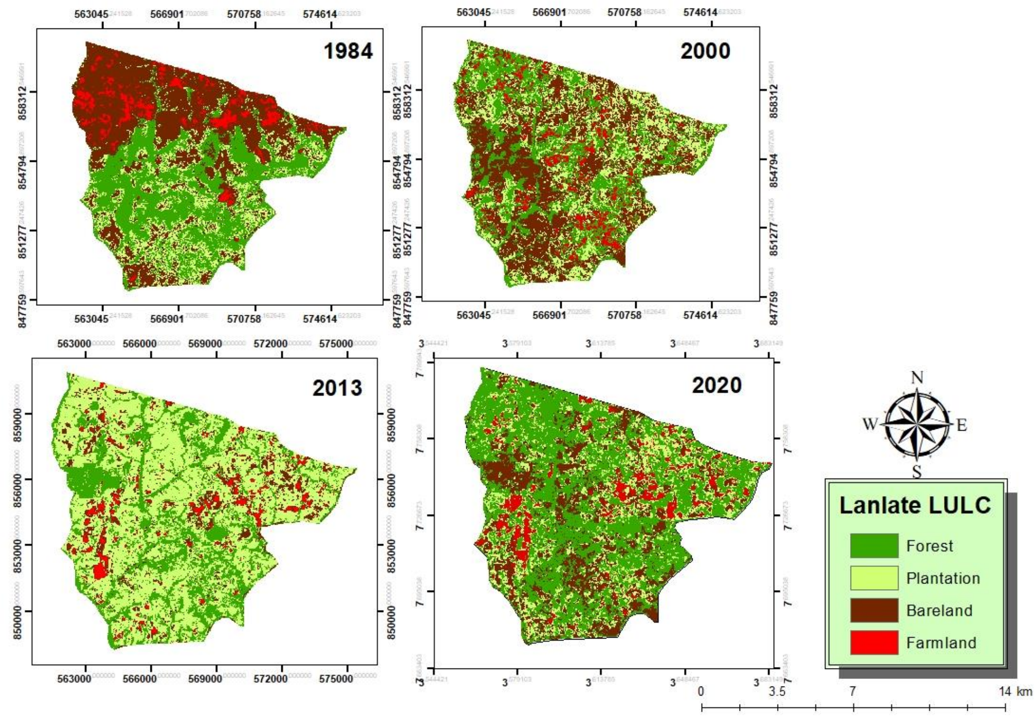

Figure 3: LULC change in Lanlate Forest Reserve between 1984 and 2020

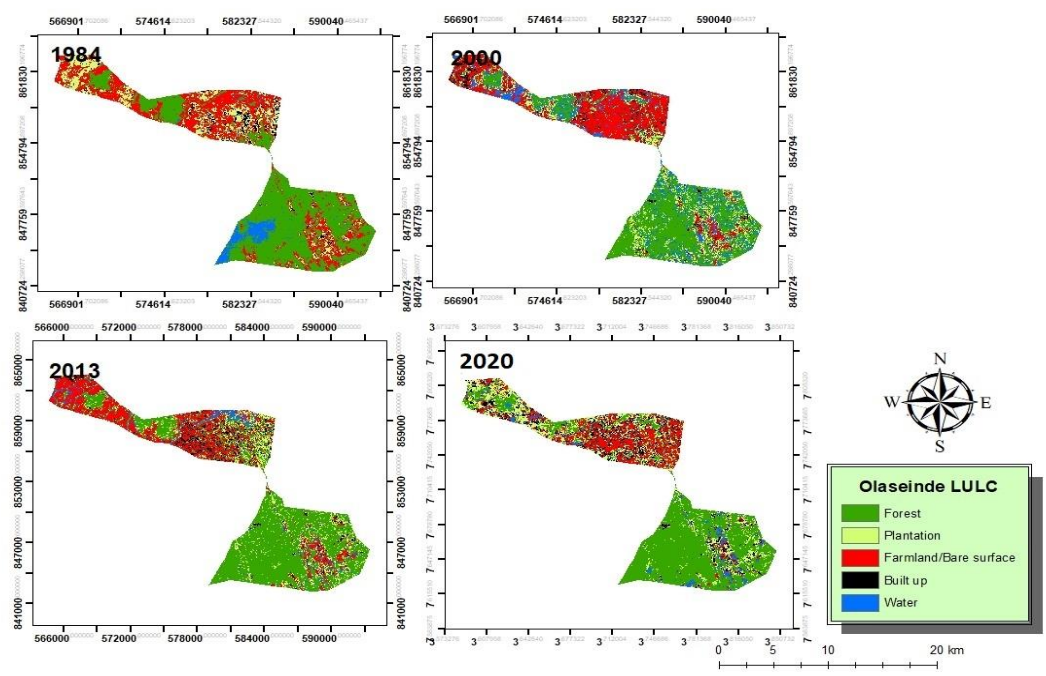

Figure 4: LULC change in Olaseinde Forest Reserve between 1984 and 2020

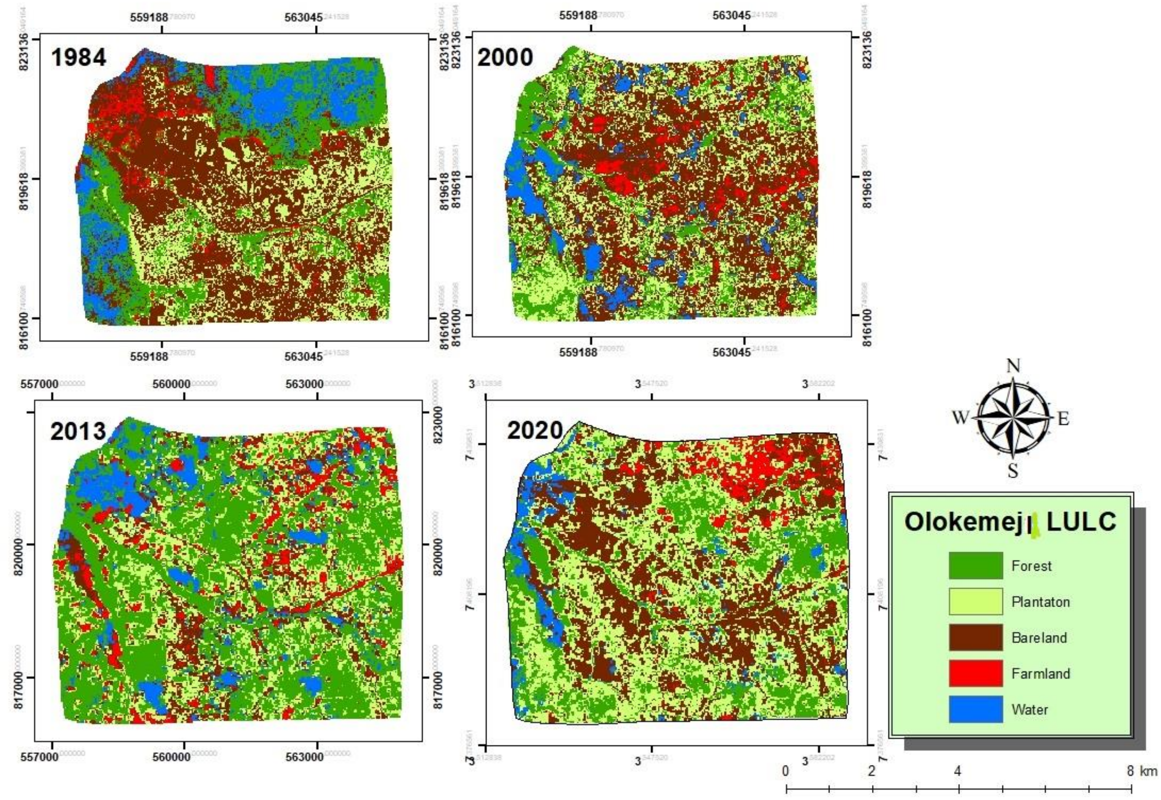

Figure 5: LULC change in Olokemeji Forest Reserve between 1984 and 2020

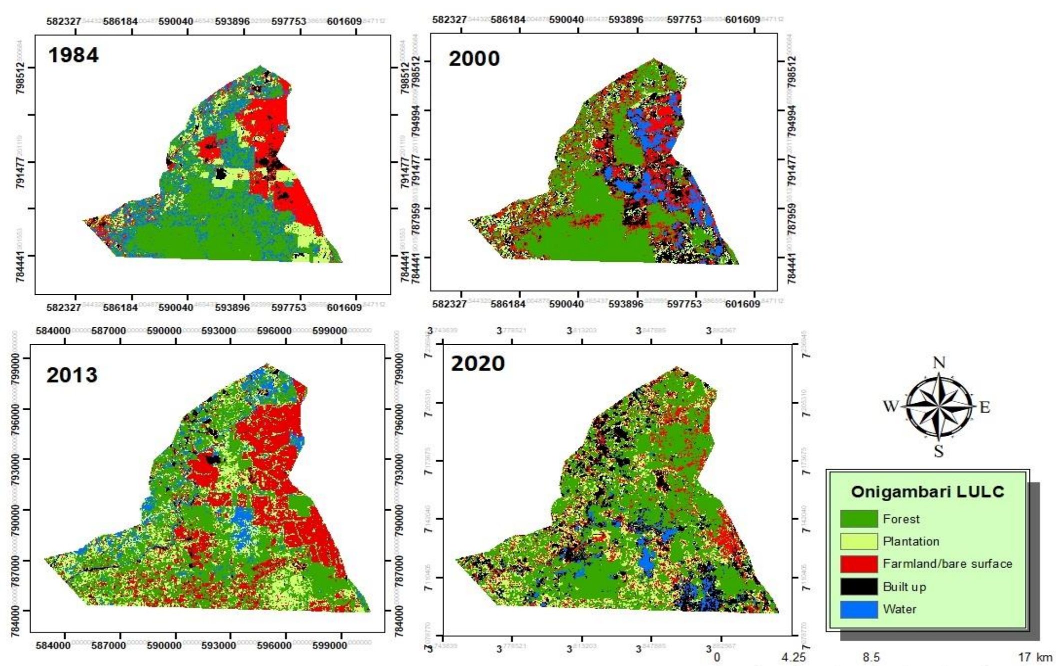

Figure 6: LULC change in Onigambari Forest Reserve between 1984 and 2020

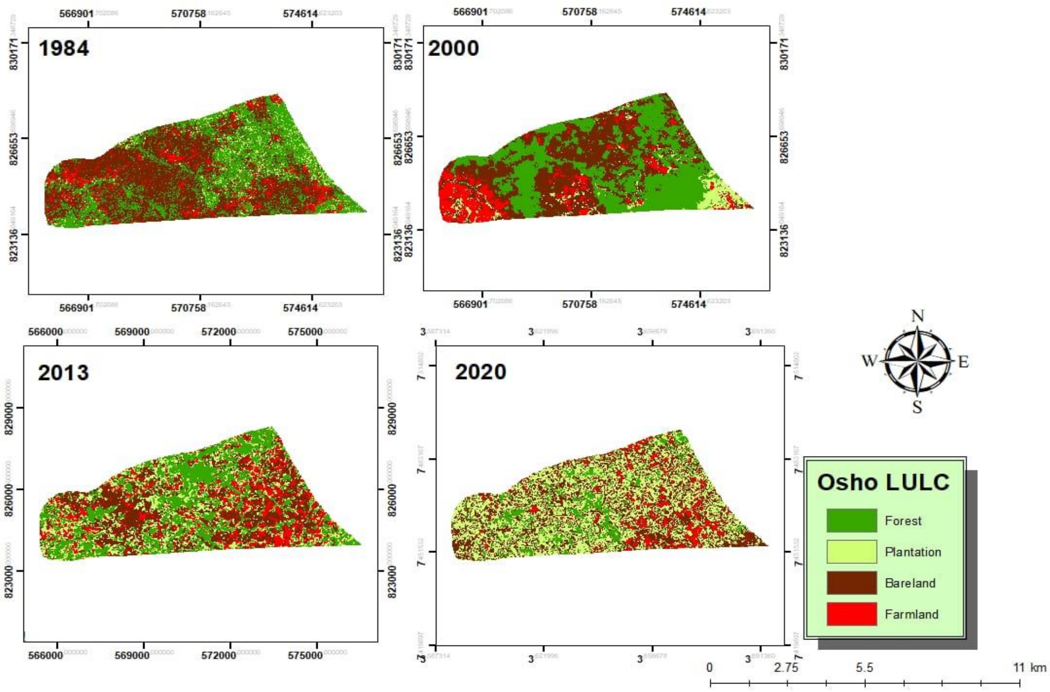

Figure 7: LULC change in Osho Forest Reserve between 1984 and 2020

DISCUSSION

Of the total land area (approximately 330,441 ha) covered by forest reserves in Oyo state, only 18% is predominantly covered by natural forest. This implies that, according to this study, within 32 years (i.e., study period), there has been a loss of more than 29,000 ha of forested area. These figures do not come as a surprise because of a report from the world bank (2018) that the forest estate in Nigeria in 1990 was about 19% of its landmass, compared to 2018 with about 7% of the total landmass.

Agricultural expansion is largely responsible for the damages in the forested areas in Oyo state. For example, Onigambari Forest reserve, with about 13,747.68 ha total landmass, had approximately 6,591.24 ha forested area and 2,729.07 ha of agricultural land/bare land in 1984. In 2000, the forested areas decreased by -2.36%, while farmland increased by 0.52%. The forested area also drastically reduced by -5.71% in 2013, while agricultural lands increased by a whopping 8.28%. However, the matter changed in 2020 probably because of several conservation efforts in the forest reserve (Haastrup *et al*., 2020); forested areas increased by 11.29%, while agricultural lands decreased by -15.53%. According to Adedeji *et al*. (2015), a large expanse of forested regions of Onigambari was lost due to overexploitation and other land uses, including agricultural land use within 30 years. The significant drivers of land-use change in Onigambari forest, aside from agricultural expansion, include rising demand for timber products and closeness of the forest reserve to major cities, where timber is in high demand. Another factor is the fact that the forest reserve is well-connected by excellent and easily accessible roads (Adedeji *et al.*, 2015).

Out of all the forest reserves, Ijaiye recorded the most damage due to agricultural expansion. About one-fourth (25%) of the land area has been converted to farmland; about 12% has been converted to buildings, and about 5% to infrastructural development. If the trend in Ijaiye forest reserve continues unrestrained, the trees in the forest reserve may only last for about 15 years before they are removed (Phillips and Ceesay, 2020). Given the amount of tree cover remaining and the rate of illegal harvesting in Ijaiye forest reserve, it can be concluded that the management of the reserve is far from sustainability, and all these are in a bid to expand agricultural lands (Phillips and Ceesay, 2020).

Overall, between 1984 and 2020, the forested forest reserves in Oyo state have reduced by a whopping 35%, while agricultural land has increased by an outrageous 12%. This could be attributed to a host of factors such as population increase, outdated forest laws, lack of sensitization on biodiversity conservation, among others. Jaiyesimi *et al*. (2012) further stressed that large-scale encroachments, conversion of forest land to non-forestry uses and ineffective implementation of forest policies and legislation have all hampered sustainable management of the forest reserves.

CONCLUSION AND RECOMMENDATION

The study showed that all the forest reserves changed significantly in composition and configuration over the past 36 years. Agricultural expansion contributed substantially to the loss of forest cover in all the forest reserves, with Ijaiye forest reserve being the most pronounced. The study also predicted that forest cover would continue to decline in all the forest reserves if the rate of deforestation and degradation remains unchecked.

Based on the findings of this study, the following recommendations are made:

i. the state government should enforce laws protecting the forest reserves and take proper measures against whoever violates the laws.
ii. all degraded forest reserves should be rehabilitated and restored without further delay.
iii. the government should place strict measures on the forestry sector in Oyo state, such as placing a ban on the exploitation of species used mainly for charcoal, just as it was done in Kwara State.
iv. joint forest management should be considered in partnership with the boundary communities to ensure reasonable conservation effort.

REFERENCES

Adedeji, O.H., Tope-Ajayi, O.O. and Abegunde, O.L. (2015). Assessing and Predicting Changes in the Status of Gambari Forest Reserve, Nigeria Using Remote Sensing and GIS Techniques. *Journal of Geographic Information System* 7: 301-318.

Akpan-Ebe, I.N. (2017). Restoration in Nigeria: History, Current Practice and Future Perspectives. *Reforesta* 3: 105-115.

Alamu and Agbeja (2011). Deforestation and Endangered Indigenous Tree Species in South- West Nigeria. *International Journal of Biodiversity and Conservation* 3(7): 291-297.

Alo, A.A (2017). Spatial Distribution of Forest Reserves and Sawmills in Oyo State, Nigeria. *Forests and Forest Products Journal* 10: 60-72.

Babatunde, T. O., Babatunde, O. O, Okeleke, S. O., Aduloju, A.R. and Agboola, F. O. (2020). Assessment of Commercial Importance and Determinant Factors Influencing Collection of Non-Timber Forest Products in Adjoining Communities of Lanlate Forest Reserve of Oyo State, Nigeria. *Journal of Research in Forestry, Wildlife and Environment* 12(1): 62- 69.

Eboh, E. C. and Ujah, O. C. (2003). Measurement of Sustainability Indicators of Forests in Nigeria: A case study of forest reserves in Enugu State, Nigeria. Retrieved from http://EconPapers.repec.org/RePEc:wpa:wuwpot:0508011 on 28th of July, 2021.

Ehlers, M, Jadkowski, M. A., Howard, R.R. and Brostuen, D.E. (1990). Application of SPOT Data for Regional Growth Analysis and Local Planning. *Photogrammetric Engineering and Remote sensing* 56 175-180.

FAO (2015). Retrieved from www.fao.org/forestry/sfm/85084/en on 17th of July, 2021.

Gao, Y., Skutsch, M., Paneque-Galvez, J. and Ghilardi, A. (2020). Remote Sensing of Forest Degradation: A Review. *Environmental Research Letters* 15(10): 1-18.

Haastrup, N.O., Ayodele, A.A., Fadoyin, A.S., Sangotoyinbo, O.A., Olatunji, O.A. and Agboje, I. (2020). Perception Towards Forest Resources Utilization among Enclaves in Onigambari Forest Reserve, Oyo State. *International journal of research and innovation in applied science* 5(7): 108-111.

Jaiyesimi M. A., F.A., Adekanbi D.I., Akankuku A.I. and Obafunsho O. E. (2012). Forest Conservation Policy: The Role of State Forestry Department in Oyo State. *Continental Journal of Agricultural Science* 6(3): 1-7.

National Bureau of Statistics (NBS) (2017). Demographic Statistics Bulletin for Nigeria. Pp 26.

National Bureau of Statistics (NBS) (2010). Annual Abstracts of Statistics. Pp 611.

Phillips, F.C. and Ceesay, E.K. (2020). Livelihood Dependence and Forest Reserve Management in Ijaiye Forest Reserve, Oyo State, Nigeria. *International Journal of Forestry and Horticulture* 6(2): 26-39.

Soneye, A. Balogun, I. and Daramola, A. (2017). Impacts of Agriculture and Biomass Energy Production on Forest Conversion: The Case of Igangan Forest Reserve of Ibarapa Region, South-West Nigeria. *Unilag Journal of Humanities* 4(2): 110-122.

World Bank (2018). *Forest Law*: Manual for Sustainable Development, Washington, DC.

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GROWTH AND YIELD RESPONSE OF UPLAND RICE CULTIVARS TO WATER DEFICIT CONDITION AT DIFFERENT GROWTH STAGES ON SANDY LOAM SOIL IN IBADAN

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ABSTRACT
Drought is a major abiotic constraint in upland rice field, causing severe yield loss of more than 50%. Southwestern Nigeria, which covers almost 30% upland rice fields are purely rainfed and rainfed farming is no longer reliable due to fluctuation in rainfall pattern and volume causing drought in rice field. The need to understand response of upland rice cultivars to moisture deficit at different phenological stages is important to device appropriate drought management strategy in upland rice field. Information on response of upland rice cultivars to water deficit condition at different growth stages is scanty. Therefore, response of 12 upland rice cultivars (URC) to water deficit condition at tillering, panicle initiation and grain filling on sandy loam was investigated. The study was a 4x12 factorial, arranged in a completely randomized design with six replicates was conducted in screenhouse during the early and late dry seasons of 2018 in Ibadan. Treatments included twelve URC: OFADA, IGBIMO, FARO-16, FARO-44, FARO-60, IR-64, APO, NERICA-4, NERICA-5, NERICA-7, NERICA-8 and VANDANA, water stressed at tillering, Panicle Initiation (PI) and Grain Filling (GF) and Well-Watered Soil (WWS served as control). Three weeks old rice seedling was transplanted into pot containing 5 kg soil. Data were collected on plant height (cm), leaf area (cm^2), number of tillers, dry matter and yield components. Data were analyzed using analysis of variance (ANOVA) and means separated with LSD ($p<0.05$). APO cultivars had significantly tallest plant (99.42 and 113.18) at 6 and 12 WAT, while OFADA was tallest (143.26) at 9 WAT. IR-64 cultivar had highest number of tillers (3.17, 3.75 and 4.17) at tillering, PI and GF, respectively than other cultivars. The highest unfilled grain weight (1.67 g) was recorded in IR-64. FARO-60 had the highest dry root (2.26 g), shoot (6.33 g) and total biomass (9.05 g) which were significantly higher than other cultivars. VANDANA had higher filled grain (3.71g) and grain weight (3.93 g) than other cultivars. Drought stress reduced growth and yield of upland rice cultivars severely at tillering and panicle initiation stages than at grain filling stage. Growth of APO was significantly similar to OFADA while, VANDANA had the highest grain yield relative to other cultivars.

Keywords: Drought, yield components, upland rice cultivars, growth and biomass yield

INTRODUCTION

Rice forms a major part of the Nigerian diet and most populations in developing countries (Sakariyawo *et al*., 2013). Harfold, (2011) reported that rice consumption in Nigeria is higher than that of any other staple crops due to increase in population, rapid urbanization and changing eating habits. Nigeria relied on importation to meet the increasing rice demand. Rice importation profile of Nigeria stands at approximately 3 MT annually, whereas local production stands at 2 MT (FAO, 2017). Similarly, Uduma et al (2016) noted that the inability of local supply to meet up with rice demand has given rise to the high importation of rice in Nigeria.

Studies have shown that biotic and abiotic stresses are the major constraints affecting rice production (Ismaila *et al.,* 2010). Water deficit is an abiotic factor affecting arable crops particularly rice production in Nigeria (Dada *et al.*, 2018). It causes stomata closure (Santos and Carlesso, 1998), and other metabolic processes that limit normal growth and development (Jalal *et al*., 2012). Rice crop have been reported to be susceptible to drought stress which causes yield loss in rice field (Pantuwan *et al.,* 2002). However, some varieties have been reported to be tolerant than others, out-yielding those subjected to the same level of drought (Dada *et al.,* 2018).

Plant tolerance to drought is generally complex due to interactions between factors causing damage and various physiological responses within the plant (Manivannan *et al*., 2008). An adequate understanding of rice response to water deficit is required to select the most appropriate varieties tolerant of this abiotic limitation in order to increase rice productivity. Timing, duration, severity, and stage of exposure have roles in determining how plants respond to water deficit. Other factors include stage of plant development (Singh *et al*., 2012).

Screening for drought tolerant varieties and determining the growth stage(s) at which water deficit is most detrimental to rice plant development is necessary to evolve appropriate drought mitigation approach that could be deployed for improving yield of upland rice. Equally, identification and selection of varieties with high level of tolerance to drought for further breeding programme is expedient for improving upland rice production.

More information is however, needed on morphological response of upland rice cultivars to drought stress at different stages of growth. This is necessary to adequately determine the stage at which rice plant is most likely to be affected by water deficit condition. Therefore, the aim of this study was to investigate the response of twelve upland rice cultivars to water deficit condition at various growth stages in Ibadan, southwestern Nigeria.

MATERIALS AND METHODS

Study site

The study was a pot experiment, carried out between 2018-2019 in the screen house of the Department of Crop Protection and Environmental Biology, Faculty of Agriculture, University of Ibadan, Nigeria (7°.45′E; 3°.89′N, 227m above sea level). The ambient temperature of the screen house was 32-40°C while the relative humidity was 66-85% and the average precipitation during the trial was1260 mm.

Soil collection and analysis

The soil was collected from a field at University of Ibadan Teaching and Research Farm. Prior to transplanting, routine soil analysis were performed following standard analytical methods described by IITA (1979).

Sources of rice seeds

Twelve upland rice cultivars were investigated to establish their responses to drought. These included nine commonly cultivated lines: OFADA, IGBIMO, FARO-16, FARO-60, FARO-44, NERICA-4, NERICA-5, NERICA-7, NERICA-8, were collected from rice farmers during preliminary filed survey in southwestern, Nigeria while IR-64, VANDANA and APO were collected from Africa Rice Center (WARDA), Nigeria sub-station, located at the International Institute of Tropical Agriculture (IITA), Ibadan.

Nursery and transplanting

The seeds of the cultivars were raised in nursery beds for two weeks after which they were transplanted to the prepared pots each, filled with 5 kg soil. One vigorous seedling with three fully formed leaves was transplanted per pot.

Treatments and experimental design

There were 48 treatments derived from combination of twelve upland rice cultivars and phenology at which water stress was imposed: tillering, panicle initiation and grain filling while, treatment without imposition of water stress served as the control. The treatments were arranged in completely randomized design (CRD) and replicated six times. A total of 288 pots were used. A repeat trial was carried out following same procedures employed in the first trial. All cultural practices were applied as appropriate.

Imposition of water stress

Prior to imposition of water stress, transplanted seedlings were adequately nurtured for two weeks to ensure that they were well established and all have uniform development. Drought was imposed at active tillering for 14 days only, while drought was imposed for ten days each at panicle initiation and grain filling stages.

Water stress treatment was imposed twice at tillering at seven days interval. In this treatment, irrigation was withheld for seven consecutive days till the 8th day when plants were irrigated to field capacity with 600 mL water representing 100% of water required to attain field capacity. Field capacity was determined following the method of Saxton and Rawls (2006). At the 9th day, water stress treatment resumed for another seven days. Other plant sets, not subjected to water stress continued to receive water when soil moisture was low with 300 mL water representing 50% of water required to attain field capacity. Drought was imposed at panicle initiation and grain filling each for ten days at five days intervals. Whenever the stressed plants were to be unstressed after drought treatments, they were irrigated with 600 mL and subsequently with 300 mL based on soil moisture level test carried out, usually every other day till harvest.

Data collection

Data were collected after the plants had been water stressed for a specific period of time based on the treatment. Morphological parameters such as plant height (cm), numbers of tillers, leaf area, panicle initiation, grain filling and dry matter accumulation.

Soil moisture content determination

The moisture level was monitored daily at 9:00 hour and 15:00 hour by probing the moisture sensor at the center of the pots at 8-9 cm depth using the soil moisture meter (LMS-714) before and after irrigation.

Data Analysis

Data were analyzed using analysis of variance (ANOVA) of Statistical Analysis System (SAS, 2000) and different means were separated by Least Significant Difference (LSD) at $p \leq 0.05$.

RESULTS

Effect of water deficit condition stages on the vegetative growth of upland rice cultivars at different growth

Generally, imposition of drought at all the growth stages had no significant effect on the height of the plants, however the plants were taller at grain filling than any other growth stage (Table 1). The height of the different rice cultivars differed significantly in response to water limiting conditions. Cultivar APO had the tallest height which was statistically similar to IGBIMO, NERICA-7 and IGBIMO all through the growing periods except at 9 Weeks After Transplanting (WAT) when OFADA had the tallest height. NERICA-8 had the shortest plant height all through the sampling period. The interaction between the two factors showed that water deficit condition had no significant influence on height of upland rice cultivars at 6 WAT. However, these factors had significant influence on the height of upland rice cultivars at 9 and 12 WAT (Table 1).

Water stress imposition across the growth phases had significant effect on the leaf area of upland rice cultivars. Plants stressed at tillering and panicle initiation had reduced leaf area than plants water stressed at grain filling stage (Table 2). The upland rice cultivars responded differently to imposition of drought at varying growth stages. Cultivar APO had the highest leaf area (68.84 cm^2) at 8 WAT which was statistically similar to IGBIMO, OFADA and NERICA-7 cultivars. At10 WAT NERICA-7 had the highest leaf area (71.53 cm^2) which was not statically different from IGBIMO, OFADA and APO, but differs from other cultivars. At 12 WAT, NERICA-5 leaf area was highest among the cultivars (63.93 cm^2). The interaction between varieties and growth stages had no significant influence on leaf area of upland rice cultivars at 8 WAT. However, these factors affected leaf area if the crop significantly at 10 and 12 WAT (Table 2).

Water stress imposition had no significant effect on tiller formation at the phenological stages when drought was imposed on the crop. However, drought had significant effect on numbers of tillers produced by the different rice cultivars. IR-64 had the highest number of tillers (3.17, 3.75 and 4.17) which was significantly similar to number of tiller produced by FARO-44 and FARO-60 but differs from other cultivars. NERICA-4 recorded the lowest number of tillers across the growth phases (Table 3). The interaction shows that growth period and varieties had no significant influence on number of tillers at 6 and 12 WAT except at 9 WAT when these factors significantly influenced number of tillers formed (Table 3).

Table 1: Plant height of upland rice cultivars under water deficit condition at different growth stages

	Weeks after transplanting								
	6			9			12		
	Year 1	**Year 2**	**Mean**	**Year 1**	**Year 2**	**Mean**	**Year 1**	**Year 2**	**Mean**
Stage of drought imposition(GS)									
Tillering	77.93a	92.19a	83.69a	81.51a	100.45a	92.41a	94.71ab	90.01a	91.43a
Panicle initiation	73.91a	94.40a	83.32a	85.07a	98.28a	90.94a	87.24b	94.38a	90.31a
Grain filling	78.92a	99.89a	88.44a	91.69a	134.21a	110.94a	96.04a	98.37a	96.82a
Control	73.68a	97.26a	89.90a	87.51a	100.09a	92.55a	91.73ab	101.39a	95.31a
LSD (p≤0.05)	**6.35**	**7.62**	**5.56**	**7.58**	**43.72**	**20.56**	**8.54**	**11.82**	**10.94**
Cultivars (CUL)									
NERICA-4	75.53b-d	81.04e	78.29cd	81.08bc	89.08b	85.08b	83.27cd	81.62d	82.44ef
NERICA-5	67.13d	86.78de	76.95cd	83.34bc	96.31b	89.83b	90.28b-d	94.67a-d	92.47b-e
NERICA-7	89.58a	99.88a-d	94.73ab	103.60a	111.14b	107.37ab	106.57a	94.06b-d	100.31ab
NERICA-8	67.56d	77.04e	67.56d	74.86c	80.01b	74.86b	77.58d	79.61d	77.58f
FARO-16	66.03d	87.12de	76.57cd	71.54c	93.87b	82.70b	79.11d	89.84b-d	84.48d-f
FARO-44	64.75d	88.01de	76.38cd	75.97c	92.98b	84.47b	77.93d	94.90a-d	86.42c-f
FARO-60	73.15cd	99.33b-e	84.24bc	93.12ab	101.48b	97.34b	99.90ab	97.48a-d	98.69bc
APO	88.77a	110.07a	99.42a	103.98a	114.73b	109.35ab	112.13a	114.22a	113.18a
IGBIMO	88.63a	109.03a	98.83a	100.86a	111.98b	106.42ab	105.66a	101.50a-c	103.58a
IR-64	65.28d	90.08c-e	77.68cd	76.27c	92.68b	84.48b	78.82d	84.00cd	81.43ef
OFADA	82.63a-c	106.12ab	94.37ab	92.48ab	194.04a	143.26a	100.56ab	108.86ab	104.71ab
VANDANA	84.29ab	101.82a-c	93.05ab	98.17a	92.57b	95.37b	97.40a-c	95.23a-d	96.31b-d
LSD (p≤0.05)	**11.28**	**13.51**	**9.63**	**13.87**	**72.36**	**31.61**	**15.23**	**19.60**	**12.01**
Interaction									
GS x CUL	ns	ns	ns	ns	*	*	ns	*	*

GS= Drought imposition stage, CUL = Cultivars, LSD = Least Significant Difference at p≤0.05

Table 2: Leaf area (cm²) of upland rice cultivars under water deficit condition at different growth stages

	Weeks after transplanting								
	6			9			12		
	Year 1	**Year 2**	**Mean**	**Year 1**	**Year 2**	**Mean**	**Year 1**	**Year 2**	**Mean**
Stage of drought imposition (GS)									
Tillering	44.68a	58.50ab	50.33ab	53.37ab	57.89b	54.48b	56.79ab	41.29b	48.39ab
Panicle initiation	40.02a	53.92b	48.25b	48.36b	56.29b	52.35b	48.78b	43.48ab	46.50b
Grain filling	47.28a	67.29a	56.38a	59.92a	53.86a	61.25a	69.16a	48.14ab	54.72a
Control	45.31a	68.78a	55.42a	54.61ab	60.55b	53.63b	54.87ab	50.48a	52.46ab
LSD (p≤0.05)	**6.92a**	**10.57**	**6.51**	**8.95**	**7.69**	**6.14**	**11.37**	**8.67**	**7.27**
Cultivars (CUL)									
NERICA-4	40.59cd	0.67e	46.34cd	48.51cd	0.92d	45.03e	44.38de	0.67e	40.78c
NERICA-5	46.28a-d	0.83ed	56.46abc	55.68bcd	0.83d	55.65b-e	70.29ab	0.83ed	63.93a
NERICA-7	57.94a	2.17bc	67.55a	73.88a	2.25abc	71.53a	73.72a	1.42cde	44.86bc
NERICA-8	38.04d	0.60e	38.04d	52.82bcd	0.82d	52.82cde	43.23de	0.57e	43.23c
FARO-16	36.11d	2.58ab	44.11cd	42.63de	2.67abc	50.50de	45.17cde	2.42abc	44.86bc
FARO-44	40.59bd	3.58a	48.23cd	50.49bcd	3.25a	55.69b-e	53.78bcd	3.42a	56.89ab
FARO-60	44.03bcd	2.42bc	53.36bc	60.93abc	2.75abc	60.75a-d	64.08abc	2.83ab	58.18ab
APO	57.43a	1.83bcd	68.84a	73.35a	1.75cd	69.38a	68.68ab	1.83bcd	57.70ab
IGBIMO	56.30ab	1.75bcd	62.78ab	64.65ab	2.00bc	65.55ab	69.07ab	1.83bcd	57.48ab
IR-64	35.73d	2.42bc	44.62cd	40.51de	2.92ab	46.60e	43.16de	2.83ab	39.51cd
OFADA	52.23abc	2.42bc	63.17ab	54.53bcd	1.83cd	63.15abc	59.06a-d	1.83bcd	58.78ab
VANDANA	40.40cd	1.50cde	37.64d	30.75e	2.42abc	28.40f	30.18e	1.25ed	27.40d
LSD (p≤0.05)	**12.3**	**1.07**	**11.28**	**15.59**	**1.02**	**10.64**	**19.85**	**1.01**	**12.59**
Interaction									
GS x CUL	ns	ns	ns	*	*	*	*	*	*

GS= Drought imposition stage, CUL = Cultivars, LSD = Least Significant Difference at p≤0.05

Table 3: Number of tillers formed by upland rice cultivars under water deficit condition at different growth stages

	Weeks after transplanting								
	6			9			12		
	Year 1	Year 2	Mean	Year 1	Year 2	Mean	Year 1	Year 2	Mean
Stage of drought imposition (GS)									
Tillering	1.11a	1.91a	1.43a	1.16a	1.94a	1.55a	2.86ab	1.94a	2.40a
Panicle initiation	1.42a	1.82a	1.54a	2.17a	2.33a	2.25a	2.25b	2.12a	2.19a
Grain filling	1.56a	1.88a	1.68a	2.25a	1.91a	2.08a	3.22a	1.82a	2.52a
Control	1.25a	2.45a	1.75a	2.08a	2.39a	2.24a	2.89ab	2.16a	2.53a
LSD (p≤0.05)	**0.59**	**0.64**	**1.97**	**0.76**	**0.62**	**0.47**	**0.92**	**0.61**	**0.57**
Cultivars (CUL)									
NERICA-4	0.17e	0.67e	0.42d	0.92ef	0.92d	0.92de	1.50e	0.67e	1.08f
NERICA-5	0.33e	0.83ed	0.58d	1.00def	0.83d	0.92de	1.33e	0.83ed	1.08f
NERICA-7	1.67de	2.17bc	1.67bc	1.58c-f	2.25abc	1.92c	2.25cde	1.42cde	1.83ef
NERICA-8	0.25e	0.60e	0.25d	0.58f	0.81d	0.58e	1.92de	0.60e	1.92def
FARO-16	1.4dc	2.58ab	2.00bc	2.25bcd	2.67abc	2.46bc	3.56bc	2.42abc	3.00bcd
FARO-44	2.5ab	2.42bc	2.46ab	3.42ab	2.92ab	3.17ab	4.17ab	3.42a	3.79ab
FARO-60	2.45abc	2.42bc	2.42ab	3.42ab	2.75abc	3.08ab	4.17ab	2.83ab	3.50abc
APO	1.50bcd	1.83bcd	1.67bc	2.5bc	1.75cd	2.13c	3.17bcd	1.83bcd	2.50cde
IGBIMO	1.50bcd	1.75bcd	1.63bc	1.50c-f	2.00bc	1.75cd	1.78ed	1.83bcd	1.79ef
IR-64	2.75a	3.58a	3.17a	4.25a	3.25a	3.75a	5.50a	2.83ab	4.17a
OFADA	0.50de	2.42bc	1.46c	1.75c-f	1.83cd	1.79cd	1.17e	1.83bcd	2.21def
VANDANA	1.50bcd	1.50cde	1.50c	1.92cde	2.42abc	2.17c	3.17bcd	1.25ed	2.21def
LSD (p≤0.05)	**1.06**	**1.07**	**0.74**	**1.39**	**1.02**	**0.82**	**1.65**	**1.01**	**0.99**
Interaction									
GS x CUL	ns	ns	ns	ns	*	*	*	ns	ns

GS= Drought imposition stage, CUL= Cultivars, LSD = Least Significant Difference at p≤0.05

Effect of water deficit condition on yield and yield components of upland rice cultivars at different growth stage

The result of yield components of upland rice cultivars as influenced by water deficit condition is presented in (Table 4). Water deficit condition had significant influence on yield component all through the growth stages. Imposition of drought at tillering, panicle initiation and grain filling reduced number of panicles formed by 30.3%, 25.2% and 20.5% respectively, relative to well-watered plants. Similarly, the control plants had the highest panicle number (2.34), weight (2.40 g) and number of spikelet (11.75) than other treatment.

VANDANA had the highest number of panicle (2.88 g) which was significantly higher than other varieties. Weight of panicle was highest (2.84 g) in FARO-60 while IR-64 had highest number of spikelets (13.30). The interaction between the two factors showed that number of panicles and spikelets were not significantly influenced by growth stages and varieties. However, these factors had significant effect on weight of panicle (Table 4).

There was significant effect on yield and yield components of upland rice cultivars (Table 5), as control plants had highest value of filled grain and grain weight (3.32 and g) which was significantly different from other growth stages. Filled grain, unfilled grain and grain weight of the different rice cultivars differed significantly in response to water limiting conditions. VANDANA had the highest value of filled grain and grain weight (3.71 g) which was statistically different from other cultivars all through the growing periods. IR-64 had highest value of unfilled grain weight (1.67) which was statically similar to NERICA-8 cultivar but differ from other cultivars. Interaction among the two factors varieties and growth stages: had significant effect on yield and yield components of upland rice cultivars as shown in (Table 5).

Effect of water deficit condition on dry matter accumulation of upland rice cultivars at different growth stage

There was no significant difference among the growth phases as regards dry matter accumulation by upland rice cultivars as shown in Table 6. The response of different upland rice cultivars to water deficit condition however differed significantly. FARO-60 had the highest dry matter partitioned into the root (2.26 g) which was statistically different from NERICA-4, NERICA-8 and VANDANA cultivars but similar to others cultivars. FARO-60 had the highest dry matter partitioned into the shoot and total biomass (6.33 and 9.05 g) than other cultivars. The interaction between growth stages and varieties had significant influence on dry matter accumulation of shoot and total biomass upland rice cultivars except dry root weight that was not significantly influenced by these factors (Table 6).

Table 4: Yield components of twelve upland rice cultivars at different growth stages under water deficit condition

	Number of panicle			Weight of panicle (g)			Number of spikelets		
	Year 1	**Year 2**	**Mean**	**Year 1**	**Year 2**	**Mean**	**Year 1**	**Year 2**	**Mean**
Stage of drought imposition (GS)									
Tillering	1.67a	1.88b	1.75b	1.93a	1.73bc	1.83b	6.36a	9.30cb	7.69b
Panicle initiation	1.86a	1.42b	1.63b	2.21a	1.34c	1.78b	6.78a	7.83c	7.19b
Grain filling	1.78a	1.91b	1.86b	1.76a	2.31ab	2.02ab	6.00a	12.70b	9.35ab
Control	1.92a	2.67a	2.34a	2.45a	2.73a	2.40a	7.67a	16.94a	11.75a
LSD (p≤0.05)	**0.45**	**0.50**	**0.33**	**0.61**	**0.70**	**0.46**	**2.56**	**3.58**	**2.37**
Cultivars (CUL)									
NERICA-4	1.58cd	1.5ed	1.54c	2.06a-e	1.32d	1.69b	8.17bc	10.92ab	9.54abc
NERICA-5	1.33d	1.5ed	1.42c	2.78a	1.59bcd	2.18ab	8.53bc	11.33ab	9.96abc
NERICA-7	2.17bc	1.25e	1.71bc	2.71ab	1.46d	2.08ab	5.58dc	8.42b	7.00c
NERICA-8	1.50cd	1.00e	1.50c	1.65cde	0.59dc	1.61b	6.83dc	4.00b	6.83c
FARO-16	1.67cd	2.08bcd	1.88bc	1.43de	2.72ab	2.07ab	6.42dc	12.67ab	9.54abc
FARO-44	1.75bcd	2.83ab	2.29ab	1.70b-e	2.65abc	2.18ab	2.58d	16.75a	9.67abc
FARO-60	1.92bcd	2.00cde	1.96bc	2.40a-d	3.29a	2.84a	4.92dc	11.42ab	8.17bc
APO	1.25d	2.00cde	1.63c	1.01e	2.00bcd	1.51b	2.67d	11.50ab	7.08c
IGBIMO	1.33d	1.67ed	1.50c	2.07a-e	1.67bcd	1.87b	3.67d	11.92ab	7.79bc
IR-64	1.75bcd	2.50abc	2.71a	2.57abc	2.31a-d	2.55ab	11.50ab	15.12a	13.30a
OFADA	1.42cd	1.42ed	1.42c	2.02a-e	1.54dc	1.78b	5.75dc	7.42b	6.58c
VANDANA	3.25a	2.92a	2.88a	1.78a-e	1.75bcd	1.76b	13.75a	11.17ab	12.46ab
LSD (p≤0.05)	**0.78**	**0.82**	**0.58**	**1.05**	**1.16**	**0.80**	**4.42**	**5.94**	**4.11**
Interaction									
GS x CUL	ns	*	ns	ns	*	*	*	*	ns

GS= Drought imposition stage, CUL = Cultivars, LSD = Least Significant Difference at p≤0.05

Table 5: Yield and yield components of twelve upland rice cultivars at different growth stages under water deficit condition

	Filled Grain WT			Unfilled Grain WT			Grain WT		
	Year 1	**Year 2**	**Mean**	**Year 1**	**Year 2**	**Mean**	**Year 1**	**Year 2**	**Mean**
DIP									
Tillering	1.23b	0.91b	1.07b	1.61a	0.50b	1.06a	2.63ab	1.59b	2.10b
Panicle initiation	0.98b	0.97b	0.98b	1.37a	0.70ab	1.04a	2.29ab	1.67b	2.03b
Grain filling	1.08b	0.93b	1.01b	1.30a	0.92a	1.11a	2.12b	1.89b	2.15b
Control	2.99a	3.64a	3.32a	0.16b	0.00c	0.08b	3.08a	3.76a	3.35a
LSD (p≤0.05)	**0.57**	**0.66**	**0.45**	**0.52**	**0.31**	**0.32**	**0.82**	**0.92**	**0.64**
Cultivars (CUL)									
NERICA-4	2.62b	1.78ab	2.11cb	0.92abc	0.21cd	0.56cd	3.20bc	1.88ab	2.55bcd
NERICA-5	2.67b	1.92ab	2.29b	1.30abc	0.32cd	0.81bcd	3.58b	1.77b	2.68bc
NERICA-7	1.23cd	1.55ab	1.39cde	1.67abc	0.23cd	0.70bcd	2.28b-e	1.76b	2.02bcd
NERICA-8	1.48c	0.70b	1.48b-e	1.23abc	0.85ab	1.23ab	1.00e	2.40ab	2.68bc
FARO-16	0.65cd	1.59ab	1.21de	1.67abc	0.65bc	0.91bcd	1.78de	2.24ab	2.01bcd
FARO-44	0.68cd	1.63ab	1.16de	1.27abc	0.83ab	1.05bc	1.95cde	2.45ab	2.00bcd
FARO-60	0.70cd	1.28ab	0.99de	1.51ab	0.59bcd	1.05bc	2.21c-e	1.88ab	2.04bcd
APO	0.67d	0.83b	0.65e	0.98abc	0.83b	0.90bcd	1.44e	1.66b	1.55d
IGBIMO	0.58cd	1.95ab	1.11ed	0.85bc	0.46bcd	0.65bcd	1.18e	2.21ab	1.69cd
IR-64	0.48c	0.65b	1.56bcd	2.76a	2.58a	1.67a	2.91bcd	2.77ab	2.84ab
OFADA	1.42cd	1.32b	1.37cde	0.66bc	0.26cd	0.46cd	1.99cde	3.38a	2.68bc
VANDANA	4.88a	2.53a	3.71a	0.53c	0.13d	0.33d	5.33a	2.53ab	3.93a
LSD (p≤0.05)	**0.89**	**1.10**	**0.77**	**0.91**	**0.51**	**0.56**	**1.36**	**1.54**	**1.11**
Interaction									
GStages	**	**	**	*	**	**	**	**	**
Varieties	**	*	**	**	**	*	*	ns	*
GS x CUL	*	*	*	*	ns	*	*	*	*

GS= Drought imposition stage, CUL = Cultivars, DIP= Drought Imposition Period

Table 6: Dry matter accumulation by upland rice cultivars at different growth stages under water deficit condition

	Dry root weight (g)			Dry shoot (g)			Total biomass weight (g)		
	Year 1	**Year 2**	**Mean**	**Year 1**	**Year 2**	**Mean**	**Year 1**	**Year 2**	**Mean**
Stage of drought imposition (GS)									
Tillering	1.09a	1.98a	1.46a	4.68a	3.89a	4.29a	5.84a	5.70b	5.84a
Panicle initiation	1.15a	1.82a	1.45a	4.63a	3.88a	4.26a	5.90a	5.13b	5.36a
Grain filling	1.10a	2.14a	1.56a	5.01a	4.31a	4.62a	5.94a	6.21ab	5.99a
Control	1.08a	2.32a	1.62a	4.29a	4.50a	4.28a	5.53a	7.80a	6.43a
LSD (p≤0.05)	**0.42**	**0.62**	**0.40**	**1.46**	**1.17**	**0.92**	**1.75**	**2.02**	**1.28**
Cultivars (CUL)									
NERICA-4	0.61c	0.90de	0.75b	2.43e	1.78d	2.10d	3.23de	2.56d	2.89d
NERICA-5	1.13bc	1.83dc	1.48a	4.00b-e	2.69dc	3.34cd	4.88c-e	6.41bcd	4.65cd
NERICA-7	1.87a	1.87dc	1.87a	6.28ab	3.53bcd	4.90abc	8.12ab	7.43ab	7.77ab
NERICA-8	0.57c	1.84dc	0.57b	2.58e	3.46bcd	2.58d	3.15e	2.54d	3.15d
FARO-16	1.08bc	2.98ab	2.03a	4.84a-e	5.46ab	5.15ab	6.10a-e	8.06a	7.08abc
FARO-44	1.08bc	2.39abc	1.74a	5.18a-d	5.82a	5.50ab	6.26a-d	8.26a	7.26ab
FARO-60	1.56ab	2.96ab	2.26a	6.89a	5.83a	6.33a	8.98a	9.13a	9.05a
APO	1.48ab	1.62cde	1.55a	6.28ab	4.59abc	5.44ab	8.23ab	5.95abc	7.08abc
IGBIMO	1.23abc	2.06bc	1.65a	5.16a-d	4.78abc	4.67abc	5.81b-e	6.40ab	6.10bc
IR-64	1.43ab	2.06bc	1.75a	5.80abc	4.68ab	5.23ab	6.95a-c	6.83ab	6.89abc
OFADA	0.63c	3.37a	2.00a	3.10ed	4.51abc	3.80bcd	4.05c-e	6.56ab	5.30bcd
VANDANA	0.58c	0.67e	0.63b	3.31cde	1.73d	2.52d	3.88de	2.74cd	3.31d
LSD (p≤0.05)	**0.72**	**1.02**	**0.69**	**2.53**	**1.94**	**1.59**	**3.03**	**3.35**	**2.22**
Interaction									
GS x CUL	ns	*	ns	*	*	*	*	ns	*

GS= Drought imposition stage, CUL = Cultivars, LSD = Least Significant Difference at p≤0.05

DISCUSSION

Evaluating the effect of water deficit condition at various growth stages showed that water deficit at any stage would reduce yield of rice plant (Salam *et al.*, 2001). However, the duration of stress, the stage of plant growth and development at which the plant was exposed to drought and severity contributed to plant response to abiotic stress (Adejumo *et al.*, 2018) this could be the reason why rice plants that were subjected to water deficit condition at panicle initiation and tillering growth phase had reduced growth and yield parameters when compared to those that were water stressed grain filling.

The better growth performance displayed by the following cultivars APO, OFADA, NERICA-7, FARO-44, FARO-60 and IR-64 in terms of plant height, leaf area and tiller numbers all through the growth period suggest these cultivars may have the potential to tolerate drought irrespective of the growth stages and could be look into for further breeding program. Bouman and Toung (2001) reported that different cultivars might have different responses to the same drought stress, timing and intensity.

There was reduced number of tillers most especially at tillering and panicle initiation stage when compared to the control and grain filling phase. However the high number of tillers that was more in plants subjected to water deficit condition at grain filling phase than the control plants suggests that rice plant was more tolerant to water deficit condition at grain filling stage than other growth phases. Rahman et al. (2002) reported similar experience that tiller numbers of rice plant was reduced significantly under moisture deficit condition at different growth stages. When water shortage occurs at the tillering stage, the cell division and expansion processes are impaired resulting in poor growth and development (Dada *et al*., 2018). The high number of tillers and leaves displayed by IR-64 cultivars which is the susceptible cultivar shows that the cultivar has potential for early growth or may displayed those attribute because it was under stress.

Dry matter accumulation was reduced by moisture stress mostly at tillering and panicle initiation stage possibly due to impaired nutrient uptake, which limits photosynthate formation and partitioning into biological and economic yield. The observed increased partitioning of dry matter into root is an indication of drought avoidance in a bid to maximize uptake of available water (Barnabas *et al.,* 2008). Also water stress at tillering effectively led to reduced total biomass; this may be due to decrease in photosynthesis rate and dry matter accumulation. However, high dry matter was partitioned in FARO's varieties than any other varieties.

Water stress caused a significant reduction in grain yield of upland rice cultivars. However, it was more severe at panicle initiation period than other growth phases. Among the varieties, VANDANA having the highest grain yield suggests it was tolerant to moisture stress while IR-64 and APO having the least grain yield suggests their susceptibility to drought. The differences in grain yield may be directly linked to the recovery rate after stress imposition at different stages. Recovery from water stress is a function of growth stage and severity of the stress (Kato *et al.* (2007). Also Bouman and Toung (2001) reported that different cultivars might have different responses to the same drought stress, timing and intensity.

CONCLUSION

Rice plant was more sensitive to water deficit condition at tillering and panicle initiation stage than at grain filling phase. However, drought at panicle initiation stage had reduced grain yield than at tillering phase of upland rice cultivars. It can be concluded that cultivars recommended for south western Nigeria were frequent drought occurs are those with appropriate phonological development to escape early drought and ability to maintain growth when drought occurs suddenly due to climate change. Consideration of these characters in plant breeding should increase the efficiency of plant improvement in south western Nigeria. The study concluded that water condition beyond tillering and panicle initiation growth phases should be avoided.

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REFERENCES

Adejumo, S. A., Okechukwu, S. E. and Luis, A. J. M. (2018). Okra growth and drought tolerance when exposed to water regimes at different growth stages. *International journal of vegetable science*.DOI: 10.1080/19315260.2018.1501788.

Bouman, B. A. M. and Toung, T. P. (2001). Field water management to save water and increase its productivity in irrigated lowland rice. *Agric. Water Manage*. 49 (1): 11-30.

Dada, O. A., Lawal, O. E., Kutu, F. R. and Olaniyan, A. B. (2018).Osmotic stress mitigation in upland NERICA field using compost augmentation and silicon enrichment. *Research on Crops* 19.2: 151-162

Halford, N. G. (2011). The role of plant breeding and biotechnology in meeting the challenge of global warming. In :*Planet Earth 2011– Global Warming Challenges and Opportunities for Policy and Practice,* Carayannis E. (ed.). ISBN : 978-953-307-733-8.

Ismaila, U., Gana, A. S., Tswanya, N. M. and Dogara, D. (2010). Cereals production in Nigeria : Problems, constraints and opportunities for betterment. *Africa J. Agric Res.* 5: 1341- 50.

Manivannan, P., Jaleel, C. A., Chang-Xing, Z., Somasundaram, R., Azooz, M. M. and Panneerselvam, R. (2008). Variations in growth and pigment composition of sunflower varieties under early season drought stress. *Global J. Mol. Sci*. 3(2):50–56.

Pantuwan, G. M., Fukai, S., Cooper, S. R and O'Toole, J. C. (2002a). Yield response of rice (*Oryza sativa* L.) genotypes to different types of drought under rainfed lowlands. Grain yield and yield components. *Field Crop Research*., 73 (2-3):153-168.

Saxton, K. E. and Rawls, W. J. (2006). Soil water characteristic estimates by texture and organic matter for hydrologic solutions. *Soil Science Society of America Journal* **70** : 1569-78.

Statistical Analysis System (SAS) Institute (2002). *SAS/STAT User's Guide. Version 8. 6th edn.* SAS Inst. Cary., North Carolina. pp. 112. Su, Z., Su, X., Ma, H., Guo, N. L., Sukiran, B., Guo,

Uduma, B. U., Samson, O. A. and Mure, U. A. (2016). Irrigation Potentials and rice self-sufficiency in Nigeria: A review. *African Journal of Agricultural Research*, 11(5), 298- 309.

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COCOA PRODUCTION IMPROVEMENT IN SOME MAJOR PRODUCING COUNTRIES OF THE WORLD

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ABSTRACT

Cocoa is an important tropical and perennial crop whose seed (bean) is generally consumed across the globe. It is one of the most consumed soft commodities globally. It is an important raw material in the beverage, confectionary, cosmetics and pharmaceutical industries. The annual decline in cocoa bean production has been observed over the decades while there has been an increase in demand and a projected increase in future demand. This study aims to observe the production trend over the years and also make yield improvement propositions in the top 10 producing countries. Secondary data on the top 10 cocoa producing countries in the world which are Cote d'Ivoire, Ghana, Indonesia, Nigeria, Cameroon, Brazil, Ecuador, Peru, Dominican Republic and Colombia were sourced from the Food and Agricultural Organization (FAO) database which covered a period of 30 years (1990 - 2020). Data extracted were data on land area harvested (ha), yield per hectare (t/ha) and production (t) for each country which were analyzed using empirical and descriptive analysis. The result showed that Brazil, Ghana, Indonesia, and Nigeria currently experienced a decline in land area harvested as of 2020 when compared with 2010 by 10%, 9.4%, 4.2% and 0.9% respectively. Indonesia and Nigeria only recorded a decline in production in 2020 when compared with 2010 by 12.5% and 14.8%, respectively. Colombia, Cote d'Ivoire, Indonesia and Nigeria are critically experiencing a decline in yield per hectare for about at least two decades. Rehabilitation or rejuvenation of old plantations was recommended for Cameroon, Colombia, Ghana, Indonesia and Nigeria. Adoption of effective pest control measures was recommended for Cameroon, Cote d'Ivoire and Indonesia. Government policies, agronomic and management practices in cocoa production in Peru should be understudied by other growing countries to boost production in meeting the ever growing demand for cocoa beans.

Keywords: *Cocoa, Countries, Improvement, Production, Trend, Yield.*

INTRODUCTION

The cocoa bean is the seed derived from the *Theobroma cacao* L. tree which is indigenous to the Amazon region of South America. It is an important tropical and perennial crop whose bean seed is widely consumed all over the world. (World Cocoa Foundation Report, 2014). It is cultivated at an altitude of less than 1,312 feet above sea level with an ideal temperature range between 65°F and 90°F annual rainfall of at least 101.6 cm and at most 1016 cm. Small scale farmers in Africa, Latin America, Asia, and Oceania produce the majority of the world's cocoa, with farmers having 1 to 10 hectares holding and cultivating more than 90% of the total crop (Poelmans and Swinnen, 2016). It has been evaluated that about 5 to 6 million farmers from these regions produce cocoa beans (International Cocoa and Coffee Organization [ICCO], 2013).

A cocoa tree begins to produce fruit called pod which houses the bean seed after 3 or 4 years, though some new varieties produce fruit earlier. After 5 to 10 years, depending on the variety, a productivity peak is achieved as trees older than 20 years tend to produce a lower quantity of pods (Franzen and Borgerhoff, 2007). Cocoa tree production is determined by a variety of elements, including genetic code, soil quality, weather conditions, tree age and pruning, inputs used, and other farming techniques (Hütz-Adams *et al*., 2016).

Cocoa beans are processed to produce cocoa butter, chocolate liquor and cocoa powder which are the primary materials for making chocolate and products such as ice cream, bakery products and cocoa beverages (Payne *et al*., 2010). Despite its importance in the confectionary industry, it is also majorly used in the cosmetics and pharmaceutical industries (Beg *et al*., 2017).

Currently, the top 10 cocoa producing countries in the world, in the ranking order, are Cote d'Ivoire, Ghana, Indonesia, Nigeria, Cameroon, Brazil, Ecuador, Peru, Dominican Republic and Colombia. They jointly produced 91.5% (5,268,666 tonnes) of the global annual production of (5,756,953 tonnes) with Cote d'Ivoire contributing the most with a production of 2,200,000 tonnes (38.2%) to the total global annual production according to FAOSTAT (2020). Chocolate demand and consumption are heavily concentrated in the United States and Europe. China, India, and Russia's growth as major consumers of cacao products has brought about concern in the cocoa sector about the future availability of cacao ((Janssen and Riera, 2016). Demand for cocoa is growing by 2.5 percent annually in China, Russia, India, and Brazil (Squicciarini and Swinnen, 2016) which are major cocoa bean consumers, but global production has been declining by 1.5 percent per year over the past decade (FAOSTAT, 2018). The International Cocoa Organization (ICCO, 2022) has released its projection for the world crop production for the year 2021/22, which shows that cocoa bean supply is predicted to fall by 5% (4.955 million tonnes), while global market sector demand is expected to rise by 3%.

There is a need to evaluate some of the production factors as used in the Food and Agricultural Organization (FAO) database such as total area of land harvested, total production in tonnes and quantity of yield per hectare in major producing countries to improve and increase cocoa bean productivity and also maintain the ever increasing demand of cocoa bean in this era of fall in supply. Due to cocoa's significant economic importance and impact on the well-being of millions of farmers, it's critical to comprehend and quantify the concerns and prospects for future cocoa demand and supply. Therefore, this study aims to: observe the production trend for the past 30 years in each of the top 10 cocoa bean producing countries and also proffer yield improvement recommendations for the countries.

METHODOLOGY

Top 10 cocoa producing countries including Cote d'Ivoire, Ghana, Indonesia, Nigeria, Cameroon, Brazil, Ecuador, Peru, Dominican Republic and Colombia were only considered in this study. Secondary data was mainly used for this study. Data on cocoa production variables such as land area harvested (ha), yield per hectare (t/ha) and production (t) for each of the countries were sourced online from the Food and Agricultural Organization (FAO) database which covered a period of 30 years (1990 - 2020) but presented per decade (1990, 2000, 2010 and 2020). Data on yield per hectare from the FAO database were converted to t/ha using the formula:

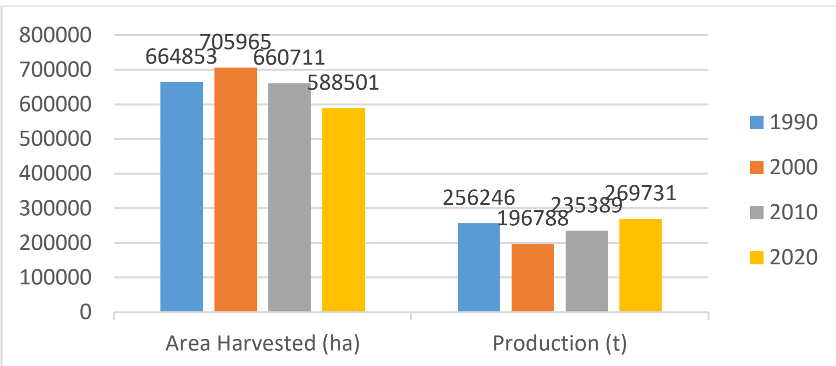
t/ha = (hg/10,000); where t/ha = tonnes/hectare; hg= hectogram; 10,000 hg = 1 t.

The study attempts to analyze land area harvested, yield per hectare and production of cocoa beans using empirical analysis over the period of years under observation to study the production trend for improvement. This method was checked through descriptive statistics analysis. A rank table was used to express the positions of the cocoa production variables of the countries collectively in the year 2020.

RESULT AND DISCUSSION

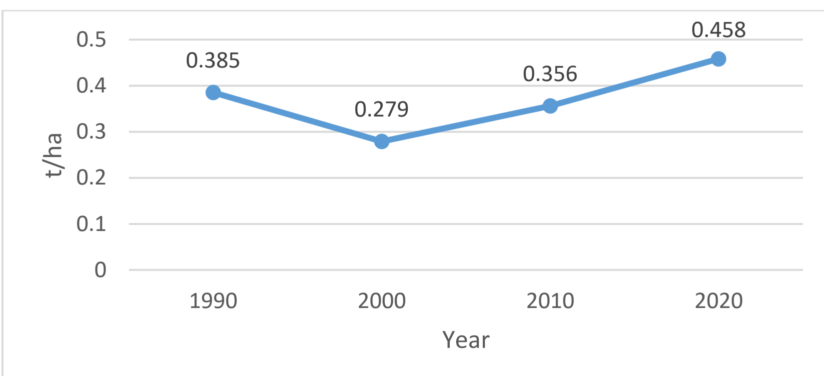
1. Brazil

Brazil is currently the 7th largest producer of the cocoa bean. Land area harvested in 2000 (705,965 ha) increased from 664,853 ha in 1990 but experienced a decline in 2010 (660,711 ha) and 2020 (588,501 ha) as shown in Fig 1a. This implies that there is a steady decrease in land area of cocoa harvested which has declined beyond what it was in 1990. This corresponds with the findings of Clay (2004), that cocoa, coffee, and sugarcane are tropical crops in Brazil that have been linked to tropical deforestation over the years. Deforestation of the Atlantic rainforest of the southern Bhia in Brazil, which is a major cocoa producing forest has also played a major role in the decline in land areas harvested (Saatchi *et al*., 2002). Production of cocoa beans decreased in 2000 (196,788 t) from 256,246 t in 1990 despite the increase in land area harvested which is due to the decline in yield per hectare in 2000 (0.279 t) as revealed in fig 1b. However, despite the decline in land area of cocoa harvested in 2010 and 2020, there was an increase in production of 235,389 t and 269,731 t in both periods respectively. This was so because there was a continuous increase in yield per hectare (Fig 1b) in 2010 (0.356 t/ha) and 2020 (0.458 t/ha). Alvarez (2018) also observed that there has been an annual increase in cocoa yield (kg/ha) over the years in the country.



Source: FAOSTAT, 2020

Figure 1a: Brazil's cocoa land area harvested and production in 1990, 2000, 2010 and 2020

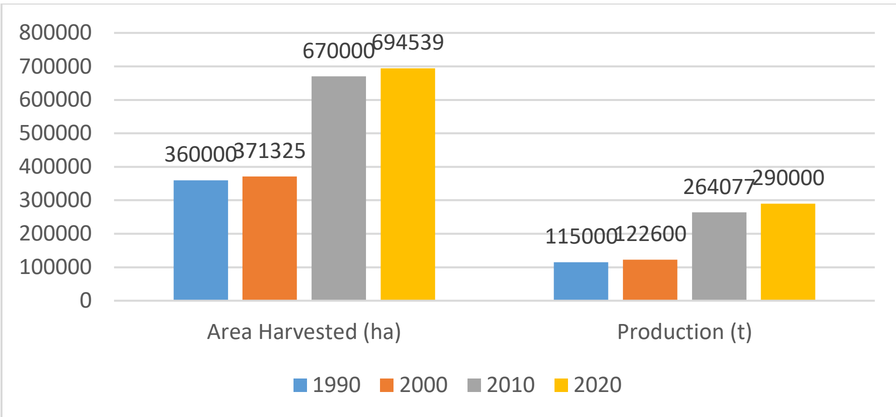


Source: FAOSTAT, 2020

Figure 1b: Brazil's cocoa yield per hectare in 1990, 2000, 2010 and 2020

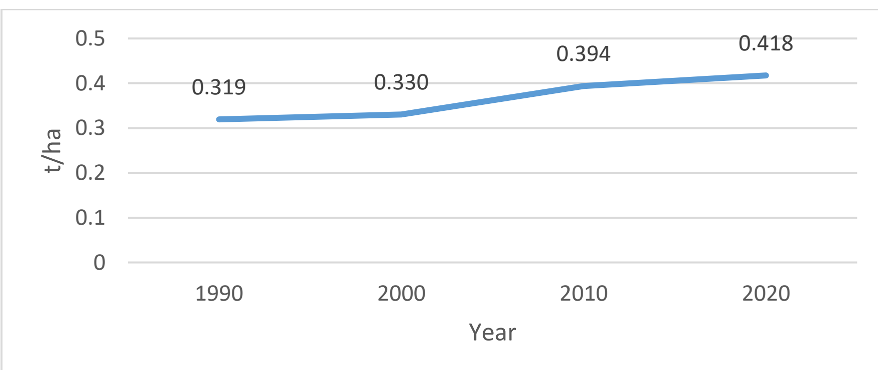
2. Cameroon

Cameroon is the 6th largest producer of cocoa beans. There was an increase in land area harvested, production and yield per hectare (Fig 2a and 2b) in 1990, 2000, 2010 and 2020 respectively. This implies that there has been an increase in area harvested and yield per hectare resulting in increased cocoa bean production over the period observed. There was an annual and periodic increase in cocoa bean production in Cameroon as reported by Nicodeme *et al*. (2017). Both the quantity produced and the harvested area have increased significantly from 75,000 t and 380,000 ha in 1961 to 209,000 t and 670,000 ha in 2013 (FAO, 2016). There was a drastic increase in land area in 2010 (670,000 ha) which almost doubled that of 2000 (371,325 ha) with about 80.4% increase in land area. Within the same period of 2000 to 2010, production increased notably from 122,600 t to 264,077 t, which is about 115.4% increase in cocoa bean production (Fig 2). This value was also boosted by the increase in yield per hectare for the year 2010 (0.394 t/ha) as there was also about 19.4% increase between the year 2000 (0.330 t/ha) and 2010 (0.394 t/ha). However, the aging of cocoa plants has been recognized as a primary problem, followed by insufficient inputs and heavy rainfall spells, which resulted in the spread of diseases such as black pod (Wessel and Quist-Wessel, 2015).



Source: FAOSTAT, 2020

Figure 2a: Cameroon’s cocoa land area harvested and production in 1990, 2000, 2010 and 2020

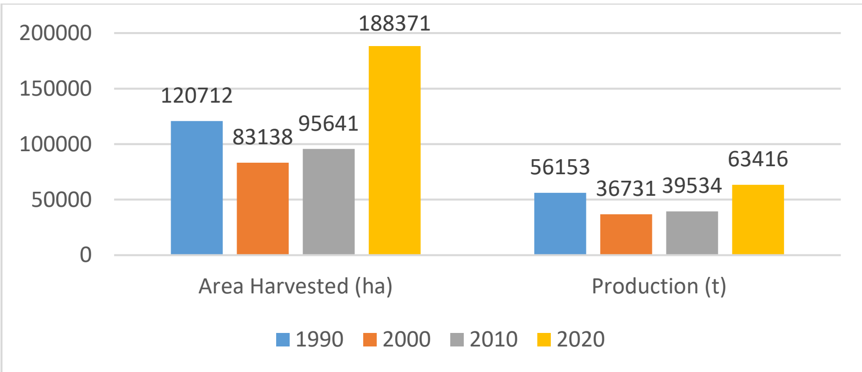


Source: FAOSTAT, 2020

Figure 2b: Cameroon’s cocoa yield per hectare in 1990, 2000, 2010 and 2020

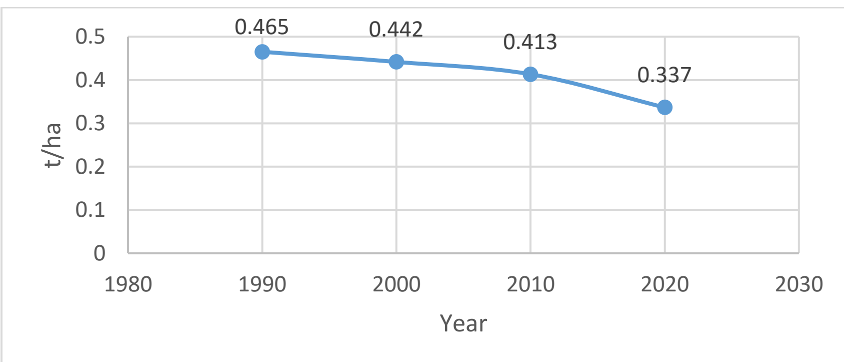
3. Colombia

Colombia is currently ranked 10th main producer of the cocoa bean. This rank among the main producers is most likely expected because of the relatively small area of land harvested compared to the top five producers. The area of land harvested experienced a decline in 2000 (83,138 ha) from 120,712 ha in 1990 (Fig 3). It increased in 2010 (95,641 ha) and almost doubled in 2020 (188,371 ha) with about 97%. In 2020, production increased to 63,415 t which is about 40% increase to that of 2010 (39,534 t). Despite the increase in production after the year 2000, yield per hectare has consistently been decreasing from 1990 to 2020 (Fig 3b) having a value of 0.337 t/ha in 2020 from 0.465 t/ha in 1990. This implies that the increase in area harvested has not been able to influence a significant increase due to the constant decline in yield per hectare of cocoa bean in Colombia. The yield decline could be as a result of poor soil nutrient management in cocoa growing areas of the country which was proven by Uribe *et al*., 2001 who reported that research on the effect of fertilizer application is rare in the country. A decline in the yield of cocoa beans per hectare was also attributed to the old hybrid cocoa genotypes cultivated in most of the plantations (Ortiz-R. et al. 2014).



Source: FAOSTAT, 2020

Figure 3a: Colombia's cocoa land area harvested and production in 1990, 2000, 2010 and 2020

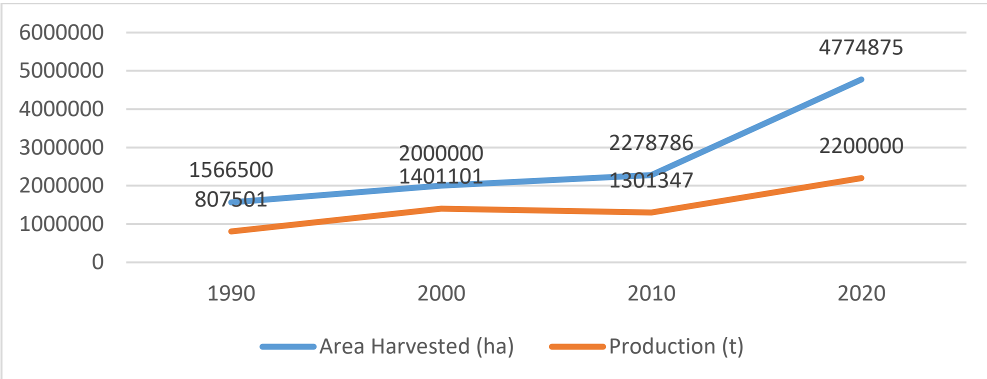


Source: FAOSTAT, 2020

Figure 3b: Colombia's cocoa yield per hectare in 1990, 2000, 2010 and 2020

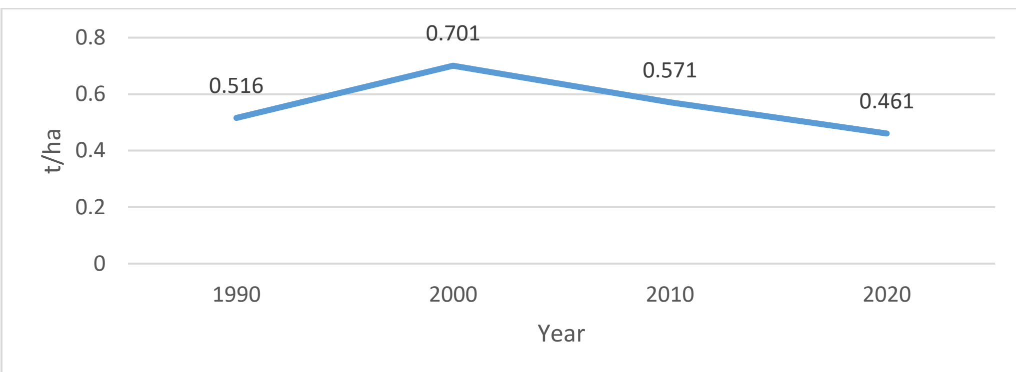
4. Cote d'Ivoire

Cote d'Ivoire is the leading producer of cocoa beans in the world and currently holds the largest area of land harvested (4,774,875 ha) but not the highest yield per hectare. Cote d'Ivoire tops cocoa production globally by a wide margin due to the large area of land used in cultivating the crop (FAO, 2020). Production has been increasing with an increase in the area of land harvested except in 2010 (Fig 4a). There was a significantly sharp increase in the area of land harvested in 2020 (4,774,875 ha) compared to 2010 (2,278,786 ha) which is about 109.5% increase while 45.5% increase was only observed between 1990 and 2010. Despite about 138% increase in land area harvested between 2000 (2,000,000 ha) and 2020 (4,774,875 ha) production was only increased by 57%. The underproduction occurred as a result of the progressive fall in yield per hectare after the year 2000 (Fig 4b). Yield per hectare declined from 0.701 t/ha in 2000 to 0.571 t/ha in 2010 and 0.461 t/ha in 2020. The drop in yield per hectare was majorly noticeable in 2010 as production dropped from 1,401,101 t in 2000 to 1,301,347 t in 2010. These observations indicate that despite Cote d'Ivoire being the largest producer of the cocoa bean, the decline in yield is hindering the production at a maximum. According to Kozicka *et al*., (2018), the ever declining productivity per hectare is attributed to serious and persistent issues of pests and diseases affecting the crop in the major growing areas.



Source: FAOSTAT, 2020

Figure 4a: Cote d'Ivoire's cocoa land area harvested and production in 1990, 2000, 2010 and 2020



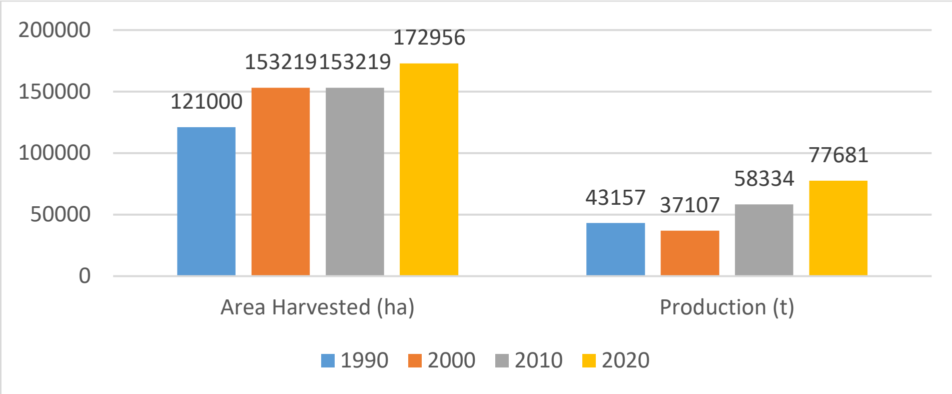
Source: FAOSTAT, 2020

Figure 4b: Cote d'Ivoire's cocoa yield per hectare in 1990, 2000, 2010 and 2020

5. Dominican Republic

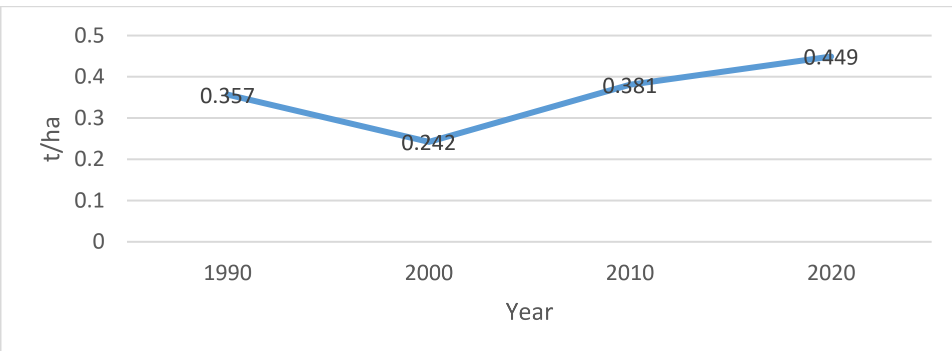
The Dominican Republic is the 9th largest producer of cocoa in the world. Fig 5a shows that there was no improvement in land area harvested in 2000 (153,219 ha) and 2010 (153,219 ha) as it remained the same though there was an improvement in 2000 (153,219 ha) when compared with 1990 (121,000 ha) with about 26.6% increase while there was also 12.9% increase in land area harvested from 2010 (153,219 ha) to 2020 (172,965 ha). An increase in production was observed in 2010 (58,334 t) than 2000 (37,107 t) despite having the same land area harvested. This was made possible by the increase in yield per hectare in 2010 from 0.242 t/ha in 2000 to 0.381 t/ha (Fig 5b). After the decline in production and yield per hectare observed in 2000, both have been increasing notably. The yield per hectare value in 2020 (0.449 t/ha) exceeded what it was in 1990 (0.357 t/ha) before the decline in 2000 (0.242 t/ha). Limited land area harvested obtained in this country has made improving the yield per hectare year after year a priority which the government has been proactive about with the creation of a ten year National Action Plan in 2017 in collaboration with the UNDP's Green Commodities Programme to multiply yields in the next 10 years (Kozicka, 2018). Cuello *et al*.

(2015) has also stated that obtaining a yield of 1.5 t/ha of cocoa bean is possible among cultivating farmers in the country.



Source: FAOSTAT, 2020

Figure 5a: Dominican Republic's cocoa land area harvested and production in 1990, 2000, 2010 and 2020

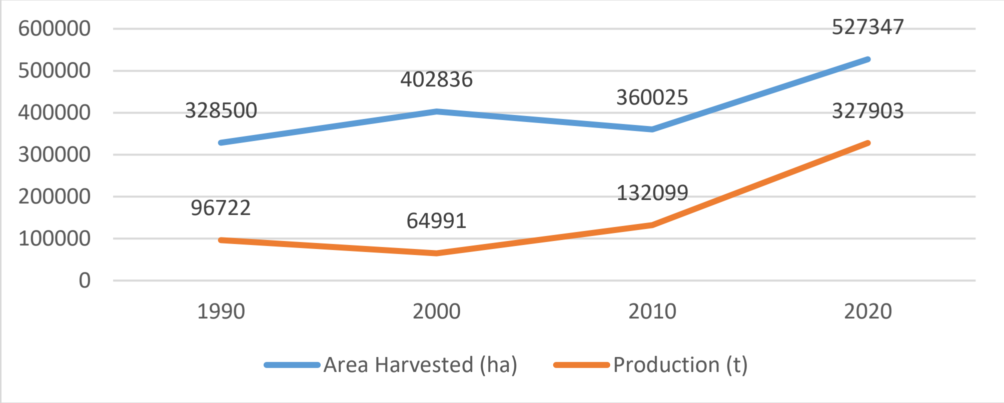


Source; FAOSTAT, 2020

Figure 5b: Dominican Republic's cocoa yield per hectare in 1990, 2000, 2010 and 2020

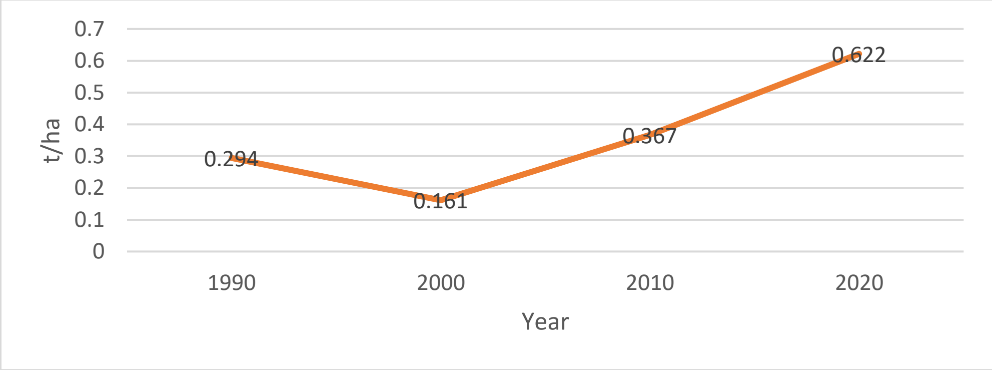
6. Ecuador

Ecuador ranked 5th among the top 10 producing countries of the world. A decline in land area harvested was observed in 2010 (360,025 ha) as against the increase experienced in 2000 (402,836 ha) when compared with 1990 (328,500 ha) (Fig 6a). After the decline in land area harvested in 2010, it increased in 2020 to 527,347 ha which is about 46.5% increase. Regardless of the increase in land area harvested in 2000, there was a decline in production (64,991 t) which was due to the very poor low yield per hectare (0.161 t/ha) experienced during the period as shown in Fig 6b. Vega and Beillard (2015) reported that the decline in yield experienced before 2010 was a result of the high occurrence of Witches Broom and Frosty Pod Rot Disease of cocoa in the country. Due to the gradual increase in yield per hectare in 2010 (0.367 t/ha) and 2020 (0.622 t/ha), it influenced production positively in 2010 (132,099 t) despite the decline in land area harvested same year as production also increased in 2020 (327,903 t) which was aided by the 46.5%% increase in land area harvested in 2020 (Fig 6a). Yield per hectare positively improved from 0.161 t/ha it was in 2000 when compared to the current yield per hectare in 2020 by 285.5% (Fig 6b). According to Villacis *et al*. (2020), the government of the country is playing a major role in increasing cocoa bean production by engaging farmers in programs that provides credits for expansion or input, promoting the rehabilitation of older or moribund farms and good management practices. Ecuador has intensified cultivation of the high-yielding and disease-resistant clone in recent years to boost production (Vega and Beillard, 2015)



Source: FAOSTAT, 2020

Figure 6a: Ecuador's cocoa land area harvested and production in 1990, 2000, 2010 and 2020

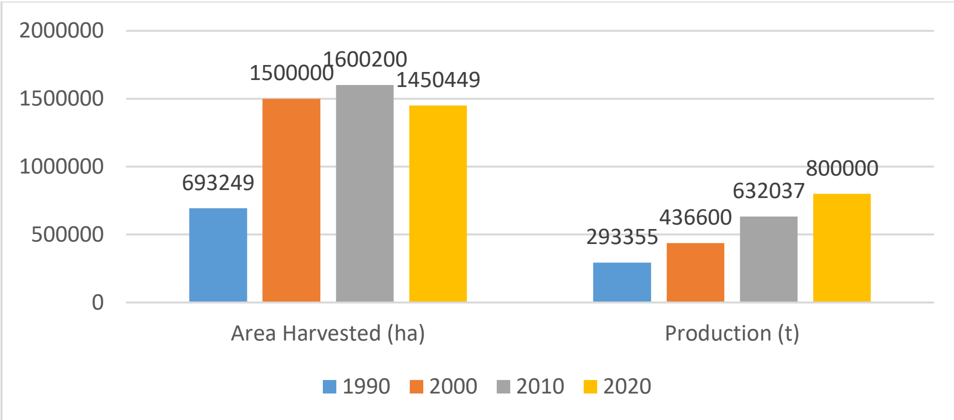


Source: FAOSTAT, 2020

Figure 6b: Ecuador's cocoa yield per hectare in 1990, 2000, 2010 and 2020

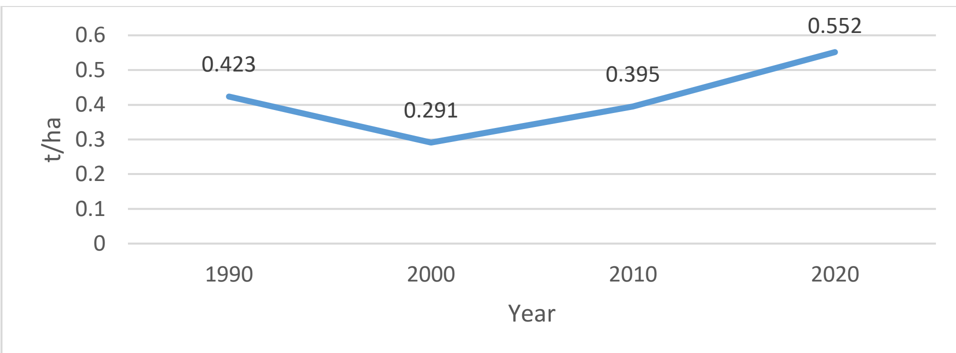
7. Ghana

Ghana is presently ranked 2nd largest producer of cocoa beans in the world. From Fig 7a, the land area harvested of cocoa beans in the country was 693,249 ha in 1990 but increased by 116.4% in 2000 (1,500,000 ha). It further increased by % 6.7% in 2010 (1,600,200 ha) before a decline of about 9.4% was recently experienced in 2020 (1,450,449 ha). This recent decline in land area harvested could be a result of aging farmers who could not afford to manage large farm areas and also an increase in moribund cocoa trees. (Wessel and Quist-Wessel, 2015). Regardless of the recent decline in land area harvested in 2020, production increased by 26.6% from 632,037 t in 2010 to 800,000 t in 2020. There was a decline in yield per hectare (Fig 7b) in 2000 by 31.2% from 0.423 t/ha in 1990 to 0.291 t/ha although it didn't affect production in 2000 as the yield increased from 293,355 t in 1990 to 436,600 t in 2000. This was possible because of the over 100% increase in land area harvested in 2000 compared to 1990. Yield per hectare is currently the highest so far in 2020 (0.552 t/ha) when compared to 1990 (0.423 t/ha), 2010 (0.395 t/ha) and 2000 (0.291 t/ha) as shown in Fig 7b. COCOBOD is a Ghanaian government-owned cocoa marketing board, whose production-supporting initiatives are seen as the driving forces behind this upward trend of cocoa bean production in the country (Asante-Poku and Angelucci, 2013).



Source: FAOSTAT, 2020

Figure 7a: Ghana's cocoa land area harvested and production in 1990, 2000, 2010 and 2020

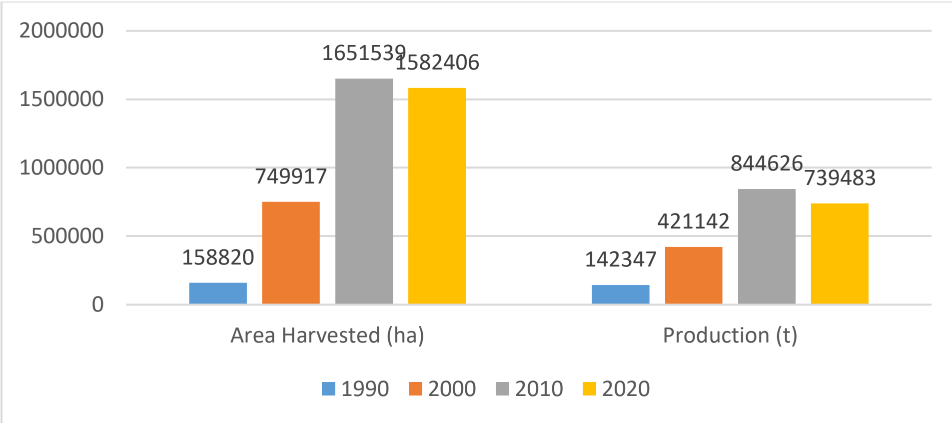


Source: FAOSTAT, 2020

Figure 7b: Ghana's cocoa yield per hectare in 1990, 2000, 2010 and 2020**.**

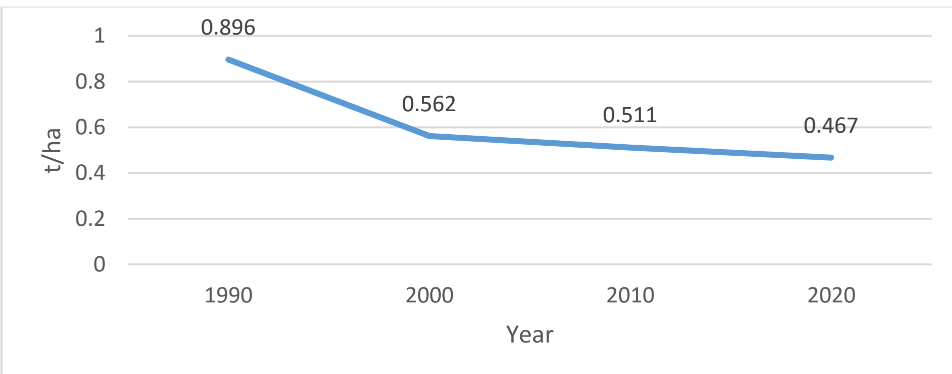
8. Indonesia

Indonesia is the 3rd most important cocoa bean producer in the world. In Fig 8a, there was a notable increase of 372.2% in land area harvested in 2000 (749,917 ha) when compared with 1990 (158,820 ha) and also a noticeable increase of 120.2% was observed in 2010 (1,651,539 ha) when compared with 2000. A slight decline in land area harvested was recently observed in 2020 by 4.2% when compared with 2010. A similar trend was also observed in production as the increase in the land area harvested brought about the increase in production in 2000 (421,142 t) and 2010 (844,626 t) while the decrease in land area harvested resulted in a decline in production in 2020 (739,483 t). From Fig 8b yield per hectare declined per decade with the highest decline in 2000 when it dropped from 0.896 t/ha in 1990 to 0.562 t/ha. According to McMahon *et al*. (2015), yields from cocoa farms are being seriously affected by the spontaneous spread of Cocoa Pod Borers which is affecting cocoa bean quality and yield realized per unit area. Also, moribund trees which were planted in the 1980s, poor farmers skill in cocoa management, inadequate understanding of pest and disease control have also been identified as factors hindering productivity (Tothmihaly and Ingram, 2017). The current yield per hectare is 0.467 t/ha. These results show that regardless of the increase in land area harvested which has influenced the increase in production, a consistent drop in yield per ha has resulted in underproduction in the country as Indonesia can produce double of their current production if yield per hectare is improved on.



Source: FAOSTAT, 2020

Figure 8a: Indonesia's cocoa land area harvested and production in 1990, 2000, 2010 and 2020.

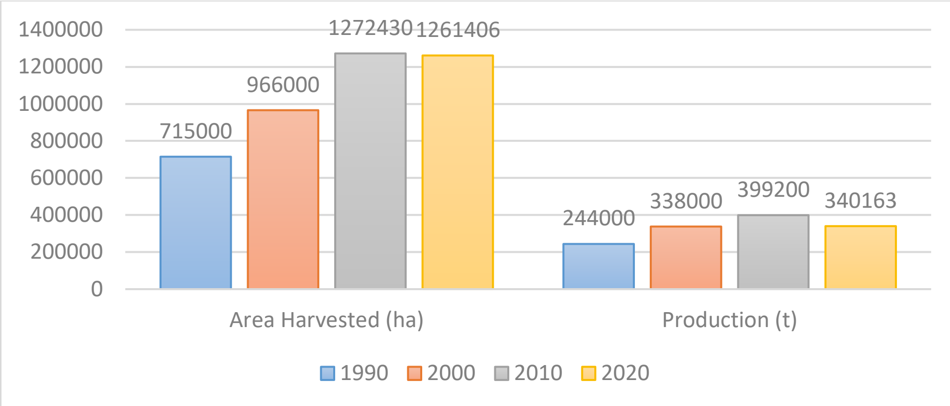


Source: FAOSTAT, 2020

Figure 8b: Indonesia's cocoa yield per hectare in 1990, 2000, 2010 and 2020

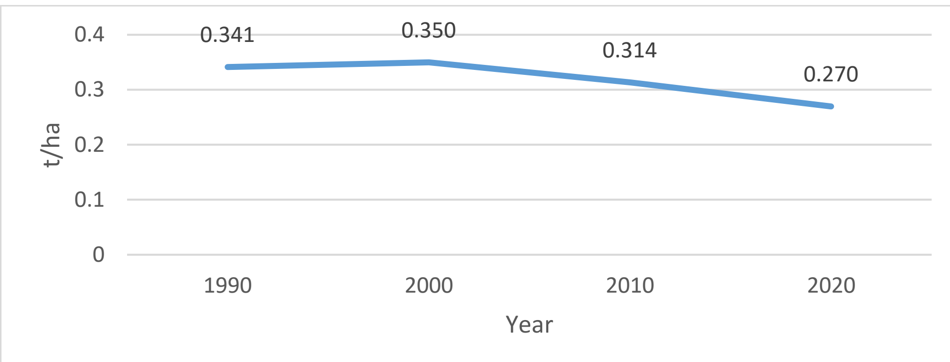
9. Nigeria

Nigeria is ranked 4th among the main producers of cocoa beans in the world. In Fig 9a, there was a notable increase in land area harvested from 1990 to 2010 before a slight decline was observed in 2020 (1,261,406 ha) with about 0.9% when compared with 2010 (1,261,406 ha). Production also followed the same trend as there was an increase in production in 2000 (338,000 t) and 2010 (399,200 t) before a decline in 2020 (340,163 t) by 14.8% from its value in 2010. This implies that in Nigeria, the latest decline in land area harvested of 0.9% resulted in a 14.8% decline in yield per hectare as against the expected corresponding 0.9% decline. The very poor yield per hectare production of 0.270 t/ha was responsible for the increase in the decline rate in production for the year 2020 (Fig 9b). Yield per hectare production of cocoa bean in the country has been generally poor as the highest yield per hectare was recorded in 2000 with 0.350 t/ha. The primary causes of decreased yields in recent decades have been increase in aging farmers and moribund trees which are over four decades old while others include the prevalence of diseases and pests, lack of agricultural mechanization, and lack of agricultural extension services (Cadoni, 2013; Hütz-Adams *et al.*, 2016). Nigeria is currently underproducing at a very wide margin as the country can triple annual production with the current land area being cultivated.



Source: FAOSTAT, 2020

Figure 9a: Nigeria's cocoa land area harvested and production in 1990, 2000, 2010 and 2020

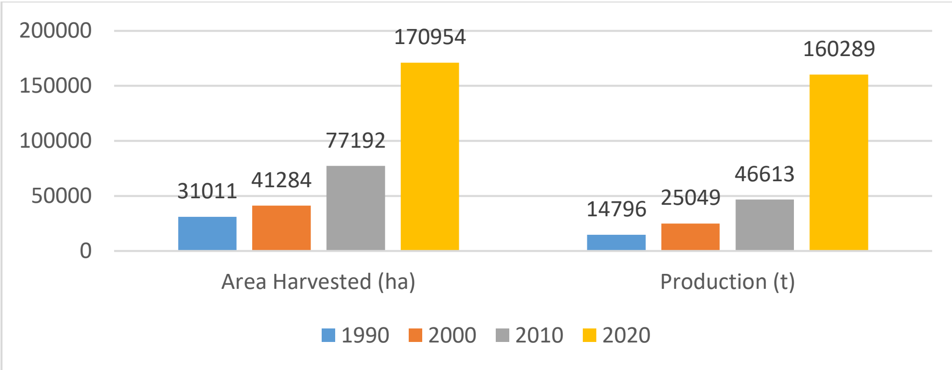


Source: FAOSTAT, 2020

Figure 9b: Nigeria's cocoa yield per hectare in 1990, 2000, 2010 and 2020

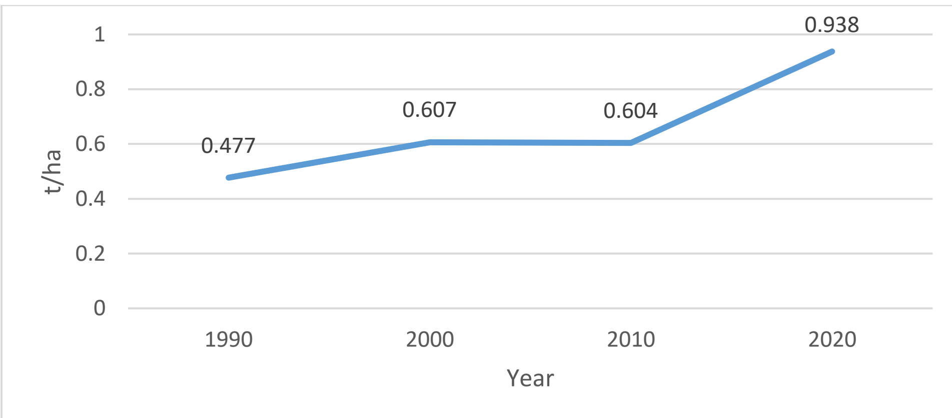
10. Peru

Peru is currently ranked as 8th producer of cocoa beans among the top 10 leading producers in the world but the 1st in terms of yield per hectare production (FAOSTAT, 2020). It also has the least land area harvested of all the top 10 leading countries which are majorly responsible for its rank and the extremely low production as shown in Fig 10a. Land area harvested improved in 2000 (41,284 ha), 2010 (77,192 ha) and 2020 (170,954 ha). Land area harvested increased by 121.5% in 2020 when compared with 2010. Production tripled in 2020 (160,289 t) by the increase in land area harvested (170,954 ha) and increase in yield per hectare (0.938 t/ha) observed in 2020 (Fig 10b). The least yield per hectare recorded was in 1990 (0.477 t/ha). There was an insignificant decrease in yield per hectare in 2010 (0.604 t/ha) when compared with 2000 (0.607 t/ha) by 0.2% which improved notably in 2020 (0.938 t/ha) by 55.3% when compared with 2010. Cultivation of Cocoa CCN51 variety which is a high yielding variety is one of the main reasons for the growing performances of the cocoa sector in the country and also, Integrated Pest Management strategies (IPM) were at the heart of government initiatives to control and reduce pest occurrence, specifically Witches' Broom and Frosty Pod Rot (Kozicka *et al.*, 2018).



Source: FAOSTAT, 2020

Figure 10a: Peru's cocoa land area harvested and production in 1990, 2000, 2010 and 2020



Source: FAOSTAT, 2020

Figure 10b: Peru's cocoa yield per hectare in 1990, 2000, 2010 and 2020

Table 1: Cocoa Producing Countries ranked in terms of area harvested, production and yield/ha as of 2020

COUNTRY	RANK		
	Area Harvested (ha)	Production (t)	Yield/ha (t/ha)
Brazil	6th	7th	6th
Cameroon	5th	6th	8th
Colombia	8th	10th	9th
Cote d'Ivoire	1st	1st	5th
Dominican Rep.	9th	9th	7th
Ecuador	7th	5th	2nd
Ghana	3rd	2nd	3rd
Indonesia	2nd	3rd	4th
Nigeria	4th	4th	10th
Peru	10th	8th	1st

Source: FAOSTAT, 2020.

CONCLUSION AND RECOMMENDATION

As yield per hectare continues to improve in Brazil, deforestation of cocoa forests should be discouraged by the government to keep up with production in this phase of ever increasing demand for cocoa beans by the consuming nations.

No negative trend was observed in the production of cocoa beans in Cameroon as yield per hectare, areas harvested and production continues to improve over the years. Rehabilitation or rejuvenation of low productive plantations must be encouraged while farmers must be trained in preventing and controlling their farms from black pod disease during humid periods.

Colombia is underproducing regardless of the increase in cultivated land area and production over the years. Rehabilitation of old plantations and proper soil nutrient management must be adopted to boost production.

Research on effective measures to handle the age-long pest infestation of cocoa plantations which has been the major problem limiting production in Cote d'Ivoire must be set up as the country can produce more if productivity in terms of yield per hectare can be improved.

Due to the relatively small area of land currently being cultivated with cocoa in the Dominican Republic compared with the top 5 producing nations, productivity in terms of yield per hectare must continue to improve as it has been improving for the past 2 decades.

The government of Ecuador must continue to promote the programs and schemes that have been set aside for cocoa farmers to improve productivity, which has been one of the major factors responsible for their increase in productivity over the years.

Avoiding consistent decline in cultivating land areas of cocoa in Ghana must be prevented despite the increase in yield per hectare over the years. Youths and agile farmers should be encouraged in cultivating cocoa while rehabilitation or rejuvenation of moribund plantations must be put in place.

Indonesia has continued to experience a decrease in productivity in terms of yield per ha of cocoa bean over the years regardless of their rank as the 3rd main producer. The dominance of aging cocoa plantations in the country can be addressed by training farmers on rehabilitation and rejuvenation techniques while farmers also should be trained on effective pest and good management practices.

Nigeria is currently ranked lowest in terms of productivity in yield per hectare among the top 10 producers of the world. Encouragement of youths and agile farmers into cocoa bean production must be put in place. The rapid rehabilitation or rejuvenation of low-yielding plantations with high-yielding varieties should be done. Extension services to cocoa farmers should also be improved upon.

Peru's present productivity in yield per hectare is the best among the leading producers. However, production can be improved by increasing the current land area used in cocoa cultivation which is the least among the top growers in the world.

Generally, there is a need to evaluate the performance of the CCN51 cocoa variety which is high-yielding and dominantly cultivated in Peru for the production of cocoa beans in other producing countries with low productivity in terms of yield per hectare.

Peru's agronomic practices, farm management practices, cocoa government programs and policies promoting cocoa bean production should be understudied by other producing countries to boost their production to meet the demand for the ever increasing supply of cocoa beans.

REFERENCES

Alvarez, A. V. B. (2018). *The influence of climate on supply chain risk management* (Doctoral dissertation).

Asante-Poku, A., and Angelucci, F. (2013). Analysis of incentives and disincentives for cocoa in Ghana (Technical notes series). Rome.

Beg, M. S., Ahmad, S., Jan, K., and Bashir, K. (2017). Status, supply chain and processing of cocoa-A review. *Trends in food science and technology*, *66*, 108-116.

Cadoni, P. (2013). Analysis of incentives and disincentives for cocoa in Nigeria. Rome:

MAFAP, FAO. Retrieved from http://www.fao.org/3/a-at586e.pdf

Clay J (2004) World agriculture and the environment. Island Press, Washington DC. Competitiveness of cocoa production and improving the income of cocoa producers in West and Central Africa. Bonn, Germany: Südwind.

Cuello, J., Morales, M. E., and Rib, S. (2015). National Cocoa Action Plan for Sustainable Development. National Cocoa Commission of Dominican Republic, United Nations Development Programme (UNDP).

FAOSTAT (2018), (available at http://www.fao.org/faostat/en/#data/QC).

FAOSTAT. (2020). Food and Agriculture Organization of the United Nations (FAO). FAOSTAT Database. https://www.fao.org/faostat/en/#data/QCL. Accessed 02/03/2022.

Food and Agricultural Organisation (FAO). 2016. Available: http://www.faostat.fao.org/ Accessed 03/03/2022.

Franzen, M., and Borgerhoff Mulder, M. (2007). Ecological, economic and social perspectives on cocoa production worldwide. Biodiversity and conservation, 16(13), 3835-3849.

Hütz-Adams, F., Huber, C., Knoke, I., Morazán, P., and Mürlebach, M. (2016). Strengthening the competitiveness of cocoa production and improving the income of cocoa producers in West and Central Africa. SÜDWIND eV Kaiserstr., Bonn, Germany.

Hütz-Adams, F., Huber, C., Knoke, I., Morazán, P., and Mürlebach, M. (2016). Strengthening the

ICCO. (2013). Origins of Cocoa And Its Spread Around The World. Retrieved August 30, 2018, from https://www.icco.org/about-cocoa/growing-cocoa.html

ICCO. (2022). ICCO cocoa figures reveal global supplies expected to drop 5% this year. https://www.confectioneryproduction.com/news/38737/icco-cocoa-figures-reveal-global-supplies-expected-to-drop-5-in-the-next-year/. Accessed 4/03/2022.

Janssen, E., and Riera, O. (2016). Too Hot to Handle: The Explosive Growth of Chocolate in India. In M. P. Squicciarini and J. Swinnen (Eds.), The Economics of Chocolate (pp. 419–438). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780198726449.001.0001

Kozicka, M., Tacconi, F., Horna, D., Gotor, E. (2018). Forecasting cocoa yields for 2050. Bioversity International, Rome, Italy. 49 p., ISBN: 978-92-9255-114-8, URI: https://hdl.handle.net/10568/93236.

M. P. Squicciarini, J. F. Swinnen, The economics of chocolate (Oxford University Press, 2016).

McMahon, P., bin Purung, H., Lambert, S., Mulia, S., Susilo, A. W., Sulistyowati, E. and Keane, P. (2015). Testing local cocoa selections in three provinces in Sulawesi:(i) Productivity and resistance to cocoa pod borer and Phytophthora pod rot (black pod). *Crop Protection* 70: 28-39.

Nicodeme T.G., Suqun, Bosambe M.N. (2017). The Economic Analysis of Resource Used Efficiency for Cocoa Production in Cameroon: The Case Study of Lekie Division. *American Journal of Rural Development* 5(5): 123-137.

Ortiz-R, O. O., Gallardo, R. A. V., and Rangel, J. M. (2014). Applying life cycle management of Colombian cocoa production. *Food Sci. Technol. Campinas* 34(1): 62–68. https://doi.org /10.15 0/ S0101-20612014005000006.

Payne, M. J., Hurst, W. J., Miller, K. B., Rank, C., and Stuart, D. A. (2010). Impact of fermentation, drying, roasting, and Dutch processing on epicatechin and catechin content of cacao beans and cocoa ingredients. *Journal of Agricultural and Food Chemistry* 58(19): 10518-10527.

Poelmans, E., and Swinnen, J. (2016). A Brief Economic History of Chocolate. In M. P. Squicciarini and J. Swinnen (Eds.). The economics of chocolate (pp. 11–42). Oxford University Press.

Saatchi, S., Agosti, D., Alger, K., Delabie, J., and Musinsky, J. (2001). Examining fragmentation and loss of primary forest in the southern Bahian Atlantic forest of Brazil with radar imagery. *Conservation Biology* 15(4): 867-875.

Tothmihaly, A., and Ingram, V. (2017). How can the productivity of Indonesian cocoa farms be increased? (Research Training Group (RTG) 1666 "GlobalFood" No. 103). Global Food Discussion Papers. Göttingen.

Uribe, A., Méndez, H., and Mantilla, J. (2001). Effect of balanced fertilization on cocoa yield. *Better Crops International* 15(2): 3.

Vega, H., and Beillard, M. J. (2015). Ecuador Cocoa Update and Outlook. United States Department of Agriculture Foreign Agricultural Service (USDA). Retrieved from https://gain.fas.usda.gov/Recent GAIN Publications/Ecuador Cocoa Update and Outlook_Quito_Ecuador_2-18-2015.pdf

Villacis, A., Alwang, J., and Barrera, V. (2020). Does the Use of Specialty Varieties and Post-Harvest Practices Benefit Farmers? Cocoa Value Chains in Ecuador.

Wessel, M., and Quist-Wessel, P. M. F. (2015). Cocoa production in West Africa, a review and analysis of recent developments. NJAS - *Wageningen Journal of Life Sciences* 74–75: 1–7. https://doi.org/10.1016/J.NJAS.2015.09.001

World Cocoa Foundation Report: 13. (2014). http://worldcocoafoundation.org/ about-cocoa/cocoa-market-statistics/.

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PATTERNS OF FOREST COVER CHANGE IN OYO STATE, SOUTHWEST NIGERIA: A CALL FOR IMMEDIATE CONSERVATION ACTION

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ABSTRACT

The ability of Nigerian forest reserves to support livelihoods and provide ecosystem services such as improved primary healthcare delivery, sustainable food production, income generation, and carbon sequestration to mitigate climate change impacts, is currently constrained by deforestation and other anthropogenic factors. Hence, a clear understanding of the underlining pattern and process of forest cover loss is required to ensure that appropriate methods and approaches are developed to promote conservation in these forest reserves. This study assessed the pattern of forest cover change in five forest reserves (Gambari, Ijaiye, Lanlate, Opara, and Igangan) in Oyo State, southwest Nigeria over 30 years. Landsat Thematic Mapper (TM) and Landsat Enhanced Thematic Mapper Plus (ETM+) were used for assessing the forest cover loss for the years 1990, 2000, and 2020. There was a significant change in the vegetation cover of the forest reserves with decreases observed over the three decades. From 1990 to 2020, the reduction in forest cover ranged from 42.26% (Opara forest reserve) to 91.21% (Igangan forest reserve). This high rate of deforestation and forest degradation in Oyo State highlights the need for immediate conservation action. In addition, relevant stakeholders and policymakers must intensify efforts focused on the restoration and rehabilitation of degraded forest reserves in the state.

Keywords: *Land use change, degradation, deforestation, enrichment planting, light forest.*

INTRODUCTION

Forests were reported to cover over 25% of the earth's land surface and contained about 75% of terrestrial carbon (Eludoyin and Iyanda, 2019). These forests provide ecosystem services and support 60% of the population in developing countries with nutritional and health requirements (Faleyimu and Agbeja, 2012; Eludoyin and Iyanda 2019). Unfortunately, the continued increase in the rate of industrialization, agricultural production, urbanization, and the human population has resulted in the destruction of forest ecosystems with negative consequences on global surface temperatures (Arshad *et al.*, 2014)

Nigeria has one of the highest rates of deforestation in Africa, approximately 3.5% or 350,000– use changeof about 410,000 hectares per year between 2010 and 2015 (Keenan *et al.*, 2015). Oyo state is strategically located in the transition zone between the rainforest and savanna ecological zones of Nigeria. Hence, rainforests are found in the southeastern parts of Oyo state while other areas are classified as savannah. The forests located in the state are under serious anthropogenic pressure resulting in their degradation, conversion to agricultural lands, and urbanization (Ezebilo, 2004; Yusuff and Alamu, 2019). Forests are important sources of social-economic, and ecological benefits to people in the state. Hence, there is an urgent need for immediate conservation action and encourage sustainable management (Adedeji *et al.*, 2015; Khadijat *et al.*, 2021). This study assessed the pattern of forest cover changes in selected forest reserves in Oyo State. The assessment will provide the requisite information for the management of forest reserves in the state for improved livelihood.

MATERIALS AND METHODS

STUDY AREA

Oyo State is located in the southwestern region of Nigeria and covers around 2,650,000 hectares (Jatto *et al.*, 2021). It shares boundaries with

Kwara State in the north, Osun State in the east, Ogun State in the south, and Ogun and the Republic of Benin in the west. It is located between latitudes 7° 3'0.26"N and 9° 11'6.10"N, and longitudes 2°42'25.14"E and 4°33'23.84"E. There are nine designated forest reserves in the state representing 342,461 hectares of the land mass (Alo, 2018). Four reserves (Opara, Igangan, Ago Are I and II, Oke Iho) are located in the western part, while five (Olokemeji, Lanlate, Ijaiye, Osho and Gambari) are in the south.

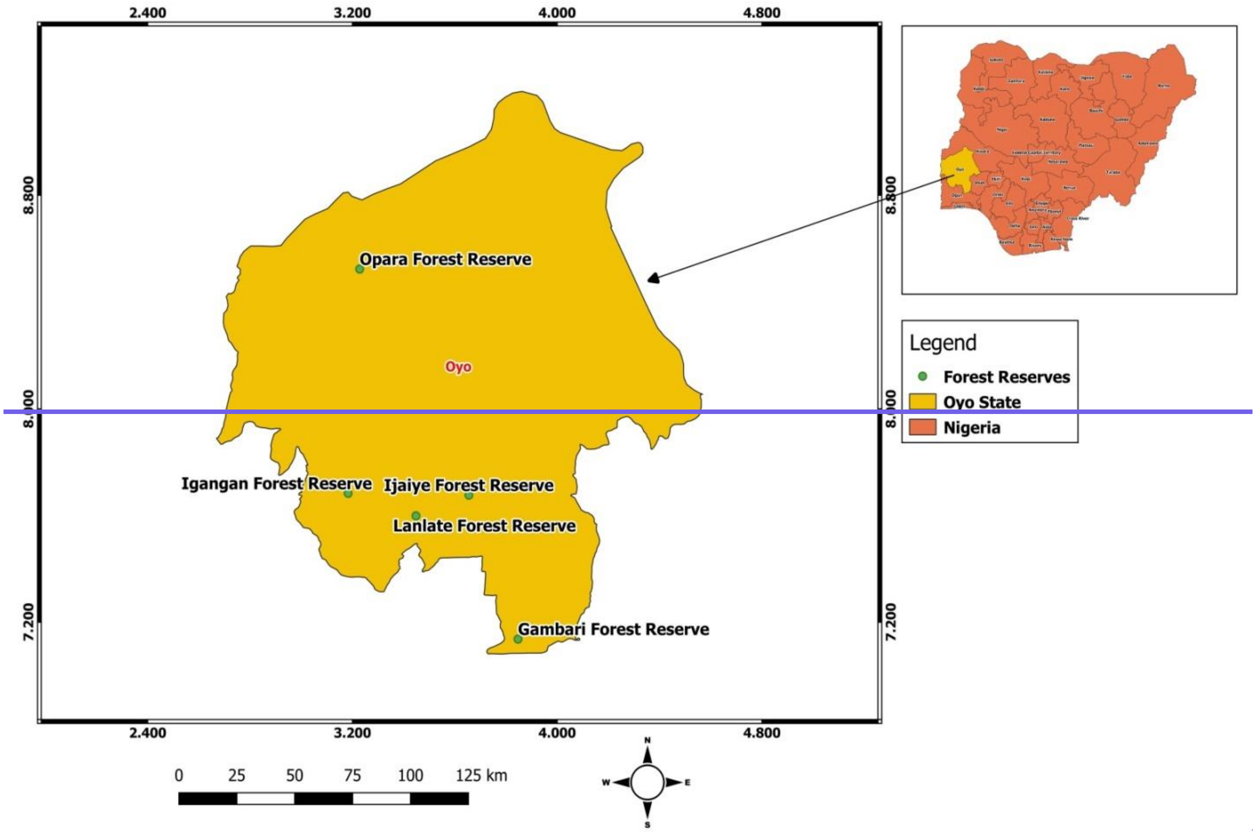

Figure 1: Five forest reserves in Oyo State (inset: map of Nigeria indicating Oyo state)

Table 1: Forest reserves location

Location	Land Area (hectares)	Percentage forest covered	Coordinate
Opara	248,640	72.6	7° 3'0.26"N and 9°11'6.10"N and 2°42'25.14"E and 4°33'23.84"E.
Igangan	39,627	11.57	7°43'0" N, 3°37'0"E
Ijaiye	28,491	8.32	7.677° N, 3.6599°E
Gambari	11,431	3.34	7˚25′ and 7˚55′N, 3˚53′ and 3˚90′ E,
Lanlate	7,507	2.19	7.7501° or 7° 45' 0.3" north

Data Sources Classification and Processing

Landsat Enhanced Thematic Mapper Plus (ETM+) and 8 OLI satellite data for the years 1990, 2000, and 2020 for selected forest reserves were downloaded. The images were accessed from the United States Geological Survey National Center for Earth Resources Observation and Science. The image was rectified in reference to the Universal Transverse Mercator (UTM).

The image (Landsat 7 ETM + and 8 OLI satellite) were pre-processed using Normalized difference vegetation index (ENVI) environments using the dark object subtraction method. This method was adopted for the visual improvement of the image. The vegetation indices (VI) were assessed as described by Jiang *et al.* (2006) and the spectral VI was selected according to their higher accuracy and sensitivities to forest cover monitoring. Natural color composite (NCC) was generated using suitable combinations of bands from the acquired Landsat satellite images (Good and Giordano, 2019). The ENVI 5.1 environments were used to classify the Landsat images for the years 1990, 2000, and 2020. The resulting images from the classification were used for the forest cover classes based on the Maximum Likelihood Supervised Classification (MLSC) algorithm (Biro et al., 2013). The identified forest cover classes were Forest, Light Forest/Shrub, and no forest. The classified forest cover maps were validated to ensure accuracy.

RESULTS AND DISCUSSION

Forest cover change

The total forest area of Gambari forest reserve was 12,065.58 ha in 1990, which was reduced to 9530.19ha in 2000, with 21% of the forest cover being lost in 10 years, forest cover loss increased with 43.23% being lost by 2020 and remaining forest cover in the reserve being 6848.55ha of the high forest area by 2020 (Figure 2). A similar trend was observed in Igangan forest the high forest area which was about 60% of the total land area as forest area in 1990, (Table 1) and was reduced to 36% in 2000 and to 17% in 2020 (Figure 3). Ijaiye forest reserve had a total land area of 27129.24ha, of which the high forest area was 14988.34ha in 1990, which is about 55% of the total land area as forest area in 1990 (Table 1), it was 34% in 2000 and to about 27% in 2020. Lanlate forest reserve and Opara forest reserve also follow a similar pattern, about 26% of Lanlate forest reserve land area constitute high forest area in 1990, and was reduced to 20% and 17% respectively in 2000 and 2020 (Figure 4). The light forest area which was mostly dominated by shrubs in Gambari forest covers an area of (28%) in 1990 dramatically increasing to 41% in 2000, and 51% in 2020. Similarly, The non-forested area covers which were 4% land area in 1990 increased to 5% in 2000, and 10% in 2020 (Table 1). The situation was similar with Igangan forest reserves, about 33% of the total land area in Igangan forest in 1990 was the light forest area which increased to 41% in 2000, and 47% in 2020 (Figure 5). The non-forested area 6% in 1990, increased 22% in 2000, and 35% in 2020. The trend follows a similar pattern when compared with other reserves (Ijaiye and Opara forest reserve (Figure 5&6)). The loss in forest cover persists, which in turn leads to an increase in light forest area and non-forest, by shrubs/ Light forest in Ijaiye forest covers area increased from 3% in 1990 to33% in 2000, very massive, and to 35% in 2020. The non-forested area also increased 11% in 1990 to 31% in 2000, and to 36% in 2020. Gambari forest reserves have lost about 49.15% of their forest area, Ijaiye forest reserves lost about 56.37% of its forest within the same range, Lanlate lost 37.77%, Opara forest reserves lost 42.26% and the worst was observed in Igangan forest reserves that losses about 91.21% of the forest area with 1990 to 2020. Previous studies have highlighted the high rate of degradation and forest cover loss in Nigeria (Olajuyigbe, 2018). Alamu and Agbeja (2011) described the current rate of deforestation in the Southwest as a massive de-reservation of forest cover. Khadijat *et al.*, (2021), reported that there is evidence of current human activities continue such as deforestation in the same study area, they revealed that the forest cover will continue to be threatened if nothing is done immediately to salvage the situation. Some of the major causes of forest cover loss in the state include indiscriminate tree harvesting, agricultural expansion and urbanization (Chakraborti *et al*., 2010**).** The forest areas are drastically reducing while the non-forest areas are expanding. The agricultural expansion causes increased degradation and removal of tree cover to accommodate agro-pastoral and livestock grazing, particularly at Igangan Forest reserve. Igangan Forest reserve had been largely converted to a grazing reserve because of the influx of herders and variability in the settler families (Babalobi, 2011). Ebrima (2003) reported that about 89.1% of Ijaiye forest reserve had been recently converted to agricultural land. In fact, it has been estimated that 2% of the forest cover would be lost annually to deforestation, and Ijaiye forest reserve would be de-reserved after 15years (Francis and Ebrima, 2003). Lanlate forest reserve has been reported to be porous and accessible to the local dwellers, (Babatunde *et al*., 2020). Opara forest reserve which is the largest reserve in Oyo State, had lost a large portion of its area (Alo, 2018). However, a slight change was observed in 2000, when non-forest area in the reserve decreased slightly. This could be because of a possible reforestation or enrichment planting program in the area. This study has provided empirical evidences on the ongoing human activities such as deforestation in most of the forest reserves in Oyo State. The deforestation is one of the main drivers of forest cover lose in the State. The result from this study is in agreement that the tropical forests are faced with persistent encroachment of human activities such as deforestation and expansion of agricultural activities (Khadijat *et al.*, 2021).

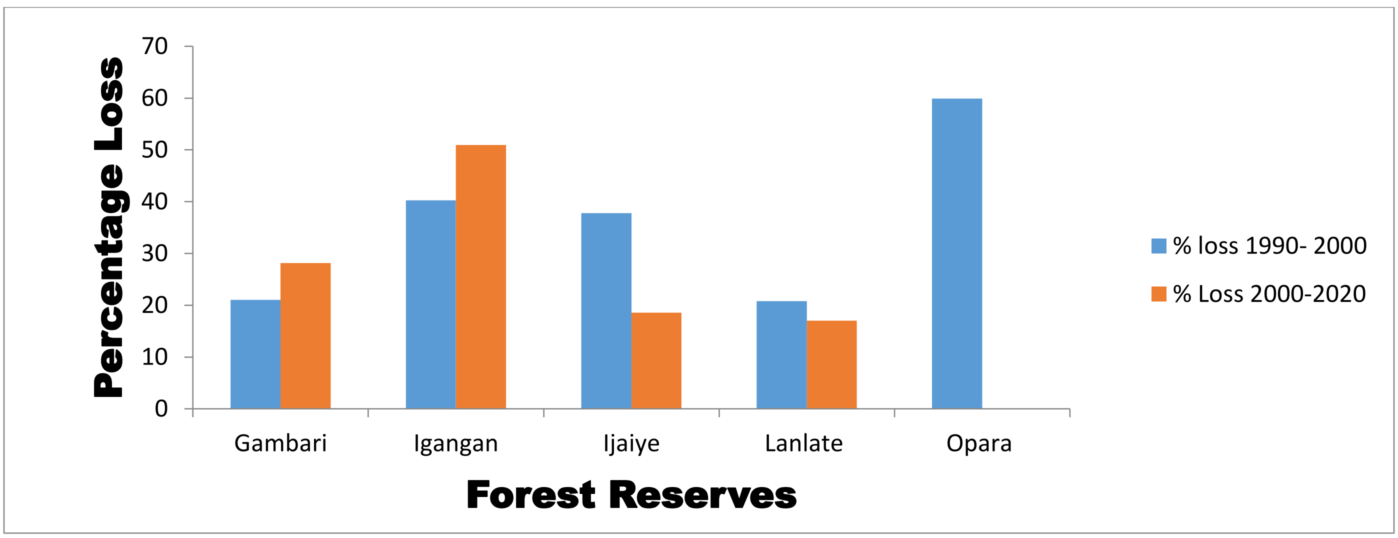

Figure 2: Percentage forest cover loss in the forest reserves

Table 1: Land Use Classification of Selected Forest Reserves in Oyo state Nigeria

Category		**1990 (Ha)**	**1990(%)**	**2000 (Ha)**	**2000(%)**	**2020 (Ha)**	**2020(%)**
Reserve	**Gambari**						
Forest		12066	67.719	9530.2	53.489	6848.6	38.438
Light Forest/Shrub		68.5	28.448	7410.6	41.593	9160.4	51.414
Non-Forest		682.92	3.833	876.24	4.918	1808.1	10.148
Total		17817	100	17817	100	17817	100
Reserve	**Igangan**						
Forest		23673	60.505	14137	36.132	6936.4	17.729
Light Forest/Shrub		12935	33.059	16218	41.451	18494	47.27
Non-Forest		2517.8	6.4353	8770.9	22.417	13695	35.002
Total		39126	100	39126	100	39126	100
Reserve	**Ijaiye**						
Forest		14988	55.248	9322.5	34.363	7591.6	27.983
Light Forest/Shrub		8939.8	32.953	9219.8	33.985	9528.5	35.123
Non-Forest		3201.1	11.8	8587	31.652	10009	36.894
Total		27129	100	27129	100	27129	100
Reserves	**Lanlate**						
Forest		2692.6	26.272	2133.3	20.814	1770.8	17.278
Light Forest/Shrub		6864.3	66.975	6295.6	61.426	4795.8	46.793
Non-Forest		692.11	6.7529	1820.2	17.759	3682.4	35.929
Total		10249	100	10249	100	10249	100
Reserve	**Opara**						
Forest		100853	45.86	40409	18.372	47549	21.618
Light Forest/Shrub		76138	34.66	141117	64.158	113292	51.507
Non-Forest		42962	19.53	38427	17.471	59111	26.875
Total		**219953**	**100**	**219953**	**100**	**219953**	**100**

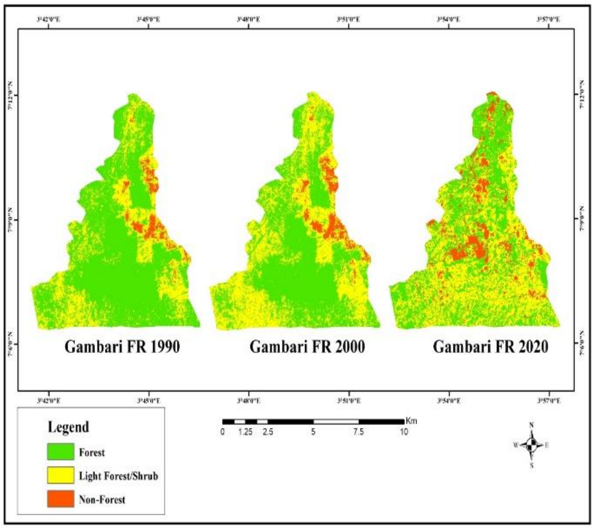

Figure 3: Forest cover Change in Gambari Forest Reserves

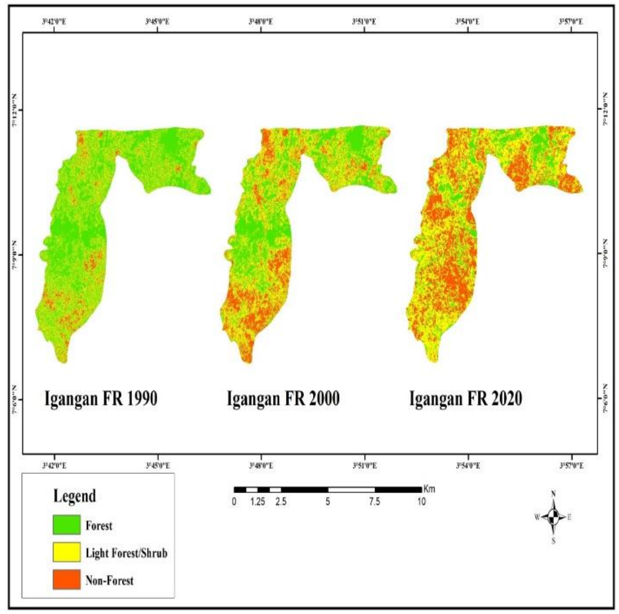

Figure 4: Forest cover Change in Igangan Forest Reserves

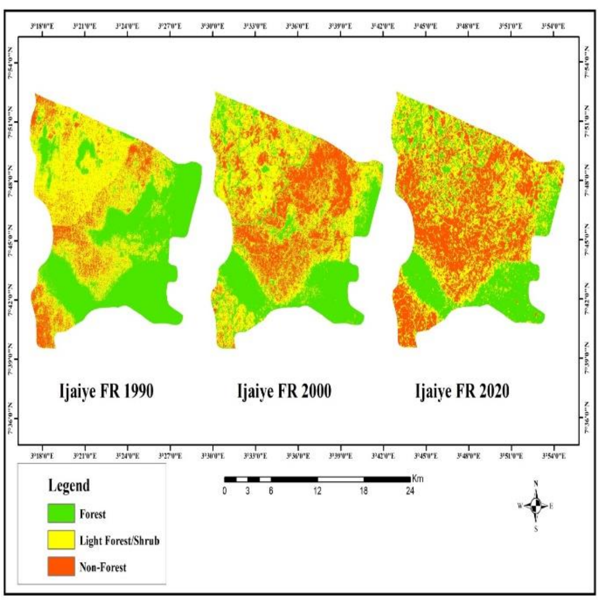

Figure 5: Ijaiye FR Landsat Image Classification

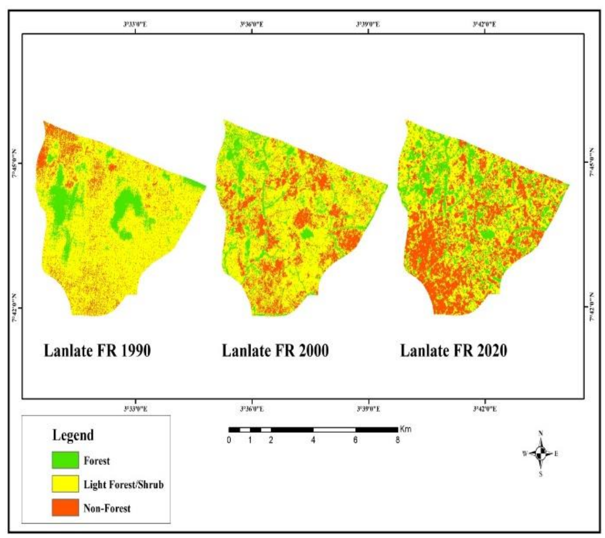

Figure 6: Forest cover Change in Lanlate Forest Reserves

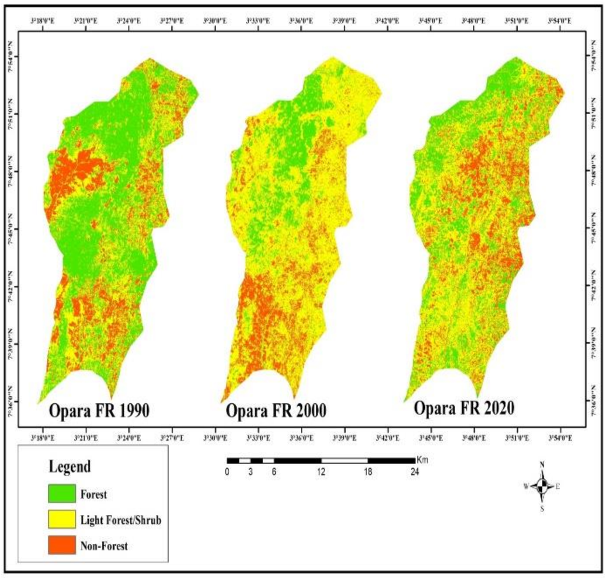

Figure 7: Forest cover Change in Opara Forest Reserves

CONCLUSION

This study on the investigation of pattern forest cover changes in five forest reserves in Oyo State, using Landsat Enhanced Thematic Mapper Plus (ETM+) to assess the forest cover loss for the years 1990-2020. The results were clear based on the forest cover analysis, the selected forest reserves were being degraded at a high rate and this portends danger to the natural resources in the state, this may invariably poses danger to the fast-growing population in the state. Both the rural and urban dwellers in the state depend largely on forest products to sustain their daily livelihood. Hence, there is an urgent need to promote a community-based forest management system where all the stakeholders will be involved in the process of rehabilitation, reforestation and solving the land-use conflicts in the state.

REFERENCES

Abiodun, B.J., Salami, A.T., Matthew, O.J., and Odedokun, S. 2013. Potential impacts of afforestation on climate change and extreme events in Nigeria. *Climate dynamics* 41.2: 277-293.

Adedeji, O.H., Tope-Ajayi, O.O., and Abegunde, O.L. 2015. Assessing and predicting changes in the status of Gambari forest reserve, Nigeria using remote sensing and GIS techniques. *Journal of Geographic Information System* 7.2: 301-318.

Ahenkan, A. and Boon, E. 2011. Non-timber forest products (NTFPs): Clearing the confusion in semantics. *Journal of Human Ecology* 33.1: 1-9.

Aigbe, H.I. and Oluku, S.O. 2012. Depleting forest resources of Nigeria and its impact on climate. *Journal of Agriculture and social research (JASR)* 12.2: 1-Alabi *et al.,* (2017),

Alamu, L.O. and Agbeja, B.O. 2011. Deforestation and endangered indigenous tree species in South-West Nigeria. *International Journal of Biodiversity and Conservation* 3.7: 291-297.

Alo, A. A. (2018). Spatial Distribution of Forest Reserves and Sawmills in Oyo State, Nigeria. *Forests and Forest Products Journal* 10: 60-72.

Arshad A., Somana R., and Shahid I. 2014. Deforestation and its impacts on climate change an overview of Pakistan papers on global change 21:51–60.

Asiedu, E., 2006. Foreign direct investment in Africa: The role of natural resources, market size, government policy, institutions and political instability. *World economy* 29.1: 63-77.

Azeez, I. O., Popoola, L., and Shulamite, I. O. 2017. An assessment of the forest regeneration potential of the Taungya system of farming in Oyo State, south-western Nigeria. Southern Forests: *Journal of Forest Science* 79: 1-9.

Babalobi, O. O. 2011. Participatory Epizootiology Research of Settled Pastoralists in Igangan Grazing Reserve, Southern Guinea Agro-Pastoral Zone, Oyo State, Nigeria: First Report. *Nigerian Veterinary Journal* 32.1:16 – 20.

Babatunde, T.O., Babatunde, O.O., Okeleke, S.O., Aduloju, A.R., and Agboola, F.O. 2020. Assessment of commercial importance and determinant factors influencing collection of non timber forest products in adjoining communities of lanlate Forest Reserve of Oyo State, Nigeria. *Journal of Research in Forestry, Wildlife and Environment* 12.1: 62-69.

Booth, T.H. and Saunders, J.C. 1985. Applying the FAO guidelines on land evaluation for forestry. *Forest ecology and management* 12.2: 129-142.

Chakraborti, A.K., Garg, S.K., Kumar, R., Motiwala, H.F., and Jadhavar, P.S. 2010. Progress in COX-2 inhibitors: a journey so far. *Current medicinal chemistry* 17.15: 1563-1593.

Eludoyin, A.O. and Iyanda, O.O. 2019. Land cover change and forest management strategies in Ife nature reserve, Nigeria. *GeoJournal* 84.6: 1531-1548.

Faleyimu O. I. and Agbeja B. O. 2012. Constraints to forest policy implementation in the southwest Nigeria: causes, consequences and cure. *Resources and Environment* 2.2: 37-44.

FAO/IUSS Working Group, 2010. A framework for land evaluation. Rome: *Soils Bulletin* 31: 25–42.

Francis Chimezie Phillips and Ebrima K. Ceesay, 2003: Livelihood Dependence and Forest Reserve Management in Ijaiye Forest Reserve, Oyo State, Nigeria. *International Journal of Forestry and Horticulture* 6.2: 26-39.

Geerling C. 1974: Upper Ogun and Opara Game Reserves Gazetted in Western State, Nigeria. *Environmental Conservation* 1.4: 304.

Hall, J.B. 1977. Forest-types in Nigeria: an analysis of preexploitation forest enumeration data. *The Journal of Ecology* 187-199.

Ilori, O.W. and Ajayi, V.O. 2020. Change detection and trend analysis of future temperature and rainfall over West Africa. *Earth Systems and Environment* 4.3: 493-512

Intergovernmental Panel on Climate Change (IPCC), 2002. Climate Change: Synthesis Report In A Contribution of Working Group I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Watson, R.T., (Ed.), Cambridge University Press, Cambridge, UK 397: 239-397.

Jaiyesimi M. A., Adekanbi D.I., Akankuku A.I., and Obafunsho O. E. 2012. Forest Conservation Policy: The Role of State Forestry Department in Oyo State. *Continental J. Agricultural Science* 6.3: 1 – 7.

Jatto, K.A., Akanbi, S.O., Adeoye, A.S., and Oke, O.O. 2021. Livelihood Diversification among Arable Farm Households in the Forest Zone of Oyo State, Nigeria. *Nigeria Agricultural Journal* 52.2: 130-136.

Keenan, R.J., Reams, G.A., Achard, F., de Freitas, J.V., Grainger, A., and Lindquist, E. 2015. Dynamics of global forest area: Results from the FAO Global Forest Resources Assessment 2015. *Forest Ecology and Management* 352: 9-20.

Khadijat, A., Anthony, T., Ganiyu, O., and Bolarinwa, S. 2021. Forest cover change in Onigambari reserve, Ibadan, Nigeria: Application of vegetation index and Markov chain techniques. *The Egyptian Journal of Remote Sensing and Space Science* 24.3: 983-990.

Oyebo M.A. 2002. Prospects for private forestry in Nigeria.: Popoola L (ed.), Forest, people and environment: proceedings of a national workshop in Benin City, Edo State, Nigeria, 5–6 September 2002. Ibadan: Forestry Department, Edo State; FAN-Consult. 88–102.

Percy, K.E., Jandl, R., Hall, J.P. and Lavigne, M., 2003. The role of forests in carbon cycles, sequestration, and storage. *IUFRO Newsletters* 1: 1-5.

Peters, O. 2004. Assessing vulnerability to deforestation under different property rights regimes: a study of forest communities in Southeast Nigeria. *Advanced Institute on Vulnerability to Global Environmental Change* 3-21.

Potapov, P., Hansen, M., Stehman, S.V., Pittman, K., and Turubanova, S. 2009. Gross forest cover loss in temperate forests: Biome-wide monitoring results using MODIS and Landsat data. *Journal of Applied Remote Sensing* 3.1: 033569.

Ridder, R.M. 2007. Global forest resources assessment 2010: options and recommendations for a global remote sensing survey of forests. *FAO For. Resour. Assess. Programme Work Pap* 141

Udayashankara, T.H., Sadashiva, Murthy, B.M., and Madhukar, M. 2016. Impact of Climate Change on Rainfall Pattern and Reservoir Level. *Journal of Water Resource Engineering and Management* 3.1: 10–14.

Yusuff, Z.O. and Alamu, L.O. 2019. Effectiveness Of Forest Management As Affected By The Land Use Act In Onigambari Forest Reserve, Oluyole Local Government Area Ibadan, Nigeria. *Advances in Social Sciences Research Journal* 6: 12.

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ANTIMICROBIAL ACTIVITIES OF GOLDEN SHOWER (*CASSIA FISTULA* L.) LEAVES EXTRACTS

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ABSTRACT

Fabaceae are known for diverse medicinal values since ancient times. Yellow shower (Cassia fistula Linn.) belongs to this family. This study evaluated the phytochemical constituent and anti-microbial activities of Cassia fistula leave extracts. Ethanolic extract of the collected leaves was prepared and screened for some active chemical constituents (flavonoids, phenols, alkaloids) and antioxidants (DPPH and Hydrogen peroxide). The antibacterial potential of the extract was tested against two gram-positive (Staphylococcus aureus and Pseudomonas aeruginosa), and two gram-negative (Escherichia coli and Salmonella typhi) using the disc diffusion method. Generally, there was no significant growth inhibition of all the isolates by C. fistula leaves extract in the concentrations tested (100 to 400 mg/ml). However, the growth inhibition of S. aureus increased linearly with an increase in the concentration of C. fistula leaves extracts. S. typhi was not sensitive to the leaves extract in the concentrations tested. The microbial activity of the Cassia fistula leaves extract was due to the presence of various secondary metabolites. Hence, this plant is a good source of bioactive natural products for pharmaceutical research.

***Keywords**: Cassia fistula, secondary metabolites, antioxidant, antibacterial, natural products.*

INTRODUCTION

Plants remain the most abundant natural primary source of active pharmaceuticals and are invaluable in the ethnomedical treatment of diverse ailments. Medicinal plants are frequently sources of numerous phytochemicals, some of which are usually responsible for their biological actions (Olasehinde, 2012). Fabaceae are known for diverse medicinal values, since ancient times yellow shower (*Cassia fistula* Linn) belongs to this family. The golden shower has become extensively diffused in various Countries including Mauritius, India, South Africa, Mexico, China, West Indies, East Africa and Brazil as an ornamental tree for its beautiful bunches of yellow flowers. The numerous yellow blooms of *Cassia fistula* make it a popular decorative plant in the tropics. *Cassia fistula* is a tree that grows to a height of 6–9m, and has a straight trunk, pale grey and smooth bark when young, brown and rough as it matures. The branches are thin and spread widely (Hafez, 2019). *Cassia fistula* reproduces naturally by seeds, although it can also be propagated vegetatively through Cutting and layering (Okusanya, 2015).

Cassia fistula is very important in different traditional medicinal systems because it possesses distinctive properties, valuable in treating dermal infections, inflammatory conditions, ulcers, rheumatism, jaundice as well as anorexia (Pawar, 2017). The root has purgative effects; treats heart-related illnesses, fever, biliousness, nausea, and retention. The different portions of the plant species have exhibited numerous medicinal benefits, for instance, hypoglycemic antioxidant and antitumor potentials.

Previous studies have been conducted on the root, fruit and stem back of *Cassia fistula* leaf extract because of this, the present study aimed to investigate the phytochemical constituents and antimicrobial activity of ethanolic extract of *Cassia fistula* leaf. This species' seeds are used as a remedy for treating gastritis and diarrhoea, as well as an insect repellent. In addition to improving appetite, the seeds are used to alleviate biliousness. Skin disorders, syphilis, leprosy, and tuberculosis are all treated using the roots. Burning feelings can also be relieved using root extracts. Throat diseases, inflammation, liver issues, chest troubles, asthma, and rheumatism are all treated with the fruits, which has been reported by (Pawar, 2017).

In recent times, people are becoming more interested in using C. fistula seeds to cure piles and rheumatism in the study area (Maiduguri). However, there is less concern about the usage and efficacy of the other parts of the plant to treat other ailments in Nigeria and elsewhere around the world. The objectives of the study were to: determine some secondary metabolites/ phytochemicals in *Cassia fistula* leaves extract; determine some antioxidants in the leaves extract; determine the anti-microbial activities of *Cassia fistula* leaves extracts.

MATERIALS AND METHODS

Source of *Cassia fistula*

Fresh *Cassia fistula* leaves were collected from University of Maiduguri Campus in November 2021. It was identified and authenticated by Mr Sule Buba Sarah, a botanist in the Department of Biological Sciences, University of Maiduguri, Nigeria.

Preparation of *Cassia fistula* leaves extract

The collected sample was thoroughly washed with tap water and then shed-dried for 6 days. The dried leaves were ground into powder separately using a mechanical grinder and sieved (2 mm). The powder was stored in an airtight leader until analysis.

Exactly 300g/L of the powder was used for the extraction with pure ethanol using Soxhlet. The extract was evaporated to dryness in a silver tray and stored in a glass container at 25±2 °C.

Preliminary phytochemical screening

The ethanol extract of the leaf *Cassia fistula* was subjected to preliminary phytochemical testing to detect the presence of different chemical compounds.

Flavonoids content

The total flavonoid content was estimated using the procedure described by (Zhishen *et* al. 1999). The total flavonoid content of *cassia fistula* leaves extract was obsessed at the absorbance of standard compound (quercetin) at 510nm, at different concentrations. Standard curve of quercitin indicated the equation of $y = 0.528x + 0.031$ and $R^2 = 0.992$, where: y = absorbance at 510 nm, x = total phenol in the extracts.

Phenolic content

The total phenolic content of *Cassia fistula* was estimated using the Folin-Ciocalteau reagent (Sidduraju, 2003). The total phenolic content was also observed at an absorbance of standard compound (gallic acid [725nm]) at different concentrations. Standard curve of Gallic Acid indicated the equation of $y = 0.021x + 0.076$ and $R^2 = 0.960$, where: y = absorbance at 725 nm

x = total phenol in the extracts.

Determination of alkaloids

The total alkaloid was determined (Obadoni, 2001). Alkaloid = weight of residue / weight of sample × 100. Alkaloids = 7.60%.

Antioxidant activities

DPPH radical scavenging activity

The ability of *Cassia fistula* extracts to scavenge the DPPH radicals was assessed by using the method of Blois (1958). Absorbance control – Absorbance sample / Absorbance control × 100. DPPH = 73.3%

Hydrogen peroxide radical scavenging activity

The scavenging ability of the ethanol extract of *Cassia fistula* on hydrogen peroxide was determined (Serteser *et al*., 2009). 1 – Absorbance sample / Absorbance control × 100. Hydrogen peroxide = 69.4%

Sources of bacterial strains

The bacteria strains were obtained from Department of Veterinary Microbiology University of Maiduguri, Nigeria.

Determination of zone of inhibition

The stock cultures were incubated for 24h at 37°C on nutrient agar, in vitro antibacterial activities were examined for the ethanolic extracts. Antibacterial activities of the leaves were tested against four (4) pathogenic bacteria (two gram-positive and two gram-negative) using the disk diffusion method. Zones of inhibition were measured according to Kirby (1956).

Antimicrobial activities

The concentrations (400mg/ml, 200mg/ml, 100 mg/ml and control) were prepared by diluting the stock concentration (12g/L) of the leaves extract in sterilized distilled water.

The isolates were sterile in 5ml of 98% normal saline in test tubes and seeded into the surface of the prepared media, and incubated at 37°c for 24 hrs. The leaves extracts were then screened for their antibacterial activities against *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Salmonella typhi*.

Data Analysis

Data were subjected to one-way ANOVA using a statistical package (DSAASTAT Ver. 1.101) and Duncan's multiple range test (DMRT) was used to compare the means at P = 0.05. Error m bars present standard deviation (SD).

RESULTS

Phytochemical screening

The Qualitative phytochemical screening of the leaves extracts of *Cassia fistula* showed the presence of flavonoids, alkaloids and phenols. The concentration of alkaloid was the highest, while phenolic content was the least (Table 1).

Microbial activity

Generally, the growth inhibition of the leaves extracts of *Cassia fistula* on all the isolates at the concentrations tested (100 mg/ml to 400 mg/ml) were not significantly different (P < 0.05). However, the growth inhibition of *S. aureus* increased linearly with the increase in the concentration of *C. fistula* leaves extracts. The growth inhibition zone ranged from 10 to 18mm for all the sensitive bacteria. *S. typhi* was not sensitive to the leaves extract in all the concentrations tested (figure 1).

Table 1: Phytochemical screening test for the ethanolic extract of *Cassia fistula*

Component	Test	Scoring
Flavonoid	Pew's	++
Alkaloid	Dragedorff's	+++
Phenol	Sodium hydroxide	+

+ = Low, ++ = Moderate, +++ = High

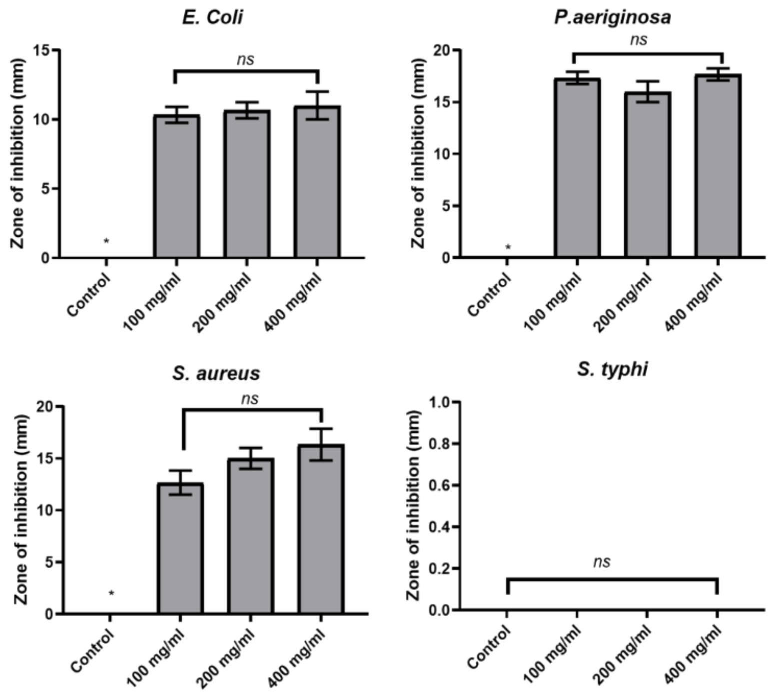

Figure 1: Sensitivity of different bacterial isolates exposed to *C. fistula* leaves extracts.

DISCUSSION

Plants with medicinal value contain a huge number of pharmaceutically important substances that are being studied for the identification of innovative herbal medications for a variety of life-threatening diseases such as cancer, ulcers, and tumours. Bioactive molecules derived from medicinal plants have been found to suppress microbial growth and have radical scavenging properties**. (**Alamholo and Amraie, 2021). *Cassia fistula* is well-known for being a rich source of glycosides, tannins, and flavonoids, all of which may be beneficial, medically and nutritionally.

In this study, the preliminary qualitative phytochemical screening of *Cassia fistula* leaves revealed the presence of alkaloid, phenol and flavonoid. These Secondary metabolites are reported to have many biological and Therapeutic properties. (Alamholo and Amraie, 2021). These findings also support the view of Bhalodia and Shukla (2011) who observed antibacterial and antifungal effects of leaves extracts *Cassia fistula* on some species. This results similarly show that the extracts of *Cassia fistula* were found to be effective against all the isolates tested except for S. *typhi*.

The microbial activity of the *Cassia fistula* leaves extract was due to the presence of various secondary metabolites. Hence, this plant is a good source of bioactive natural products for pharmaceutical research.

CONCLUSION

This finding supports the traditional therapeutic claims that *Cassia fistula* is used to cure microbe-caused illnesses and is a rich source of naturally occurring bioactive chemicals. Cassia fistula is a rich in naturally occurring bioactive chemicals, the antimicrobial activity against the isolates indicates that the plant could be used to make drugs with a broad spectrum of activity, and polyphenolics, which are abundant in the plant's extracts could be very beneficial.

The microbial activity of the *Cassia fistula* leaves extract was due to the presence of various secondary metabolites. Hence, this plant is a good source of bioactive natural products for pharmaceutical research. Further studies should be carried out extensively to assess the potential efficacy of other solvents and different parts (seed, flower and stem back, roots, flower, pod) of the plant against some other bacterial isolates.

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REFERENCES

Alamholo, M., and Amraie, Y. (2021). Evaluation of Susceptibility and Resistance of Human Infectious Bacteria and Identification of Bioactive Compounds in *Pistacia atlantica*, *Cassia absus*, and *Quercus persica*. *Pharmaceutical and Biomedical Research*.

Baur, A. W., Kirby, W. M. M., Sherris, J. C. T., and Turch, M. (1966). Antibiotic susceptibility testing by a standardized single disk method. *American Journal Clinical Pathology*, 45(4), 493-496.

Bhalodia, N. R., and Shukla, V. J. (2011). Antibacterial and antifungal activities from leaf extracts of *Cassia fistula* L.: An ethnomedicinal plant. *Journal of Advanced Pharmaceutical Technology and Research*, *2*(2), 104.

Blois, M. S. (1958). Antioxidant determinations by the use of a stable free radical. *Nature*, 181(4617), 1199-1200.

Hafez, S., Othman, S., Ibrahim, H., Seida, A., and Ayoub, N. (2019). Chemical constituents and biological activities of Cassia genus. *Archives of Pharmaceutical Sciences.* Ain Shams University, 3(2), 195-227.

Kirby, W. M., Yoshihara, G. M., Sundsted, K. S., and Warren, J. H. (1956). Clinical usefulness of a single disc method for antibiotic sensitivity testing. *Antibiotics Annual*, 892-897.

Obadoni, B. O., and Ochuko, P. O. (2002). Phytochemical studies and comparative efficacy of the crude extracts of some haemostatic plants in Edo and Delta States of Nigeria. *Global Journal of Pure and Applied Sciences*, *8*(2), 203-208.

Okusanya, O. T., Shonubi, O. O., and Babalola, S. E. (2015). Natural seed germination and seedling dynamics in cultivated population of Cassia fistula Linn. in Nigeria. *African Journal of Agricultural Research*, *10*(8), 865-870.

Olasehinde, G. I., Ayanda, O. I., Ajayi, A. A., and Nwabueze, A. P. (2012). In-vivo antiplasmodial activity of crude n-hexane and ethanolic extracts of Moringa oleifera (LAM.) seeds on Plasmodium berghei. *International Journal of Medicinal Plant Research*, *1*(5), 50-54.

Pawar, A. V., and Killedar, S. G. (2017). Uses of Cassia fistula Linn as a medicinal plant. *International Journal for Advance Research and Development*, *2*(3).

Serteser, A., Kargıoğlu, M., Gök, V., Bağci, Y., Özcan, M. M., and Arslan, D. (2009). Antioxidant properties of some plants growing wild in Turkey. *Grasas Y Aceites*, 60(2), 147-154.

Siddhuraju, P., and Becker, K. (2003). Antioxidant properties of various solvent extracts of total phenolic constituents from three different agroclimatic origins of drumstick tree (Moringa oleifera Lam.) leaves. *Journal of Agricultural and Food Chemistry*, 51(8), 2144-2155.

Yele, S. U., and Veeranjaneyulu, A. (2010). Toxicological assessments of aqueous extract of Eugenia jambolana stem bark. *Pharmaceutical Biology*, 48(8), 849-854.

Zhishen, J., Mengcheng, T., and Jianming, W. (1999). The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. *Food Chemistry*, *64*(4), 555-559.

Zimmermann, M. (1983). Ethical guidelines for investigations of experimental pain in conscious animals. *Pain*, 16(2), 109-110.

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ANTIOXIDANT RESPONSE OF METAL STRESSED CYPERUS IRIA AMENDED WITH ORGANIC AND INORGANIC FERTILIZER

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ABSTRACT

The antioxidant stress response of Cyperus iria in heavy metal polluted soil was investigated. A factorial experiment fitted into Randomized Complete Block Design (RCBD) was adopted. The research was conducted at the Centre for Ecological Studies, University of Port Harcourt Nigeria. Weighing balance (Setra 480S, USA) was used to weigh 2kg homogenized heavy metal contaminated soil collected from an abandoned metal scrap dumpsite at Ikoku Rivers State Port Harcourt into planting bags of height 18cm, diameter 14cm and with a surface area of 0.0985m^2. The filled bags were arranged in 4 blocks (A, B, C, and D) in addition to an uncontaminated soil designated as block E. The amendment concentration treatments were A_1: NPK (40g/2kg), A_2: NPK (80g/2kg), A_3: NPK (120g/2kg), B_1: orange peel (100g/2kg), B_2: orange peel (200g/2kg), B_3: orange peel (300g/2kg), and C_1: plantain peel (100g/2kg), C_2: plantain peel (200g/2kg), C_3: plantain peel (300g/2kg) block D and E with (0g) stand as control and double control respectively of 12 replications for each sub plot. Equal height, weight and vigour of Cyperus iria seedlings were transplanted from the nursery into all treatment pots. The antioxidant enzymes of Cyperus iria such as superoxide dismultase (SOD), glutathione (GSH), proline (P) and carotenoid (CA) were analysed at 60 and 120 days after planting. Results showed that organic and inorganic amendments were effective in decreasing oxidative stress of Cyperus iria plants in polluted soil. The antioxidant reduction rate showing the least were in order: CA (300g PP), GSH (100g and 300g OP), P (120g NPK) and SOD (300g OP). Therefore, the amendments decreased excess production of Reactive Oxygen Species, hence conferring tolerance ability on Cyperus iria in pollution prone site.

Key words: *Amendments, Heavy metals, Antioxidant biological marker, Reactive oxygen species.*

INTRODUCTION

Cadmium (Cd) and lead (Pb) are non-essential elements to plants. These elements are predominately found in air, water and soil posing serious concern to human health. The effects of Pb on plants are observed directly on plant growth and metabolism showing visible symptoms like stunted growth resulting in membrane disorganization. Antioxidative defence mechanism protects the plants cells from oxidative damage caused by Reactive oxygen species (ROS) due to heavy metals.

Biomarkers are biochemical, physiological or histological changes that measure effects of, or exposure to, toxic chemicals or environmental perturbation such as heavy metal pollution, depletion in nutrients, excess fertilizer application (Luebke *et al.*, 1997), in general but not exclusively pertain to a response at a specific organ, cellular or subcellular level of organisation (O'Halloran *et al.*, 1998), measuring biochemical endpoints (Bresler *et al.*, 1999). These cellular and molecular responses can be used as early warning pointer of environmental stress, before whole-organism effects become apparent (Regoli *et al.*, 1998). Exposure to high environmental levels of metals can induce synthesis of biomarker responses (Irato *et al.*, 2003). Biomarkers are being increasingly recognised as accurate and cost-effective methods for identifying the *in situ* toxic effects of pollutants on biota (Brown *et al.*, 2004). Naturally, molecular oxygen (O_2) is release into the environment on a regular basis by photosynthetic organisms. The regular release of molecular oxygen has increased the concentration of Reacting Oxygen Species (ROS). The production of Reactive Oxygen Species occurs when plants are subjected to stress conditions and production of O_2 molecule is frequently scavenged by plant biomarkers. This includes catalase, gluthathione and super oxide dismultase (Foyer, 2005). The ROS alongside with antioxidant production are constantly in equilibrium which may be influenced by environmental stress. Environmental pollutants generally cause an increase in peroxidative processes within cells, causing oxidative stress (Cheung *et al.,* 2001; Nusetti *et al.,* 2001). Hydroxyl radicals are produced in electron transfer reactions, and are potent oxidants capable of damaging important cell components, such as proteins and DNA (Doyotte *et al.*, 1997; Cheung *et al.*, 2001). Lipid peroxidation (LPO) has often been used as a biomarker of environmental stress, reflecting damage to cell membranes from free radicals (Ringwood *et al.*, 1999) and is an important feature in cellular injury (Reddy, 1997). The extent of damage caused by oxygen radical production is dependent on antioxidant defences, which include antioxidant enzymes and free radical scavengers, such as glutathione (Doyotte *et al.*, 1997). Therefore, antioxidant enzymes is a common biomarker used in environmental monitoring (Regoli *et al.*, 1998). The enzymes usually respond rapidly and sensitively to biologically active pollutants (Fitzpatrick *et al.*, 1997). Some of the most commonly used antioxidant enzyme biomarkers include catalase and glutathione-s-transferase. Catalase is induced by the production of hydrogen peroxide in the cells and catalyses the reaction, which reduces this compound to water and oxygen (Regoli *et al.*, 1998). Glutathione-s-transferase catalyses the conjugation of a large variety of xenobiotics containing electrophilic centres to reduced glutathione (Principato and Regoli 1995; Sharma *et al.*, 1997). Concentrations of this enzyme have been found to increase with exposure to contaminants (Fitzpatrick *et al.*, 1997). Glutathione (GSH) is often used in biomarker studies, as it is an overall modulator of cellular homeostasis (Ringwood *et al.*, 1999). The reduced form conjugates with electrophilic xenobiotics transforming them into water soluble products (Nusetti *et al.*, 2001).

Many studies examine the responses of organisms to contamination, using the endpoints of reduced growth performance of plants or Antioxidant enzyme biomarkers in reproduction (Wright and Welbourne, 2002). Using a combination of biomarkers including antioxidant enzymes (CAT and GST) and free radical scavengers (GSH) in both a field and laboratory situations, ensure that all aspects of the biochemical effects of metal exposure are being assessed. Since antioxidative defense mechanisms protects the plant from Reactive Oxygen Species (ROS) damage, antioxidant enzymes like SOD, CAT, GSH are always on the increase when a plant is expose to pollution stress. It is expected that result obtained from the investigation will give a clearer view on the plant pollution stress interaction.

MATERIALS AND METHODS

Study Area

This research was carried out at the Center for Ecological Studies, University of Port Harcourt, located on geographical coordinates: Latitude 4.90428^o N and Longitude 6.92297^o E. The climate condition of the area is characterized by temperature range of 36 ^oC and 45 ^oC for daily and annual range respectively.

Sources of Material and Processing

Land race of sweet orange was acquired from Otutu-Amaumara Ezinihitte Mbaise LGA., Imo State. The sweet orange is popularly known as 'Oroma or Epe' in their native tongue. The ripe plantain obtained from Kaiama in Kolokuma/Opukuma L.G.A, Bayelsa State is popularly referred to as 'Beribe'. The plantain and orange peels were removed mechanically by hand peeling. The peels (waste) generated from mechanical process were dried and processed into powder form, which was then analyzed to make certain the nutritional value and heavy metals content of the peels (Table 1). The NPK 20:20:20 was obtained from Rivers State Agricultural Development Program (ADP) Rumuodomaya, Port Harcourt.

Table 1: Nutrient and metal of the peels waste used

S/N	Parameter	Orange peels waste	Plantain peels waste
1	Phosphorus (mg/kg)	66.51	36.84
2	Sodium (mg/kg)	474.85	137.45
3	Potassium (mg/kg)	66,285	26,743
4	Magnesium (mg/kg)	1208	1614
5	Calcium (mg/kg)	278.70	4,400.10
6	Nitrogen %	0.119	0.196
7	Ash %	11.50	16.40
8	Fe (mg/kg)	767.7	483
9	Zn (mg/kg)	13.05	236.50
10	Pb (mg/kg)	ND	ND
11	Cd (mg/kg)	ND	ND
12	pH	5.56	9.08

ND = Not detected

Experimental Design

Factorial experiment fitted into Randomized Complete Block Design (RCBD) was adopted as a design for this experiment. A suspected heavy metal polluted soil was acquired from an abandoned metal scrap site at Ikoku Rivers State Port Harcourt on geographical coordinate: Latitude 4.80083° N and Longitude 6.991093° E alongside with uncontaminated soil obtained from a fallow land at University of Port Harcourt, at depth 0-20 cm using a spade. The soils collected were analysed to ascertain heavy metal content and other physicochemical properties. This was known as baseline analysis (Table 2). The soils were bulked together, homogenized and transported to the Centre for Ecological Studies University of Port Harcourt. The collected soil was mixed thoroughly, dried and sieve through 2 mm mesh to obtain a homogenous soil (fine fraction) composite. Weighing balance (Setra 480S, USA) calibrated in (kg) was used to weigh two kilograms (2 kg) of the homogenized soil into planting bags. The bags were arranged in 4 blocks (A, B, C, and D) alongside with uncontaminated soil designated as batch E. Batch A was subdivided into 3 sub plots designated as A_1, A_2 and A_3. The same division process was adopted for block B and C as B_1, B_2 and B_3, C_1, C_2 and C_3 of 12 replications for each subplot.

Amendment Treatments

The three amendments were NPK, orange and plantain peels powder. Each amendment was weighed on weighing balance (Setra 480S, USA), NPK was added to block A, orange peel to block B and plantain peels to block C. Each block was subdivided into 1,2, and 3 as A_1, A_2, A_3; B_1, B_2, B_3 and C_1, C_2, C_3. Amendment treatments were added as follows: Amendment treatment A_1: NPK (40g/2kg), A_2: NPK (80g/2kg), A_3: NPK (120g/2kg), Treatment B_1: orange peel (100g/2kg), B_2: orange peel (200g/2kg), B_3: orange peel (300g/2kg), and Treatment C_1: plantain peel (100g/2kg), C_2: plantain peel (200g/2kg), C_3: plantain peel (300g/2kg) while no amendment was added to block D and E. That is 0g amendment which stand as control and double control respectively. After two weeks of post amendment treatments. Two seedlings of test plant raised in the nursery from seeds for 3 weeks which was properly identified at the University of Port Harcourt Herbarium as *Cyperus iria* Linn was planted into various blocks. The planted seedlings were of the identical size and vigour. The experimental area was shaded with transparent rubber zinc as to control directly rain water. Watering was done 4 times a week using 500 ml and weeding was done by hand picking when the need arose. The experiment was monitored at 60 days interval. On the 60th day, six replicates from each plot were carefully harvested; shoots were separated from roots by cutting using a sharp knife. The collected samples with proper labelling in accordance to their amendment treatments were taken to the laboratory immediately in an ice packed cooler for analysis. The parameters analysed were proline, carotenoid, glutathione and superoxidase dismutase.

Table 2: Physicochemical properties and heavy metal content of polluted and unpolluted soil

S/N	Parameter	Unpolluted	Polluted soil
1	Moisture (%)	45	43
2	Bulk density (%)	1.5	1.7
3	Particle density (%)	5.8	5.1
4	Porosity	0.35	0.3
5	SOM (%)	12	24
6	Sand (%)	95.6	93.6
7	Silt (%)	0.10	0.7
8	Clay (%)	4.3	5.7
9	Chloride (mg/kg)	213	3687
10	Sulphate (mg/kg)	28.4	269
11	Nitrate (mg/kg)	71.9	138
12	Phosphorus (mg/kg)	1.35	0.82
13	Sodium (mg/kg)	120	132
14	Calcium (mg/kg)	110	120
15	Magnesium (mg/kg)	258	280
16	Potassium (mg/kg)	43	68
17	pH	5.10	8.43
18	Conductivity (μsCm^{-1})	90	1193
19	Iron (mg/kg)	48.2	4410
20	Zinc (mg/kg)	0.94	107.5
21	Lead (mg/kg)	130	167.3
22	Cadmium (mg/kg)	0.80	15.3

Note: SOM = Soil Organic matter

Samples and Laboratory Analysis

Analytical Techniques

Superoxide dismultase (SOD)
The determination of SOD was based on the inhibition of NADI-phenazinemethosulpahte nitribleutetrazoliumformazon formation. The end coloration obtained was extracted into butonal and measured at 560 nm. The mixture containing 1.2 ml of sodium pyrophosphate buffer, 0.1 ml of phenazinemethosulphate (PMS), 0.3 ml of nitroboluetrazolium (NBT), 0.2 ml of enzyme preparation and made up with water to a volume of 2.8 ml. The commencement of SOD determination was achieved by the addition of 2 ml of NADH and incubated for 90 seconds at 30 ^oC. After incubation, 0.1 ml of glacial acetic acid was added to bring the reaction to a stop. The reaction was shaken with 4.0 ml of n-butanol. This was read at 560 nm in a spectrophometer (Genesys 10-S, USA). Enzyme activity (1 unit) was considered as the enzyme that gave 50 % inhibition of nitroboluetrazolium reduction in 1 minute.

PROLINE
Proline was extracted using a cold extraction procedure by mixing 20-50 mg fresh weight aliquots with 0.4 ml of ethanol water (40:60 v/v). The reaction mixture was left overnight on the pellet and supernatant pooled was used for the analyses. The solutions (store at 20 ^0C) Extract: 20 to 50 times diluted fresh weight (w/v), typically in a 70:30 ethanol: water mixture (v/v) (Hummel *et al.*, 2009). Standard proline solution ranging from 0.04 to 1 mM, in the same medium as the one used for the extraction. Reaction mix: ninhydrin 1 % (w/v) in acetic acid 60 % (v/v), ethanol 20 % (v/v) protect from light.

ESTIMATION OF TOTAL CAROTENOIDS

Total careteniod was determined using the method of Zakaria *et al.* (1979). As to avoid photolysis, the determination of carotenoid was carried out in dark. The homogenized sample 0.5g was saponified with 2.5 ml of 12 % alcoholic potassium hydroxide in a water bath for 30 mins at 60 ^oC. The extract was transferred into a separating funnel containing

15 ml of petroleum ether. The lower aqueous layer was poured into another separating funnel while the upper petroleum ether layer containing caroteniods was collected. This procedure was repeated continuously until colourless layer was observed. Sodium was added to petroleum ether as to remove excess mixture and final volume was noted. The yellow colour absorbance was read using a spectrometer (Gensys 10-S, USA) at 450 nm and 503 nm using petroleum ether as blank.

ESTIMATE OF REDUCED GLUTATHIONE (GSH)

Glutathione was determined by adopting the method of Moron *et al.* (1979). The mixture 2.5 ml of 5 % TCA homogenized plant sample (0.5g) was collected and the precipitated protein was centrifuged at 1000 rpm for 10 mins. The supernatant (0.1 ml) was use to estimate GSH. The supernatant (0.1 ml) was made up to 1.0 ml with 0.2 M sodium phosphate buffer (pH 8.0). Standard GSH corresponding to concentrations between 2 and 10 moles were also prepared, 2.0 ml of freshly prepared DTNB (5.5-dithiobis nitrobenzoie acid) solution was added as to intensify the yellow colour which was measured using spectrophotometer (Gensys 10-S, USA) at 412 nm after 10 mins. The values were expressed as nmoles GSH/g sample.

Statistical Analysis:

The data generated (means and standard error of mean) was estimated using the Statistical Analysis System (SAS version 9.0).

RESULTS AND DISCUSSION

Biomarkers are biological components triggered when a plant is perturbed. Plant biomarkers are well-known as plant stress enzymes. Increase metals accumulation influenced the equilibrium between scavengers and Reactive Oxygen Species (ROS). Increase Reactive Oxygen Species (ROS) is activated due to stress such as metal toxicity and this may have led to cellular damage of biomolecules (lipid, protein and nucleic acids). Gill (2010) and Yang *et al*. (2011) report that toxic nature of metals and nutrient depletion trigger excess production of ROS.

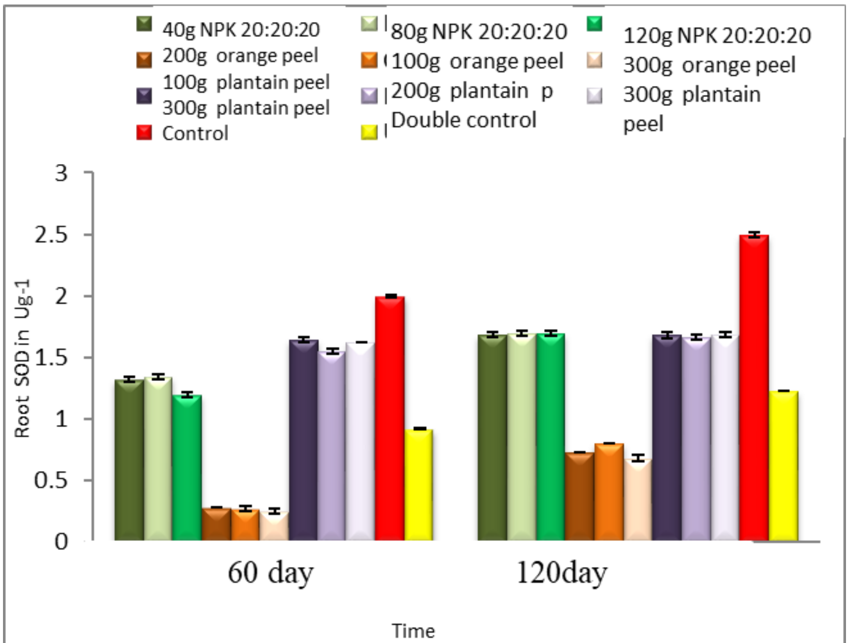

Fig. 1 Effects of amendments on SOD activity in the root of *Cyperus iria* under metal stress

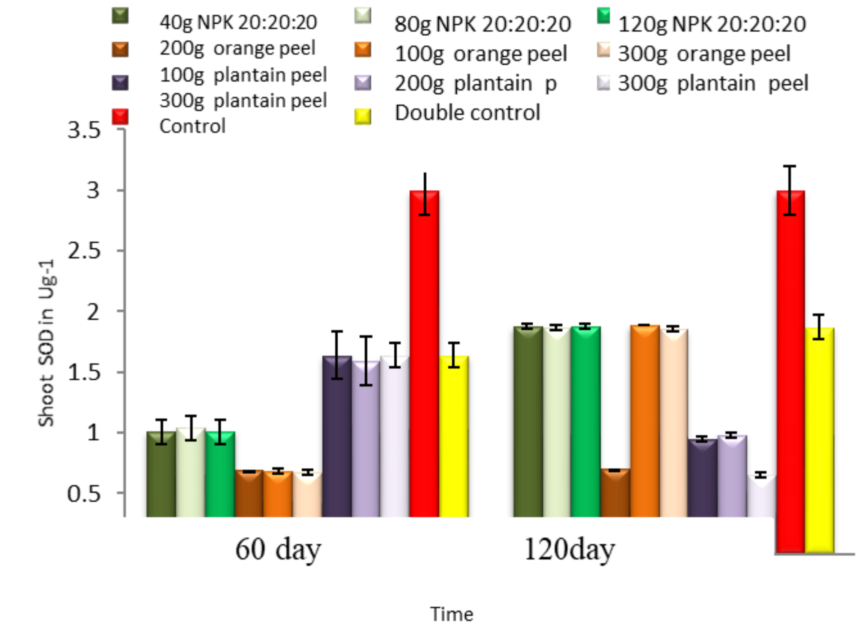

Fig. 2 Effects of amendments on SOD activity in the shoot of *Cyperus iria* under metal stress

Proline

The various amendments showed decrease on proline activity in roots and shoots of *Cyperus iria* as presented in Figure 3 and 4. Reduction was found in shoot of *Cyperus iria* grown in amended polluted soil. The least decrease in root and shoot proline activity in 60 days was observed in 40 g NPK (20:20:20) and 200g plantain peel amendment respectively, while highest increase in shoot and root was in control (polluted soil without amendment).

The decrease observed in proline activity of *Cyperus iria* grown in different concentrations of organic amendments is understandable since the amendments used are biodegradable by micro-organisms which make them a Low-Molecular Weight Organic Acids (LMWOA's)whose upon its addition might have acidified the soil. Furthermore, NH^{+}_{4}, CO_2 acid during microbial degredation of LMWOA's may be responsible for the decrease in pH (Albanell *et al.*, 1988; Zulfigar *et al.*, 2012). Additionally, soil pH also plays a major role in nutrient availability (Yashin *et al.*, 2014). Due to nutrients availability, the depressing effects of heavy metals could be controlled hence leading to proline decrease. The phenomenon of proline accumulation is known to occur under water deficit, salinity, low temperature, heavy metal exposure and UV radiations (Sharma, 2006). Apart from acting as osmolyte for osmotic adjustment, proline contributes to stabilizing sub-cellular structures (e.g., membranes and proteins), scavenging free radicals and buffering cellular redox potential under stress conditions.

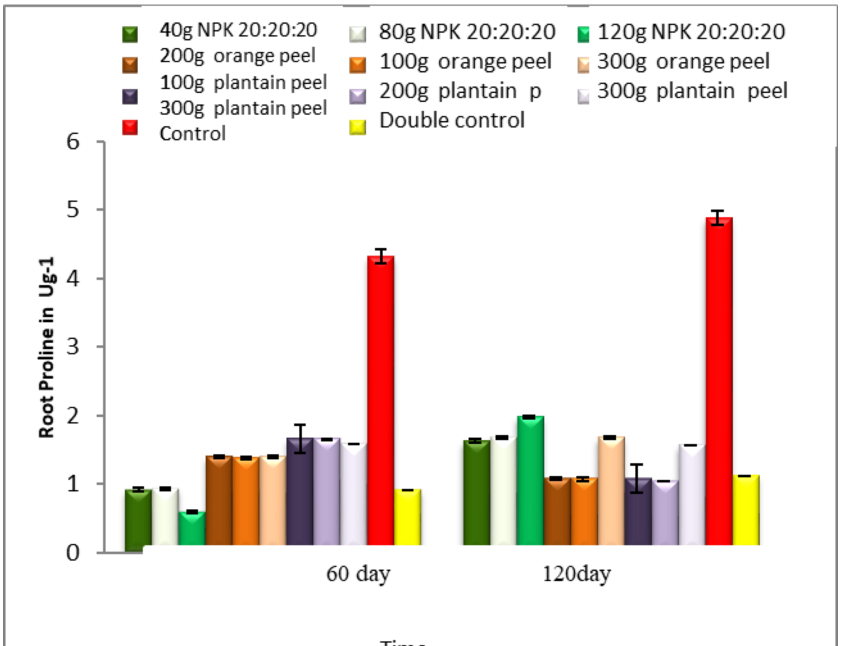

Fig. 3. Effects of amendments on Proline activity in the root of *Cyperus iria* under metal stress

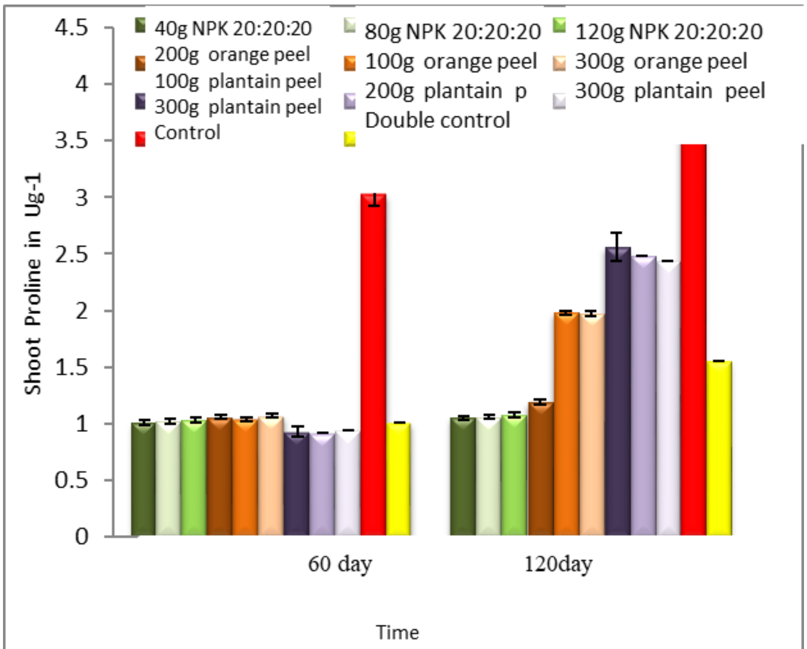

Fig. 4. Effects of amendments on Proline activity in the shoot of *Cyperus iria* under metal stress

CAROTENIOD

The various amendments showed decrease in caroteniod activity in roots and shoots of *Cyperus* plants is presented in Figure 5and 6. The root of plant grown in NPK, orange peels, plantain peels amendment, control and double control accumulate high caroteniod. Least decrease in caroteniod antioxidant biomarker in root of *Cyperus iria* was observed in 300 g plantain peel soil amendment at 60 and 120 day and also in 100g and 300g orange peel amendment for shoot, while highest caroteniod in shoot and root antioxidant activity was found in control (polluted soil) at 60 and 120 day respectively. Several types of pigments are present in plants such as chlorophylls, xanthophylls and carotenoids. Among these, chlorophyll is the most abundant and important pigment in higher plants; responsible for photosynthesis as they capture light. In several cases, heavy metals are known to reduce the productivity by reducing the rate of photosynthesis. The increase in response of carotenoid content of *Cyperus iria* grown in control soil could be attributed to the toxicity nature of Pb and Cd. This corresponds to the results of Padmaja *et al.* (1990) who observed a decline in the pigment composition of plants exposed to heavy metal stress.

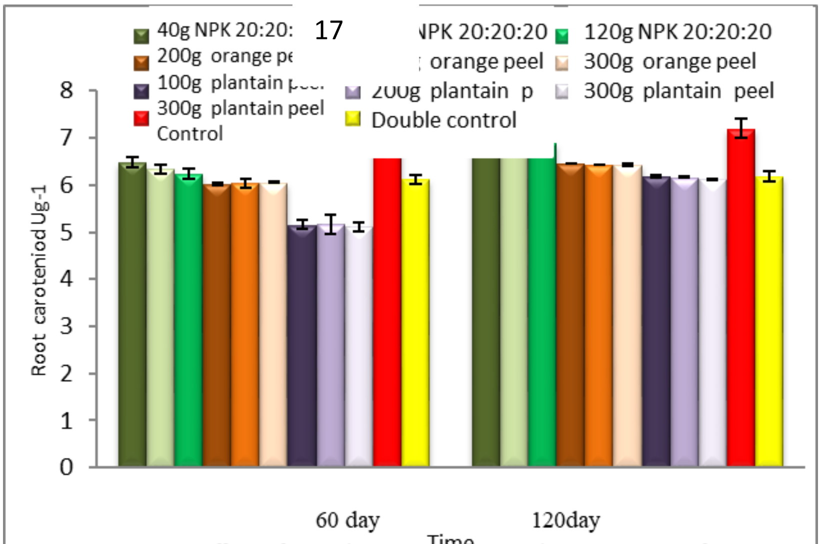

Fig. 5. Effects of amendments on carotenoid activity in root of *Cyperus iria* under metal stress

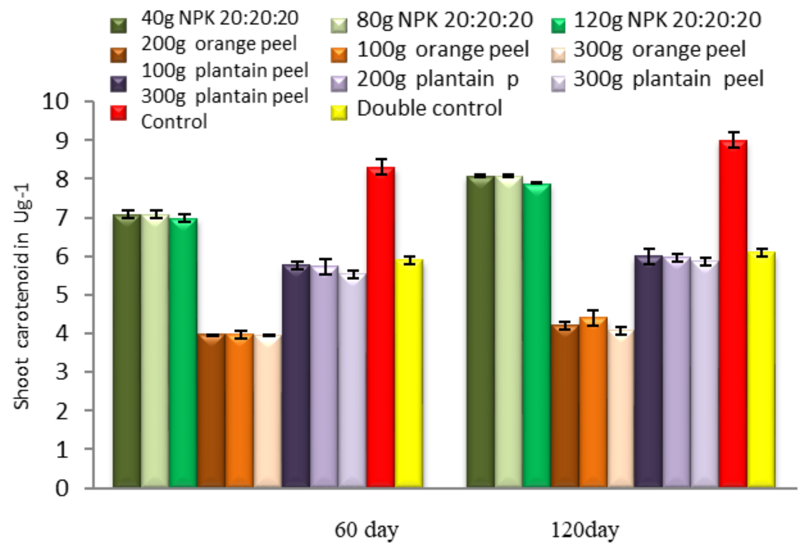

Fig. 6. Effects of amendments on carotenoid activity of carotenoid activity in shoot of *Cyperus iria* under metal stress

GLUTATHIONE (GSH)

Glutathione (GSH) is a key component in met 18 scavenging due to the high affinity of metals to its thiol (-SH) group and as a precursor of phytochelatins (PCs). Besides metal homeostasis, plants possess a well-equipped antioxidative defense system to manage the metal-imposed oxidative challenge (Cuypers *et al*. 2010). The cysteine residue on GSH renders it an important antioxidant that, in addition to its primary antioxidant capacities, acts as a substrate for the regeneration of other essential antioxidants (Foyer *et al*. 2011). In this way, GSH performs in both metal homeostasis and the antioxidative defense, which influence the levels of free reduced GSH and its cellular redox state *i.e.*, oxidized glutathione disulfide (GSSG) *versus* reduced GSH]. Furthermore, the GSSG/GSH redox balance transmits specific information in order to fine tune cellular signaling pathways and responses under environmental stress conditions (Seth *et al*. 2012). The various amendments showed a decrease on GSH activity in roots and shoots of *Cyperus* plants is presented in Figure 7 and 8. The root of plant grown in NPK, orange peels, plantain peels amendment, control and double control showed increase in GSH content. Decrease in GSH antioxidant biomarker in root of *Cyperus iria* was observed in amended and double control at 60 and 120 day. The decrease in GSH content of *Cyperus iria* grown in amended soil may be attributed to the cushion effects due to nutrient availability. Thess findings are understandable since nutrient depletion has been report as a phenomenon leading to reactive oxygen production in plants (Sharma, 2006). The increase in GSH production found in *Cyperus iria* grown in control soil could be attributed to the toxicity nature of the studied metals. This result corroborated with Seth *et al.* (2012) who reported that metal toxicity affects GSH at all levels.

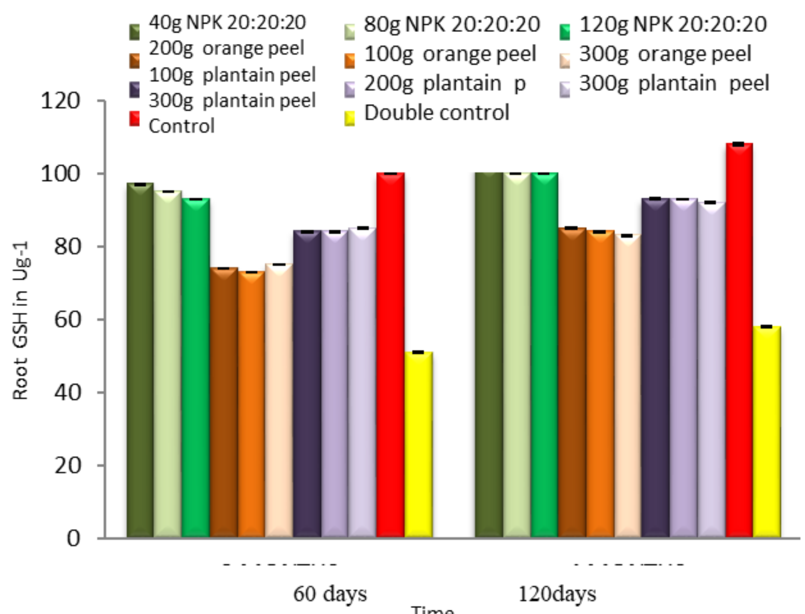

Fig. 7. Effects of amendments on GSH activity in root of *Cyperus iria* under metal stress

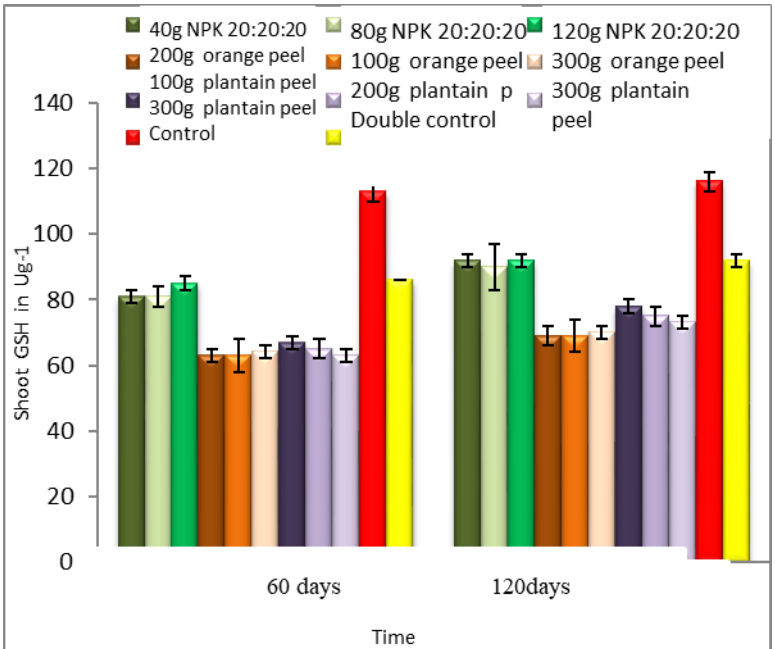

Fig. 8. Effects of amendments on GSH activity in shoot of *Cyperus iria* under metal stress

CONCLUSION

The present investigation lay credence to the fact that the addition of amendments such as NPK (20:20:20), orange and plantain peels can enhance the tolerance ability of plant species grown in contaminated soils to cope with heavy metal stress. The result demonstrated a significant decrease in antioxidant enzymes with addition of amendments. Conclusively, plant species grown in soil contaminated with heavy metal and the potential environmental perturbation ranging from heavy metal toxicity and nutrients depletion may be controlled by soil amendments addition as to enhance plant tolerance to pollution stress.

REFERENCES

Albanell, E., Plaixats, J and Cabrero T. (1988). Chemical changes during vermi-composting (*Eisenia Andrei)* of sheep manure mixed with cotton industrial wastes. *Biology Fertilizer and Soil*. 6: 266-269.

Asada, K. (1994). Production and action of active oxygen species in photosynthetic tissues *In* C.H. Foyer and P.M. Mullineaux (Eds.) Causes of Photooxidative Stress and Amelioration of Defense systems in Plants. CRC Press, Inc., Boca Raton.

Bresler, V., Bissinger, V., Abelson, A., Dizer, H., Sturm, A., Kratke, R., Fishelson, L. and Hansen, P.D. (1999) Marine molluscs and fish as biomarkers of pollution stress in littoral regions of the Red Sea, Mediterranean Sea and North Sea. *Helgol Marine Research,* 53: 219-243.

Brown, R.J., Galloway, T.S., Lowe, D.M., Browne, M.A., Dissanayake, A., Jones, M.B. and Depledge, M.H. (2004). Differential sensitivity of three marine invertebrates to copper assessed using multiple biomarkers. *Aquatic Toxicology,* 66: 267-278.

Cheung, C.C.C., Zheng, G.J., Li, A.M.Y., Richardson, B.J. and Lam, P.K.S. (2001). Relationships between tissue concentrations of polycyclic aromatic hydrocarbons and antioxidative responses of marine mussels, *Perna viridis*. *Aquatic Toxicology,* 52: 189-203.

Cuypers A., Plusquin M., Remans T., Jozefczak M., Keunen E., Gielen H., Opdenakker K., Nair A.R., Munters E., Artois T.J., (2010). Cadmium stress: An oxidative challenge. *Biometals*. 2010;23: 927–940.

Doyotte, A., Cossu, C., Jacquin, M., Babut, M. and Vasseur, P. (1997). Antioxidant enzymes, glutathione and lipid peroxidation as relevant biomarkers of experimental or field exposure in the gills and the digestive gland of the freshwater bivalve *Unio tumidis. Aquatic Toxicology,* 39: 93-110.

Fitzpatrick, P.J., O'Halloran, J., Sheehan, D. and Walsh, A.R. (1997). Assessment of a glutathione-s-transferase and related proteins in the gills and digestive gland of *Mytilus edulis* (L.), as potential organic pollution biomarkers. *Biomarkers*, 2: 51-56.

Foyer, G (2005). Noctor, Redox homeostasis and antioxidant signalling: a metabolic interface between stress perception and physiological responses, *Journal of Plant Cell*. 4:1866-1875.

Foyer C.H., Noctor G. (2011). Ascorbate and glutathione: The heart of the redox hub. *Plant Physiol.* 155:2–18

Gill, S.S, and Tuteja, N. (2010). Polyamines and abiotic stress tolerance in plants. *Plant Signal Behaviour*, 51:26-33.

Irato, P., Santovito, G., Cassini, A., Piccinni, E. and Albergoni, V. (2003). Metal accumulation and binding protein induction in *Mytilus galloprovincialis*, *Scapharca inaequivalvis*, and *Tapes philippinarum* from the Lagoon of Venice. *Archives of Environmental Contamination and Toxicology,* 44: 476-484.

Luebke, R.W., Hodson, P.V., Faisal, M., Ross, P.S., Grasman, K.A. and Zelikoff, J.T. (1997) Aquatic pollution-induced immunotoxicity in wildlife species. *Fundamental and Applied Toxicology*. 37: 1-15.

Nusetti, O., Esclapes, M., Salazar, G., Nusetti, S. and Pulido, S. (2001). Biomarkers of oxidative stress in the polychaete *Eurythoe complanata* (Amphinomidae) under short-term copper exposure. *Bulletin of Environmental Contamination and Toxicology*, 66: 576.581.

O'Halloran, K., Ahokas, J. and Wright, P. (1998). The adverse effects of aquatic contaminants on fish immune responses. A*ustralasian Journal of Ecotoxicology*, 4: 9-28.

Padmaja K, Prasad DDK, Prasad ARK. (1990). Inhibition of chlorophyll synthesis in Pharsalus vulgaris Seedlings by cadmium acetate. *Photosynthetis*. 24:399–405

Prochazkova, D., R.K. Sairam, G.C. Srivastava, and D.V. Singh. (2001). Oxidative stress and antioxidant activity as the basis of senescence in maize leaves. *Plant Sci*. 161:765-771.

Principato, G. and Regoli, F. (1995) Glutathione, glutathione-dependent and antioxidant enzymes in mussel, *Mytilus galloprovincialis*, exposed to metals under field and laboratory conditions: implications for the use of biochemical biomarkers. *Aquatic Toxicology*, 31: 143-164

Reddy, P.S. (1997). Modulations in antioxidant enzymes in the gill and hepatopancreas of the edible crab *Scylla serrata* during exposure to cadmium and copper. *Environmental Bulletin*, 6: 589-597.

Regoli, F., Nigro, M. and Orlando, E. (1998). Lysosomal and antioxidant responses to metals in the Antarctic scallop *Adamussium colbecki. Aquatic Toxicology,* 40: 375-392.

Ringwood, A.H., Conners, D.E., Keppler, C.J. and Dinovo, A. (1999). Biomarker studies with juvenile oysters (*Crassostrea virginica*) deployed *in situ*. *Biomarkers*, 4: 400-414.

Sharma, S., Nemecz, S.K., Zhu, S. and Steele, V.E. (1997). Identification of chemoprotective agents by screening for induction of glutathione-stransferase as a biomarker. *Methods in Cell Science*, 19: 49-52.

SAS Institute Inc (2002). SAS for Windows Release 9.1, Canny, United States of America, Statistical Analysis Systems Institute Incorporated.

Seth C.S., Remans T., Keunen E., Jozefczak M., Gielen H., Opdenakker K., Weyens N., Vangronsveld J., Cuypers A (2012). Phytoextraction of toxic metals: A central role for glutathione. *Plant Cell Environ* 35:334–346.

Sharma SS, Dietz KJ (2006). The significance of amino acids and amino acid-derived molecules in plant responses and adaptation to heavy metal stress. *J Exp Bot*.;57:711–26.

Tewari, R.K., P. Kumar, N. Tewari, S. Srivastava, and P.N. Sharma. (2004). Macronutrient deficiencies and differential antioxidant responses-influence on the activity and expression of superoxide dismutase in maize. *Plant Sci*. 166:687-694.

Wright, D.A. and Welbourne, P. (2002). *Environmental toxicology*. Cambridge University Press, Cambridge.

Yang, Y., Cochran, D.A., Gargano, M.D., King, I., Samhat, N.K., Burger, B.P., Sabourin, K.R., Hou, Y., Awata, J., Parry, D.A., Marshall, W.F., Witman, G.B. and Lu, X. (2011). Regulation of flagellar motility by the conserved flagellar protein CG34110/Ccdc135/FAP50. *Molecular. Biology of Cell* 22(7): 976--987.

Yashim, ZI; Israel, OK; Hannatu, M. (2014). A study of the uptake of heavy metals by plants near metal scrap dumpsite in Zaria, Nigeria. *Journal of Applied chemistry* 27:325-415.

Zulfiqar, Z., Wahid, A., Farooq, N., Maqbool, N and Afran, M (2012). Phytoremediation of soil cadmium by using *Chenopodium* species. *Pakistan Journal of Agricultural Science*. 49:43-52.

ASSESSMENT OF EARLY GROWTH AND NODULATION PERFORMANCE OF *PENTACLETHRA MACROPHYLLA* SEEDLINGS ON SOILS OF CONTRASTING FERTILITY IN SOUTHEASTERN NIGERIA

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ABSTRACT

Pentaclethra macrophylla (PM) is an indigenous leguminous and agroforestry tree whose seeds are used as spices in Nigeria. This study was carried out to assess the response of early seedling growth vigour and root nodulation of PM to soil media with contrasting fertility. Seedling growth of PM on low nutrient soils (alluvium, Ferruginous Sandstones (FS) and sandstones) and nutrient enriched Nursery Medium (NM - control) was evaluated in 35 kg-pots for 24 weeks. The experiment was laid out in completely randomised design with eight replicates. Seedling Sturdiness Quotient (SQ), Number of Root Nodules (NRN) and Dry Weight-DW (g) were determined using standard procedures. Data were analysed using descriptive statistics and ANOVA at $\alpha_{0.05}$. The seedlings SQ ranged from 4.03±1.23 to 3.40±0.59 in sandstone and NM raised seedlings, respectively; although these were not remarkably different from each other and the control NM. The mean NRN on sandstones (17.37±3.42) and FS (20.62±7.84) were similar and significantly higher than alluvium (4.12±1.65) and NM (3.37±2.50). The mean DW on alluvium (10.82±2.03), sandstones (12.62±1.95) and FS (11.00±1.07) were similar but significantly higher than NM (8.36±1.31) at $p < 0.05$. By inference therefore, low nutrient sandstone and ferruginous sandstone soils stimulated seedling growth and nodulation of Pentaclethra macrophylla.

***Keywords**: Agroecosystem, Nigeria, Pentaclethra macrophylla, plant nutrients, root nodulation, tree legumes.*

INTRODUCTION

The value of legumes in soil fertility improvement and sustainability has been well known for centuries, and well researched and reviewed, especially for annual grain legumes and perennial forage legumes (Sprent, 2001; Sprent, 2005; Adams *et al.*, 2010). Many species of legumes have nodules on their roots containing bacteria which possess the capacity of fixing atmospheric nitrogen, some of which are then available to the host plant and the soil nitrogen is increased by sloughed, disintegrated nodules as well as decomposed host plant litters (biomass) like leaf droppings. In this association (symbiosis), the bacteria are in return supplied with carbohydrates by the host (Flynn and Idowu, 2015). This characteristic has made such legumes of great importance in agriculture and food production. They provide protein-rich food for humans and livestocks; they play important role in crop rotation and are used in admixture with grasses in leys and pastures. Some are also used as cover crops and green manures (Diabate *et al.*, 2005; Meena *et al.,* 2018). In addition, afforestation and reforestation practices, establishment of shelter belts and restoration of soils with N-fixing legume trees/shrubs had been noted to constitute vital option in recovery of degraded land areas, besides other secondary benefits from non-timber forest products of such trees (de Faria *et al*., 2010; Chagas Junior *et al.*, 2012).

Nodules on perennial legumes are long-lived and will fix nitrogen through the entire growing season as long as field conditions are favourable. In contrast, nodules on annuals are short-lived and will be replaced constantly during the growing season. At the time of pod fill, nodules on annual legumes generally lose their ability to fix nitrogen because the plant feeds the developing seed rather than the nodule (Zahran, 1999; Flynn and Idowu, 2015).

The uses of leguminous trees for a variety of food, livestock feed and fuel wood purposes in different regions of the world had been reviewed (Lewis *et al*., 2005; Wojciechowski, 2006). Tree legumes are widely distributed throughout the tropics and sub-tropical regions;

and many of them are valuable for fixing atmospheric N_2 just as the herbaceous annual legumes. Among the essential nutrients for plant growth, nitrogen is the most expensive and energy-consuming, and potentially an environmental pollutant. Mixed crops with N_2-fixing trees (NFTs) have been thought to maintain biodiversity and sustainability of systems in the tropics (Ng and Hau, 2009; Fairhurst, 2012).

Observation of nodulation in leguminous tree species native to the primary tropical rainforest in Guinea (West Africa) revealed that among the Mimosoideae sub-family, few non-nodulating genus/species observed included *Parkia bicolor* A. Chev., *Parkia biglobosa* (Jacq.) R. Br. Ex G. Don., *Newtonia* [2 spp] and *Adenopodia scelerata* (A.Chev) Brean; while majority of the species (including *Albizia* [6 spp], *Pentaclethra macrophylla* Benth., *Tetrapleura tetraptera* (Schumach & Thonn.) Taub. and others) were found with nodulating ability (Diabate *et al.,* 2005; Sprent, 2005). *Pentaclethra macrophylla*, otherwise known as African oil bean, is an indigenous leguminous and agroforestry tree whose seeds are used as spices and potential vegetable oil in Nigeria (Ogbu *et al.*, 2020). This study, therefore, was carried out with objective to assess early seedling growth vigour and root nodulation of *P. macrophylla*, on soil media with contrasting fertility.

MATERIALS AND METHOD

Locations of study and source of planting materials

The experiment was carried out at the Teaching and Research Farm of the Federal College of Agriculture (FCA), Ishiagu, Ebonyi State, Nigeria. Ishiagu lies within the southeast derived savanna ecological zone of the country. It is located on latitude 05º 52'N, longitude 07º 35'E and altitude 57 m above sea level. Rainfall distribution is bimodal with peaks in the months of July and September or October. The dry season spans November to March or April with a characteristic cold dry dust laden interval known as harmattan, during the months of December through to February. Seeds of African oil bean (*Pentaclethra macrophylla*) for the experiments were sourced from Ishiagu and its environs where the species naturally thrived as well as constituted part of the traditional home garden setting and food culture of the people. Matured seeds for germination trials were collected from wild stands in the community.

Experimental design, treatments and agronomic practices

In this early growth study of *P. macrophylla,* three soil media of contrasting fertility and one regular nursery growth medium were collected and used for pot experiment (de Faria *et al.,* 2010; Chagas Junior *et al.,* 2012). The soil media were: alluvium soil from alluvial plane forest vegetation within vicinity of nearby Ivo River in Ishiagu; san dstone soil from continuously cultivated land and ferruginous sandstone soil from fallow land site within the Federal College of Agriculture (FCA) Ishiagu. Nursery growth medium which was made of mixture of topsoil, compost and river sand in ratio 1:2:3, respectively by volume was used. Therefore, there were four treatments namely: alluvium soil (treatment one – T1), marginal sandstone soil (T2), ferruginous sandstone soil (T3) and nursery growth medium (T4). The treatments were replicated eight times and laid out in a completely randomized design (CRD). The different soil media and nursery growth medium (35 kg each) were bagged in 40 cm by 50 cm polyethylene bags accordingly. One hundred freshly harvested mature seeds from wild in Ishiagu were sown in nursery tray filled with topsoil collected from site where matured *P. macrophylla* trees are situated at FCA Ishiagu Tree Crop Plantation. At four weeks after sowing, eight healthy seedlings were randomly selected and assigned to each of the four treatments which were planted in the medium-filled polyethylene bags. The transplanted seedlings were mulched and watered every other day. Manual weeding and hand picking of insect pests were carried out as the needs arose.

Data collection and analysis

Physico-chemical analysis of the different soil media samples (collected before planting) was conducted at Soil laboratory of the National Root Crop Research Institute (NRCRI), Umudike, Abia State Nigeria; while soil textural class was determined using USDA Soil Classification. Seedlings growth was monitored for six months from the date of sowing. Seedling vigour parameters and nodulation performance for assessment of treatment effects included: - plant height (cm) and stem diameter at 2, 4 and 6 months after sowing; seedling sturdiness quotient at 2, 4, and 6 months (Jaenicke, 1999; Ahmadloo *et al.*, 2012); number of leaves at 2, 4 and 6 months; primary root length (cm) at 6 months; number of nodules at 6 months after sowing; seedling dry weight (g) at 6 months. Sturdiness quotient (SQ) = plant height (cm) ÷ stem diameter (mm).

Data collected from the experiment were analysed using analysis of variance (ANOVA), while mean separation was carried out using Fisher's Least Significant Difference (LSD) at 5% probability level. Descriptive statistics was also used where appropriate.

RESULTS

Physico-chemical properties of the soil media and nursery medium used

The physical and chemical properties of different soil media and nursery medium used as growth substrates in this experiment are presented in Table 1. The soil samples pH values varied from extremely acidic 3.6 (in alluvium soil), to strongly acidic 4.4 (in sandstone soil) and moderately acidic 5.4 (in ferruginous sandstone soil as well as nursery medium composed of 1:2:3 of local topsoil, compost and river sand). Organic matter contents of the sandstone and ferruginous sandstone soils were low (0.98% and 1.51%, respectively), unlike the alluvium soil and nursery growth medium that had higher proportion of organic matters (1.54% and 1.65%, respectively). Similarly, the Cation exchange capacity (CEC) of the two sandstone soils were also least (6.0 and 7.0 cmol/kg, respectively) among the soil media. Percent nitrogen contents of the sandstone derived soils were only moderate (0.12%), as against medium and moderately high level nitrogen in alluvium and nursery growth medium, respectively. Available phosphorus is also low in both sandstone soil (7 mg/kg) and ferruginous sandstone soil (5.1 mg/kg), in comparison to nursery medium with 23.4 mg/kg and alluvium soil which had 9.24 mg/kg.

Number of leaf

Number of leaf produced by the seedlings was only significantly different at 16 Weeks After Sowing (WAS) among the soil media and nursery growth medium. In this regard, alluvium and ferruginous sandstone soils produced highest mean number of leaves (8.13) at 16 WAS as well as (10.62 and 10.37, respectively) at 24 WAS (Table 2). Seedlings raised on alluvium soil produced highest mean number of leaves at 24 WAS, although with wider variations among the individual seedlings (10.62±3.07) unlike the less fertile sandstone and ferruginous sandstone soils that produced comparable mean number of leaves that are more uniform (10.12±2.85 and 10.37±1.85, respectively).

Plant height

Similar pattern of growth was observed in seedling plant height (Table 2), although the soil types did not indicate any statistical difference at both 16 and 24 WAS. Seedlings grown on less fertile ferruginous sandstone soil were consistently taller (37.75 cm ±9.36) than other seedlings after 16 week of growth and beyond. It is apparent from Tables 1 and 2, that alluvium soil and nursery growth medium which had higher percent nitrogen, available phosphorus and organic matter contents produced shorter seedlings (36.38cm ±6.25 and 29.63cm ±7.23, respectively) at 24 WAS.

Stem diameter and sturdiness quotient

Seedlings raised in ferruginous sandstone soil showed relatively larger stem diameter (12.33 mm ±2.26) than the ones grown on other soil media at 24 WAS. However, seedlings stem diameter at 24 WAS, generally, were not statistically different among the various soil media (Table 3). Comparatively, alluvium and sandstone soil types produced sturdier seedlings (4.01±0.42 and 4.03±1.23 respectively) than seedlings on other soil media, although there was no statistical difference among the various soil media during the 24 week of seedling growth monitoring.

Root length

Significant differences were observes in the mean root length of seedlings on various soil media at 24 WAS (Table 4). Nursery growth medium produced seedlings with extended root length (32.88 ±4.44 cm) at 24 WAS; followed by seedlings grown in sandstone soils with mean root length of 29.37 ±4.31 cm. By textural classification, both nursery medium and sandstone belonged to sandy loam soil textural class (Table 1). Seedlings grown in both sandstone and ferruginous sandstone soils did not differ significantly ($p>0.05$) in their root lengths, although they are of different soil classes (sandy loam and loamy sand, respectively).

Table 1: Pre-sowing physico-chemical properties of soil samples and nursery medium

Soil property	Alluvium soil	Sandstone soil	Ferruginous sandstone soil	Nursery medium
pH water	3.6	4.4	5.4	6.0
Available P (mg/kg)	9.24	7	5.1	23.4
Organic matter (%)	1.54	0.98	1.51	1.65
Carbon (%)	0.92	0.46	0.50	0.96
Nitrogen (%)	0.14	0.12	0.12	0.23
Exchangeable bases (cmol/kg) Ca	1.60	4.20	4.00	8.00
Mg	1.8	1.8	0.8	3.2
K	0.16	0.07	0.1	0.35
Na	0.02	0.08	0.1	0.26
Exchangeable acidity (cmol/kg)	2.10	2.5	2.2	2.0
Cation exchangeable Capacity (cmol/kg)	9.88	6.0	7.0	13.82
Base saturation (%)	40.0	80.0	69.0	85.39
Particle size (g/kg) Sand	18.0	77.0	73.0	65.8
Silt	50.0	12.0	18.0	17.4
Clay	32.0	11.0	9.0	16.8
Textural class	Sand clay loam	Sandy loam	Loamy sand	Sandy loam

Table 2: Effect of soil types on *P. macrophylla* Benth. seedlings number of leaf and plant height across 24 WAS

Soil types	Number of leaf			Plant height (cm)		
	8WAS	**16WAS**	**24WAS**	**8WAS**	**16WAS**	**24WAS**
Alluvium soil	4.38±1.51	8.13±1.64	10.62±3.07	29.88±3.26	34.53±4.81	36.38±6.25
Sandstone	4.75±0.71	7.75±2.38	10.12±2.85	27.06±3.05	33.38±9.63	33.69±14.06
Ferruginous sandstone	4.88±1.46	8.13±1.36	10.37±1.85	24.13±4.39	34.13±6.35	37.75±9.36
Nursery medium	5.38±1.51	7.25±1.67	9.0±3.07	22.31±4.71	28.0±4.75	29.63±7.23
$LSD_{(0.05)}$	Ns	0.87	ns	3.67	ns	Ns
CV (%)	18.37	16.14	18.0	15.28	14.96	22

Values are mean ± SD (n = 8)

Number of root nodules

Mean number of root nodules were considerably more in seedlings raised on less fertile (sandstone and ferruginous sandstone) soils with 17.37±3.42 and 20.62±7.84 nodules respectively (Table 4); and least on more fertile alluvium soil and nursery growth medium with 4.12 and 3.37 mean number of nodules, respectively at 24 WAS. It is also obvious from Table 4 that the soils with lesser nitrogen and available phosphorus contents produced seedlings with more number of nodules in their roots and vice versa. In fact, nursery medium with highest soil nitrogen content (0.23%) and available phosphorus (23.4 mg/kg) had seedlings with lowest mean number of root nodules which were significantly lower than that of sandstone soil and ferruginous sandstone soil ($p<0.05$).

Seedling Dry weight

Sandstone derived soil produced seedlings with significantly highest mean dry matter (12.62 g ±1.95); followed by seedlings grown on ferruginous sandstone soil with 11.0 g ±1.07.

On the contrary, the least dry matter recorded was by nursery growth medium (8.36 g ±1.31). Dry matter production of the seedlings were significantly different (p<0.05) at 24 WAS on all the soil types used as well as nursery growth medium. From Table 4, it is quite apparent that seedling dry matter production followed similar trend as observed in number of root nodules in response to the various soils physicochemical status.

Table 3: Effect of soil types on *P. macrophylla* Benth. seedlings stem diameter and sturdiness quotient across 24 WAS.

	Stem diameter (mm)			Seedling sturdiness quotient (SQ)		
Soil types	8 WAS	16 WAS	24 WAS	8 WAS	16 WAS	24 WAS
Alluvium soil	9.23±1.77	9.06±4.04	9.78±1.93	3.28±0.29	3.65±0.80	4.01±0.42
Sandstone	10.16±1.64	8.21±138	11.88±1.98	2.71±0.32	2.95±0.98	4.03±1.23
Ferruginous sandstone	7.93±3.29	9.87±2.97	12.33±2.26	3.31±1.13	3.03±0.18	3.83±0.34
Nursery medium	6.92±3.01	8.26±1.55	12.01±2.16	3.95±2.35	2.51±0.47	3.40±0.59
$LSD_{(0.05)}$	Ns	ns	ns	ns	ns	Ns
CV (%)	26.16	26.00	16.02	4..99	25.73	19.81

Values are mean ± SD (n = 8)

Table 4: Effect of soil types on *P. macrophylla* seedlings root length, number of nodule and seedling dry weight at 24 WAS.

Soil types	Root length (cm)	Root nodule count	Seedling dry weight (g)
Alluvium soil	28.50 ± 2.98	4.12 ± 1.65	10.82 ± 2.03
Sandstone	29.37 ± 4.31	17.37 ± 3.42	12.62 ± 1.95
Ferruginous sandstone	27.60 ± 5.85	20.62 ± 7.84	11.00 ± 1.07
Nursery medium	32.88 ± 4.44	3.37 ± 2.5	8.36 ± 1.31
$LSD_{(0.05)}$	2.12	5.71	2.05
CV (%)	8.60	7.86	20.00

Values are mean ± SD (n = 8)

DISCUSSION

In the experiment that evaluated natural nodulation ability and seedling growth of *P. macrophylla*, the results affirmed the test plant capacity to fix nitrogen via its root nodules (Ogbohodo and Odu, 1992; Ladipo *et al*., 1993; Diabete *et al*., 2005) on soils of contrasting fertility which are mostly acidic in nature, ranging from extremely to moderately acid soil pH in southeast Nigeria. Ohiri and Ano (1985) had reported that soils in southeastern states of Nigeria are characterized by low pH, low organic carbon and low exchangeable cations. In legumes, most nitrogen-fixing bacteria are not very active in strongly acidic soils (Miller and Donahue, 1992) Root nodulation was not much on seedlings grown in alluvium soil with extremely low soil pH, but was quite high on seedlings raised on the two sandstone derived soils. This is a case of inverse relationship between root nodule production and fertility status of the growth medium/soil in nitrogen-fixing legumes (Chagas Junior *et al.*, 2012; Flynn and Idowu, 2015).

It is also evident that root nodulation and dry matter production were remarkably significant in the low fertility sandstone soils than in the apparently fertile alluvium soil with high organic matter, moderate available phosphorus and medium nitrogen content; and the formulated nursery growth medium characterized by similar high fertility profile. The above ground seedling growth parameters assessed were largely non-significant across six months of monitoring with reference to stem diameter and seedling sturdiness quotient, although number of leaf was significant only at 16 WAS. This shows that *P. macrophylla* can thrive on both good and poor fertile soils of southeast Nigeria tropical rainforest and derived savanna vegetation; and has the capacity to adapt to erosion prone, highly leached soil types prevalent in the region (Ohiri and Ano, 1985; Ijioma, 2000). Moreover, this may be partly the reason (in addition to economic value) why most farmers in southeast Nigeria protect wild and volunteer stands of the species as well as allow them to coexist with agronomic and garden crops in their agroecosystems.

The differences among the contrasting soil types and nursery growth medium with regard to seedling survival rate (upon transplanting) measured by sturdiness quotient, is partly due to differences in the physical characteristics such as porosity, water holding capacity as well as fertility status. The mean sturdiness quotient range (3.40 to 4.03) of the seedlings at 24 WAS on all the various soil types are within acceptable scale range of well-built seedlings that possess high post-transplant survival percent. Mean sturdiness quotient of the seedlings was less than six, which is within acceptable level to guarantee high out planting survival rate. A sturdiness quotient greater than six has been reported as an indication of physiological imbalance resulting in spindle leggy seedlings; while an extreme small sturdiness quotient implies difficulty in seedling establishment (Mexal and Landis, 1990; Jaenicke, 1999).

It is a common practice among these farmers to prune branches of *P. macrophylla* trees in their farms during seasonal land clearing operation. Leaf litters from the cut branches as well as the ones naturally shed by the plant on routine basis make up important sources of organic matter and nitrogen for enrichment of surrounding host farm/garden soils. In this regard, it has been reported that leaf pruning of nitrogen-fixing tree legumes constitutes vital component of sustainability in agroecosystem as well as soil fertility management (Meena *et al.*, 2018). In addition, the high nitrogen leaf litters of such tree legumes used in agroforestry system as nurse trees or woody hedges may be indeed more important to crops than the shade or wind protection provided by the trees (Brewbaker, 1987).

CONCLUSION

From the foregoing research findings, the following conclusions are drawn: early growth and natural nodulation ability of *P. macrophylla* seedlings show the species capacity to produce functional root nodules for nitrogen fixation, in addition to accumulation of substantial dry matter on marginal soils. Seedling growth and root nodulation of *P. macrophylla* was encouraged in ferruginous sandstone and sandstone derived soils with low nutrient status.

REFERENCES

Adams, M.A., Simon, J. and Pfautsch, S. (2010). Woody legumes: a (re)view from the South. *Tree Physiology* 30.9: 1072 - 1075.

Ahmadloo, F., Tabari, M., Yousefzadeh, H., Kooch, Y. and Rahamani, A. (2012). Effects of soil nutritional status on seedling nursery performance of Arizona cypress (*Cupressus arizonica* var. arizonica Greene) and Medite cypress (*C. sempervirens* var. horizantalis [Mill.] Gord). *African Journal of Plant Science* 6.4: 140 – 149.

Brewbaker, J. L. (1987). Significant nitrogen fixing trees in agroforestry systems. *Agroforestry: realities, possibilities and potentials*. H.L. Gholz. Ed. Martinus Nijhoff Publishers, Dordrecht, the Netherlands. pp 31 – 46.

Chagas Junior, A.F., dos Santos, G. R., de Lima Melo, R.C., de Oliveira, A.G., Vizioli, B., Chagas, L.F.B., da Luz Costa, J. (2012). Effect of natural nodulation in the development of leguminous trees on soils of cerrado in Tocantins. *Journal of Biotechnology and Biodiversity* 3.1: 38 – 44.

de Faria, S.M.,. Diedhiou, A.G., de Lima, H.C., Ribeiro, R.D., Galiana, A., Castilho, A.F. and Henriques, J.C. (2010). Evaluating the nodulation status of leguminous species from the Amazonian forest of Brazil. *Journal of Experimental Botany* 61.11: 3119–3127.

Diabate, M., Munive A., de Faria S.M., Ba A., Dreyfus, B. and Galiana, A. (2005). Occurrence of nodulation in unexplored leguminous trees native to the West African tropical rainforest and inoculation response of native species useful in reforestation. *New Phytologist* 166:231 – 239.

Fairhurst, T. (ed.) (2012). *Handbook for Integrated Soil Fertility Management*. Africa Soil Health Consortium, Nairobi.

Flynn, R. and Idowu, J. (2015). Nitrogen Fixation by Legumes. All about discovery. College of Agricultural, Consumer and Environmental Sciences, New Mexico

State University. Retrieved May 9, 2016, from http://aces.nmsu.edu/pubs/_a/

Ijioma, M. A. (2000). Abia state. *Nigeria – A People united, A Future secured*. Vol. 2. Mamman, A.B., Oyebanji, J.O. and Petters, S.W. Eds. Federal Ministry of Information, Abuja. pp 3 – 6.

Jaenicke, H. (1999). *Good tree nursery practices: Practical guidelines for research nurseries*. ICRAF, Nairobi. pp 7 – 78.

Ladipo, D. O., Kang, B. T. and Swift, M. J. (1993). Nodulation in *Pentaclethra macrophylla* Benth: a multipurpose tree with potentials for agroforestry in the humid lowlands of West Africa. *Nitrogen Fixing Tree Research Reports* 11: 104 – 105.

Lewis, G., Schrire, B. MacKinder,B. and Lock, M. Eds. (2005). *Legumes of the world*. Royal Botanical Gardens, Kew, UK.

Meena, R.S., Das, A., Yadav, G.S. and Lal, R. Eds. (2018). *Legumes for soil health and sustainable management*. Springer Nature, Singerpore. 539 pp.

Mexal, J.G. and Landis, T.D. (1990). Targeting seedling concepts: height and diameter. *Target Seedling Symposium: Proceedings, Combined Meeting of the Western Forest Nursery Associations.* 1990 August 13-17; Roseburg, Oregon. Rose, Robin; Campbell, Sally J.; Landis, Thomas D. Eds. General Technical Report RM-200. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. pp 17 – 36.

Miller, R.W. and Donahue, R.L. (1992). *Soils: an introduction to soils and plant growth* (6th). Prentice-Hall of India, New Delhi. pp 181 – 248.

Ng, A.Y.S. and Hau, B.C.H. 2009. Nodulation of native woody legumes in Hong Kong, China. *Plant and Soil* 316: 1-2.

Ogbohodo, A. and Odu, C.T.I. (1992). A report on nodulation of *Pentaclethra macrophylla*. *Nitrogen Fixing Tree Research Reports* 10: 180 – 181.

Ogbu, JU, Awodoyin, RO and Olubode, OS. (2020). Allelopathic effect of *Pentaclethra macrophylla* Benth. leaf extracts on germination and seedling growth of Maize and Okra. *Asian Journal of Biological Sciences* 13(3): 285 - 292. DOI: 10.3923/ajbs.2020.285.292 https://scialert.net/abstract/?doi=ajbs.2020.285.292

Ohiri, A.C. and Ano, A.O. (1985). Soil physical and chemical characterization of southeastern states of Nigeria. National Root Crops Research Institute (NRCRI), Umudike, Nigeria.

Sprent, J. I. (2001). *Nodulation in legumes*. Royal Botanic Gardens, Kew, UK.

Sprent J.I. (2005). West African legumes: the role of nodulation and nitrogen fixation. *New Phytologist* 167: 326–330.

Wojciechowski, M. F., Johanna M., and Bruce J. (2006). Fabaceae. legumes. Version 14 June 2006. http://tolweb.org/Fabaceae/21093/2006.06.14 *in* The Tree of Life Web Project, http://tolweb.org/

Zahran, H.H. (1999). Rhizobium legume symbiosis and nitrogen fixation under severe conditions and in arid climate. *Microbiology and Molecular biology Reviews* 63.4: 968 – 989.

CONTRIBUTED PEER-REVIED ABSTRACTS

IBD22A01

RISK ASSESSMENT OF THE ANALGESIC, DICLOFENAC TO THE CLADOCERAN *DAPHNIA MAGNA* STRAUS, 1820

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ABSTRACT

Diclofenac (DLC) is a potent nonsteroidal anti-inflammatory drug (NSAID) sold under the trade name Voltaren among others that has been used in the treatment of pain, joint stiffness and inflammatory diseases. There are few literatures on the risk posed by DLC to *Daphnia magna*. Thus, this study aimed to investigate the risk assessment (RQ), oxidative stress and antioxidant response activity of *Daphnia magna* to DLC. The EC_{50} Value of DLC in this study was 27.16 µg/L. The laboratory analysis of DLC was observed to have induced 55% immobilization of the organism at 500µg/L from eight treatments ranging from 0-10,000 µg/L. Risk Quotient ($RQ_{Diclofenac} = 8.41$), Toxic Unit ($TU_{Diclofenac} = 3.68$) of the analgesic to tested organism, *Daphnia magna* demonstrated that the analgesic posed high risk to ladoceran, at the current exposure level. A significant ($p < 0.05$) increase in oxidative stress levels of intracellular hydrogen peroxide ($H_2 O_2$) 1000µg/L and Lipid peroxidation (MDA) (500µg/L) of the treated groups at 48 h post exposure was observed at 200 µg/L – 10,000 µg/L. The activity of the antioxidant enzymes like Glutathione-S-Transferase (GST) and Peroxidase (POD) were significantly ($p < 0.05$) upregulated activities which ranged from 500 µg/L – 10,000 µg/L. This study revealed that at (0-10,000µg/Lenvironmentally relevant concentrations) of DLC, posed adverse risk and could alter the population dynamics of *Daphnia magna* with possible hazardous effects on the aquatic food web

Keywords: Risk assessment, Oxidative stress, Antioxidant response, Diclofenac, *Daphnia magna*

IBD22A02

DISTRIBUTION PATTERN OF AN AQUATIC WEED (*LEMNA MINOR* L.) IN MAIDUGURI METROPOLIS, NIGERIA

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ABSTRACT

Duckweed (*Lemna minor* L.), a free-floating aquatic plant grows mostly nutrient-enriched environments. In agriculture and the environment, it supplies vital nutrients to fortify feeds, and as a phytoremediator of wastewater. This study evaluated the physical and chemical factors affecting distribution, biomass and proximate composition of *Lemna minor* in waterways within Maiduguri metropolis, Northeast Nigeria. Duckweeds were sampled with 25 cm × 25 cm quadrats along transect lines laid in selected riparian ecosystes in the early hours (9-11 am) in December 2021. Physical and chemical parameters of water were measured off-site, except temperature and proximate composition, and biomass of the were determined. Principal component analysis (PCA) biplots indicated that Bolori area had more phosphate (P) than other sites. PC1, PC2 and PC3 account for 99.5% variation; 67.9%, 21.3%, 10.3% respectively. The strongest positive correlations were between magnesium (K) and alkalinity, while potassium /Mg/alkalinity and total suspended solids (TSS) were negatively correlated. Proximate composition indicated 11.4-18.21% crude protein and 45.92-48.47% carbohydrate in the samples. Bray-Curti's index indicated that duckweeds in Custom area and Bolori were the most similar (99%). samples from the University of Maiduguri area had the highest wet biomass (1649 ± 140.5 g/m^2). Samples from Gwange bridge area was the lowest (598.0 ± 128.8 g/m^2). The findings provide baseline data on the potential of duckweeds as a cost-effective source of crude protein (CP) and other essential nutrients. Further research to explore its potential applications in other areas was recommended.

Keywords: *Lemna* sp., Principal component analysis (PCA), proximate composition, wastewater, crude protein (CP)

IBD22A03

SPATIO-TEMPORAL CLASSIFICATION AND PREDICTION OF LAND USE AND LAND COVER CHANGE IN FINIMA NATURE PARK, BONNY ISLAND, NIGERIA

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ABSTRACT

Impacts of land use and land cover change (LULCC) on human-environment have greatly increased great proportion as a result anthropogenic and natural processes, and putting many species at risk. Consequently, land use and land cover classes of Finima Nature Park were classified and changes observed within the last 33 years (1987 - 2021) and predicted for the next 33 years (2021 – 2054. Landsat images of 1987, 1999, 2010 and 2021 were acquired from United States Geological Survey database. The images were pre-processed, enhanced and classified into various LULC classes using Maximum Likelihood Classification in Idrisi and ArcGis10.5. Cellular Automata and Markov Chain algorithm were used for the prediction of LULCC. Result showed that dense vegetation, sparse vegetation, bare land, and water body were the main land uses and land covers in 1987 and 1999, while built up area was only observed in the years 2010, 2021 and 2054. The Kappa Coefficient values were 93%, 81%, 83% and 90% for 1987, 1999, 2010 and 2021 respectively; an indication of strong accuracy of the classification. Generally, there were changes in land use and land cover within the study periods. However, changes were mostly observed in the areas of water body and bare lands closer to the sea coast. In other words, the sea was implicated as the major driver of land use and land cover change in the park. The slight decrease in dense vegetation and sparse vegetation from 1999 to 2021, and 2021 to 2054 underscores the importance and benefit of conservation.

Keywords: Land use, Land cover change, Anthropgenic disturbances, Landsat images, Finima Nature Park

IBD22A04

KADUNA URBAN RENEWAL PROJECTS: DOCUMENTING AVIFAUNA DIVERSITY ALONG THE METROPOLITAN STRETCH OF THE RIVER KADUNA AMIDST INCREASING HUMAN ACTIVITIES

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ABSTRACT

The rate of replacement of the natural world by urban ecosystems is unprecedented. The impact of changes on populations and communities in urban areas demands attention. Urban areas around River Kaduna whose source stems from the Kujama Hill on the Jos has been undergoing structural readjustment through the urban renewal projects of the government. Two kilometre-long transects in four purposive stations were laid along the metropolitan stretch of the River. Transects were sectioned into five 400m to observe human activities and estimate environmental variables influencing bird population. Transects were routinely surveyed for an hour each week for six months for birds, environmental variables and extent of anthropogenic activities. A total of 19, 056 individual birds spread in 56 Families, 116 species and a diversity index (H) = 4.00 resulted from this study. They ranked High to low across stations; B [N = 448 (10.64 ± 15.41): H_B = 3.92] , D [N = 428 (14.04 ± 19.30): H_D = 3.77] , [N = 400 (10.25 ± 9.57): H_A = 3.85] and [N = 371 (11.27 ± 15.61): H_C = 3.76]. Bird's aquatic and terrestrial habitat distribution was in the ratio of 25 %: 75 % respectively. Urbanization and anthropogenic disturbances influence richness and abundance of birds in the study area Regular monitoring to keep track of the River Kaduna avifauna is recommended.

Keywords: Avifauna, Species abundance, Species Richness, River Kaduna and Urbanization

IBD22A05

SURVEY OF MICROBIAL DIVERSITY IN DYE-CONTAMINATED SOIL OF KOFAR NA'ISA DYEING PIT, KANO, NIGERIA

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ABSTRACT

A wide variety of microorganisms have been reported to survive in dye-contaminated soils due to their ability to metabolize synthetic dyes. This research was carried out in one of the major dyeing sites in Kano: Kofar Na'isa dyeing pit and, was aimed at detecting soil microbes (bacteria, fungi and microalgae) from the dye-contaminated soils using dilution, pour plate, streak culture and direct isolation techniques. A total of fifteen species were identified with two being bacterial species (*Bacillus megaterium* and *B. velezensis*) and the remaining thirteen being fungal species (*Aspergillus flavus, A. fumigatus, A. niger, A. orchraceus, A. parasiticus, A. striatus, A. terreus, Candida tetrigidarum, Fusarium equisite, F. oxysporum, Penicillium chrysogenum, P. digitatum* and *Rhizopus microsporus*). There were no microalgal species isolated from the soil which may be due to its toxicity. It was concluded that bacterial and fungal species can dwell and survive in dye-contaminated environments due to their ability to degrade a wide variety of contaminants. Since previous researches have shown that most microbes in dye-contaminated soils aid in remediation of the dyes, more strategies on how to produce high biomass yields of these microbes should be employed to reduce environmental contamination.

Keywords: Bacteria, Dye-contaminated Soil, Fungi, Microalgae, Microbial Diversity

IBD22A06

FLORISTIC ASSESSMENT OF NATURAL REGENERATION, 6 YEARS POST-REMEDIATION BY ENHANCED NATURAL ATTENUATION (P - RENA) OF HYDROCARBON IMPACTED LAND: A WINDOW FOR SELECTION OF NATIVE MACROPHYTE WITH REMEDIATION POTENTIAL.

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ABSTRACT

Composition and demographic status of forest regeneration in a hydrocarbon impacted site 6 years of post remediation by enhanced natural attenuation in parts of Edovna vegetation landscape wasassed using stratified systematic transect method. A total of 115,549 seedlings and 7,825 saplings ha^{-1} of 96 recruits of 70 genera under 23 families of angiosperm were found in 800 m^2 sampled site. Among dominant families, Poaceae was the richest (24 species). Poaceae had the highest hytosociological composition of recruits: frequency (1675), abundance (621), density ha-1 (49,600), IVI (104.81), diversity richness (11.75) and evenness (5.96). Herbaceous herb (HH) had highest number of recruits among regenerating life forms (*HH>HG>Sh>HCl>HS>ShCl>T*). Environmental adaptiveness and resilience among recruits revealed Chamaephytes and Hemi-cryptophytes across diverse herbaceous life forms as well as Mesophanerophytes, Microphaneropytes, Nanophanerophytes and Hemi-cryptophytes across shrubby life forms and a megaphanerophyte of the tree life form recorded. Across the degree of percentage mode of regeneration life form herbaceous life form had 40 recruits that exhibited 12 multiplier and 4 single mode of regeneration respectively. In shrubby life form four recruits exhibited 2 multiplier and 13 recruits exhibiting 2 single mode of regeneration. The demographic status of regeneration revealed a greater seedling density than sapling density. This implied a successful and new regeneration which through protection of natural regeneration can return back to it complete forest cover again.

Key words: Demography, life form, recruits, regeneration**, v**egetation.

IBD22A07

ASSESSMENT OF EFFLUENTS FROM DIFFERENT DRAINS IN UNIVERSITY OF IBADAN FOR HEAVY METALS IN SOIL, *AMARANTHUS HYBRIDUS* L. AND WATER FROM AWBA DAM, IBADAN, NIGERIA

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ABSTRACT

Indiscriminate use of heavy metal-containing fertilisers and pesticides and release of raw and ill- treated domestic wastewater into water courses pose threats to humans and environment. Awba dam is the main source of water to University of Ibadan community, however, there is a dearth of information on pollutants load in the dam. This study evaluated physical and chemical properties, and heavy metal concentration in water and sediments of Awba dam, University of Ibadan and a closeby vegetable farm with a view to assessing suitability of the dam for irrigation. Water samples (outflows to Awba dam) were collected from six sampling locations: Upstream, Midstream and Downstream of the dam and three drainages (inlet to Awba dam) from Zoological Garden, Residential Quarters and the Faculty of Technology (Tech). Sediment samples were collected from the dam, while vegetable and soil samples were collected from the farm. Physical and chemical parameters (pH, Dissolved Oxygen (DO), Biochemical and Chemical Oxygen Demand (BOD, COD), Nitrate and Phosphate) and heavy metals (Cd, Cr, Co, Ni and Pb) in water, sediment, *Amaranthus hybridus* and soil were determined using standard methods. Data were analysed at p<0.05. Significant differences (p<0.05) were observed in the results. The DO was highest at Tech (3.77 mg/L) and highest values (14.67 and 57.06 mg/L) of BOD and COD were obtained, respectively at upstream, all above the WHO limits. This implied presence of organic contaminants from animals (Zoological garden), agricultural and domestic wastes. Highest Nitrate level (36.45 mg/L) was at Tech and lowest 20.44 mg/L at downstream, similar Phosphate values ranged from 0.09-0.61 mg/L in all locations. All heavy metal levels were in non- detectable quantities in water and *Amaranthus hybridus* samples. In sediment Cr and Co had highest values of 13.67 and 5.33 mg/kg, respectively at upstream and Ni had 12350 mg/kg at midstream, all above the USEPA Sediment Criteria. Significantly higher level of Ni may be due to runoff from constant application of fertilisers from nearby farmlands. Similarly, Ni had the highest value (18811.00 mg/kg) in soil. Based on the high values of COD in water samples and high Nickel contents in sediment and soil samples, there is need for regular monitoring and evaluation of the Awba Dam water quality.

Keywords: Awba dam, Water Quality, Heavy metals, *Amaranthus hybridus*, Contamiated soil.

IBD22A08

EFFECT OF NITROGEN FERTILISER ON FOLIAR DISEASE OF CASSAVA (*Manihot esculenta* Crantz)

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ABSTRACT

Cassava is the most important tropical root crop because of its starchy roots which serves as a main source of carbohydrates, vitamins and minerals. It's yield is affected by many diseases, especially fungi. Cassava's need for fertiliser is increasing as traditional method of maintaining soil fertility is unsustainable under intensive production system. This study was conducted in the field to determine the effect of Nitrogen application on incidence and severity of fungal diseases of 16 cassava varieties. The experiment was laid out as a split plot in a randomized complete block design with three replications. The main plot consisted of 16 cassava varieties while the subplots were two rates of nitrogen fertiliser (0 and100 kg/ha) applied as urea. The varieties were scored for disease incidence and severity from the sixth month on a monthly basis. Symptoms observed on the field were leaf spot and blight. Fungi were isolated from soil and infected leaf samples using standard procedure. The fungal isolates were identified and their pathogenicity was determined. Disease incidence from 0kg/ha plots ranged from 13.88% to 92.86%, while incidence observed from plots treated with 100 kg/ha N ranged from 0% to 30%. Disease severity index from 0kg/ha plots ranged from 9.09% to 72.39%, while severity index observed from the 100 kg/ha N plots ranged from 0.00% to 27.66%. IBA090090, I070539, IBA070539, I011797, IBA070337 and IBA980505 varieties were resistant. Fungi identified were *Aspergillus flavus, Aspergillus niger, Penicillium* species*, Phoma species, Curvularia* species, *Torula* species, and *Rhizopus* species. *Aspergillus flavus*, and *Phoma* species were pathogenic. Cassava that received 100kg/ha N were less susceptible to diseases, while one with no fertilizer application were suspected to be predisposed to attacks by pathogenic organisms.

Keywords: Cassava, Nitrogen fertiliser, Fungi pathogens, Disease severity, Foliar diseases

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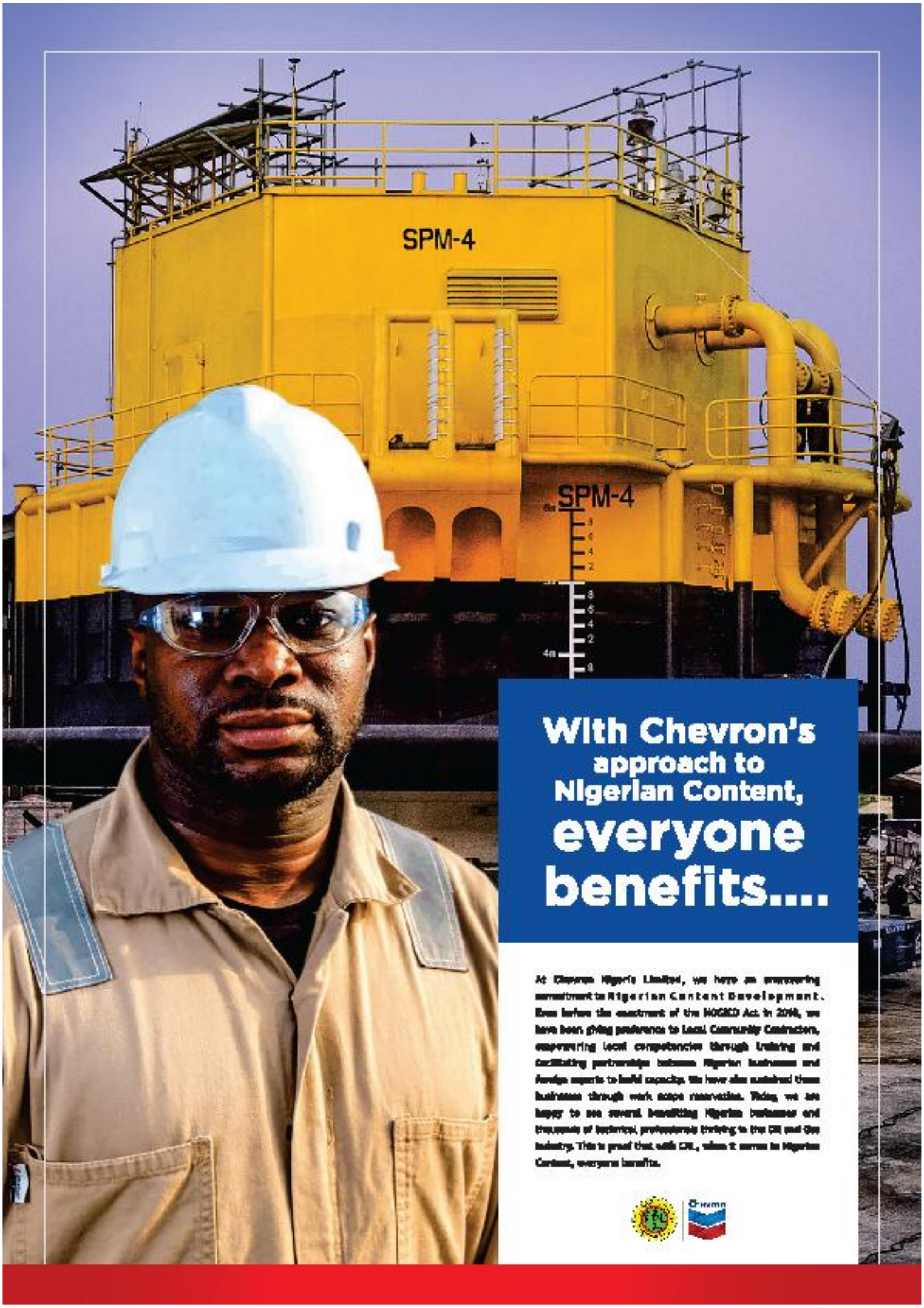
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