



**AFRICAN JOURNAL OF GEOGRAPHICAL
SCIENCES (AJGS)**



Vol.1 No.2 2020

ISSN: 2786-9741



AFRICAN JOURNAL OF GEOGRAPHICAL SCIENCES (AJGS)

Vol. 1 No. 2, 2020

ISSN: 2786-9741



**A Publication of the Department of Geography and Planning
Faculty of Environmental Sciences
University of Jos, Jos, Nigeria**

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EDITORIAL INTRODUCTION

Soils properties and management have been in the front burner of environmental issues in Nigeria. This is especially so that the Nigerian government has placed agriculture at the top of its priority. Soils management has therefore become a research area of prime interest. Olowolafe et al., Galadima et al. and Mande present interesting results on soils management issues. Olowolafe et al. report that current tillage operations may be significantly affecting the physical and chemical compositions of alfisols on the Jos Plateau, Nigeria, negatively. Current tillage practices could lead to a reduction in soil organic matter and make the soils more susceptible to degradation. Tillage practices, therefore, need to be undertaken with caution. Mande examine erodibility of soils in Angwan Rimi area of Kaduna State. The results show that the soils structure is generally loose and highly susceptible to erosion. To help stabilize the soils, communal tree planting, grass fallowing and use of organic manure are recommended. Galadima et al. examine the effects of one such recommendation, use of organic manure (poultry droppings), on selected properties of lateritic soils derived from basalts on the Jos Plateau. Using an experimental design, the study finds that soils with poultry dropping manure had higher organic matter content, total nitrogen content, and exchangeable Mg content than soils without. Poultry dropping application apparently can build up the organic matter content of soils and improve their fertility. To address issues of low pH found in the study area, liming is recommended.

Idehen et al. presents results of a study on the patterns, trends and interrelationships among essential climatic variables (ECV) in Okada town, Edo State. The ECVs include maximum and minimum temperature (T_{Max}, T_{Min}), rainfall, soil moisture (SM), potential evapotranspiration (PET) and normalized difference vegetation index (NDVI). Results show that the ECVs are on an upward trend, signifying that Okada town may be gradually warming up. This is an important finding that localizes global warming at the grassroots.

The consequences of global warming are manifold. Among them is flooding. Duchi et al, and Laka et al both provide important insights into this problem. Duchi et al. assesses flood vulnerability in Lokoja, Nigeria. The

study finds that the floods of 2012 and 2015 were more extensive and impactful in Lokoja than the one of 2011. Agricultural and residential areas are found to be the most vulnerable land uses in the town. The industrial areas are the least vulnerable. A flood management plan and an enforcement task force are recommended. Laka et al. present results on the perception of impacts of flood events in Shimankar river basin in Plateau State. Between 2006 and 2016, residents reported that floods occurred every year, with 2012 being the worst. Flood impacts on agrarian livelihoods were worse than for others. Diseases such as cholera/diarrhea, malaria, typhoid and bilharziasis were also reported as common. Coping strategies included assistance from friends and families of victims, use of sand bags to stave off floods in properties, and government interventions.

Omada et al. assessed access to domestic water supply in Gyel, Plateau State. The study finds that public water sources in the area are clustered around the planned sections and only 32% of those outside this section has access to public water sources. About 71% of residents face water scarcity problem as water supply sources are distant, and require large amount travel time and/or inconsistent. Badamasi et al. investigated pollution indices of several water supply sources in Langtang area of Plateau State. The study reveals that water sources are significantly polluted by iron (Fe), zinc (Zn), As, cadmium (Cd), lead (Pb), Manganese (Mn), aluminium (Al), pesticides and pherols and exhibit poor turbidity quality. Ground water sources are seriously contaminated by Fe, Pb and phenols, with a strong presence of calcium (Ca) and magnesium (Mg) as well; while surface water sources are polluted by coliform bacteria. The overall verdict is that the sources of water supply for domestic consumption in the study area are contaminated and not safe for human consumption. This calls for immediate action on water sanitation and hygiene.

Wastes management and slum areas are two important areas of research that examine hygiene and health related issues in the society. Balogun and Yakubu assessed waste management and environmental sustainability in Lokoja. The study reports that the current waste management situation in the study area is

seriously deplorable. The presence of government in waste management is grossly inadequate and requires urgent redress to avoid potentials for diseases outbreak. There are also potentials for more impactful flooding following the blockages of water channels and drainages by wastes indiscriminately dumped by residents and businesses without caution. There is need for provision and designation of wastes dumpsites and the empowerment of the state waste management agency to ensure proper wastes disposal and evacuation from the metropolis. Abbas and Isyaku's findings on medical wastes management practices at ABU Teaching Hospital and ABU Health Services in Zaria are relatively more uplifting even though there is still room for improvement. The study reveals that waste receptacles, storage containers and dumpsites are well distributed at both medical facilities; and sharps and other infectious materials are adequately separated. The absence of colour coding, central purpose-built storage facility and recycling, however, leaves much to be desired. More sustainable waste management practices can still be implemented at both medical facilities.

Bature et al. evaluated the level of participation of residents of Kabong in upgrading the slum conditions in their neighbourhood. The study finds that the community development association and individuals have made some contributions to upgrading facilities in the area especially schools, health clinic, culverts and in environmental sanitation. The government has also regraded and upgraded some roads, provided electricity power and water sources in the community. However, there is still an apathy towards greater participation by most residents. The community association has its work cut out in mobilizing for an all-out resident participation in upgrading the neighbourhood.

John-Abebe and Osirike, and Mamman and Aule present interesting results of spatial analyses of maternal mortality, and of distribution of secondary schools, respectively. John-Abebe and Osirike find that maternal mortality is higher during/after delivery, and women of ages 30 to 34 appear to be vulnerable. The maternal mortality ratio is calculated from the lifetime risk as 3877 deaths per 100,000 live births. The rural areas had a slightly higher maternal mortality ratio of 4041 while the urban

areas have 3806 per 100,000 live births. These are disturbing findings.

Mamman and Aule present findings from the spatial analysis of the spread of secondary schools in three LGAs of Benue State, one in each Senatorial District. The study reports that in Logo and Gboko LGAs, there is a clustering tendency for distribution of secondary schools. In Obi LGA, however, the distribution tends towards dispersion. Importantly, there are several districts in Logo and Obi LGAs without any secondary school facility. This demands immediate attention.

Anyamele et al. studied the characteristics and challenges of small scale industries in Jos. Some of the findings are that most of the businesses are financed by personal savings of entrepreneurs and employ seven or less persons. Low funding and poor patronage are important challenges.

Women provide significant labour in the informal economy sector. Abdullahi et al. investigated the involvement of women in stone quarrying activities in Jalingo. The authors find that most of the women are between the ages of 36 and 45 and earn between N2000 and N4000 only daily in the quarries. The study also finds that there is a relationship between the age of women and their daily earnings.

Bombom et al. provide a demonstration of the potentials of remote sensing techniques to determine fire burn severity. The Yankari Games Reserves was used as the study area. The results show that the fire season starts in November. By January, most of the reserves is severely burnt. The study finds that fires typically start from the periphery and gradually the central areas are affected except the riparian areas around River Gaji, which bisects the park. The study holds promise for environmental management of parks especially in areas where resources are not readily available for comprehensive ground studies. It is capable of identifying areas of priority for further investigation and to reduce costs.

There is no doubt that the compendium of research findings in this edition is enriching. Many areas of research interests are represented with interesting and thought-provoking results, some of which deserve to be examined more closely and critically.

Dr. Leonard S. Bombom
Secretary, Editorial Committee
Editor, AJGS

TABLE OF CONTENTS

Editorial Board	i
Notes to Contributors	ii
Editorial Introduction	v
Effects of tillage operations on the properties of an alfisol on the Jos Plateau, Nigeria Emmanuel A. Olowolafe, Obadiah A. Zailani, Joshua S. Galadima and Chinedu J. Anyamele	1 – 8
An assessment of medical waste management practices in Ahmadu Bello University Teaching Hospital and Ahmadu Bello University Health Services, Zaria, Nigeria Idowu I. Abbas and Farida Isyaku	9 – 20
Spatial analysis of maternal mortality in Southern Senatorial District of Edo State, Nigeria Rebecca O. John-Abebe and Animam B. Osirike.....	21 - 37
Pollution load and health risk indices of domestic water sources in selected communities of Langtang area, Plateau State, North-Central Nigeria Badamasi J. Saidu, Daniel D. Dabi, Augustine C. Eziashi, Amina A. Abubakar, Christopher N. Beka and Christian Y. Oche	38 - 49
The patterns, trends and interrelationships among essential climatic variables in Okada town, Edo State, Nigeria Osaretin F. Idehen, Innocent E. Omobude and Deborah Kurugbe	50 – 67
Analysis of spatial patterns of secondary schools in the senatorial zones of Benue State, Nigeria Mamman S. Jibril and David S. Aule	68 - 78
Residents’ perception of the impact of flood in Shimankar river basin, Shendam LGA of Plateau State, Nigeria Isaac S. Laka, Nandom N. Ladep, Chinedu J. Anyamele and Emmanuel T. Bot.....	79 - 91
Assessing solid waste management and environmental sustainability in Lokoja, Nigeria Joseph O. Balogun and Khadijat N. Yakubu	92 – 103
Assessment of flood vulnerability in Lokoja metropolis, Kogi State, Nigeria Fidelis C. Duchi, Sunday K. Habila and Laraba S. Rikko	104 - 117
Characteristics and challenges of small-scale industries in Jos North LGA, Plateau State, Nigeria Chinedu J. Anyamele, Leonard S. Bombom, Timothy K. Gontul, Nandi D. Dabis, Folashade J. Ojo, Muhammad A. Labiru, Imegi J. Ozemelah, Gideon Baklit, Obadiah A. Zailani and Nandom N. Ladep	118 - 128
Participatory slums upgrading in Kabong community of Jos, Nigeria Yusufu A. Bature, Samuel M. Maton and Rebecca Sati.....	129 - 140
Women involvement in stone quarrying activities in Jalingo, Taraba State, Nigeria Ibrahim Abdullahi, Ahmad M. Yushau and Samuel Daniel	141 – 149

Assessment of access to domestic water supply sources in Gyel district of Jos, Plateau State, Nigeria Meshach A. Omada, Andesikuteb Y. Ali, Ezra L. Vivan, Clement Y. Giwa, Simo S. Watson and Hyacinth M. Daloeng	150 – 161
Effects of poultry droppings application on selected properties of lateritic soils derived from basalts on the Jos Plateau, Nigeria Joshua S. Galadima, Isaac S. Laka and Emmanuel A. Olowolafe.....	162 - 171
Erodibility of soil in Angwan Rimi, Zango Kataf LGA, Kaduna State, Nigeria Hosea K. Mande	172 - 182
Exploring burn severity of seasonal fire in Yankari National Park, Nigeria, using Landsat data Leonard S. Bombom, Sunday D. Goshit, Elisha J. Dung and Ibrahim D. Choji	183 - 200

EFFECTS OF TILLAGE OPERATIONS ON THE PROPERTIES OF AN ALFISOL ON THE JOS PLATEAU, NIGERIA

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Abstract

One of the major constraints to sustainable agriculture on the Jos Plateau is soil erosion. This is due to the nature of the topography of the area. Most smallholders in the area carry out tillage operations for many purposes. These include ridging across slopes to control erosion, seed bed preparations and weed control, among other operations that are done manually by using hoes. This study was conceived to determine the effects of tillage operations on some of the physical and chemical properties of the Alfisols, which are the most widely cultivated soils in the area. Two types of soil data were collected: Soil profile pits' data and surface soil data. Standard procedures were employed in the detailed laboratory determinations of soil properties. The results show that tillage operations have led to significant differences in both soil physical and chemical characteristics of the soils. Despite the fact that the conventional tillage has been practised just for only four years, the results here show that tillage practices have significantly affected the organic matter, total N, exchangeable Ca, K, Mg contents and CEC of the soils. Perhaps, this is as a result of rapid decomposition under minimum and conventional tillage due to aeration and oxidation. Therefore, tillage practices need to be carried out with caution because soils in the tropical environments generally experience the reduction of organic matter and are susceptible to degradation because of such practices.

Keywords: Tillage operations, Soil properties, Alfisols, Tropical environment

INTRODUCTION

One of the major constraints to sustainable agriculture on the Jos Plateau is soil erosion. This is due to the nature of the topography of the area. Most smallholders in the area carry out tillage operations for many purposes. These include ridging across slopes to control erosion, seed bed preparations, weed control and incorporation of crop residues and herbicides, manually by using hoes (Olowolafe and Dung, 2000). Generally, in Nigeria, ridge tillage is the practice of planting or seeding crops in rows on the top, along both sides or in the furrows between the ridges which are prepared at the beginning of every cropping season (Lal, 1990). Larger farms use plows and harrows pulled by tractors, which results in the complete inversion of the top 20 to 30 cm of the soil. However, there are some areas where no tillage operation is still being practised. No-till or zero-tillage is characterized by the elimination of all mechanical seed bed preparation except for the opening of a narrow strip or hole in the ground for seed placement (Lal, 1983). All these operations have been in practice for long without the attempt to investigate the effects of such tillage operations on the soil properties on the Jos Plateau. There is paucity of information on the effects of tillage practices on soil

properties (physical, chemical and biological) in the area. Since the actual effects of tillage operations differ from one climatic area to another, among other factors (Mahboubi *et al.*, 1993), this study was conceived to determine the effects of tillage operations on some of the physical and chemical properties of Alfisols, which are the most widely cultivated soils in the area.

MATERIALS AND METHODS

Study Area

Figure 1 presents the map of Jos city which shows the study area. The city is located on the Jos Plateau in the central Nigeria and it lies between latitude 8° 30' and 10° 30' N and longitude 8° 20' and 9° 30' E. The average elevation of the study area is about 1,250 metres above sea level. Though the climate of the area is markedly influenced by its altitude and position across the seasonal migration of the Inter-Tropical Discontinuity (ITD), it is the wet and dry type classified as Tropical rainy (Aw) climate by Koppen (1923). It has a mean annual rainfall of about 1,260mm (1,050-1,403mm), peaking between July and August. The mean annual temperature is about 22°C, but mean monthly values vary between 19.4°C in the coolest month of December when the area comes under the

influence of the cool and dry desiccating north-easterly tropical continental air mass (harmattan) and 24.5°C in the hottest month of April. The soil moisture regime is ustic and the soil temperature regime is inferred to be isohyperthermic (USDA, 1999). The area lies within the northern Guinea Savanna vegetation zone, an open woodland with tall grasses (Keay, 1953). The geology

of the Jos city area comprises Precambrian basement complex rocks (migmatites, gneiss and older granites) and some areas of younger granites. The experimental site lies within the area underlain by crystalline Basement Aplo-pegmatite Granite-gneiss (Macleod, et al, 1973).

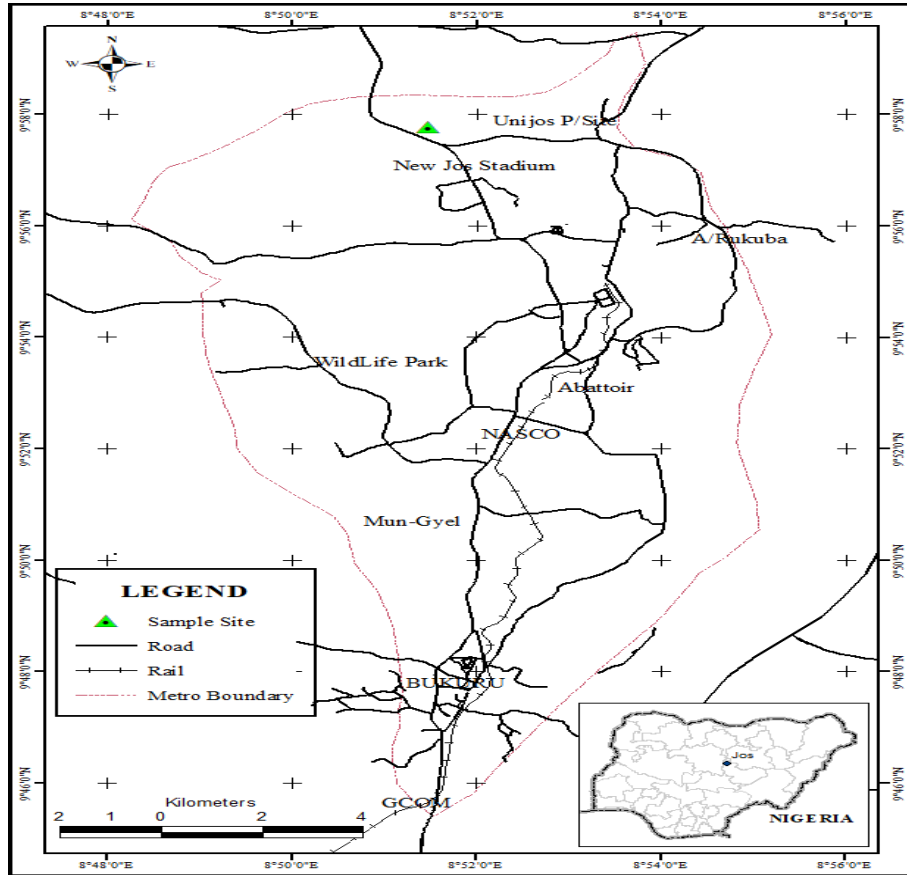


Figure 1. Jos city showing the Study Area.

Materials

The study is within the premises of the Commonwealth Comprehensive College, located to the north-west of the Jos city (Latitude 09° 57' N; Longitude 08° 51' E) (see Figure 1). The college was established in the year 1989. The experiment took place in the area designated for arable crop production by the staff of the College. For this study, three tillage types were considered: a). Zero tillage: this is the area where there is no form of cultivation, it is a grassland where there is no soil disturbance. Though the grasses were always regularly cut and left on the soil surface, there has not been any form of tillage at all. b). Minimum tillage: This involved the usage of simple hand tools (hoes and cutlasses), which is the usual practice in the savanna environment where old ridges from previous

cultivation were split by forming a new ridge in a furrow between two old ridges (Beets, 1990; Agbenin, 1998; Olowolafe and Dung, 2000). Maize has always been cultivated on this portion for 25 years. c). Conventional tillage: During land preparation, the soil is always ploughed up to the depth of 20 cm, harrowed and ridged. The crop produced here is upland rice and it has been cultivated for only four years. NPK (20:20:20) fertilizer and chicken droppings are used as fertilizers on both farms.

Soil Sampling

Two types of soil data were collected: Soil profile pits' data and surface soil data. In each of the treatment areas (no-tillage, minimum tillage and conventional tillage), one profile pit was located in the central part of each

field. Therefore, a total of three soil profile pits were dug and described according to FAO (2006) guidelines, while the soils were classified in line with USDA (1999 and 2014) Soil Taxonomy. The various genetic horizons were sampled for laboratory analysis. The second sampling concerned the surface (0 – 15cm) soils, which were collected with the use of stratified random sampling technique. An area of 30m by 20m was chosen in each of the three treatment areas. This area was divided into 6 grids of 100m² each and within each of these, four sampling sites were chosen by throwing up a coin four times. The four surface soil (0-15cm depth) samples taken at the points where the coin landed, were mixed to form the composite sample, out of which sizeable portion was taken. Hence, six surface soil samples were taken from each of the three treatment sites. ANOVA test was the statistical technique used to test the significance of difference among the three treatment sites.

Methods of Soil Analysis

Standard procedures were employed in the detailed laboratory analysis. Laboratory determinations made include the following: Particle size analysis was made by using the hydrometer method outlined by Day (1965) and modified by Gee and Bauder (1986). Measurement of pH was done in a 1:2.5 suspension in water and KCl. Organic matter was determined using the Walkey and Black (1934) method of acid dichromate digestion and the titration was done with ferrous sulphate solution. Available phosphorus was extracted using dilute HCl/NH₄F as described by Bray and Kurtz (1945) while total nitrogen was determined following wet oxidation micro-Kjeldahl method (Bremner and Mulvaney, 1982). The extraction of Ca, Mg, Na and K was made using 1N ammonium acetate at pH 7.0 (USDA, 1972), and Ca and Mg were measured by an Atomic Absorption Spectrophotometer (AAS) while K and Na were measured by flame photometer. The extraction for exchangeable acidity and CEC were carried out by using 1N KCl solution.

RESULTS AND DISCUSSION

Tables 1 and 2 present soil profile data and the summary of surface soil data respectively. The analysis of variance was made at a significance difference of 5%. Concerning the textural properties, table 1 shows that there is no difference in the amounts of clay, silt and sands between the first two horizons in soil profile 1, perhaps because there is no disturbance due to tillage. However, in soil profiles 2 and 3, affected by

minimum and conventional tillage respectively, there are differences in the clay, silt and sand contents between their first two horizons, indicating the effects of tillage. This explains the significant difference among the three soil profiles' data in table 2 in their contents of clay, silt and sands. This may have resulted in the alteration of soil structure and porosity, with a consequent increase in infiltration and reduced runoff. Tillage operations are known to bring about the mixing and re-mixing of soil particles from the subsoils to surface soils and vice versa.

Similarly, Mbagwu and Bozzoffi (1989) reported that tillage encourages the movement of finer particles from the surface soils to sub-soils, all these may have led the differences in texture.

Table 1 does not show much difference in soil pH values among the three soil types. However, table 2 shows that there is a significant difference in the results of analysis of variance for the surface soils. It shows that surface soils with minimum tillage has the highest pH mean value of 6.11 while the those of the conventional tillage has the minimum mean value of 5.79, indicating that tillage practices lead to pH reduction. Similarly, IITA (1983) has observed relatively higher pH value of 5.9 in no-tillage surface soils compared to a value of 5.3 in a conventionally ploughed soils after growing 24 consecutive maize crops. This can be related to the influence of relatively higher organic matter contents in no-tillage soils.

Table 1 shows a general trend of decrease of organic matter down the three soil profiles. This is actually expected because the surface soil is always the receiver of leaves and organic materials before decomposition and humification processes commence. The table shows that soils with zero tillage has the maximum value of 4.48% of organic matter in the surface horizon and also the highest mean value of 4.65% from the result of ANOVA in table 2 where there is also a significant difference among the three soil types in their organic matter contents. This obviously indicates that zero tillage practice has increased the soil organic matter contents. According to Brady and Weil (1996), tillage is one of the major management practices that most influence soil organic matter contents. This is because intensive tillage aerates the soils and breaks up the organic residues and thereby increases the rates of decomposition and mineralization of soil organic matter leading to carbon loss and this is why the practice of conservation agriculture promotes organic carbon stabilization (Umar et al., 2011).

EFFECTS OF TILLAGE OPERATIONS ON THE PROPERTIES OF AN ALFISOL ON THE JOS PLATEAU, NIGERIA

Table 1 Some of the physical and chemical properties of the soils

Sample No	Horizon Symbol	Horizon Depth(cm)	Clay %	Silt %	Sand %	Text. Class	pH (water)	OM %	TN %	Avail P ppm	Ca meq/100g soil	Mg meq/100g soil	K meq/100g soil	Na meq/100g soil	EA(H+Al)	CEC cmol(+)/kg soil
Soil Profile No. 2: Zero Tillage																
1	Aw1	0.-15	20	18	62	SL	5.59	4.48	0.130	20	1.84	0.52	0.51	0.013	1.61	4.50
2	Aw2	15-32	20	18	62	SL	6.05	2.17	0.120	19	1.94	0.58	0.58	0.017	1.65	4.47
3	Bt1	32-56	36	23	41	CL	6.18	0.97	0.036	9	1.98	0.62	0.62	0.019	1.67	4.83
4	Bt2	56-77	38	22	40	CL	6.56	0.52	0.024	4	2.12	0.66	0.66	0.021	1.71	5.13
5	BC	77-120	40	20	40	C	6.82	0.45	0.018	3	2.17	0.67	0.67	0.023	1.74	5.22
6	C	120+	42	20	38	C	6.39	0.34	0.013	2	2.21	0.69	0.69	0.024	1.75	5.20
Soil Profile No. 2: Minimum Tillage																
7	Ap1	0.-12.	18	16	66	SL	6.02	3.79	0.120	10	1.36	0.42	0.14	0.011	1.56	3.72
8	Aw2	12.-25	20	18	62	SL	6.28	3.00	0.091	7	1.82	0.53	0.45	0.016	1.58	4.30
9	Bt1	25-50	38	22	40	CL	6.86	1.24	0.043	5	2.00	0.62	0.47	0.022	1.61	4.64
10	Bt2	50-75	48	22	30	C	6.94	0.59	0.026	3	2.12	0.64	0.52	0.029	1.62	4.82
11	BC	75-115	49	22	29	C	7.04	0.14	0.022	2	2.36	0.66	0.57	0.026	1.64	5.16
12	C	115+	49	23	28	C	7.12	0.21	0.011	2	2.42	0.68	0.9	0.028	1.65	5.27
Soil Profile No. 3: Convventional Tillage																
13	Ap1	0.-12.	18	16	66	SL	5.89	4.13	0.130	13	1.81	0.52	0.48	0.017	1.60	4.48
14	Aw2	12.-.25.	20	18	62	SL	5.97	3.79	0.120	10	1.85	0.58	0.52	0.013	1.63	4.48
15	Bt1	25-55	38	22	40	CL	6.12	0.69	0.036	7	1.96	0.62	0.57	0.022	1.63	4.70
16	Bt2	55-70	36	23	41	CL	6.16	0.59	0.024	6	2.00	0.66	0.62	0.016	1.65	4.84
17	BC	70-110	36	23	41	CL	6.22	0.45	0.018	4	1.94	0.65	0.63	0.012	1.64	4.73
18	C	110+	36	18	62	SC	6.02	0.38	0.013	2	1.82	0.54	0.58	0.014	1.61	4.54

Similarly, some other authors have affirmed that tillage practice can influence the concentration and distribution of soil organic matter (SOM) in the profile with higher SOM content in surface layers with zero tillage than with conventional tillage (Jantalia et al., 2007; Lal, 1982). Hence, the implementation of non-tillage, followed by the return of plant residue to farm land, which can be an efficient approach to raise up soil productivity and the accumulation of soil carbon (Kumar et al., 2014; Yuan, Shi & Zhao 2018), as well as to reduce GHG emissions. Globally, the shift in soil tillage practice from conventional to conservation system effectively protects the soil under cropping, increases soil quality, reduces SOM decline rate, as well as improves the endurance of the cropping system (Mehra et al., 2018).

Differences between total N levels under tillage practices in the surface soils (0-15 cm) as shown in table 2, closely followed the pattern observed for organic matter. Table 2 shows that surface soils with zero-tillage have the highest amount of total nitrogen and there is a significant difference among the soils in their contents of the element. This also shows that tillage operations have significant effects on the contents of total nitrogen. Lal (1976) observed a similar result and obtained twice the amount of total nitrogen in the no-tillage soils compared to that of conventionally ploughed soils. It is generally accepted

that as a result of minimum tillage the soil organic matter increases in the upper five centimeters of a soil mainly due to the fact that the crop residues are not mechanically mixed into the soil as with conventional tillage (Baeumer and Bakermans, 1973; Lal 1976; Blevins *et al.*, 1983; Mahboubi *et al.*, 1993; Ismail *et al.*, 1994).

There is also significant difference among the soils in their available phosphorus contents and the element has the highest values in soils of zero tillage treatment both in the profile pit and surface soils (i. e. tables 1 and 2). The more phosphorus availability under zero tillage compared to conventional and minimum tillage may be due to surface placement of crop residues in zero-tillage in comparison with incorporation of crop residues with tillage as earlier observed by other researchers (Ismail et al. 1994). El- Baruni and Olsen (1979) suggested that the solubility of P is known to be enhanced by the presence of organic matter. Similarly, higher extractable P levels have been reported in zero tillage than in tilled soils (e.g. Duiker and Beegle 2006, Du Preez et al., 2001). Extractable P in zero tillage system was 42% greater at 0-5 cm, but 8- 18% lower at 5-30 cm depth compared with conventional tillage (Ismail et al., 1994). Another factor that may have influenced the availability of the element is soil pH (Brady & Weil, 1996; and Landon, 1991).

Table 2 Statistical summary of the surface soil data

Treatment	Zero Tillage		Minimum Tillage		Conventional Tillage		Test of Significance		
	Mean	STD.	Mean	STD.	Mean	STD.	F. Critical	F. Cal.	Significance
Clay%	21.8	1.761	11.0	3.011	21.5	3.125	3.682	31.15	Significant
Silt%	18.5	0.548	12.7	1.033	18.0	1.673	3.682	45.16	Significant
Sand%	59.7	2.280	76.4	3.933	60.5	4.750	3.682	36.72	Significant
pH	5.84	0.140	6.11	0.056	5.79	0.084	3.682	17.85	Significant
OM%	4.65	0.362	1.25	0.316	3.78	1.044	3.682	42.45	Significant
N%	0.145	0.010	0.045	0.011	0.118	0.032	3.682	39.00	Significant
AP(Ppm)	18.2	4.535	8.7	2.160	14.3	6.890	3.682	5.66	Significant
Ca (meq/100g)	1.62	0.035	1.12	0.139	1.80	0.099	3.682	74.82	Significant
Mg (meq/100g)	0.58	0.045	0.38	0.024	0.52	0.039	3.682	47.02	Significant
K (meq/100g)	0.552	0.067	0.385	0.035	0.455	0.117	3.682	6.50	Significant
EA(H ⁺ A13 ⁺)	1.61	0.018	1.56	0.008	1.60	0.014	3.682	20.83	Significant
CEC (Cmol/Kg)	4.5	0.080	3.3	0.160	4.3	0.185	3.682	105.38	Significant

It becomes much more available at pH levels between 6.0 and 8.0, while it becomes less available at lower pH (< 6.0) where the element is liable to be fixed by Al, Fe and Mn (Euroconsult, 1985; Mizota & van Reeuwijk, 1989). Since the pH of surface soils with the conventional and zero tillage treatments are less than 6.0, they have higher values of available phosphorus, while the minimum tillage soils with pH of > 6.0 have lower values of the element.

In the same vein, exchangeable magnesium, potassium, acidity and cation exchange capacity have highest values in surface soils of zero tillage treatment. This also explains the significant differences among the soils in these properties as shown in table 2. This shows that tillage operations influence these soil properties. Similarly, IITA (1983) obtained the same results in Ibadan between no-tillage and conventionally ploughed soils. Likewise, Agbenin (1998) observed a higher amount of exchangeable cations in the surface soils than in the minimum and conventionally tilled area of an Isohyperthermic Typic Haplustalf at the Institute of Agricultural Research Farm, Samaru in the northern Guinea Savanna zone of Nigeria. Zero tillage conserves and increases availability of nutrients, such as K. Govaerts et al. (2007) found that the K concentration increased significantly with increasing residue retention. Higher organic carbon contents at the soil surface, commonly observed under conservation agriculture, can increase the cation exchange capacity (Duiker & Beegle, 2006). According to Lal (1979) and Aina (1979), one profound effect of tillage in soils is reduction in organic matter and CEC, among other parameters.

Several studies have indicated that one adverse effect of tillage in the tropics is the reduction of soil organic matter, plant nutrients such as nitrogen, phosphorus and exchangeable bases (Lal, 1976; Agbenin, 1998; Blanco-Canqui et al., 2005; McVay et al. 2006; Pereira et. al. 2007; Thomas et al. 2007; López-Fando & Pardo 2009; Lenart & Sławiński 2010). In general, our results are in agreement with those obtained by these studies. Despite the fact that the conventional tillage has been practised for just four years, the results here show that tillage practices have significantly affected the organic matter, total N, available K, Mg content and CEC of the soils. Perhaps, this is as a result of rapid decomposition under minimum and conventional tillage due to aeration and oxidation, as earlier explained. Perhaps, this is why some authors have remarked that large scale mechanized farms in West Africa are noted for their limited successes (Lal, 1974 and 1979; Lenart & Sławiński 2010). Such projects should be approached

with caution. Unrealistic adoption of such technology from the temperate in the tropical environments can lead to disastrous consequences. Soils in tropical areas generally experience the reduction of organic matter and are susceptible to degradation because of such practices (Anda et al., 2010; Ermadani, Yulnafatmawita & Syarif, 2018).

CONCLUSION

This study concluded that tillage practices have led to significant differences in both the textural and chemical characteristics of the soils. Despite the fact that the conventional tillage has been practised for just only four years, the results here show that the practices have significantly affected the organic matter, total N, exchangeable Ca, Mg, K contents and CEC of the soils. Perhaps, this is as a result of rapid decomposition under minimum and conventional tillage due to aeration and oxidation as a result of high temperature in the tropics. Therefore, tillage practices need to be carried out with caution because soils in the tropical environments generally experience the reduction of organic matter and are susceptible to degradation because of such practices.

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AN ASSESSMENT OF MEDICAL WASTE MANAGEMENT PRACTICES IN AHMADU BELLO UNIVERSITY TEACHING HOSPITAL AND AHMADU BELLO UNIVERSITY HEALTH SERVICES, ZARIA, NIGERIA

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Abstract

Healthcare services are aimed at improving wellbeing and preventing potential human health risks and environmental hazards. In the process, however, wastes that are potentially harmful are generated. Poor management of these healthcare waste (HCW) exposes the health workers, patients, waste handlers and the general public to health risks. Thus, this study assessed HCW management practices at Ahmadu Bello University Teaching Hospital (ABUTH) Zaria and Ahmadu Bello University Health Service (ABUHS) A.B.U. Zaria. The study utilised questionnaire administered to all the heads of waste management units in each of the hospitals (4 at the ABUTH and 1 with the Medical Director at the ABUHS) for assessing the effectiveness of HCW management practices in accordance to the Townend and Cheeseman (2005) guidelines. The study established the total quantity of HCW generated at ABUTH and ABUHS at 845kg and 77kg per day respectively; which translates to 1.18kg and 1.54kg per day per bed at ABUTH and ABUHS respectively. The study revealed the availability of (190 at the ABUTH and 2 at the ABUHS) operational staff specifically responsible for medical waste management and personal protective equipment for use by medical waste handlers in both ABUTH and ABUHS. The study further revealed the availability of well distributed receptacles, storage containers, dumpsites and separation of collection of sharps or infectious materials at both ABUTH and ABUHS. The study, however, also established absence of colour coding, central purpose-built storage facility, recycling on healthcare waste management in both ABUTH and ABUHS. It was concluded that both the ABUTH and ABUHS are classified as Level 2 hospitals based on their operational performance in accordance with the Townsend and Cheeseman (2005) guidelines, which implies that some aspects are considered sustainable while some other aspects considered unsustainable. The study recommended more sustainable practices in the management of HCW. Given the importance of effective healthcare waste management practices and the current unsustainable level of performance, the study recommended further study on the effects of the healthcare wastes from the two hospitals on the environment (soil, water and air).

Keywords: Healthcare, Waste, Management, Practice, Effectiveness

INTRODUCTION

The World Health Organization (WHO) (2002) defined healthcare waste as “any solid waste that is generated in the diagnosis, treatment, or immunization of human beings or animals, in research pertaining thereto, or testing of biological, including but not limited to soiled or blood-soaked bandages, culture dishes and other glassware”. United States Environmental Protection Agency (USEPA, 1989) refers to hospital waste as all biological or non-biological waste that is discarded and not intended for further use and this includes pathological, infectious, hazardous chemicals, radioactive wastes, stock cultures, blood and blood products, animal carcasses, pharmaceutical wastes, pressurized containers, batteries, plastics, low-level radioactive wastes, disposable needles, syringes, scalpels and other sharp items. Others include food service, cleaning and miscellaneous waste (Oyeleke

and Istifanus, 2009), toxic chemicals, cyto-toxic drugs, flammable and radioactive wastes that can often be considered infectious (Caltivelli, 1990).

The sustainable management of Healthcare Waste (HCW) has continued to generate increasing public interest due to the health problems associated with the exposure of human beings to potentially hazardous waste arising from healthcare (Tudor, Noonan and Jenkin, 2005). Whilst hospitals and healthcare units are supposed to safeguard the health of the community, the mismanagement of HCW poses health risks to people and the environment by contaminating the air, soil and water resources. Presently, considerable gap exists with regards to the assessment of healthcare waste management practices particularly in Nigeria and in several other countries in sub-Saharan Africa (Adegbite, Nwafor, Afon, Abegunde and Bamise, 2010).

Studies on Hospital solid waste have been carried out by different researchers. (Longe and Williams, 2006) surveyed medical waste management practices and their implications to health and environment in metropolitan Lagos. The study assessed management practices in four hospitals ranging in capacity from 40 to 600 beds. The study established average generation rate of medical waste of 0.562kg/bed/day to 0.670kg/bed/day; with infectious waste accounting for between 26 to 37% of the total volume. Only two of the hospitals investigated carried out treatment of their infectious and sharp waste types by incineration before final disposal.

Nemathaga, Maringa, and Chimuka, (2008) studied hospital solid waste management practice in Limpopo province of South Africa. The author looked at the issues and current short comings faced by many hospitals in the province. According to the study, a major policy implementation gap was identified between the national government and the hospitals. Although modern practices such as landfills and incinerators were reported to be used, daily operations were not carried out in accordance with these minimum standards. The authors also noted that there was no proper separation of waste according to the classification demanded by the national government.

Ajimotoke and Aremu (2009), in a study titled "case study evaluation of health-care waste challenges in Hospitals within Ilorin metropolis", found out that about 177.67Kg of waste was generated daily and the average waste generated per bed/per day was 1.56Kg. They further reported that the management of the waste was often poor, with a mixture of potentially infectious and non-infectious waste being a common sight in the hospital waste bins and hospital environment.

Abah and Ohimain (2011), in the study entitled "health care waste management in Nigeria", focused on the estimation of the quantity, evaluation of the waste segregation practice and determination of the knowledge of health care workers regarding healthcare waste management. The findings revealed that the average amount of health care waste was 0.62Kg/person/day at the out patients ward and that the proportions of respondents who had received specific training in the management of healthcare waste was 11.5% (6/52). The number who understood the importance of HCW management in the provision of safety to the public was 46% (24/52).

Toyobo, Baba and Oyeniyi (2012) appraised the medical waste characteristics and management practices in University College Hospital (UCH), Ibadan and Obafemi Awolowo Teaching Hospital Ile-Ife in Nigeria. The authors examined characteristic of waste

generation, identified waste disposal methods, assessed waste management practices, and highlighted possible suggestions towards a healthy environment for patients for the case studies. The study revealed improper waste management handling and open dump disposal methods in the two hospitals. The study subsequently recommended proper trainings and workshops should be conducted to make the resident doctors and waste management teams in the hospitals aware of the issues and practices of hospital waste management. Beside this, the study recommended that the regulation of audit process in this life sensitive issue should be maintained. Studies on healthcare wastes have not been adequately undertaken and reported in the present study area. It is not clear at this point in time what the nature of HCW is, how much is being generated and how they are managed in the study area. Besides, existing literature (Nemathaga et al., 2008; Toyobo et al., 2012) indicate that there appears to be much difference in the way and manner waste generated in various healthcare institutions are managed in Nigeria, hence, the necessity for this research, designed to compare Ahmadu Bello University Teaching Hospital (ABUTH) and Ahmadu Bello University Health Service (ABUHS) because of the potential high risk to the health of the vast number of people who are mainly students, staff, visitors and the communities at large.

The specific objectives of the study were to:

- (i) characterize the nature of the Healthcare Waste (HCW) generated in the two hospitals;
- (ii) determine the quantity of HCW generated in the hospitals;
- (iii) identify and map out the waste dumpsites of the two hospitals; and
- (iv) assess the effectiveness of HCW management practices in the hospitals.

MATERIALS AND METHODS

The data used for the research were:

- (i) Co-ordinates of the waste dumpsites which was sourced from the study area using the Global Positioning System (GPS).
- (ii) Quantity of waste generated per bed per day in each of the hospitals: The amount was calculated using a weight measuring scale.
- (iii) The effectiveness of HCW management practices in the two hospitals collected using structured questionnaires administered to each of the waste management heads in the hospitals.

- (iv) The topographic map sheet of the study area was sourced from the map library of the Department of Geography, Ahmadu Bello University, Zaria.

From the reconnaissance survey, it was discovered that two (2) staff were involved in waste handling at ABUHS while one hundred and ninety (190) staff were involved in waste handling at the ABUTH. The head of the waste management unit and the Medical Director of ABUHS completed the questionnaire while the four heads of waste management units at ABUTH also completed the questionnaire. Purposive sampling technique was used for the survey and frantic efforts were made to collect all the questionnaires.

To characterise the nature of the Healthcare Waste (HCW) generated in the two hospitals. Using the UNEP/WHO (2005) categorization, an inventory of the nature of wastes generated in the two hospitals were collated.

To determine the quantity of HCW generated in the hospitals, the different types of waste generated and collected in the out-patient and in-patient wards over a period of one week were weighed using a

weighing balance to determine the quantity of each type of waste generated per day in each hospital. The entire quantity of waste generated were weighed together each day prior to disposal at the dumpsites and recorded. Calculations of average quantity of waste per bed per day were carried out by dividing the total quantity of waste by the number of beds in each hospital.

In order to assess the HCW management practices of the two hospitals, an overall performance rating was assigned using the approach outlined in the guidelines suggested by Townsend and Cheeseman (2005).

After the dumpsites have been identified in the study area, the GPS was used to pick the coordinates of the dumpsites and these coordinates were transferred to the GIS environment where the base map (topographic map of the study area) was used to generate the dumpsites map using Arc GIS.

RESULTS AND DISCUSSION

The characterization and the nature of the HCW generated in the hospitals using the UNEP/WHO (2005) format is as presented in Table 1.

Table 1 The character and nature of the HCW in the hospitals

Waste Category	ABUHS				ABUTH			
	Yes	%	No	%	Yes	%	No	%
Recyclable wastes	2	100	0	0	190	100	0	0
Biodegradable wastes	2	100	0	0	190	100	0	0
Other non-risk wastes	2	100	0	0	190	100	0	0
Human anatomical wastes	0	0	2	100	160	84.21	30	15.79
Sharps	2	100	0	0	190	100	0	0
Non-hazardous Pharmaceutical wastes	2	100	0	0	190	100	0	0
Potentially hazardous Pharmaceutical wastes	2	100	0	0	177	93.12	13	6.8
Hazardous Pharmaceutical wastes	2	100	0	0	174	91.58	16	8.42
Cyto-toxic pharmaceutical wastes	2	100	0	0	162	85.26	28	14.74
Blood and body fluids	2	100	0	0	190	100	0	0
Infectious wastes	2	100	0	0	190	100	0	0
Highly infectious wastes	2	100	0	0	165	86.84	25	13.16
Other hazardous wastes	0	0	2	100	180	94.74	10	5.26
Radioactive wastes	0	0	2	100	80	42.11	110	57.89

Source: Author's fieldwork (2020)

From table 1, at the ABUHS, the respondents indicated that all the waste categories according to UNEP/WHO classification were present except radioactive waste, other hazardous waste and human anatomical waste were not present. However, it was recorded that all the waste categories according to UNEP/WHO classification were present at the ABUTH.

The quantity of wastes generated in the two hospitals could not be done using the standard UNEP/WHO (2005) guide because the waste in both hospitals were not sorted. Hence, the quantity of the daily waste generated was done according to the Department/Unit where the waste was generated. These are shown in table 2 for ABUTH and table 3 for ABUHS.

Table 2 Quantity of Healthcare Waste at ABUTH

S/No	Department/Unit	Weight (Kg)
1	Male and Female Medical Wards	237
2	Microbiology, Haematology & Paediatric Wards	81
3	Obstetrics and Gynaecology Ward	76
4	Accident and Emergency & Labour Wards	160.5
5	Chemical Pathology	12
6	Clinical Pharmacology Ward	5
7	Mortuary	22
8	Male and Female Surgical Wards	168.5
9	General Out Patient Department (GOPD) laboratory	74
10	Sharp boxes	9
	Total	845

Source: Author’s fieldwork (2020)

From table 2, the total quantity of HCW generated at ABUTH is shown as 845kg per day. With 717 beds in the ABUTH, the quantity of HCW per bed per day is 1.18kg. The table further shows that male and female medical wards generated the highest quantity of wastes (237kg), followed by the male and female surgical

wards (168.5kg), then the Accident and Emergency & labour wards (160.5kg). The Table also shows that Clinical Pharmacology Ward generated the least quantity of waste (5kg). Figure 1 shows the distribution of the HCW in percentages.

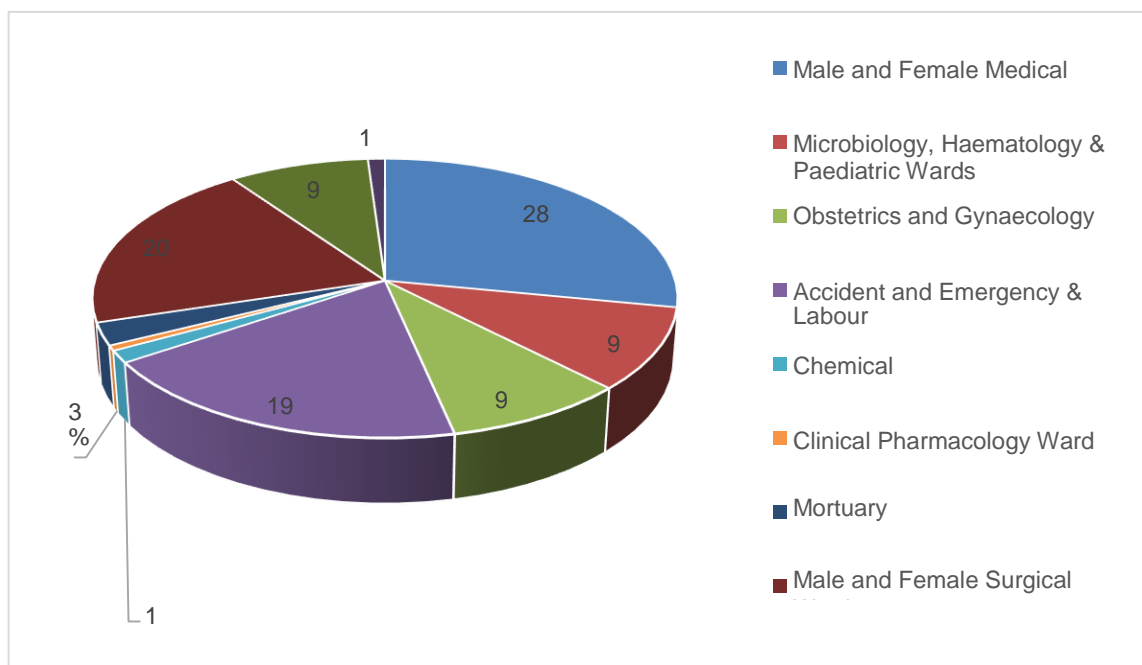


Figure 1 Proportion of Weight of HCW in different locations at ABUTH

Source: Author’s fieldwork (2020)

As shown in Figure 1, the units with leading proportions are Male and Female Medical Wards

(28%), Male and Female Surgical wards (20%) and Accident and Emergency & Labour wards (19%).

Table 3 Quantity of Healthcare Waste at ABUHS

S/No	Department/Unit	Weight (Kg)
1	Emergency	5
2	Dressing room	4.5
3	Laboratory	45
4	Safety box	3.5
5	Pharmacy	1
6	Injection room	1
7	General Out Patient Department (GOPD) laboratory	17
	Total	77

Source: Author’s fieldwork (2020)

The total quantity of HCW generated at ABUHS was 77kg per day. With the 50 beds capacity, the quantity of HCW at ABUHS per bed per day is 1.54kg. It is of equal importance to point out that several medical activities (such as delivery, surgery, etc) were not being carried out at ABUHS. When there

was a need for these activities, the cases were referred to the ABUTH. The proportion of HCW generated in the different units of ABUHS is shown in figure 2. The locations with leading proportions are laboratory (58%) followed by the General Out-Patient Department laboratory (22%).

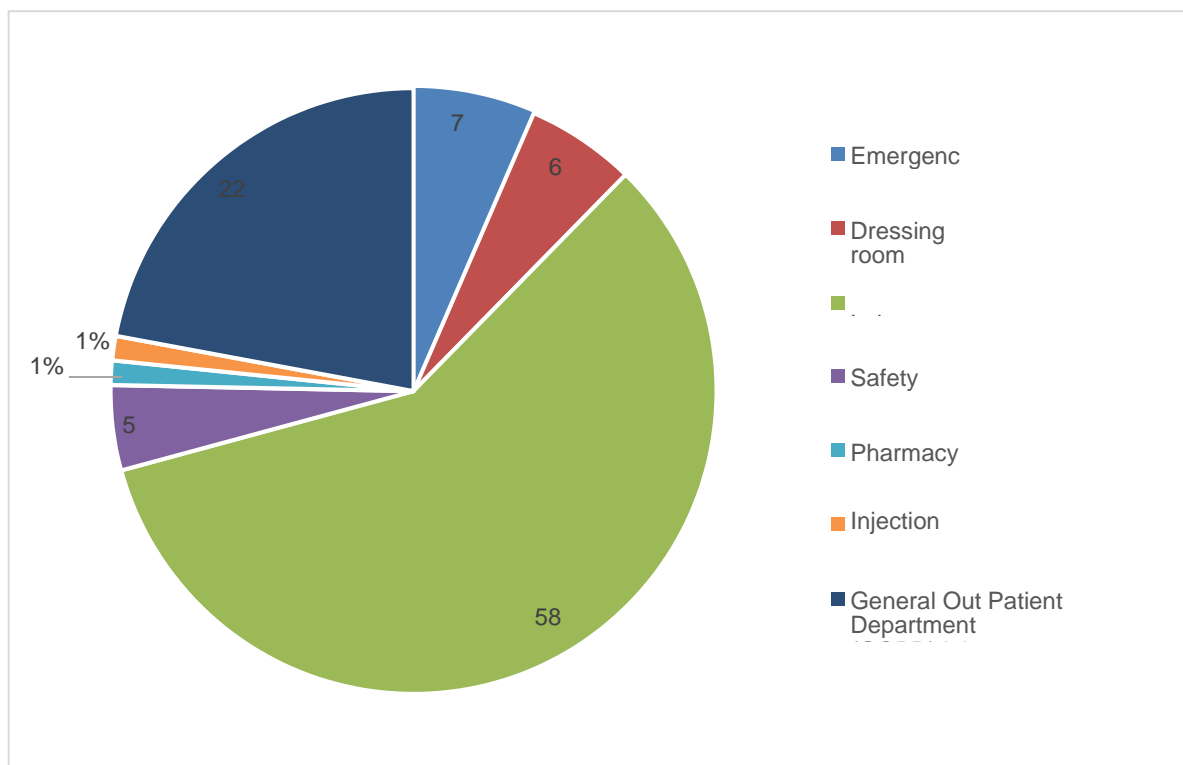


Figure 2 Quantity of HCW from different units at ABUHS
Source: Author’s fieldwork (2020)

The location of the dump sites within the premises of

the two hospitals is as presented in Figure 3

AN ASSESSMENT OF MEDICAL WASTE MANAGEMENT PRACTICES IN AHMADU BELLO UNIVERSITY TEACHING HOSPITAL AND AHMADU BELLO UNIVERSITY HEALTH SERVICES, ZARIA, NIGERIA

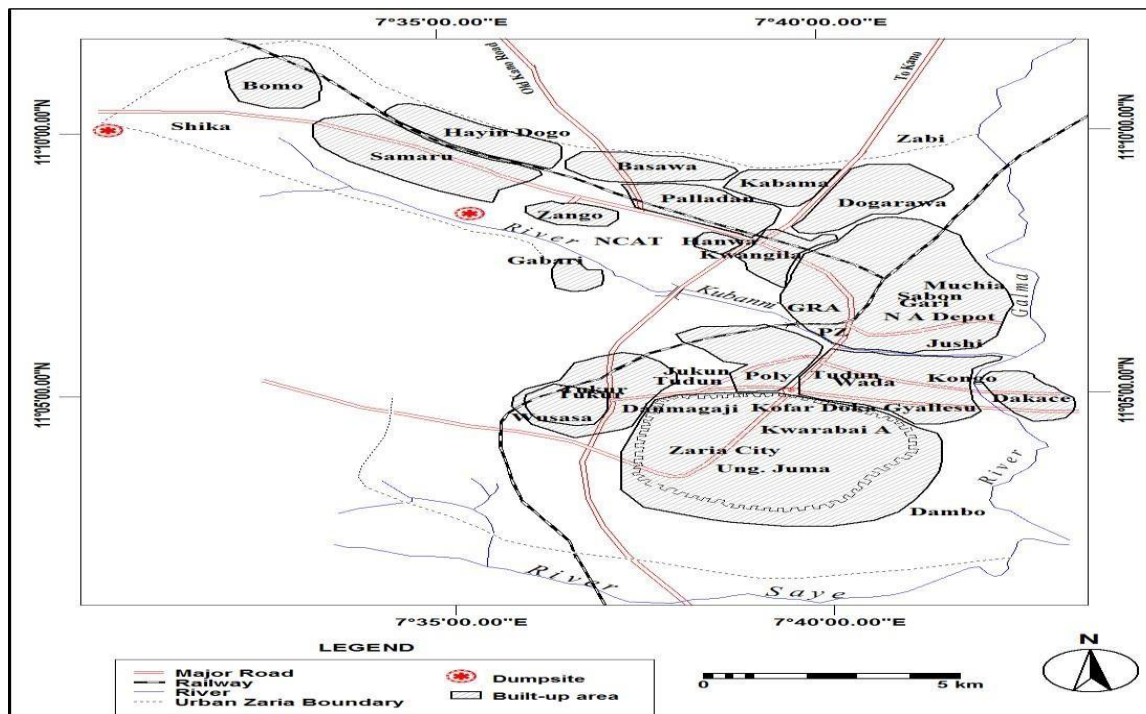


Figure 3 Location of Dumpsites for ABUTH and ABUHS
Source: Modified from Map of Urban Zaria

The effectiveness of HCW management practices in the two hospitals was investigated using the questionnaire administered to the waste handlers and also by another

set of questionnaire administered to the heads of the waste management units at the hospitals. The results are therefore presented in table 5.

Table 5 Assessment of effectiveness of healthcare waste management at ABUTH and ABUHS

Measure	ABUTH	ABUHS
<i>Level of awareness of top management on sustainable development (SD):</i>		
All top management trained in sustainable development	X	X
Some top management trained in sustainable development	X	X
All top management aware of sustainable development	(50%)	X
Some top management aware of sustainable development	(25%)	(100%)
Management unaware of sustainable development	(25%)	X
<i>Level of commitment of top management to sustainable development (SD):</i>		
High level	(50%)	(50%)
Some level	(25%)	(50%)
Minimal level	X	X
No commitment	X	X
Conduct of Mass balance	(100%)	X
Availability of cases of corruption	(25%)	X
<i>Level of awareness of best value:</i>		
Best value undertaken in the hospital	(25%)	X
There is awareness of best value	X	(50%)
There is minimum awareness of best value	(75%)	(50%)
There is a lack of awareness of best value	X	X

Table 5 Contd

Measure	ABUTH	ABUHS
<i>Level of awareness of continuous improvement:</i>		
Continuous improvements undertaken in the hospital	X	X
Some continuous improvements take place	(50%)	(50%)
Minimum continuous improvements take place	(50%)	(50%)
No continuous improvements take place	X	X
Availability of ISO 14001 certification	X	X
Availability of a staff consultative committee	(100%)	(100%)
Availability of a patient consultative committee	(50%)	X
Availability of a health and safety committee	(75%)	X
Availability of a health and safety representative	X	X
Availability of equal opportunities policy and framework	X	X
Availability of Investor in People (or similar) scheme	X	X
<i>Current state of health and safety:</i>		
There is health and safety awareness	(100%)	(50%)
There is a health and safety policy	(25%)	(50%)
There is a health and safety advisor	X	X
There are health and safety posters in use	(75%)	(50%)
There are basic protective clothing	(75%)	(100%)
There are full protective clothing	X	X
<i>Energy and Water usage practice:</i>		
Availability of energy policy	X	X
Conduct of regular checks on energy use	(50%)	(100%)
Use of renewable energy sources	(25%)	X
Conduct of regular checks on level of water consumption	(25%)	X
Availability of insulation in buildings	(25%)	(50%)
Conduct of regular checks to detect water wastage	(25%)	X
Availability of car sharing scheme	(75%)	X
Recovery of heat and power from wastes	X	X
Level of usage of public transport	Medium (100%)	Low (100%)
<i>Current state of purchasing and supply (procurement) of goods:</i>		
Uncoordinated purchasing and supply	X	X
Purchasing and supply is coordinated	(100%)	(100%)
There is some control on suppliers through tendering	X	(100%)
There is usually detailed specifications for goods	X	(100%)
There are usually no detailed specifications for goods	X	X
There are no waste prevention practices	X	X
There are waste prevention practices	X	(100%)
We work with suppliers and service providers to reduce materials used, reduce packaging and use of hazardous chemicals	X	X
We work with suppliers and service providers to reduce materials used, reduce packaging, eliminate heavy metals, reduce use of hazardous chemicals, identify materials for recycling and to reuse recycled products	X	X
There are no regards for clean production practices by suppliers	X	X
We conduct stock management	X	(50%)
There are no regards for rate of use of facilities depending in economic circumstances	X	X
We always conduct life cycle assessments and consider whole life costs of materials	X	X

Table 5 Contd

Measure	ABUTH	ABUHS
Availability of budget for waste management	X	X
Availability of operational staff responsible for waste management	(100%)	(100%)
Availability of strategy or policy for waste management	(25%)	(100%)
Availability of training on waste management	(100%)	(100%)
Venue of waste management trainings	Within the hospital (100%)	Within the hospital (100%)
Availability of Personal Protective Equipment	(100%)	(100%)
Presence of receptacles/storage containers	(75%)	(100%)
Availability of colour coding	X	X
Separation of collection for sharps or infectious wastes	(25%)	X
Availability of central purpose-built facility for waste storage	(25%)	(100%)
Availability of temporary waste storage facility	(100%)	(100%)
Average storage duration at temporary facility	Less than 24hrs (100%)	Less than 24hrs (100%)
Presence of dumpsite within hospital complex	(100%)	(100%)
Dumping of waste in open waste disposal site	(100%)	(100%)
<i>Current waste transportation practice:</i>		
Transportation of all non-hazardous municipal solid wastes collected in open topped vehicles	(100%)	X
Compaction of wastes	X	(100%)
Transportation of all non-hazardous municipal solid wastes collected in enclosed compaction vehicles	(100%)	(50%)
Conduct documentation for Transport of Dangerous Goods (TDG)	X	X
Appointment of TDG advisers	X	X
Separation of segregated wastes in enclosed vehicles	X	X
Availability of dedicated vehicles for hazardous wastes	X	X
Application of Basle Convention Requirements	X	X
Availability of recycling	X	X
Seeking to improve local economy and employment by developing use of recyclables	X	X
<i>Current waste treatment practice:</i>		
Availability of autoclaving of laboratory wastes	X	X
Practice of crude incineration of hazardous wastes	(75%)	(100%)
Use of single cell incineration plant	X	X
Use of multiple-chamber incineration plants	X	X
Recycling of residuals from incineration	X	X
Conduct of incineration according to international standards	X	X
Use of disinfected wastes as renewable fuel after shredding	X	X
Burying of wastes	(100%)	(100%)
Use of chemicals to disinfect body fluids	(100%)	(100%)
Practice of waste pre-treatment	(100%)	(100%)
Use of other advanced waste treatment technologies	X	X

Table 5 Contd

Measure	ABUTH	ABUHS
<i>Waste disposal practice:</i>		
Presence of scavenging and recycling by residents on dumpsites	(100%)	X
Presence of scavenging by animals and insects on dumpsites	(100%)	X
Availability of reports of recycling of syringes for re-use from the dumpsites	X	X
Availability of fencing and security for the dumpsite	X	X
Presence of environmental pollution at the dumpsite	(100%)	(100%)
The dumpsite posing as danger to public health	(100%)	(100%)
<i>Availability of any engineered sanitary landfill for hazardous wastes</i>	(100%)	X
External contracting of waste treatment	(75%)	X
<i>Method of waste transportation:</i>		
Open vehicles	(100%)	X
Enclosed compaction vehicle	X	X
Trolley	X	(100%)
Wheeled Vehicles	X	X
Trucks	X	X
Frequency of outside transportation of waste	Daily (100%)	Daily (100%)
<i>Final destination of wastes</i>		
Open dumpsite	(100%)	(100%)
Landfills	X	X
Shredding	X	X
Buried	X	X

Source: Adapted from Townend and Cheeseman (2005); *X means 0%

From table 5, 50% of the respondents from ABUTH indicated that all top management were aware of sustainable development, 25% indicated that some top management were aware of sustainable development while 25% indicated that management were unaware of sustainable development. The table also shows that all the respondents indicated that some top management were aware of sustainable development. The table shows that 50% of the respondents indicated high level of commitment of top management to sustainable development at both ABUTH and ABUHS; and that the remaining 50% of the respondents indicated some level of commitment of top management to sustainable development at both ABUTH and ABUHS. The table shows that all of the respondents from ABUTH indicated that mass balance was conducted while all the respondents from ABUHS indicated that mass balance was not conducted. The table further shows that 75% and 100% of respondents indicated that cases of corruption were not available with respect to waste management at ABUTH and ABUHS respectively. The table shows that 75% and 50% of the respondents indicated that there was minimum awareness of best value at ABUTH and ABUHS respectively. Furthermore, 50% of the respondents indicated that there was awareness of best value at ABUHS.

The table reveals that 50% each of the respondents from ABUTH and ABUHS indicated that some continuous improvements took place while the remaining 50% each of the respondents indicated that minimum continuous improvements took place at the two hospitals. The table shows that both ABUTH and ABUHS did not have ISO 14001 certification. The table also shows that 100%, 50% and 75% of the respondents from ABUTH respectively indicated availability of staff consultative committee, availability of patient consultative committee and availability of health and safety committee. The table further shows that 100% of the respondents from ABUHS indicated availability of staff consultative committee. The table shows that there was health and safety awareness (100%), policy (25%), posters in use (75%) and basic protective clothing (75%) at the ABUTH. The table also shows that there was health and safety awareness (50%), policy (50%), advisor (100%), posters in use (50%) and basic protective clothing (100%) at the ABUHS. The table shows that the following energy and water usage practices took place at ABUTH: conduct of regular checks on level of energy use (50%), use of renewable energy sources (25%), conduct of regular checks on level of water consumption (25%), availability of insulation in buildings (25%), conduct of regular checks to detect water wastage (25%) and

availability of car sharing scheme amongst staff (75%). The table also shows that the following energy and water usage practices took place at ABUHS: conduct of regular checks on level of energy use (100%) and availability of insulation in buildings (50%). The table shows that all the respondents indicated medium and low levels of usage of public transport by staff at ABUTH and ABUHS respectively. The table also shows that of all the identified purchasing and supply practices, all the respondents indicated only that purchasing and supply was coordinated at ABUTH. In addition, the table shows availability of the following purchasing and supply practices at ABUHS: that purchasing and supply was coordinated (100%), there was some control on suppliers through tendering (100%), there were usually detailed specifications for goods (100%), there were waste prevention practices (100%) and conduct of stock management (50%). The table shows that all the respondents from ABUTH and ABUHS respectively indicated that there was no specific budget for waste management. This implies overwhelming evidence of non-existence of specific budget for waste management in the case study hospitals. From the table, it is shown that all the respondents from ABUTH and ABUHS respectively indicated that there were operational staff specifically responsible for medical waste management in the hospitals. The table reveals that 25% and 100% of respondents from ABUTH and ABUHS respectively indicated that their hospitals had specific policy or strategy for medical waste management. The table also shows that all the respondents from ABUTH and ABUHS respectively indicated that the hospitals had specific training on medical waste management.

The table further shows that all the trainings workshops conducted on medical waste management by both ABUTH and ABUHS were held in-house within the respective hospitals. The table reveals that all the respondents from ABUTH and ABUHS indicated that there was available personal protective equipment for use by medical waste handlers. The table also shows that 75% and 100% of respondents from ABUTH and ABUHS respectively indicated that there were receptacles and storage containers available in their hospitals for medical waste management. The table further shows that all the respondents from ABUTH and ABUHS indicated that there were no colour coding practices for receptacles in their hospitals for medical waste management. The table also reveals that 75% and 100% of respondents from ABUTH and ABUHS respectively indicated that there were no separations of collection for sharps or infectious materials in their hospitals. The table also shows that

25% and 100% of respondents from ABUTH and ABUHS respectively indicated that there was central purpose-built facility as well as temporary waste storage facility available in the hospitals.

The table further shows that all respondents from both ABUTH and ABUHS indicated that the wastes were stored in the temporary waste storage facility for an average of less than 24 hours. The table shows that all the respondents from ABUTH and ABUHS indicated that there were dumpsites within their respective hospitals for medical waste management and that wastes from their hospitals were dumped in open disposal sites. The table also shows that from the identified current waste transportation practices, all the respondents at ABUTH practice transportation of all non-hazardous municipal solid wastes collected in open topped vehicles (100%) and transportation of all non-hazardous municipal solid wastes collected in enclosed compaction vehicles (100%). The table further shows that from the identified current waste transportation practices, the respondents at ABUHS practice compaction of wastes (100%) and transportation of all non-hazardous municipal solid wastes collected in open topped vehicles (50%). The table also shows that all the respondents from ABUTH and ABUHS indicated non-availability of recycling of medical waste management in both hospitals and that no improvement to local economy and employment by developing use of recyclables were sought at both hospitals. The table shows the current waste treatment practices at ABUTH to include of crude incineration of hazardous wastes (75%), burying of wastes (100%), use of chemicals to disinfect body fluids (100%) and practice of waste pre-treatment (100%). The table also shows the current waste treatment practices at ABUHS to include crude incineration of hazardous wastes (100%), burying of wastes (100%), use of chemicals to disinfect body fluids (100%) and practice of waste pre-treatment (100%). The table further shows that 75% and none of the respondents from ABUTH and ABUHS respectively indicated that there was external contracting of waste treatment in their respective hospitals and that open vehicles was the dominant methods for transporting wastes at ABUTH while the use of trolleys was the dominant method at the ABUHS. The table also shows that all the respondents indicated open dump sites as final destinations of wastes from both ABUTH and ABUHS and that the frequency of outside transportation of wastes as daily at both ABUTH and ABUHS. The table shows the waste disposal practices at ABUTH to include presence of scavenging and recycling by residents on dumpsites

(100%), presence of scavenging by animals and insects on dumpsites (100%), presence of environmental pollution at the dumpsites (100%) and the dumpsite posing as danger to public health (100%).

The table also shows the waste disposal practices at ABUHS to include presence of environmental pollution at the dumpsite (100%) and the dumpsite posing as danger to public health (100%). The table shows the disposal methods for different waste categories at the ABUTH and reveals that burial method was popular for disposing human anatomical wastes (75%), potentially hazardous pharmaceutical waste (100%), hazardous pharmaceutical waste (75%), cyto-toxic pharmaceutical waste (100%), blood and body fluids (75%) and radioactive waste (50%). The table also shows that incineration was popular for disposing other non-risk wastes (25%), sharps (100%), non-hazardous pharmaceutical wastes (25%), hazardous pharmaceutical waste (25%), blood and body fluids (25%), infectious waste (100%), highly infectious waste (100%), other hazardous waste (100%) and radioactive waste (75%). The table further shows the open dumping to popular for disposing recyclable waste (100%), biodegradable waste (100%), other non-risk waste (75%) and non-hazardous pharmaceutical waste (75%). The table shows the disposal methods for different waste categories at the ABUHS and that burial method was popular for disposing human anatomical wastes (50%), sharps (100%), potentially hazardous pharmaceutical wastes (100%), hazardous pharmaceutical wastes (50%) and blood and body fluids (100%). The table further shows that incineration was popular for disposing recyclable waste (50%), biodegradable waste (50%), other non-risk waste (100%), non-hazardous pharmaceutical waste (100%) and highly infectious waste (100%). The table also shows that open dumping was popular for disposing biodegradable waste (50%) and other non-risk waste (50%).

Going by the scores obtained from the two hospitals assessed as shown in the table. It is clear that both hospitals were operating in a manner with some aspects that were considered sustainable and others that were considered unsustainable. Hence, in accordance with the Townend and Cheeseman (2005) guidelines, both the ABUTH and ABUHS can be classified as Level 2 hospitals based on their operational performance.

CONCLUSION

Healthcare services are aimed at preventing potential human health risks and environmental hazards as well as improving wellbeing. In the process, however,

wastes that are potentially harmful are generated. Poor management of these healthcare wastes (HCW) exposes the health workers, patients, waste handlers and the general public to health risks. The management practices at ABUTH and ABUHS give room for so much concern considering the fact that both hospitals are classified as Level 2 hospitals based on their operational performance in accordance with the Townend and Cheeseman (2005) guidelines. The hospitals have enormous population influx based on patronage and the availability of high number of students on training should be seen to be high above board in waste management to avoid outbreak of infection.

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AN ASSESSMENT OF MEDICAL WASTE MANAGEMENT PRACTICES IN AHMADU BELLO UNIVERSITY TEACHING HOSPITAL AND AHMADU BELLO UNIVERSITY HEALTH SERVICES, ZARIA, NIGERIA

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SPATIAL ANALYSIS OF MATERNAL MORTALITY IN SOUTHERN SENATORIAL DISTRICT OF EDO STATE, NIGERIA

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Abstract

Nigeria accounts for high percentage of global maternal deaths and most studies on maternal mortality has been tied to hospital data that capture only the percentage of women that finally receive care from any of the existing orthodox health facilities. A population-based research on maternal death offers a more prospective approach at identifying areas of challenges. This research seeks to investigate spatial variations of maternal deaths in Southern Senatorial District of Edo State, Nigeria. Community-based survey design was employed to investigate the level of maternal mortality. To examine significance and spatial relationship, measurement of total fertility rate, maternal mortality ratio, lifetime risk and proportion of maternal death, descriptive statistical and cartographic methods were used. Data was collected from 2100 respondents using the indirect sisterhood method. The findings show that Total Fertility Rate for the study area was 4.605 and the maternal mortality ratio (MMR) calculated from the lifetime risk was 3877 per 100, 000 live births. Comparative analysis showed the period and place of maternal death was during /after delivery at health facilities in the study area. Most maternal deaths in the study area were between the age groups of 25–29 and 30–34 years occurring more amongst married women. Spatial variation of maternal mortality levels between urban areas and rural areas was (3806 and 4041) per 100,000 live births, respectively. With increased maternal risk across the study area, there is need for policies and actions that will accelerate the progress needed to achieve the SDG 3.1 goal by 2030.

Keywords: Indirect sisterhood, Lifetime risk, Maternal mortality, Total fertility ratio

INTRODUCTION

Maternal mortality has received greater worldwide focus as one of the public health problems but, skeletal facts exist on maternal mortality and morbidity causes across geographical space especially in the developing world. This is occasioned by the fact that most women who died from maternal causes occur where there are no vital registrations of maternal deaths, and accessing health care is not paramount to countless number of sick women (Filippi, Chou, Ronsmans, Graham & Say, 2016). One main challenge faced in managing the situation is the accurate measurement of maternal mortality levels. There is need to improve on the inequalities among sub-populations due to the innumerable maternal deaths. This is also a problem even in countries that have low maternal mortality levels. As the Millennium Development Goals era ended by 2015 and now the Sustainable Development Goals era has begun, maternal mortality information is vital to identify the various challenges and make reproductive women health care in this era a top priority (Langer, Horton & Chalamilla, 2013).

Countries in Sub-Saharan Africa and South of Asia have about ninety (90) percent of global maternal mortality. Maternal mortality ratio of 546 per 100,000

live births is recorded for countries in the Sub-Saharan of Africa; with yearly maternal death of about 201,000. The region has more than 65 percent of total universal maternal mortality yearly. Next to this region is South Asia, with maternal mortality ratio of more than 180 or yearly mortality figures of 66,000 which accounts for about 20 percent of global maternal deaths (World Health Organization [WHO], 2015). The high number and associated problems of maternal and child deaths necessitated the focus across geographical space on countries with more than sixty-nine percent of maternal mortality worldwide by United States Agency for International Development (USAID, 2015). This includes countries in Africa, Asia, Middle East and Latin America with more focus on the African continent than any other continent in the world. The continent records the highest maternal deaths with high number of indirect cause of deaths related to AIDS amongst sub-Saharan Africa adults of reproductive age 15-49 years. This age bracket constitutes 5 percent HIV prevalence rate (WHO, 2015).

Developing countries have the most maternal deaths while developed countries record about one percent of deaths (Bhutta, Darmstadt, Hasan & Haws, 2005; WHO, 2015). Studies have shown great

differences in equity between inter-state and intra-state, with increasing number of maternal mortality observed in poor clan communities (Banerjee, John, & Singh, 2013; Subha Sri & Khanna, 2014; Montgomery, Ram, Kumar & Jha, 2014; Okigbo, Adegoke & Olorunsaiye, 2017; Anastasi, Ekanem, Hill, Adebayo Oluwakemi, Abayomi, & Bernasconi, 2017). In 2015, countries like Nigeria and India recorded about 33 percent of the global maternal mortality worldwide which is approximately 58,000 and 45,000 maternal deaths respectively (WHO, 2015). In 2000, Millennium Development Goals (MDGs) was adopted globally and maternal health was listed as one of its goals. Countries were committed to the Millennium Development Goals 5, which was to reduce the number of maternal death by the year 2015. Countries like Nigeria, Central African Republic, Congo, Cameroon, Gambia and Mauritania made no progress, while India, Sierra Leone, Ghana, Chad, Liberia and Niger made inadequate progress toward achieving the MDG 5 goal (WHO, 2015). Nigeria is not on track towards achieving MDG 5 targets in 2015. In Nigeria, Oyibo, Watt & Weller (2017) showed that maternal mortality is a major challenge in the reproductive health arena.

Studies on circumstances surrounding maternal deaths and complications are mostly hospital based data sources from hospital/clinical records, interviews and observations (Hussein et al., 2016). Cham, Sundby, and Vangen (2005) in a qualitative study of rural Gambia state that a site-specific data might be vital for modifying existing policy and implementation, even though it is a known fact on the universal causes of continued high maternal mortality rates. Several other studies in Africa have sued for more apt data on the level, trend and factors responsible for maternal mortality across geographical space that have importance on the poor, those in rural areas/districts and urban slums in developing countries (Bougangue, 2010; Mohammed, Elnour, Mohammed, Ahmed, and Abdelfattah, 2011; Garenne, Kahn, Collinson, Gómez-Olivé, & Tollman, 2013).

In Nigeria, studies' utilizing geospatial techniques and approaches in analysing maternal mortality from data collected with health facility records was carried out (Kolo, Adamu, Mairiga and Chutiyami, 2017; Uriri 2015). Kolo et.al. (2017) reported temporal and spatial pattern of antenatal care, hospital deliveries and maternal deaths from 2001 to 2010 in Borno State. The state recorded maternal death ratio of 3448 per 100, 000 live births with Northern Borno recording highest ratio of 1373 per 100,000 live births and the least in Southern Borno (894 per 100,000 live births). In Delta State, the temporal and spatial

distribution/pattern of factors of maternal death, and mortality from 2003-2010 was analyzed in the context of human development indicators (Uriri, 2015). These studies added baseline data at local specific level across their respective state.

STATEMENT OF THE PROBLEM

Globally, among all areas of human development, maternal death and pregnancy complications have been less successful. Child bearing results in severe health challenge for women in reproductive age. On average, over 800 women die daily from pregnancy and childbirth complications, maternal deaths were more in sub-Saharan Africa (550) and South Asia (180) (WHO, 2015). In transiting from the Millennium Development Goal to the Sustainable Development Goal era, maternal deaths seem quite extreme in this age (Global Burden of Disease, 2015). With global regional progress achieved, there are still reports of alarming levels of maternal deaths in sub-Saharan Africa region. Most maternal mortality is preventable as evidently proven from records depicting vast differences amongst the richest and poorest countries. Maternal mortality lifetime risk is 1 in 3,300 in developed nations when compared to 1 in 41 in developing countries (WHO, 2015).

In developing countries, maternal deaths have not been critically examined which is evident from the few studies carried out in the areas (Chung, 2003). The patterns of maternal mortality reveal large levels of inequity between and within countries. In most developing countries, there is lack of quality records on maternal deaths and with the application of different research methodologies for measuring trends and level as well as causes of maternal mortality create a difficult situation in evaluating observed trends across nations (Hakkert, 2001; Hill, Abouzahr, & Wardlaw, 2001). A study in Brazil showed the utility of the spatial analysis of temporal evolution and distribution of maternal mortality that were above WHO recommended values as well as depicting regions with highest mortality (Carreno, Bonilh & Dias da Costa, 2014).

Records of high maternal mortality figures in the northern part of Nigeria have been documented, maternal mortality ratio of 2,420; 1,549 and 1,100 per 100,000 live births respectively (Adamu, Salihu, Sathiakumar & Alexander, 2003; National Population Commission [NPC], 2004; Kolo et al., 2017). In South Western region, community-based studies of maternal mortality conducted gave a maternal mortality ratio of 7,778 and 1,050 per 100,000 live births. These cross-sectional household surveys reiterate the crucial need to obtain information from underprivileged, rural

dwellers, and those living in un-accessible areas with a view to ascertaining areas in need of more resources for timely interventions. It validates the significance of sub-regional, differential data among the underprivileged, distant and vulnerable people at risk of dying (Adegoke, Campbell, Ogundeji, Lawoyin & Thomson, 2013; Anastatsi et al., 2017). In Lagos State, it was discovered that there is poor recording of information, scanty health services and lack of centralized data on maternal death (Mojekwu & Ibekwe, 2014). Rural communities in Nigeria report increasing maternal which is as a result of the high level of poverty among such rural reproductive women Harrison study (as cited by Okeh, 2009).

Health facilities studies records high maternal mortality ratio of 518, 2,278, 10,118, 405 and 313 per 100, 000 live births across the South-South region of Nigeria amongst pregnant women who die from pregnancy and childbirth complications especially deaths occurring from unbooked mothers (Eghe & Omo-Aghoja, 2008; Omo-Aghoja, Aisien, Akuse, Bergstrom & Okonofua, 2010, Uzoigwe, (nd); Uriri, 2015; Saving Mother Giving Life, 2016). This region is perceived as having fewer maternal deaths and records show they also have the least number of births per woman in the country. The need to understand the reason behind this upsurge in deaths among women age 15–49 is crucial. The South-South region of Nigeria records 4.3 births per woman, the index is higher in the North West (6.7), North East (6.3) and also in the North Central (5.3) (Nigeria Demographic and Health Survey [NDHS], 2013). This clearly indicates that overtime the measures put in place to curb and help reduce these ratio across geographical areas have been ineffective even in areas seemingly to be more educated with low fertility rate and high reproductive health care utilization. Accessibility to quality health care services at health facilities depicts a glooming picture to meet the increasing need for maternal health care delivery system in the country.

Although a vast number of facility-based statistics on maternal mortality exist in developing countries such as Nigeria, they may not reflect the actual state of health of community or local women. It has been suggested that the status of women's health is better captured by population based studies, which are very scarce (Gulmezoglu, Say, Betran, Villar & Piaggio, 2004). Evidence from studies in Edo State employ individual facility data on maternal death and no dependable community estimate of maternal deaths in the state (Eghe, Lawrence & Omo-Aghoja, 2008; Doctor, Findley & Afenyadu, 2012; Agbonkheshe, 2014; Agofure & Olarniregun, 2017; Agan, Monjok,

Akpan, Omoronyia & Ekabua, 2018). Successful planning and implementation for safe motherhood program would be difficult with the obvious lack of dependable state-level data. These studies concentrated on maternal mortality and morbidity in different population and they hardly utilize spatial geographical techniques. This paves the way for this study to have recent data, spatial analysis of the increasing risk to women in our society during their child bearing period. This will also depict the true state of maternal mortality between urban and rural reproductive women in the study area utilizing the indirect sisterhood techniques to estimate maternal mortality ratio.

JUSTIFICATION FOR THE STUDY

The lack of vital registration system on birth and death has left many developing regions without credible data about the populace. Based on the poor performance of Nigeria on the Millennium Development Goals for maternal health, maternal mortality requires reliable regional information to guide policy makers on the best possible strategy to curb geographic difference especially among the worse disadvantaged groups of women to lower maternal deaths in the country. Recent high maternal death records from a government tertiary health facility in the state is of grave concern, as most cases are referrals from private clinic and health centers across the state. There is need to identify the demographic distribution and spatial locations of areas with high mortality and morbidity. The choice of communities and grass-root population studies is needed to boost inter/intra-regional planning and policy implementation scheme of safe motherhood on maternal mortality. Also, the application of indirect sisterhood method in reporting maternal death within geographic areas in the country would explain the situation on ground much when human health issues are addressed. The application of the spatial techniques will aid government on effective strategies and interventions on combatting maternal death within identified communities with the highest maternal mortality. This specific target identification will aid reduction on maternal death which is geared toward achieving the Sustainable Development Goal 3.1 in the state.

MATERIALS AND METHODS

Study Area

Edo South Senatorial District is one of the three senatorial districts in the state. It is located between latitude 5°44'N and 6° 87'N and Longitude 5° 00' E and 6° 43' E of the equator. The district comprises seven(7)

Local Government Areas that include: Oredo, Ikpoba-okha, Egor, Ovia North-East, Ovia South-West, Orhionmwon and Uhunmwode which makes up the study area (Figure 1). The total land area of the senatorial district is 10835.37 km² (NPC, 2010). Community based survey design was employed to investigate the level of maternal mortality in seven Local Government Areas of Edo South Senatorial District. Households in the selected areas/wards were visited and enquiries made regarding maternal deaths from 2008–2017. This study adopted the indirect sisterhood method in estimating maternal death in the study area. This is because, most studies that are population based still use the indirect method for estimating maternal death (Oye-adeniran et al., 2011; Adegoke et al., 2013; Mgawadere et al., 2017). The method was developed by Graham (1989) in which adult respondents report on sisters born to the same mother survival has been applied effectively in many household surveys (Olsen et al., 2000). In this part of the world, the extended family system is practiced;

therefore emphasis is on sisters born to the same mother.

A structured questionnaire was administered on 2100 adult men and women of reproductive age (15–49 years), one from each household in the selected communities. Respondents provided information on the proportion of their sisters dying during pregnancy, delivery, or post-partum (after six weeks of delivery). This study applied the multi-stage stratified random sampling design where twenty-nine communities were selected within the study area; Table 1 depicts all the communities. With the use of a Geographic Positioning System (GPS) device, coordinates of the various respondents household within the study area were collected to produce a geo-referenced map of the study area using ArcGIS 10.4. The following relevant indicators of mortality among reproductive women aged 15–49 were calculated: lifetime risk, maternal mortality ratio, total fertility rate, sampling error for maternal mortality, and proportion of maternal death.

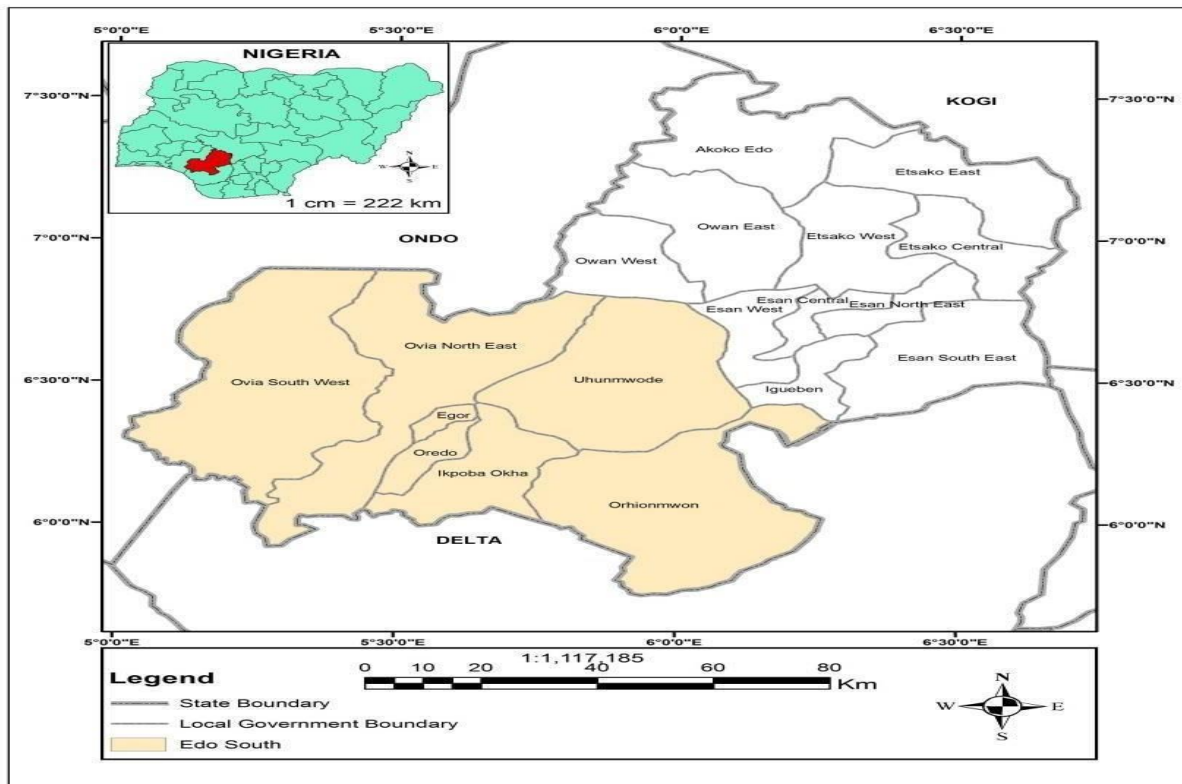


Figure 1 Edo South Senatorial District (Inset Nigeria)

Table 1 Selected Communities in Edo South Senatorial District

S/N	Local Government Area	Selected Urban Areas	Selected Rural Areas
1	Egor	Uselu, Ugbowo	Evbuotubu, Egor
2	Ikpoba-Okha	Idogbo, Gorretti	Ologbo and Obanyantor
3	Oredo	Ogbe quarters, Oredo urban (New Benin)	<i>Urhegin/Okua and Ekae</i>
4	Orhionmwon	Abiokunla1(Abudu), Urhonigbe	Ugu and Igbanke west
5	Ovia North East	Okada, Ekiadolor	Utoka and Iwu
6	Ovia South West	Iguobazuwa, Usen	Udo and Siluko
7	Uhunmwonde	Ehor, Umagbae South	<i>Ohuan, Orhua.</i>

Source: Authors' Fieldwork, 2018

The following are standard formulae for analyzing maternal mortality.

The formula for estimating **lifetime risk** of dying of maternal causes is given as:

$$Q = \sum r_i / \sum B_i \quad (1)$$

Where

Q = Lifetime risk

r_i = number of maternal mortality

B_i = i "sister units of risk of exposure

The adjustment factor is a constant, reported in the standard guidelines for the sisterhood method calculations.

The inverse of the lifetime risk of dying was used to calculate the probability of survival.

$$\text{Probability of survival} = 1 - Q \quad (2)$$

$$\text{Where: } Q = \sum r_i / \sum B_i \quad (3)$$

The maternal mortality ratio (MMR) was calculated from:

$$\text{MMR} = 1 - (\text{probability of survival}) / \text{TFR} \quad (4)$$

$$\text{Thus: } \text{MMR} = Q / \text{TFR} \quad (5)$$

The sampling error for maternal mortality is calculated as:

$$\text{SE}(\text{MMR}) = 1 - \text{MMR} / \text{TFR} \{ (1 - P / \text{BP}) + [\log(P)]^2 \text{Var}(\text{TFR}) / \text{TFR}^2 \}^{0.5} \quad (6)$$

The Upper and Lower confidence limits are calculated using the formula:

$$\text{MMRU} = \text{MMR} + Z[\text{SE}(\text{MMR})] \quad (7)$$

$$\text{MMRL} = \text{MMR} - Z[\text{SE}(\text{MMR})] \quad (8)$$

where Z is 1.96

This formula shows the relationship between the risk of death from pregnancy (obstetric risk) and the number of pregnancies per woman (total fertility rate).

Total fertility Rate combines all births per women of specific ages (five year age group)

$$\text{TFR} = \text{Age specific fertility rate} * 5 \text{ (derived from NDHS, 2013 for the State)} \quad (9)$$

$$\text{Proportion of maternal death} = \frac{\text{number of maternal death}}{\text{All female death at ages 15-49}} \quad (10)$$

RESULTS AND DISCUSSION

The respondents reported a total numbers of 4287 sisters, out of which 4036 were those sister aged 15–49 years (Table 2). Of these numbers, three thousand five hundred and ninety-three (3593) were those sisters alive as at the time of data collection and 443 were recorded as dead. Table 3 clearly shows the number of dead sisters by their local government areas. Deduced from respondents' information, there are a total of four hundred and forty-three (443) dead sisters, of which three hundred and fifty-four (354) are reported cases of death due to pregnancy, childbirth and immediate postpartum period. The percentage of sisters who had died from maternal causes was much higher in Oredo, Ikpoba-Okha and Egor with 77%.

Table 2 Age group of respondents by number of sister born of the same mother

Age Group of Respondent	Number of Sisters born of same Mother											Total No. of Respondents	Total No. of Respondent Sisters	Total No. of Respondent Sisters age 15-49
	0	1	2	3	4	5	6	7	8	9	10			
15-19	10	19	32	16	11	0	1	0	0	0	0	89	181	168
20-24	16	62	65	44	26	5	4	3	1	0	0	226	506	477
25-29	64	155	150	76	30	14	1	2	3	0	0	495	917	853
30-34	50	126	133	71	28	9	7	3	3	0	1	431	859	817
35-39	48	108	108	86	37	14	5	2	3	1	0	412	877	823
40-44	24	79	62	46	21	10	6	0	1	0	0	249	519	496
45-49	23	49	54	39	17	12	2	2	0	0	0	198	428	402
Total Number of Respondents	235	598	604	378	170	64	26	12	11	1	1	2100		
Total Number of Respondents Sisters		598	1208	1134	680	320	156	84	88	9	10		4287	
Total Number of Respondents Sisters age 15-49		581	1186	1071	608	275	132	84	80	9	10			4036

Source: Authors' Fieldwork, 2018

Table 3 Number of dead sisters from maternal causes by local government areas

Number of Sisters Born of Same Mother	Local Government Areas							Total
	Egor	Ikpoba Okha	Oredo	Orhionmwon	Ovia North East	Ovia South West	Uhunmwode	
Alive	808	855	958	195	228	265	284	3593
	91.3%	88.7%	86.6%	89.9%	86.4%	92.7%	90.1%	89%
Dead from Maternal Causes	53	97	121	21	29	17	16	354
	6%	10%	11%	9.7%	10.9%	5.9%	5.1%	8.8%
Dead from other Causes	24	12	26	1	7	4	15	89
	2.7%	1.3%	2.4	0.4%	2.7%	1.4%	4.8%	2.2%
Total	885	964	1105	217	264	286	315	4036
	100%	100%	100%	100%	100%	100%	100%	100%

Source: Authors' Fieldwork, 2018

Figure 2 depicts maternal mortality among reported sisters in respect to the period it occurred (pregnancy, childbirth and immediate postpartum). There was spatial variation in the period by which these maternal deaths occurred within the study area. A total of (45) deaths occurred at pregnancy in Egor, Ovia North-East and Ovia South-West LGAs at pregnancy when

compared with (21) dead sisters at the immediate postpartum while Ikpoba-Okha, Oredo, Orhionmwon and Uhunmwode LGAs recorded (105) deaths at Childbirth. Overall, the number of deaths due to obstetric causes occurred more in childbirth (138) and closely followed by pregnancy period with (115) and immediate postpartum period (101) deaths.

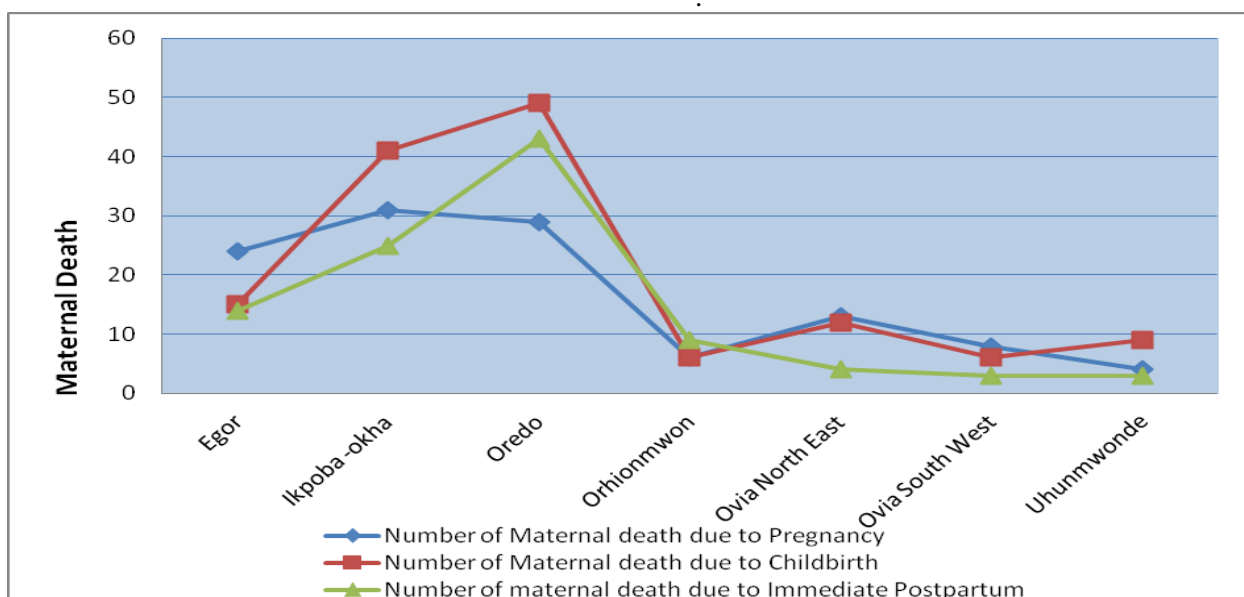


Figure 2 Numbers of dead sisters due to obstetric causes in the study area
Source: Authors' Fieldwork

Maternal death among the different age groups of dead sisters is depicted in Table 4. There was high mortality among the age groups of 25–29 years (n=86) and 30–34 years (n= 84) for dead sisters. Next to these age group were sisters 20–24 years (n=59). The spatial

analysis of the percentage shows that Oredo has 28% and Ikpoba–Okha has 24% of maternal deaths among age groups 25–29 years. Oredo and Orhionmwon were the two highest local government areas with maternal deaths from age group 30–34 years with 30% and 28%

respectively. Table 5 shows the information on dead sisters' marital status. There are over seventy-seven percent of married dead sisters with Oredo having eighty-six percent of these deaths within the LGAs,

while there are twenty-two percent of Unmarried (single person) dead sisters mostly from Ovia North-East and Ovia South-West LGAs.

Table 4 Age group of dead sisters (maternal deaths) in Edo South Senatorial District

Age Group of Dead Sisters	Local Government Areas							Total
	Egor	Ikpoba Okha	Oredo	Orhionm won	Ovia North East	Ovia South west	Uhunmwode	
15–19	7	11	9	2	5	3	1	38
Number								
Percentage	13.2%	11.3%	7.4%	9.5%	17.2%	17.6%	6.2%	10.7%
20–24	9	20	7	5	8	6	4	59
Number								
Percentage	17.0%	20.6%	5.8%	23.8%	27.6%	35.3%	25.0%	16.7%
25–29	13	24	34	5	5	3	2	86
Number								
Percentage	24.5%	24.7%	28.1%	23.8%	17.2%	17.6%	12.5%	24.3%
30–34	9	21	37	6	6	2	3	84
Number								
Percentage	17.0%	21.6%	30.6%	28.6%	20.7%	11.8%	18.8%	23.7%
35–39	9	11	19	2	3	0	3	47
Number								
Percentage	17.0%	11.3%	15.7%	9.5%	10.3%	.0%	18.8%	13.3%
40–44	4	8	8	0	1	3	1	25
Number								
Percentage	7.5%	8.2%	6.6%	0%	3.4%	17.6%	6.2%	7.1%
45–49	2	2	7	1	1	0	2	15
Number								
Percentage	3.8%	2.1%	5.8%	4.8%	3.4%	.0%	12.5%	4.2%
Total	53	97	121	21	29	17	16	354
Number								
Percentage	100%	100%	100%	100%	100%	100%	100%	100%

Source: Authors' Fieldwork

The Total Fertility Rate (TFR) was calculated using data on age group (15–49), number of births and of women in that age group as shown in Table 6. The total fertility rate calculated was utilized to determine the maternal mortality rate for the study area. The number of respondent sisters' age 15–49 from 2008–2017 was

used in the calculation of subtotal and total fertility rates. The group specific fertility subtotal (W*P) gave the TFR. The Total Fertility Rate is 4.605 with an estimated variance of 0.0235, at 95% Confidence Interval.

Table 5 Marital status of dead sisters in Edo South Senatorial District

Marital Status of Dead Sisters	Local Government Areas							Total
	Egor	Ikpoba Okha	Oredo	Orhionmwon	Ovia North East	Ovia South west	Uhunmwode	
Single Number	12	26	16	4	11	6	3	78
Percentage	22.6%	26.8%	13.2%	19.0%	37.9%	35.3%	18.8%	22.0%
Married Number	41	71	104	17	18	11	13	275
Percentage	77.4%	73.2%	86.0%	81.0%	62.1%	64.7%	81.2%	77.7%
Separated Number	0	0	1	0	0	0	0	1
Percentage	.0%	.0%	.8%	.0%	.0%	.0%	.0%	.3%
Total Number	53	97	121	21	29	17	16	354
Percentage	100%	100%	100%	100%	100%	100%	100%	100%

Source: Authors' Fieldwork, 2018

Table 6 Analytical framework for estimating total fertility rate

Column 1 Age group of Respondents	Column 2 No. of births (2008–2017)	Column 3 No. of Ever married women	Column 4 Births per woman-year	Column 5 Births over w years	Column 6 Var[P]	Column 7 Var[w*P]
W=5	Y	N	$P=y/n*T$	w*p	$p*(1-p)/n*T$	$W2>*Var[p]$
15-19	117	168	0.069	0.345	0.000590	0.014810
20-24	357	477	0.075	0.375	0.000015	0.000375
25-29	1075	853	0.126	0.630	0.000120	0.002884
30-34	1071	817	0.131	0.655	0.000014	0.003408
35-39	1297	823	0.158	0.790	0.000016	0.000404
40-44	962	496	0.194	0.970	0.000032	0.000788
45-49	674	402	0.168	0.840	0.000035	0.000869
Total	5553	4036		4.605 TFR		0.023538 Var TFR

Source: Deduced from Hanley et. al. (1996) Table A2.

*T= Time span from 2008-2017

*Standard Error (SE) of total fertility Rate =square root of 0.0235= 0.153

*95% confidence interval: 4.605±1.96 (0.153) or (4.91, 4.31)

The maternal mortality was estimated from the responses collected from two thousand one hundred respondents as shown in Table 7. The number of sister of reproductive age (15–49) years are those who are at risk of a maternal death. The maternal mortality ratio was calculated from the lifetime risk:

$$MMR= 1- [(probability of survival) 1/TFR] \quad (11)$$

The Total Fertility Rate (TFR) in Table 6, it is a vital factor in computing the Maternal Mortality Ratio (MMR). The lifetime risk of dying from maternal causes is presented in Table 7. The indirect sisterhood method was used to estimate the MMR for 2008-2017.

The TFR for this study is 4.605 and the maternal mortality ratio (MMR) calculated from the lifetime risk of 0.1664 is 3877 per 100, 000 live births. Since TFR is an estimated value, Hanley et.al. (1996) deduced that

the lower and upper limits may be subject to sampling error (SE), and therefore the following equation was used to calculate the limits:

$$SE[MMR] = 1 - MMR/TFR \sqrt{1 - P/B * P} + [\text{Log } \{p\}]^2 \text{Var } \{TFR\} / TFR^2 \quad (12)$$

Table 7 Analytical framework for estimating maternal mortality ratio

Col 1 Age group of Respon dents	Col 2 Number of Respon dents	Col 3 Total Number of Sisters	Col 4 Number of dead Sisters	Col 5 Number of Maternal Deaths	Col 6 Adjustm ent Factors (I)	Col 7 Sister- units of exposure	Col 8 Lifetime Risk of dying of maternal causes	Col 9 Proportion of dead sisters dying of maternal causes
						Col 3* Col 6	Col 5/ Col 7	Col 5/Col 4
15-19	89	168	43	38	0.107	18	2.1111	0.8837
20-24	226	477	64	59	0.206	98	0.6020	0.9219
25-29	495	853	105	86	0.343	293	0.2935	0.8190
30-34	431	817	93	84	0.503	411	0.2044	0.9032
35-39	412	823	76	47	0.664	547	0.0859	0.6184
40-44	249	496	29	25	0.802	398	0.0628	0.8621
45-49	198	402	33	15	0.900	362	0.0414	0.4545
	2100	4036	443	354		2127	0.1664	0.7991

Source: Deduced from Hagen (1995)

*Col means Column

* Estimated Total Fertility Rate (TFR) is 4.605

* Variance of Total Fertility Rate (Var TFR) is 0.02358

* Maternal Mortality Ratio (MMR) from respondents = $(1 - 0.83357)^{0.2172} = 0.03877$, that means the (MMR) is 3877 per 100,000 live births

* Standard Error Maternal Mortality Ratio [SE (MMR)] is 0.00209.

At 95% the confidence interval (CI) $\pm 1.96 (0.00209)$ is = 3466 to 4287

*Life Time Risk (LTR) which is $Q = \sum ri / \sum Bi = (354/2127) = 0.1664$, thus one divided by 0.1664 is equal to one in every six women has the probability of dying a maternal death.

According to Table 7, a total of forty-three sisters died but only thirty-eight were reported to be related to maternal causes for age group 15-19. Graham et. al. (1989) adjustment factor for the different age groups was multiplied to the number of sister to deduced sisters exposed to maternal mortality. The lifetime risk (LTR) depicts the risk of dying from maternal causes among women in different reproductive age groups. In the study area, 1 in 6 women have a chance of maternal death during her lifetime.

One key factor and highly sensitive to ascertaining the maternal mortality ratio is the total

fertility rate. Other studies have applied estimated TFR for the country, state or district in their analysis. This study also modeled various TFRs published to estimate the effect of variance of TFR on MMR within the senatorial district in Table 8. This study used TFR of 5.5 and 5.8 which was the TFR for Nigeria in 2015 and 2016 (National Bureau of Statistics [NBS], 2018) to model the MMR, which was (3255 and 3089) per 100, 000 live births. Also modeled was the TFR of 4.4 for Edo State (NDHS 2013) which gave an MMR of 4053 per 100, 000 live births and that for the state by (NBS, 2018) was 4678 per 100, 000 live births. Across

the study area, the MMR increase from the lowest TFR to the highest.

Table 8 Estimated maternal mortality rate using various total fertility rates

TOTAL FERTILITY RATE	MATERNAL MORTALITY RATIO	STANDARD ERROR OF MATERNAL MORTALITY	UPPER CONFIDENCE LIMITS	LOWER CONFIDENCE LIMITS
3.8 (NBS, 2018)	4678	0.00256	5179	4176
4.4 (NDHS, 2013)	4053	0.00219	4483	3622
5.5(NDHS, 2013)	3255	0.00175	3598	2912
5.8 (NBS, 2018)	3089	0.00165	3413	2764
4.6 (THIS STUDY)	3877	0.00209	4287	3466

Maternal mortality Ratio was estimated for urban and rural areas in Table 9 based on the TFR of 4.605 from this study. The MMR for the Urban area is 3806 per 100,000 live births with confidence intervals of (3325, 4287) while the MMR in the rural area is 4041 per 100,000 live births with confidence intervals of (3291, 4790). The maternal mortality ratio is higher for both area but much higher in the rural areas than in the urban areas of this senatorial district. The lifetime risk is high with one in every six women likely to die from maternal causes. This also depicts the statistical analysis of maternal mortality ratio across the seven local government areas in Edo South senatorial district. The least maternal mortality ratio (MMR) of 2164 per 100

000 live births was estimated in Uhumwonde local government area; the next was in Egor local government area with MMR of 2588 per 100 000 live births. Ovia South-West local government area has an estimated MMR of 2597 per 100 000 live births which is lower when compared with the MMR of 4281 per 100 000 live births for Orhionwon LGA. The highest MMR were recorded in Ovia North-East, Oredo and Ikpoba-Okha LGA with their MMR as: 4995, 4936, and 4507 per 100 000 live births respectively. There were observed spatial variation on the pattern of maternal mortality across the study area as depicted by Figures 3 to 6.

Table 9 Summary of maternal mortality in Edo South Senatorial District

Local Government Areas	MMR	TFR	SEMMR	MMR ^U	MMR ^L	LTR
Egor	2588	4.605	0.00352	3279	1896	1 in 8
Ikpoba-Okha	4507	4.605	0.00452	5394	3620	1 in 5
Oredo	4936	4.605	0.00444	5806	4066	1 in 5
Ovia North-East	4995	4.605	0.00908	6776	3214	1 in 5
Ovia South-West	2597	4.605	0.00623	3818	1376	1 in 9
Orhionmwon	4288	4.605	0.00918	6776	3214	1 in 6
Uhumwonde	2164	4.605	0.00536	3215	1113	1 in 10
Urban Areas	3806	4.605	0.00245	4287	3325	1 in 6
Rural Areas	4041	4.605	0.00382	4790	3291	1 in 6

- MMR=Maternal Mortality Ratio; TFR= Total Fertility Rate; SEMMR =Standard Error of MMR
- MMR^U = Maternal Mortality Ratio Upper limit; MMR^L = Maternal Mortality Ratio Lower limit

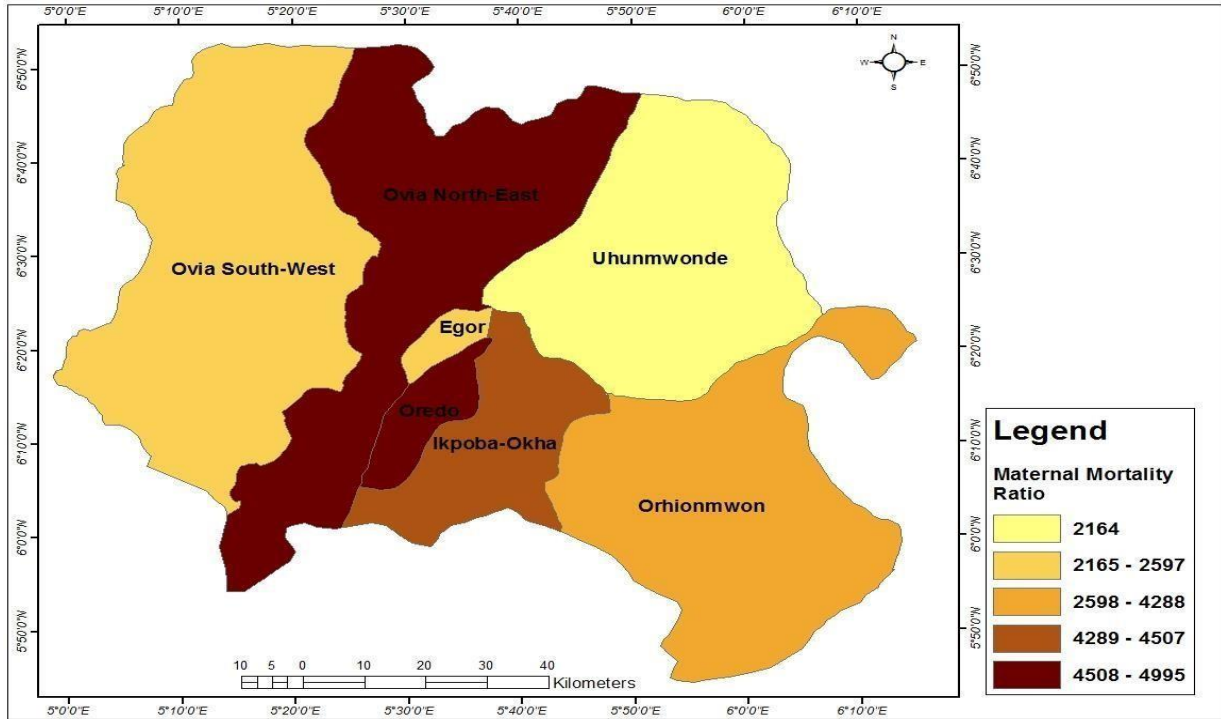


Figure 3 Maternal Mortality Ratio in Edo South
Source: Authors' Fieldwork, 2018

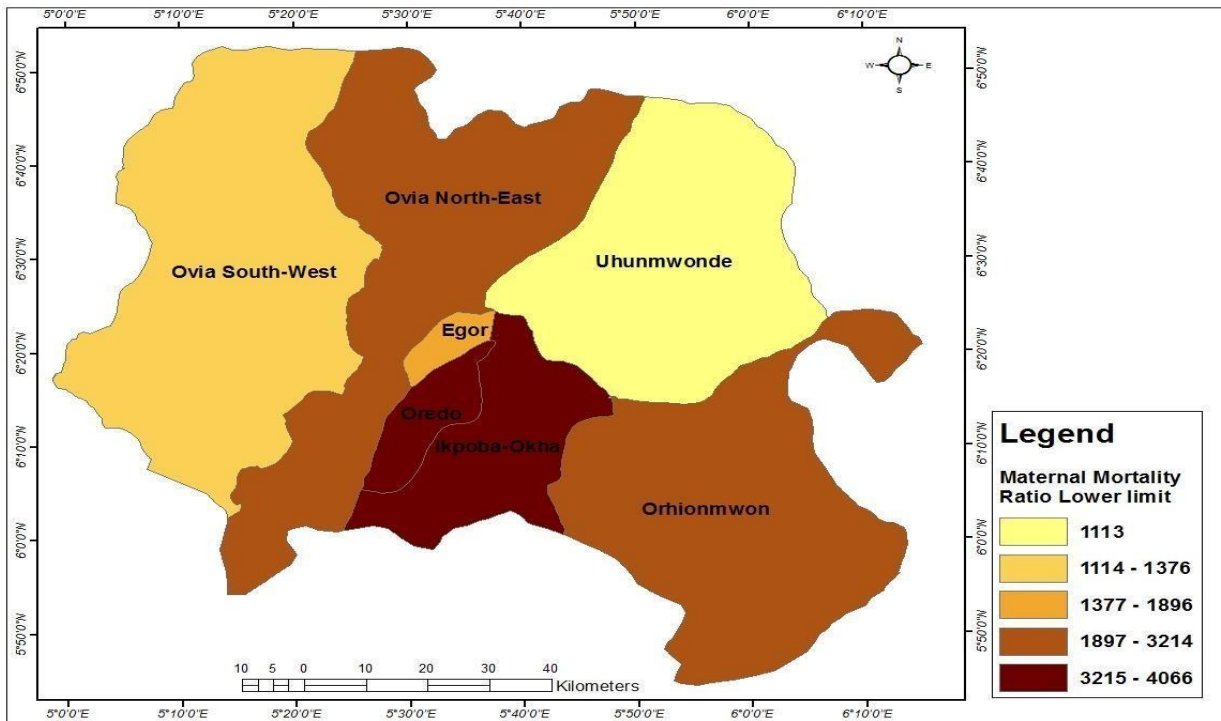


Figure 4 Maternal Mortality Ratio (Lower Limit) in Edo South
Source: Authors' Fieldwork, 2018

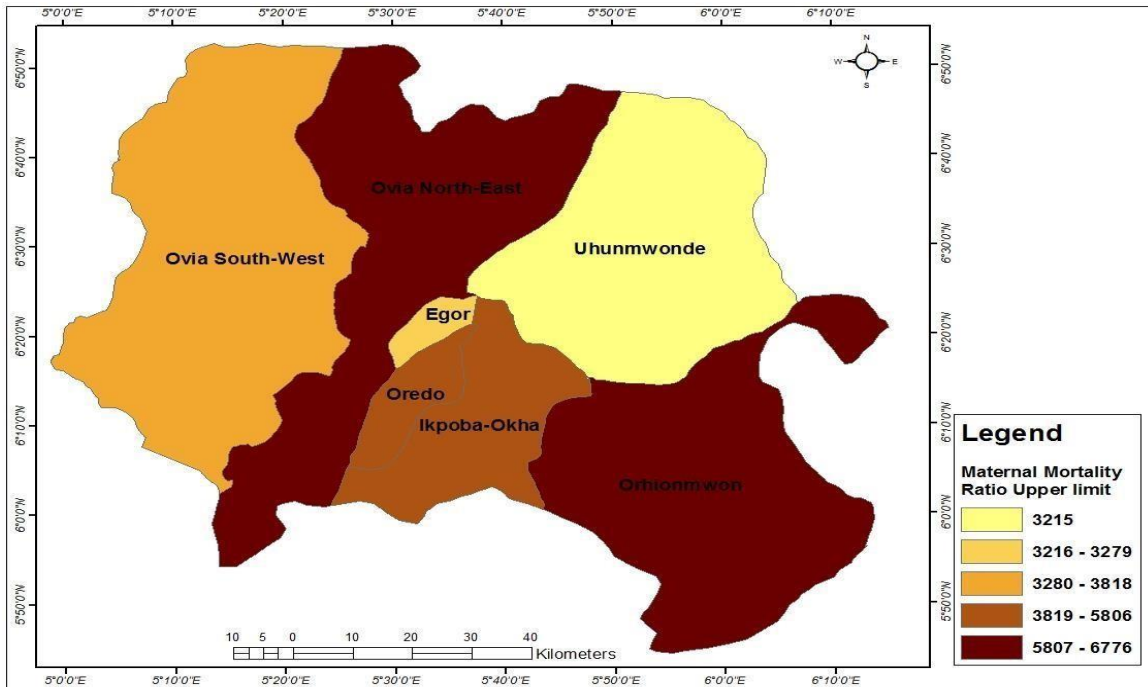


Figure 5 Maternal Mortality Ratio (Upper Limit) in Edo South
 Source: Authors’ Fieldwork, 2018

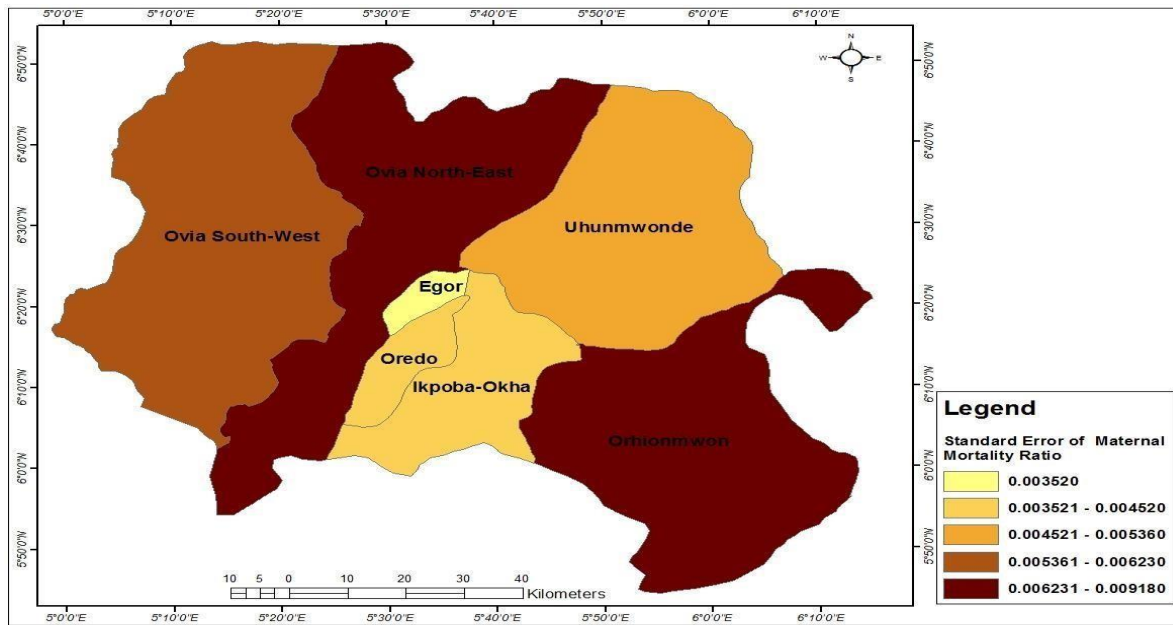


Figure 6 Standard Error of Maternal Mortality Ratio in Edo South
 Source: Authors’ Fieldwork, 2018

Maternal death was high among the age groups of 25–29 years and 30–34 years. This concurs with findings from (Bankole et al., 2009; Omo-Aghoja, et al., 2010; Doctor et al., 2012; and Adegoke et al., 2013). Maternal deaths in Oredo and Ikpoba-Okha LGAs were higher among age groups between 25–29 years. Oredo and

Orhionmwon local government areas had more maternal deaths from age group between 30–34 years. The least number of maternal deaths was among age groups 40–49 as affirmed by (NDHS, 2013). The married/unmarried (single) dead sisters recorded 77% and 22% of obstetric cause of deaths. This is not surprising as maternal deaths are identified with cohabitation and marriage being the principal risk

risk factors in pregnancy and associated complications in Nigeria (NPC, 2004).

The numbers of maternal deaths was high among first time pregnant women and were found in Ovia North-East, Ovia South-West, Uhumwonde, and Ikpoba-Okha. Parity gave rise to the high percentage of maternal mortality within the LGAs. As parity increases, the percentage of maternal deaths reduces. This agrees with Okeh (2009) and Yarzever (2014) findings that higher parity increases the chance of a maternal death. Maternal deaths interval occurred at health facilities in Oredo, Ikpoba-Okha and Egor LGAs. The time of labour, delivery and after delivery records the most maternal deaths. This negates finding from Oye-Adeniran et.al. (2014) which found more deaths occurring in pregnancy and affirms Ghebrehiwot, (2004) finding that most deaths occurred during delivery and postpartum periods. In this study the TFR is 4.605 with an estimated variance of 0.0235, at 95% Confidence Interval (CI). This was slightly higher than the estimated TFR of 4.4 for Edo State reported by (NDHS, 2013). The rate is quite high when compared to the TFR by (NBS, 2018).

The estimated maternal mortality ratio was 3877 per 100, 000 live births. The upper and lower limit at 95% confidence interval (CI) was 4287 and 3466. The 2018 NBS TFR gave an MMR of 3089 and (CI) of 3413 and 2764 while the 2013 NBS TFR of 5.5 gave a (CI) of 3598 and 2912, deduced from maternal mortality ratio of 3255 per 100, 000 live births. Edo State TFR of 4.4 by NDHS (2013) produced MMR of 4053 per 100, 000 live births and (CI) between 4483 and 3622. The 2018 computed TFR for the State by NBS produced a maternal mortality ratio of 4678 per 100, 000 live births and (CI) between 5179 and 4176. Within the study area, the MMR increase from the highest TFR to the lowest with (CI) levels ranging from 2764 to 5176.

Studies conducted across the state, reported MMR range from 322, 518, 700 to 2,282 per 100, 000 live births (Eghe & Omo-Aghoja, 2008; ESMOH, 2009; Omo-Aghoja et al., 2010; Agofure & Olaniregun, 2017). These estimated MMRs are deduced from health facilities records and reported only the percentage of pregnant women seeking health care service, this implies delays in accessing maternal health services from by most pregnant women from ante-natal to post-natal periods. About fifty percent of mothers' patronize health facilities for delivery and quite a large number do not access health facilities within the South South region. Among the states comprising the South South region, Edo State hold the highest percentage that patronize health facilities however, a wide margin still

exists that do not use health facilities especially in rural areas(NDHS, 2013).

CONCLUSION

Various models of TFRs were used to ascertain the MMR in the study area. The rural areas had higher estimated MMR than the urban areas. In each local government area, maternal mortality ratio was calculated to depict the LGAs with the highest and least maternal mortality ratio. Comparative analysis was done to show the periods of maternal death incidences among dead sisters. There were observed spatial variations on the pattern of maternal mortality measures of 3877 per 100, 000 live births across the study area. With the high record of maternal deaths occurring from the survey, it suggests a gap exists in available services and care received from existing health facilities and could be a function of any of the established delays in accessing health services. With over 55% increase in maternal mortality level compared to set SGD 3.1 targets, there is need to turn government, non-government organization and policy makers to the plight of the less privilege pregnant women especially in rural areas. To urgently address the current challenge, specific targeted goals such as quality reproductive health services (maternal health care services, family planning and excellent referral networking system); upgrading dilapidated and non-functioning health facilities and effective emergency obstetric services at the grassroot will save maternal lives.

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POLLUTION LOAD AND HEALTH RISK INDICES OF DOMESTIC WATER SOURCES IN SELECTED COMMUNITIES OF LANGTANG AREA, PLATEAU STATE, NORTH-CENTRAL NIGERIA

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Abstract

Potential health risk of metals in domestic water sources to the local population of Langtang area in Plateau State and their possible sources was investigated. Forty water samples, 20 each from surface and groundwater sources were analysed using Atomic Absorption Spectrometer method for 26 parameters and compared with the Nigerian Standard for Drinking Water Quality. Results revealed that turbidity, Fe, Zn, As, Cd, Pb, Mn, Al, pesticides and phenols seriously polluted, while coliform bacteria strongly polluted in surface water. In groundwater, only turbidity, Fe, Pb and phenols constituted serious pollutants, while Ca and Mg were strong pollutants. Chronic Daily Intakes (CDIs) of metals were in the following order; Fe > Cu > Pb > As > Cd > F > Al > Mn > Zn > Pesticides > Cr > phenols in surface water, and Fe > F > Cu > Zn > Pb > Al > Mn > Cr > As > pesticides > phenols > Cd in groundwater. Health Risk Indices (HRIs) of metals were present in the order of As > Cd > Pb > Al > Cu > Mn > Fe > Cr > Zn > F > phenols > pesticides in surface water, and Pb > F > Al > Fe > As > Cr > Zn > Mn > Cd > phenols > pesticides in groundwater. Cumulative HRIs of metals was above unity in both surface and groundwater. Metals that pose most serious risk were; As, Cd, Pb and Al with HR of 33.32, 9.84, 2.75 and 2.14, all in surface water sources. Findings showed that the domestic water sources of the selected communities in Langtang area were not safe for human consumption. It is recommended that alternative drinking water source be provided to residents by government to safeguard public health.

Keywords: Drinking water quality, Pollution index, Health risk index

INTRODUCTION

Water is an essential natural resource that sustains human life but it is not free everywhere. Its chemical composition is the prime determinant of the suitability for use. Following suspension of production at the Langtang Water Works in 2012, the only public water supply scheme in the area due to obsolete equipment and poor power supply, residents access water from any available source including: dams, boreholes, dug-wells, streams and ponds. Water is abstracted from these sources are used for domestic purposes including drinking without treatment. Besides, indiscriminate waste disposal, open defecation and unhealthy agricultural practices which involved extensive use of agro-chemicals that expose water sources to contamination are common sites in the area. Contaminants may also get into water sources through leaching from soils, rocks weathering and aerosol dissolution from the atmospheres (Jidauna, Dabi, Saidu, Abaje & Ndabula, 2013).

Although some heavy metals like Cr, Mn and Cu are essential to man, their presence in excess above certain limits are toxic (Masok, Masiteng, Mavunda &

Maleka, 2018). In contrast, metals such as Cd, Pb, Hg and As have no known benefit and are highly toxic at low concentration (Saha, Rahman, Jolly, Rahman, Sattar & Hai, 2016). These metals enter the human body through several pathways including food chain, water ingestion, dermal contact, fume and particles inhalation through mouth and nose (USEPA, 2016). The health risk indices is a useful method in determining the risk posed by these metals and has been applied by researchers to assess potential adverse health effects of exposure to contaminated water in parts of the world (Giri & Sign, 2015; Maigari, Ekanem, Garba, Harami, & Akan, 2016; Lorestani, Merrikhpour & Cheraghi, 2020). There is growing concern on the presence of toxic metals in drinking water and rural areas of developing countries have received the least attention in their health risk assessment. This becomes necessary to expand research to cover the rural communities especially Langtang area where untreated water is consumed. Studies have established that safe water is indispensable for prevention of diseases and improving quality of life (Jidauna, Dabi, Saidu, Abaje & Ndabula,

2014; Maina & Eziashi, 2017)). Therefore, this paper assesses the pollution levels of water quality parameters and determines health risk posed to human through oral ingestion of metals in drinking water.

The health risk assessment is a key element in appraising safety state of environmental resources which aid decisions on policy formulation, and its objective is to assess fitness of a resource for current and future use. This requires data on human health in a medium, estimation of magnitude of potential human exposure, toxicity assessment and characterization of risk (Lai, Hseu, Chen, Chen, Guno & Chen, 2010). Greater weights are also given to specific exposure estimates parameters such as concentration or level, duration, route and exposure frequency (UEEPA, 2012). Human exposure to metals is negligible through other pathways like dermis and inhalation in comparison to oral ingestion (Nawab, Khan, Xiaopinga, Rahman, Ali, Qamar, Khan, Rehman, Rahman, Muhammad, Khan & Shah, 2017). This informed the choice of the oral pathway being the major route that heavy metals find its way into the human body other than dermal for the determination of human health risk through water.

MATERIAL AND METHOD

Study Area

Langtang area consists of two LGAS, Langtang North and Langtang South. It is located in the lowland part of Plateau State 200km south of Jos the State capital and falls within latitudes 8°20'00" and 9°40'00" N and longitudes 9°30'00" and 10°10'00" E. It occupies a land mass of 1,626 sqkm and share boundaries with Kanke, Kanam, Pankshin, Mikang and Shendam LGAs as well as Nassarawa and Taraba States (Figure 1). It is characterized by sub-humid climate as neighboring Nassarawa and Taraba States due to similarities in

elevation. The mean low and high temperatures are 26°C and 30°C respectively. The average monthly and annual relative humidity is between 20⁰ and 28⁰ with March and April as hottest months. Mean high and low monthly rainfall range between 5mm and 50mm, while Mean annual rainfall in the area is between 165 and 322.

The relief is composed of uplands and lowlands created by interplay of tectonic elevation and erosion intensified by deforestation and deep differential chemical rock weathering (Dibal, Schoeneich, Lar, Garba, Lekmang & Daspan, 2017). The uplands in the extreme north-west of Langtang North with average elevation of 500 amsl are made of hills, mountains, and undulating terrains. The lowland cover a part of Langtang North and the whole Langtang South, have an average elevation of 150 amsl, and is characterized by plain land with pockets of outcrops of basement complex rocks and isolated hills. The original guinea savannah vegetation of the area has been replaced by a grassy savannah with occasional shrubs due to human interference through land clearance and burning for farming and firewood. This has resulted in regrown vegetation at various levels but the original woodland vegetation (gallery forest) is still found along major streams. The people are predominantly peasant farmers living in rural settings with dispersed and few nucleated patterns.

Geologically, Langtang falls within North-Central crystalline basement complex of Nigeria, and has five major geological units: biotite granite, migmatite granite, sandstone, shale/limestone intercalations, and sandy-clay/limestone. Based on FAO classification system, nine dominant soil types are found in the area namely: Vertisol, Gleysol, Leptosol, Acrisol, Lixisol, Nitisol, Alisol, Cambisol and Luvisol.

POLLUTION LOAD AND HEALTH RISK INDICES OF DOMESTIC WATER SOURCES IN SELECTED COMMUNITIES OF LANGTANG AREA, PLATEAU STATE, NORTH-CENTRAL NIGERIA

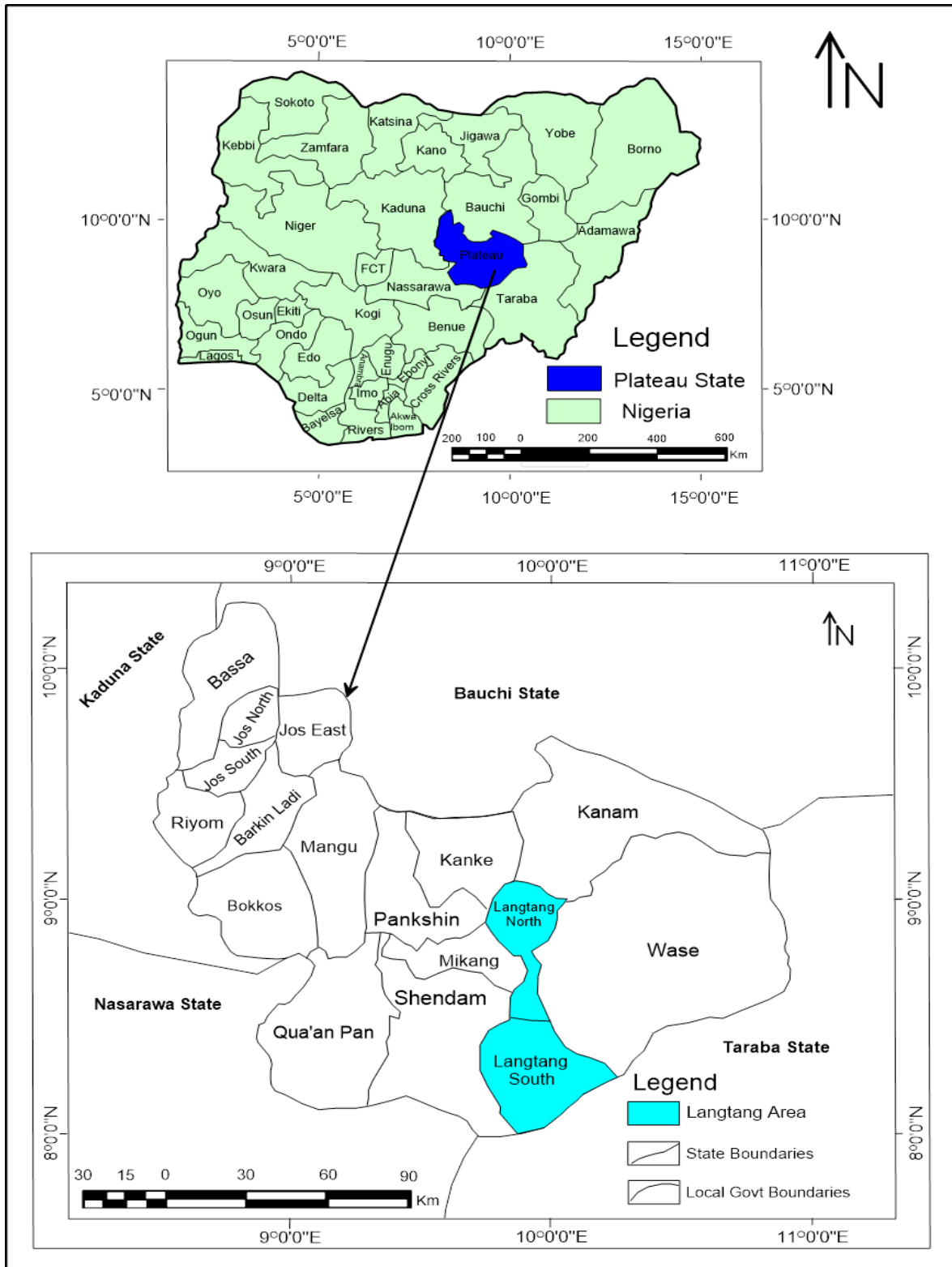


Figure 1 Plateau State; Study Area (Insert Nigeria and Plateau)

Data Collection

Samples are collected because the phenomena been studied are infinite, too large or due to limited resources (Saidu, Jidauna, Sanusi & Dabi 2019). Therefore, due to insufficient fund and time, 10 out of 46 communities were selected for this study based on water availability. A list of communities and available water sources in each was obtained from the Water and Sanitation Units at the Local Government Council secretariat of Langtang North and South. Coordinates of communities with minimum of three water sources were taken and plotted on geological map of the area which has five major geological units; biotite granite, migmatite granite, sandstone, shale/limestone and Sandy-clay/limestone. Thereafter, two communities in each of the five geological units were selected using a stratified random sampling technique with the geological boundaries serving as strata.

The random selection involved the use of a “lucky dip” with “yes” written on pieces of paper corresponding to the number of communities to be selected. All communities having three water sources and above in each stratum were dipped. Picking was done by the first author without replacement in which communities that picked “yes” were included in the sample. The 10 selected communities were: Pil-Gani, Gazum, Batkilang, Bapkwai, Zamko, Mabudi, Nassarawa, Magama, Faya and Barack (Figure 2).

Four water samples were taken from every community, one each from dug-well, borehole, dam and stream. In the communities with only three water sources, the fourth was picked from the nearest settlement within the same geological unit. The polyethylene plastic bottles (1000ml) used for sample collection were sterilized. Borehole samples were collected directly into sample container after allowing the water to flow for two minutes to avoid collecting stagnant water in the pipe and labeled S1 to S10. A clean plastic bucket tied to a rope was used to collect water from dug-wells, then poured in sample container and labeled S11 to S20. Lastly, a plastic bowl was used to fetch water from dams and streams, then poured into sampling containers and labeled S21 to S30 and S31 to S40 respectively. Sampling containers were rinsed thrice with the source water before it is filled up, and then capped and stored in field cooler with ice packs to avoid a rise in temperature that may affect result.

Names and coordinates of sample locations were taken (Table 1). Samples were moved to laboratory within 24hrs. Labile parameters such as pH, turbidity, temperature EC and TDS were determined in the field with the aid of hand held digital pH, Turbidity meter (Phep 98201), EC/TDS meter (Medfab 190), and a digital thermometer (CE 0434) for temperature. The Atomic absorption spectrophotometer (AAS) standard method was used for analysis of chemical parameters.

POLLUTION LOAD AND HEALTH RISK INDICES OF DOMESTIC WATER SOURCES IN SELECTED COMMUNITIES OF LANGTANG AREA, PLATEAU STATE, NORTH-CENTRAL NIGERIA

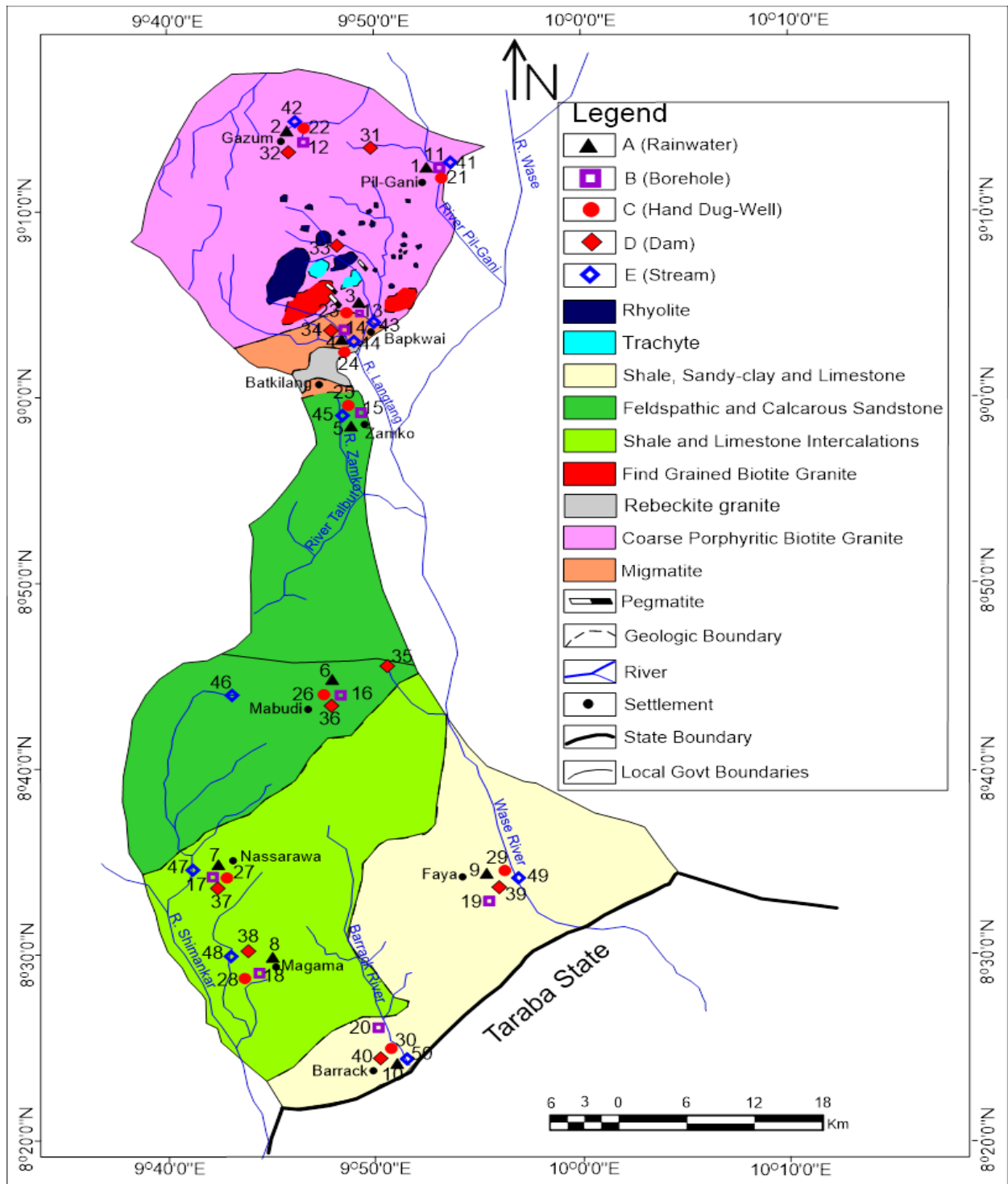


Figure 2 Geology of Selected Communities and Sample Points in Langtang Area

POLLUTION LOAD AND HEALTH RISK INDICES OF DOMESTIC WATER SOURCES IN SELECTED COMMUNITIES OF LANGTANG AREA, PLATEAU STATE, NORTH-CENTRAL NIGERIA

Table 1 Name and co-ordinate of sample locations

Sample Code	Type of Water Point	Name of Settlement	Location Name	Latitude	Longitude
S1	Borehole	Pil-Gani	Magistrate Court	09 ⁰ 12 ¹ 00.3 ¹¹	009 ⁰ 53 ¹ 21.5 ¹¹
S2	Borehole	Gazum	Gazum Market	09 ⁰ 13 ¹ 48.6 ¹¹	009 ⁰ 46 ¹ 16.9 ¹¹
S3	Borehole	Bapkwai	Gidan Dashe	09 ⁰ 4 ¹ 5.1 ¹¹	009 ⁰ 49 ¹ 00.2 ¹¹
S4	Borehole	Batkilang	Kofar Zamchir	09 ⁰ 3 ¹ 20.5 ¹¹	009 ⁰ 48 ¹ 20.4 ¹¹
S5	Borehole	Zamko	Gangara	08 ⁰ 59 ¹ 00.5 ¹¹	009 ⁰ 48 ¹ 48.3 ¹¹
S6	Borehole	Mabudi	LGC Secretariat	08 ⁰ 43 ¹ 50.3 ¹¹	009 ⁰ 47 ¹ 57.5 ¹¹
S7	Borehole	Nassarawa	Nassarawa Market	08 ⁰ 34 ¹ 3.2 ¹¹	009 ⁰ 42 ¹ 25.1 ¹¹
S8	Borehole	Magama	Magama Market	08 ⁰ 29 ¹ 46.2 ¹¹	009 ⁰ 43 ¹ 56.7 ¹¹
S9	Borehole	Faya	Fumang	08 ⁰ 32 ¹ 42.9 ¹¹	009 ⁰ 55 ¹ 13.4 ¹¹
S10	Borehole	Timjul	Timjul	08 ⁰ 25 ¹ 53.3 ¹¹	009 ⁰ 49 ¹ 59.5 ¹¹
S11	Dug-well	Pil-Gani	Samjur	09 ⁰ 11 ¹ 48.3 ¹¹	009 ⁰ 53 ¹ 3.4 ¹¹
S12	Dug-well	Gazum	Kofar Mai Angwa	09 ⁰ 14 ¹ 17.1 ¹¹	009 ⁰ 46 ¹ 23.4 ¹¹
S13	Dug-well	Bapkwai	Kofar Mai Angwa	09 ⁰ 4 ¹ 19.2 ¹¹	009 ⁰ 48 ¹ 37.4 ¹¹
S14	Dug-well	Batkilang	Kapshe	09 ⁰ 2 ¹ 38.7 ¹¹	009 ⁰ 48 ¹ 36.8 ¹¹
S15	Dug-well	Zamko	Gargawa Junction	08 ⁰ 59 ¹ 9.2 ¹¹	009 ⁰ 48 ¹ .48.4 ¹¹
S16	Dug-well	Mabudi	WAYEP Hospital	08 ⁰ 3 ¹ 57.6 ¹¹	009 ⁰ 47 ¹ 30.5 ¹¹
S17	Dug-well	Nassarawa	Gangara	08 ⁰ 34 ¹ 8.3 ¹¹	009 ⁰ 42 ¹ 32.4 ¹¹
S18	Dug-well	Bolgang	Bolgang	08 ⁰ 28 ¹ 39.5 ¹¹	009 ⁰ 43 ¹ 36.7 ¹¹
S19	Dug-well	Faya	Mr Gwomzi house	08 ⁰ 34 ¹ 10.3 ¹¹	009 ⁰ 55 ¹ 45.7 ¹¹
S20	Dug-well	Barrack	Kofar Qwag	08 ⁰ 24 ¹ 49.5 ¹¹	009 ⁰ 50 ¹ 45.8 ¹¹
S21	Dam	Dadur	Dadur Dam	09 ⁰ 13 ¹ 11.4 ¹¹	009 ⁰ 49 ¹ 35.5 ¹¹
S22	Pond	Gazum	Zamlir	09 ⁰ 13 ¹ 08.2 ¹¹	009 ⁰ 14 ¹ 17.1 ¹¹
S23	Dam	Langtang	Langtang Dam	09 ⁰ 8 ¹ 0.1 ¹¹	009 ⁰ 48 ¹ 0. 7 ¹¹
S24	Pond	Batkilang	Jan-Ruwa	09 ⁰ 3 ¹ 22.2 ¹¹	009 ⁰ 48 ¹ 4.8 ¹¹
S25	Dam	Nagane	Nagane Dam	08 ⁰ 45 ¹ 25.9 ¹¹	009 ⁰ 50 ¹ 36.2 ¹¹
S26	Dam	Mabudi	Mabudi Dam	08 ⁰ 43 ¹ 44.1 ¹¹	009 ⁰ 47 ¹ 39. 4 ¹¹
S27	Dam	Karkashe	Karkashe Dam	08 ⁰ 33 ¹ 37.9 ¹¹	009 ⁰ 42 ¹ 15.9 ¹¹
S28	Dam	Magama	Magama Dam	08 ⁰ 29 ¹ 52.3 ¹¹	009 ⁰ 43 ¹ 40.9 ¹¹
S29	Dam	Faya	Faya Dam	08 ⁰ 33 ¹ 53.7 ¹¹	009 ⁰ 55 ¹ 39.1 ¹¹
S30	Pond	Barrack	Ruwan Zak	08 ⁰ 24 ¹ 17.4 ¹¹	009 ⁰ 50 ¹ 27.2 ¹¹
S31	Stream (SW)	Pil-Gani	R. Pil-Gani	09 ⁰ 12 ¹ 32.4 ¹¹	009 ⁰ 53 ¹ 23.4 ¹¹
S32	Stream (SW)	Gazum	R. Gazum	09 ⁰ 14 ¹ 38.3 ¹¹	009 ⁰ 46 ¹ 3.5 ¹¹
S33	Stream (SW)	Bapkwai	River Bapkwai	09 ⁰ 4 ¹ 7.3 ¹¹	009 ⁰ 49 ¹ 46.9 ¹¹
S34	Stream (SW)	Batkilang	River Batkilang	09 ⁰ 2 ¹ 59.9 ¹¹	009 ⁰ 48 ¹ 43.2 ¹¹
S35	Stream (SW)	Zamko	River Zamko	08 ⁰ 59 ¹ 1.4 ¹¹	009 ⁰ 48 ¹ 13.9 ¹¹
S36	Stream (SW)	Sabon Gida	River Sabon Gida	08 ⁰ 43 ¹ 53.8 ¹¹	009 ⁰ 42 ¹ 50.4 ¹¹
S37	Stream	Nassarawa	Nassarawa lake	08 ⁰ 34 ¹ 14.3 ¹¹	009 ⁰ 41 ¹ 0.7 ¹¹
S38	Stream	Magama	Magama Lake	08 ⁰ 29 ¹ 47.5 ¹¹	009 ⁰ 42 ¹ 59.7 ¹¹
S39	Stream	Faya	Kogin Yashi	08 ⁰ 34 ¹ 3.8 ¹¹	009 ⁰ 56 ¹ 46.3 ¹¹
S40	Stream	Barrack	Kogin Yashi	08 ⁰ 24 ¹ 20.1 ¹¹	009 ⁰ 51 ¹ 20.1 ¹¹
SW =	Shallow	Well			

Determination of Pollution Load Indices

The Pollution Load Index (PLI) is a mathematical approach used to identify water quality impurities. It measures how polluted a water body or sample is at a certain location and time or the degree of its

contamination. This approach identifies individual parameters responsible for water pollution in an area, source or body, and aid in providing focus to water quality managers to develop treatment or management techniques in line with the identified impurities (Abbasi

POLLUTION LOAD AND HEALTH RISK INDICES OF DOMESTIC WATER SOURCES IN SELECTED COMMUNITIES OF LANGTANG AREA, PLATEAU STATE, NORTH-CENTRAL NIGERIA

& Abbasi, 2012). PI was calculated according to equation (1) adopted from Amadi, Okunlola, Dan-Hassan, Aminu & Ola (2015). Thus:

$$PLI = \sqrt{\left(\frac{C_i}{S_i}\right) max + \left(\frac{C_i}{S_i}\right) min} / 2 \quad (1)$$

Where C_i is maximum and minimum values of monitored parameters and S_i is the recommended standard for each variable. Pollution values of parameters were grouped into five classes from I to V according to template in Table 2 adopted from Amadi et al. (2015) and Hefni (2016).

Table 2 Template for parameter classification based on PLI values

	<1	Not polluted
II	1 - 2	Slightly polluted
III	2 - 3	Moderately polluted
IV	3 - 5	Strongly polluted
V	>5	Seriously polluted

Determination of Health Risk Indices

The primary human health indicators in risk assessments are chronic dose intakes (CDIs) and Health Risk Indices (HRIs), and CDI is an input for calculation of HRI (Khan, Lu, Khan, Zakir, Khan, Khan, Wei & Wang, 2013). This is because assessing metals risk in water requires data on the metals concentrations and the quantity of water consumed for specified period. The CDI was calculated according to equation (II) adopted from Khan et al (2013). Thus:

$$CDI = C_m D_w / B_w \quad (2)$$

Where: C_m , D_w , and B_w refers to metal concentration, daily water intake and body weight respectively.

The daily intake of drinking water for adults is 2L/day and 1L/ day for children, while 72 and 32.7kg is body weight for adults and children respectively. The oral Toxicity Reference Dose (RfD), an estimate of continuous consumption of a certain quantity of water by human population including sensitive sub-groups like children likely to be without an appreciable risk of deleterious effects during a lifetime has been determined for various variables (USEPA, 2012; Wu, Zhao, Jia, Zhang, Zhang, Cheng, 2009). RfD for non-carcinogenic risk were taken from the database in the Integrated Risk Information System, which is built by USEPA (2005). The HRIs for non-carcinogenic risk in humans was calculated according equation (III) adopted from Shah, Ara, Muhammad, Khan and Tariq (2012). Viz: $HRI = CDI / RfD$. . . Equ (III). Where, RfD is oral toxicity reference dose and CDI is chronic daily intake. When HRI values are less than unity ($HRI < 1$), then the vulnerable population is deliberated to be

safe but when it's greater than unity ($HRI > 1$), the population is said to be at risk of contracting diseases (Khan et al, 2013; Liu & Ma, 2020).

RESULTS AND DISCUSSION

Drinking Water Contaminants

The computed PLIs of surface and groundwater sources in Table 3 show water sources with turbidity, Fe, Zn, As, Pb, Al Cd, Mn, phenols and pesticides as seriously polluted. Turbidity, Fe, Zn, As, Pb, Cd and pesticides pollutants may be from domestic waste and run-off from agricultural farmlands which surround almost all surface water sources. Aluminium and Mn are in toxic amount in Alisols and Crisols (Delvaux & Brahy, 2001) and can be attributed to their high index values due to run-off from soils. Phenols are from decomposed water hyacinth, grasses, and leaves mainly in Nagane, Karkashe and Magama dams as well as Nassarawa and Magama streams. Water sources with microbial coliform bacteria were strongly polluted and were observed to be from open defecation, access to water by livestock and run-off from human and animal faeces in the environment. Moderately polluted water sources contained Mg, Cu, NO_3 and Cl. Fluoride, Ca, Cr, pH, EC, TDS, $CaCO_3$, and SO_4 were not polluted. Seriously polluted water sources contained Pb, Cd, Mn, Al, Fe and turbidity largely present in surface water sources as reported in Ilorin and Egypt (Mohamed, Ali, Ibrahim, Ayman & Seliem, 2014; Ogunkunle, Mustapha, Oyedeji & Fatoba, 2016) but not in agreement with Hefni (2016) who found surface water of Indonesia not polluted in these parameters.

POLLUTION LOAD AND HEALTH RISK INDICES OF DOMESTIC WATER SOURCES IN SELECTED COMMUNITIES OF LANGTANG AREA, PLATEAU STATE, NORTH-CENTRAL NIGERIA

Table 3 Pollution load indices of surface and groundwater parameters

Para.	Mean Surface	Calculated PLI	Status/ Remark	Mean Ground	Calculated PLI	Status/ Remark
pH	7.285	0.90182	not polluted	7.24	0.87348	not polluted
Turb.	36.522	15.8432	seriously polluted	9.598	17.53628	seriously polluted
EC	217.25	0.47508	not polluted	742.05	2.03649	moderately polluted
TDS	133.6	0.47508	not polluted	391.6	2.03691	moderately polluted
CaCo ₃	64.95	0.74336	not polluted	258.1	2.40873	moderately polluted
Ca	59.28	0.58571	not polluted	143.1	3.45681	strongly polluted
Mg	14.815	2.56424	moderately polluted	42.865	3.28977	strongly polluted
SO ₄	12.855	0.2759	not polluted	25.91	0.58707	not polluted
NO ₃	16.652	2.93341	moderately polluted	27.59	1.17593	slightly polluted
Fe	3.0175	23.6126	seriously polluted	2.264	23.57098	seriously polluted
Cl	24.155	2.40729	moderately polluted	14.62	1.14142	slightly polluted
F	0.292	0.61298	not polluted	1.798	2.74097	moderately polluted
Cu	1.228	2.06959	moderately polluted	0.4275	0.91935	not polluted
Zn	0.1653	7.975.31	seriously polluted	0.119	0.33899	not polluted
Mn	0.2305	7.77817	seriously polluted	0.0367	1.70711	slightly polluted
As	0.3257	148.492	seriously polluted	0.00855	0.12132	not polluted
Pb	0.3593	148.492	seriously polluted	0.1065	71.41778	seriously polluted
Al	0.28	7.17713	seriously polluted	0.0785	0.41421	not polluted
Cr	0.0212	0.96985	not polluted	0.0146	0.27279	not polluted
Cd	0.3218	447.834	seriously polluted	0.0009	1.17851	slightly polluted
Phe.	0.0047	28.2842	seriously polluted	0.00095	0.07107	not polluted
Pest.	0.0273	14.1421	seriously polluted	0.004	0.82843	not polluted
TC	12.75	3.41421	strongly polluted	7.1	1.27279	slightly polluted

Results also showed the groundwater sources were seriously polluted with turbidity, Fe, and Pb attributed to run-off and decomposition of Pb products into open dug-wells, strongly polluted with Ca and Mg, and moderately polluted with TDS, EC, hardness and fluoride attributed to geogenic factors such as rocks weathering and dissolution. Due to the effect of leaching and location closed to latrines and soak-away systems, groundwater sources were slightly polluted with total coliform bacteria, nitrate and chloride as well as Cd and Mn attributed to run-off in open wells. The groundwater sources was found not polluted with pH, SO₄, Cu, Zn, As, Al, Cr, phenols and pesticides. This result is similar to that of Amadi et al (2015) who found serious pollution of groundwater sources with turbidity, Fe, Pb and Mn in Minna due to run-off, and coliform bacteria for locating them closed to latrines and soak-aways. Elumalai, Brindha, and Lakshmana (2017) also reported strong pollution groundwater sources with Ca and Mg South Africa due to geogenic factors. On the contrary, Haji, Melesse and Reddi (2016) found groundwater of southern Florida not polluted with all these parameters.

Calculated Chronic Daily Intake and Health Risk Index of Surface Water Sources

The mean concentrations of Al, As, Cd, Mn and pesticides were above recommended limits. Computed HRIs for children also showed As, Cd, Pb and Al had index values of 33.32, 9.84, 2.75 and 2.14 respectively above unity as well as 30.02, 8.94, 2.49 and 1.94 for adults in the same order (Table 5). Therefore, residents that consume these water sources are vulnerable to toxicities of these metals. Arsenic toxicity includes; skin manifestation, visceral cancers, and vascular disease. While that cadmium toxicity results in kidney damage, renal disorder, and human carcinogen. Lead damage the fetal brain, causes diseases of the kidneys, circulatory system, and nervous system, while aluminum results in neuro - degenerative disorder (Liu & Ma, 2020). None observance of protection zones around water points, indiscriminate waste disposal system and use of agro-chemicals on farmlands aided by run-off were responsible for the surface water contamination with heavy metals. Lohdip, Gongden and Pam (2012), and Gongden and Lohdip (2015) have also reported As, Cd, Pb and Al of up to 2.11, 2.35, 1.98 and 3.52 respectively in Ori and Kwaikong dams in

POLLUTION LOAD AND HEALTH RISK INDICES OF DOMESTIC WATER SOURCES IN SELECTED COMMUNITIES OF LANGTANG AREA, PLATEAU STATE, NORTH-CENTRAL NIGERIA

Langtang South LGA, and Ramadan (2017) also found As, Cd and Pb far above limits in streams and ponds of Wyitt village in Jos-Bukuru Metropolis. Similarly, Rasool, Farooqi, Xiao, Masood, Kamran and Bibi, (2016) reported HRIs of As, Cd, Cr, Al and Pb as 1.5, 4.2, 8.9, 4.2 and 3.7 respectively in surface water sources of Tehsil Pakistan largely to anthropogenic

contamination. The overall HRI of surface water was 50.27 for children and 40.30 for adult far above limits posing serious health risk to both groups. Lar, Ozoji and Jibo (2014) had reported similar HRI of 30 and 25 for children and adults in soils Zamyia area in Langtang South.

Table 5 Summary of chronic daily intake and hris of metals in surface water sources

Para	Mean Conc.	CDI Children	HRI Children	CDI Adult	HRI Adult	RfD
F	0.292	0.00892966	0.111620	0.00011265	0.001408	0.08
Cu	1.228	0.03755352	0.938838	0.03411111	0.852777	0.04
Zn	0.1653	0.00505505	0.168501	0.00459166	0.153055	0.03
Mn	0.2305	0.00704893	0.352446	0.00640277	0.320138	0.02
As	0.3257	0.00996024	33.320080	0.00905277	30.017590	0.0003
Pb	0.3593	0.01098776	2.746940	0.00998055	2.495138	0.004
Al	0.28	0.00856269	2.140672	0.00777777	1.944442	0.004
Cr	0.0212	0.00064832	0.216106	0.00058888	0.196296	0.003
Cd	0.3218	0.00984097	9.840970	0.0093888	8.938888	0.001
Phe	0.0047	0.00014373	0.071865	0.00013055	0.065277	0.002
Pest	0.0273	0.00083486	0.041743	0.00075833	0.037916	0.02
Fe	3.0175	0.09227828	0.307594	0.08381944	0.279398	0.3
		Total	50.27	Total	45.30	

Calculated Chronic Daily Intake and Health Risk Index of Groundwater Sources

Calculated CDIs of metals in Table 6 revealed none exceeded the recommended daily dose limits. Similarly, none of the metals HRI was greater than unity (>1), indicating none of the metals analyzed pose serious health risk in groundwater sources for both children and adults. However, cumulatively HRI for children and adults exceeded unity with values of 3.90 and 2.54 respectively which pose immediate health risk to the people. These results were similar that of Inam,

Etim and Offiong (2014) in groundwater sources of Akwa Ibom who found HRIs of all individual metals less than unity but with a cumulative index of 5.25 and 1.62 for children and adults respectively. Olagunju, Akawu and Ugokwe (2020) also reported cumulative HRI of metals of up to 8877.94 and 930.65 for children and adults respectively in selected locations in Ibadan. On the contrary, Khan et al (2013) and Nawab et al (2017) found cumulative HRI of metals less than unity in groundwater of Swat valley and Bunner district all in northern Pakistan.

Table 6 Summary of Chronic Daily Intake and HRIs of Metals in Groundwater Sources

Para.	Mean Conc.	CDI Children	HRI Children	CDI Adult	HRI Adult	RfD
F	1.7989	0.05501223	0.687618	0.04996944	0.624305	0.08
Cu	0.4275	0.01307339	0.326834	0.01187500	0.296875	0.04
Zn	0.1195	0.00365443	0.121814	0.00331944	0.110648	0.03
Mn	0.0367	0.00112232	0.056116	0.00101944	0.050972	0.02
As	0.0085	0.00025993	0.866462	0.00023611	0.787037	0.0003
Pb	0.1065	0.00325688	0.814220	0.00295833	0.739583	0.004
Al	0.0785	0.00240061	0.600153	0.00218055	0.545139	0.004
Cr	0.0146	0.00044648	0.148827	0.00040555	0.135185	0.003
Cd	0.0009	0.00002752	0.027523	0.00002500	0.025000	0.001
Phe	0.0010	0.00003058	0.015290	0.00002777	0.013888	0.002
Pest.	0.0040	0.00012232	0.006116	0.00011111	0.005555	0.02
Fe	2.2649	0.06926299	0.230876	0.06291388	0.209712	0.3
		Total	3.90	Total	2.54	

CONCLUSION

Drinking contaminated water poses high risk to public health but domestic water quality is not monitored in Langtang area. This study revealed domestic water sources of Langtang area were polluted with 67% of the parameters analysed and health risk indices of both surface and groundwater sources were greater than unity (HRIs >1). Therefore consumption of these water sources portends a major health risk to the local population and is responsible for the high incidence of

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THE PATTERNS, TRENDS AND INTERRELATIONSHIPS AMONG ESSENTIAL CLIMATIC VARIABLES IN OKADA TOWN, EDO STATE, NIGERIA

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Abstract

A number of adjustments and changes in many socio-ecological systems globally have directly and indirectly been linked to the variable and changing patterns of climate. All human endeavours including climate-smart agriculture which guarantee sustainable food security to a large extent need in-depth understanding of interactions among essential climate variable (ECV) which are responsible for the changes. The aim of this study was to assess the interrelationships among ECV in Okada Town, Ovia North East Local Government Area of Edo State. Specific objectives were to examine the patterns and trends of ECV in Okada Town, investigate the temporal variations of ECV in the study area, and assess the interrelationships among ECV in the study area. The ECV datasets used include minimum temperature (TMin), maximum temperature (TMax), rainfall, soil moisture (SM) at the depth of 0-40cm, potential evapotranspiration (PET) and normalized difference vegetation index (NDVI). The dataset were on monthly and spanned across 40years starting from January 1980 to December 2019. They were sourced from the University of East Anglia-Climatic Research Unit, the National Aeronautical and Space Administration Goddard Space Flight Center along with the University of Maryland (repository of global climatic data). Data analyses were carried out using descriptive and inferential statistics of simple linear regression, one-way analysis of variance (ANOVA) and Pearson's Product Moment Correlation (PPMC) in Microsoft Excel and SPSS 22. The results showed that all the investigated ECV exhibited a rising trend: TMin (0.013^oC per annum; R² = 0.169), TMax (0.018^oC per annum; R² = 0.363), rainfall (1.192mm per annum; R² = 0.007); SM (0.009m³/m³ per annum; R² = 0.307), PET (0.057mm per annum; R² = 0.233) and NDVI (0.001 per annum; R² = 0.293). Also, at 95% level of confidence, it was found that all the studied ECV excluding rainfall varied with time in Okada Town. Regarding the interrelationships, the correlation coefficient (R) between TMin and TMax was 0.594 (p ≤ 0.01), TMin and NDVI (R = 0.356; p ≤ 0.05), TMax and NDVI (R = 0.347; p ≤ 0.01), rainfall and SM (R = 0.485; p ≤ 0.01) as well as SM and NDVI (R = 0.444; p ≤ 0.01). It was concluded that the upward trends in all the studied ECV is a marked indication that Okada Town is gradually getting warmer than before in recent history. The study recommended the establishment of well-equipped synoptic weather station for ECV monitoring and improved weather forecast, early warnings, disaster preparedness and risk reduction in Okada Town.

Keywords: Essential climatic variables, Climate change, Synoptic weather station

INTRODUCTION

The entire planet earth is covered with a thick blanket of air called the atmosphere which also doubles as “the womb” or “mother” of weather and climate (Ekanem and Nwagbara, 2010). The atmosphere is never stable which means that, no two days, week, months, years, decades, centuries and even places are absolutely the same in terms of the weather pattern or condition, hence, the deployment of some descriptors like “average”, “mean” and/or “aggregate”. Weather at a given location is the atmospheric condition at a given time or over a certain period as described by various hydrometeorological variables such as temperature, pressure, humidity, wind, radiation, precipitation, sunshine, evaporation, cloud et cetera. Climate on the other hand is the time- average of the weather condition of a place which is determined by averaging several years of hydrometeorological data (Rakhecha and Singh, 2009).

Elements of weather and climate are therefore, those climatic characteristics that can be expressed or explained using mere descriptive statistics for example temperature, humidity, atmospheric pressure, wind, rainfall and atmospheric particle count among others (World Meteorological Organization-WMO, 2007). It also include other physical, chemical, or biological indicators capable of offering useful insights and observed proof desirable to comprehend as well as forecast how climate of the earth evolve over time (Global Climate Observing System-GCOS, 1997). They are generally referred to as essential climatic variables (ECV) (GCOS, 2003) and are very useful in climate risk assessment, climate change mitigation and adaptation policies as well as understanding the inherent factors influencing the global climatic system (GCOS, 2010). At the moment, 54 ECV have been identified and grouped into the atmospheric (surface, upper air and composition), oceanic (physics,

biogeochemistry and biology/ecosystems) and land-based (GCOS, 2019) elements.

One also comes across extreme weather events (EWE), climatic trend and pattern, climatic anomaly, climate variability and climate change while discussing global, national, regional and local climate of place. Any weather phenomenon that is not very common at a certain location whose occurrence is capable of causing serious hazards to the humans, living organism, properties and environment is termed EWE (Intergovernmental Panel on Climate Change-IPCC, 2007). Extreme heat due to high temperature, extreme cold to low temperature, intense and excessive rainfall, floods, droughts, tropical storms like cyclones and tornadoes among others are notable examples of EWE (WMO, 2018).

Climate as well as ECV has been acknowledged as among the important factors influencing several changes, activities and processes in the environment. Elsewhere, the influence of climate on human activities as well as the interrelationships among ECV have not only been well established but scientifically confirmed (Yang, Zhang and Hao 2016, Salimon and Anderson 2018, Abera et al 2018) In humid tropical environment like southern Nigeria, long-established focus on relationships among weather and climatic elements has been restricted to rainfall, relative humidity (RH) and temperature. Igbawua et al (2016) evaluated the association between surface temperature, rainfall, RH and vegetation in the whole Nigeria using 30years (1982-2011) satellite data acquired from NASA. The correlation coefficient of 0.92 was reported between vegetation and temperature, $r = 0.72$ between vegetation and rainfall as well as $r = 0.76$ between vegetation and RH. The study also found that the health of vegetation was highly impacted by temperature as extreme temperature resulted in poor vegetation health. In Benin City, Edo State, Ukhurebor, Abiodun and Bakare (2017) assessed how RH is connected with dew point temperature (DPT) using archival data obtained from the Nigeria Meteorological Agency (NiMeT). The authors found that about 79% of the variation in RH can be explained by the characteristic pattern and trend in DPT. This query therefore arises: are rainfall and temperature the only weather and climatic elements affecting ecological and human activities? Certainly not! Other parameters otherwise referred to as ECV like soil moisture (SM), potential evapotranspiration (PET), elevation, vegetation index (VI) and wind velocity among others abound

Unfortunately, empirical studies looking at the interrelation among ECV in Ovia North East Local

Government Area (ONELGA) in general and Okada Town in particular are unidentified. The reason is not far from the lack of availability of weather and climatic information coupled with unavailability of synoptic weather station for weather observation and climate monitoring. Lack of weather observatory has also affected scientific investigation into the analysis of weather and climate characteristics in Okada Town. But with availability of high resolution remotely-sensed satellite observational data, the study was carried out effortlessly.

Albeit anthropogenic impacts on the climate system are being subtracted, analysis of historical archival data still points to the fact the global climate system will still be altered by natural processes with devastating consequences on the social, economic and political environment. Presently, nearly every agrarian community in sub-Saharan Africa is becoming increasingly susceptible to continuing changes in the patterns and trends in ECV. Recently in Okada Town, several weather and climate related phenomena have been taking place. Farming, which is the major livelihood option in Okada is dependent on climate. No farmer begins cultivation in the community without the onset of rainfall as many have complained of changing pattern of soil water.

The study focused on assessment of the patterns, trends and interrelationships among essential climatic variables (ECV) in Okada Town, Ovia North East Local Government Area of Edo State. The ECV that were investigated include rainfall, maximum temperature (TMax), minimum temperature (TMin), soil moisture, vegetation index (VI) as well as potential evapotranspiration (PET). In terms of temporal scale, this spanned from January 1980 to December 2019. This study will therefore assist stakeholders in the formulation of workable CC mitigation and adaption strategies. Also, the findings from this empirical study of ECV will facilitate enhanced appreciation of current climate, interactions in addition to aiding in the forecast of future patterns and trends in ECV. This study would act as a wakeup call for routine assessment of other ECV and environmental change indicators. In addition, it will contribute to the existing body of knowledge vis-à-vis filling some of the gaps in literature that seeks to explain interrelation among weather climatic paramete

MATERIALS AND METHODS

Study Area

This study was carried out in Okada Town, the administrative headquarters of Ovia North East LGA, Edo State, Nigeria as shown in Figure 1. The built up

THE PATTERNS, TRENDS AND INTERRELATIONSHIPS AMONG ESSENTIAL CLIMATIC VARIABLES IN OKADA TOWN, EDO STATE, NIGERIA

area in Okada Town extends from latitudes $6^{\circ} 42' 11.132''$ and $6^{\circ} 45' 0''$ and longitudes $5^{\circ} 22' 18.991''$ and $5^{\circ} 25' 28.333''$. The estimated population of Okada town is about 65,000 people (John, 2017).

Geologically, Okada Town is underlain by two principal geological formations namely, False-Bedded Rocks and Upper Coal Measures and Imo Shale (Nigeria Geological Survey Agency-NGSA, 2006).

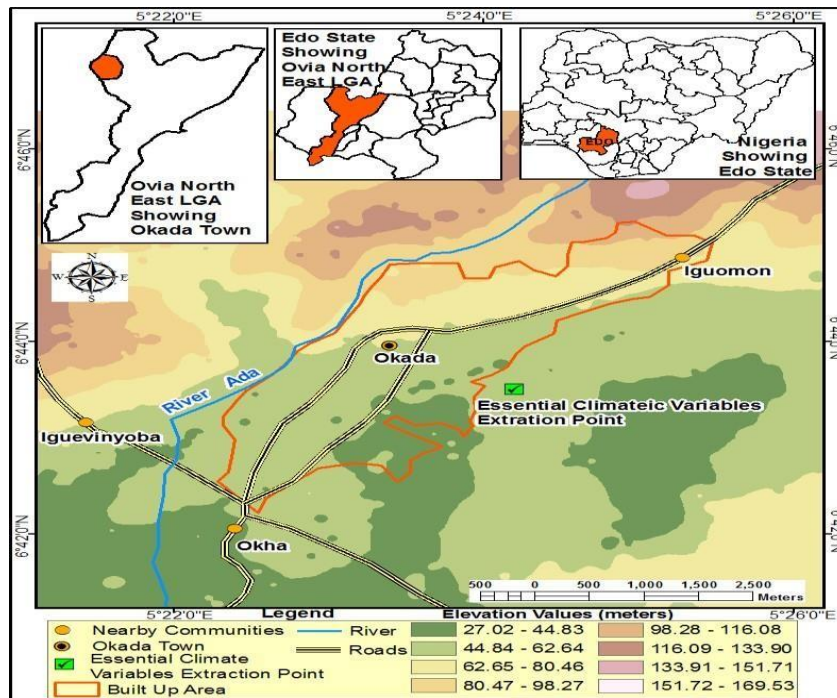


Figure 1 Okada Town in Ovia NE LGA, Edo State Showing Elevation Values
Source: Modified from Google Earth Database (2020)

The dominant soil group in Okada Town is Lixisols (International Union of Soil Sciences [IUSS] Working Group World Reference Base for Soil Resources [WRB, 2015]. The soil to some extent is acidic in nature although it could assume neutrality in response, suggestive of modest to high base saturation. (Spaargaren, 2007).

Okada Town experience a humid tropical climate characterized by two seasons, namely dry and rainy seasons. The dry season usually commences from early November to late March while the rainy season start from late March to early November. Presently, the vegetation in Okada Town is characterized by secondary lowland rainforest comprising patches of farmlands and fallow lands (Edo State Ministry of Budget, Planning and Economic Development (ESMBPED, 2014

Dataset and Sources

Major essential climate variables (ECV) used for this study include minimum temperature (TMin), maximum temperature (TMax), rainfall, soil moisture (SM) at the depth of 0-40cm, potential evapotranspiration (PET) and normalized difference

vegetation index (NDVI). The dataset were on monthly and spanned across 40years starting from January 1980 to December 2019. These ECV were selected based on their significance principally in farming as well as their influence in other socio-economic activities in Okada Town.

The high-resolution time-series (TS) gridded climatic data of month-by-month variation in climate (version 4.04 from January 1980 - December 2019) of TMin, TMax, rainfall and PET were retrieved from archives of the University of East Anglia-Climatic Research data base. Also the time series soil moisture data was downloaded from the Famine Early Warning Systems Network (FEWS NET) Land Data Assimilation System (FLDAS) website (https://disc.gsfc.nasa.gov/datasets/FLDAS_NOAH01_C_GL_MC_001/summary?keywords=FLDAS). FLDAS is part of the mission of the United States of America (USA) National Aeronautical and Space Administration (NASA) Earth Science Division and archived and distributed by the Goddard Earth Sciences (GES) Data and Information Services Center (DISC) (NASA GES DISC, 2019:6).

NDVI was sourced from NASA Goddard Space Flight Center (GSFC) and the University of Maryland (UMD) (Vermote and NOAA CDR Program, 2019). This dataset contains gridded daily NDVI derived from the NOAA Climate Data Record (CDR) of Advanced Very High Resolution Radiometer (AVHRR) Surface Reflectance. The data record spans from 1981 to 10 days before the present using data from eight NOAA polar orbiting satellites: NOAA-7, -9, -11, -14, -16, -17, -18 and -19. The data are projected on a 0.05 degree x 0.05 degree global grid. This dataset is one of the Land Surface CDR Version 5 products produced by the NASA Goddard Space Flight Center (GSFC) and the University of Maryland (UMD). Improvements for Version 5 include using the improved surface reflectance data, correcting the data for known errors in time, latitude, and longitude variables, as well as improvements in the global and variable attribute definitions.

Data Analysis

Data analyses involved comparisons using standard meteorological procedures which include the use of descriptive and inferential statistics to establish the trends and patterns of climatic variables in the study area.

Pattern and Trend of ECV in Okada Town

This was assessed using simple linear regression (SLR) which is a parametric statistical technique. Prior to the analysis, descriptive statistics which include mean, standard deviation, range, minimum, maximum, variance and coefficient of variation (CV) were computed from the time series of all the ECV datasets. Thereafter, SLR was used to analyze the linear trends of the climatic data. The SLR model based on Udofia (2011) is mathematically expressed as:

$$Y = a + bx + \epsilon \quad (1)$$

Where:

Y = the dependent variable. These include each of the ECV (TMin, TMax, rainfall, SM at the depth of 0-40cm, PET and NDVI) at annual bases.

x = the independent variable in this case time (Years, that is, 1980 – 2019),

a = the y intercept (that is where the regression line touches the y-axis).

b = the regression coefficient or slope.

e = the residual or random error term.

Temporal Variations of ECV in Okada Town

The temporal variations of ECV from 1980-2018 in Okada Town was evaluated with the aid of one-way

analysis of variance (ANOVA). However, before ANOVA was carried out, all the ECV were partitioned into four climatic periods (1980-1989, 1990-1999, 2000-2009 and 2010-2019) based on Ekpenyong (2015). The cardinal goal of partitioning the climatic data into three climatic periods was to facilitate easy decade-to-decade comparison with the view to establishing temporal variations. Interestingly, One-way ANOVA offers group-level statistics for the dependent variable, a test of variance equality, a plot of group means, range tests, pairwise multiple comparisons, and contrasts, to describe the nature of the group differences.

An important first step in the analysis of variance is establishing the validity of assumptions. One assumption of ANOVA is that the variances of the groups are equivalent. The null hypothesis based on Hays (1981) is symbolically represented as:

$$H_0: \mu_1 = \mu_2 = \mu_3 = \dots = \mu_{1/2} \quad (2)$$

Where: μ = group mean and; k = number of groups.

The mean squares are calculated by dividing each sum of squares by its degrees of freedom. The F ratios are the mean squares for each source divided by the within groups mean square. The significance level for the F is from the F distribution with the degree of freedom for the numerator and denominator mean squares. If there is only one group the ANOVA is not done; if there are fewer than three groups or the independent variable is a string variable, the test for linearity is not done (Hays, 1981). Besides, a post hoc test was further carried out on the ANOVA results to actually ascertain which particular decade varied from another using Tukey's Honestly Significant Difference Test (TUKEY) (Tukey, 1977; Hoaglin et al, 1983). The significance levels of 0.01 and 0.05 were adopted.

Interrelationships among ECV in Okada Town

In order to evaluate the interrelationships among ECV in Okada Town between 1980 and 2019, Pearson's Product Moment Correlation (PPMC) was used. The PPMC is also a statistical technique that is very useful in assessing the statistical relationship between one variable (dependent) and another (independent) as well their significance. The correlation coefficient (r) measures the strength of relationship between variables. Pearson's product moment correlation statistically represented as:

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \quad (3)$$

Where:

n = number of pairs of scores

$\sum xy$ =sum of the products of paired scores

$\sum x$ = sum of x scores

$\sum y$ = sum of y scores

$\sum x^2$ = sum of squared x scores

$\sum y^2$ = sum of squared y scores

RESULTS AND DISCUSSION

Trends and Patterns of ECV between 1980 and 2019 in the Okada Town

The result of the descriptive statistics of the investigated ECV Okada Town between 1980 and 2019 is presented in Table 1

Table 1 Descriptive statistics of ECV between 1980 and 2019 in Okada Town

Statistics	Minimum Temperature	Maximum Temperature	Rainfall	Soil Moisture (0-40cm)	PET	NDVI
Mean	22.680	31.343	1749.8	9.067	50.83	0.562
Standard Deviation	0.3851	0.3644	161.4	0.1940	1.40	0.0225
Range	1.6	1.4	709.2	0.8	5.8	0.1
Minimum	21.8	30.6	1382.1	8.6	47.6	0.5
Maximum	23.4	32.0	2091.3	9.4	53.4	0.6
Variance	0.148	0.133	26035.6	0.038	1.968	0.001
Coefficient of Variation	1.7%	1.2%	9.2%	2.14%	2.75%	4%
N (Years)	40	40	40	40	40	40

Source: Researchers’ Statistical Analysis (2020)

Trends and Patterns of Annual Minimum Temperature in Okada Town

The result of the seasonal pattern of TMin as presented in Figure 2 shows that January is the month with the

lowest TMin of 21.7OC whereas March, with the value of 24.1OC emerged as the month with highest TMin.

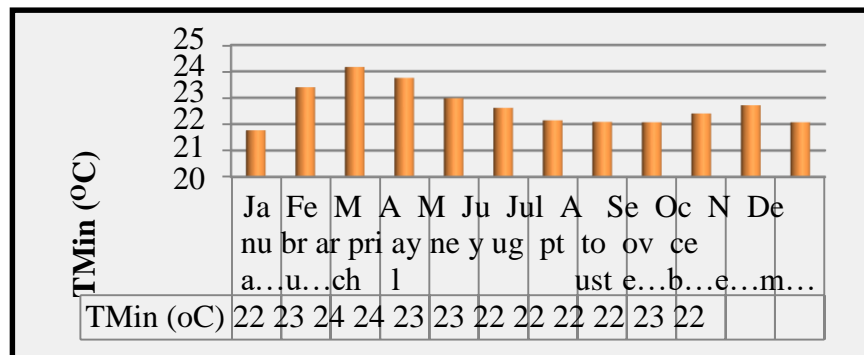


Figure 2 Monthly Pattern of Minimum Temperature in Okada Town
Source: Researchers’ Statistical Analysis (2020)

The result of annual pattern and trend in TMin (Figure 3) exhibited a rising trend at 0.013°C per annum and 16.9% probability of persisting into the future in Okada Town. In the 40years CP, 1989 had the lowest TMin of 21.8°C while 2020 recorded the highest

TMin of 23.4°C. A noticeable annual TMin decline amounting to 0.7°C was observed between 1988 and 1989 with a corresponding rise of about 0.7°C between 1989 and 1990.

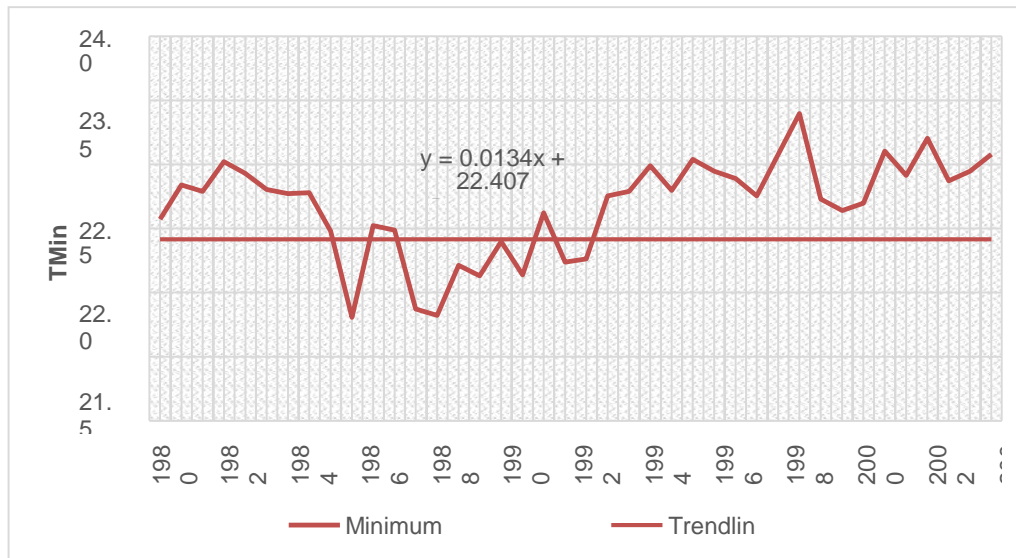


Figure 3 Annual Trends of Minimum Temperature in Okada Town (1980-2019)
Source: Researchers’ Statistical Analysis (2020)

Trends and Patterns of Annual Maximum Temperature in Okada Town

The result of the seasonal pattern of TMax as presented in Figure 4 shows that August is the month with the lowest TMax of 28°C whereas February, with the value of 34.7°C emerged as the month with highest TMax. The TMax (figure 5) exhibited an upward trend at 0.018°C per annum and 36.3% probability of the

pattern reappearing in the future in Okada Town. In the 40years CP, 1991 recorded the lowest TMax of 30.6°C and the highest TMax of 32°C was recorded in 2016. A noticeable annual TMax decline amounting to 0.8°C was observed between 1987 and 1988 with a corresponding ascend of about 0.8°C in 1980/1981 and between 1997 and 1998.

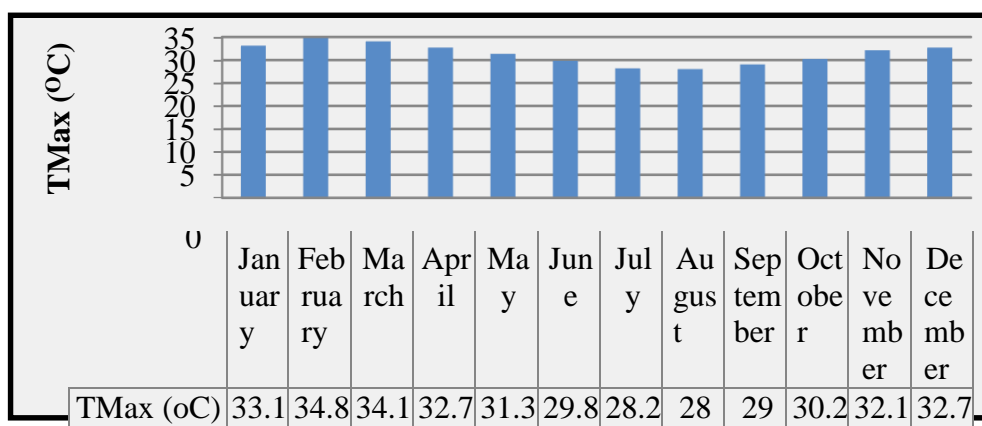


Figure 4 Monthly Pattern of Maximum Temperature in Okada Town
Source: Researchers’ Statistical Analysis (2020)

THE PATTERNS, TRENDS AND INTERRELATIONSHIPS AMONG ESSENTIAL CLIMATIC VARIABLES IN OKADA TOWN, EDO STATE, NIGERIA

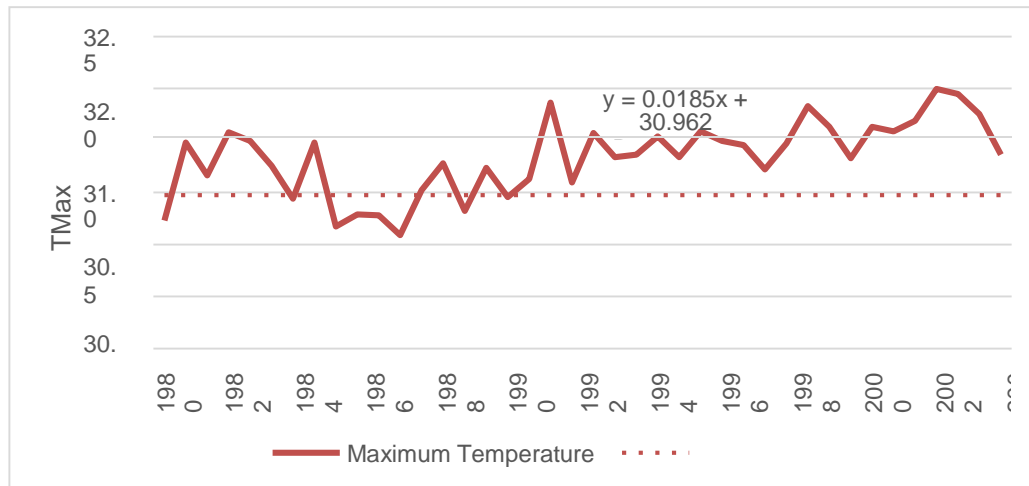


Figure 5 Annual Trends of Maximum Temperature in Okada Town (1980-2019)
Source: Researchers’ Statistical Analysis (2020)

Trends and Patterns of Rainfall in Okada Town

The quantity and the quality of available water resources both in time and space, to a large extent, depends on its amount, intensity, timing and distribution of rainfall. Precipitation does not only play a critical role in many biogeophysical cycles including water cycle, but a key sustenance of tropical and rainfed agriculture. Findings from the 40years climatic period

(1980 – 2019) revealed various levels of variability and change in the trends and patterns of rainfall in the study area. As seen in Figure 6, Okada Town receives rainfall throughout the year with two obvious peaks. The peak rainfall occurs in July (264.3mm) and September (292mm) which also doubles as the month with highest rainfall. This is typical of locations within humid tropical regions of Nigeria.

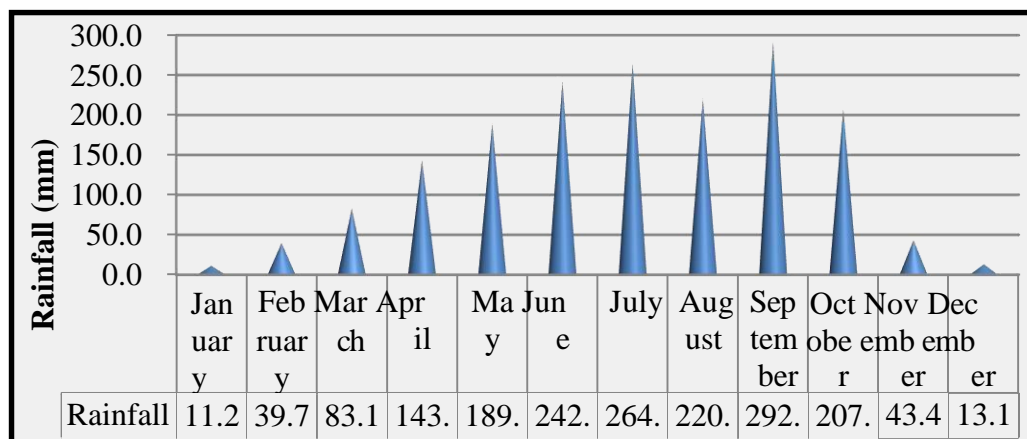


Figure 6 Monthly Pattern of Rainfall in Okada Town
Source: Researchers’ Statistical Analysis (2020)

Annual pattern displayed marked variability between 1980 and 2000 and the simple linear regression showed a near zero trend although positive at annual rate of 1.192mm ($R^2 = 0.007$). A critical look at Figure 7 shows that 1983 happened to be the driest year in the climatic period with rainfall of 1382.1mm. Conversely, it will not be unempirical to report that

1991, with total rainfall of 2091.3mm was the wettest year within the 40 years climatic period. Captivating patterns in the oscillation of MAR is also easily discernible with a sharp decline amounting to 483mm observed between 1980/81 and 474.1mm between 1991/92.

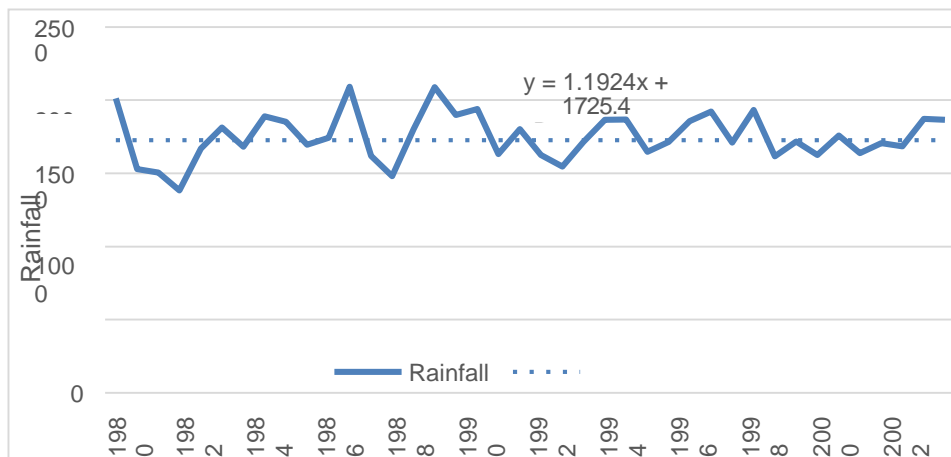


Figure 7 Annual Trends of Rainfall in Okada Town (1980-2019)
Source: Researchers’ Statistical Analysis (2020)

Trends and Patterns of Soil Moisture in Okada Town

Monthly soil moisture pattern at the depth of 0-40cm for the study period (1980-2019) as shown in Figure 8 revealed that the highest value of $0.9\text{m}^3/\text{m}^3$ was recorded in September while January and February were the months with the lowest value of $0.6\text{m}^3/\text{m}^3$.

Similarly, annual pattern of soil moisture in Okada Town between 1980 and 2019 is presented in Figure 9. Soil moisture exhibited marked oscillations with the highest content recorded in 1991 ($9.4\text{m}^3/\text{m}^3$) whereas the lowest soil moisture content was recorded in 1983 ($8.6\text{m}^3/\text{m}^3$).

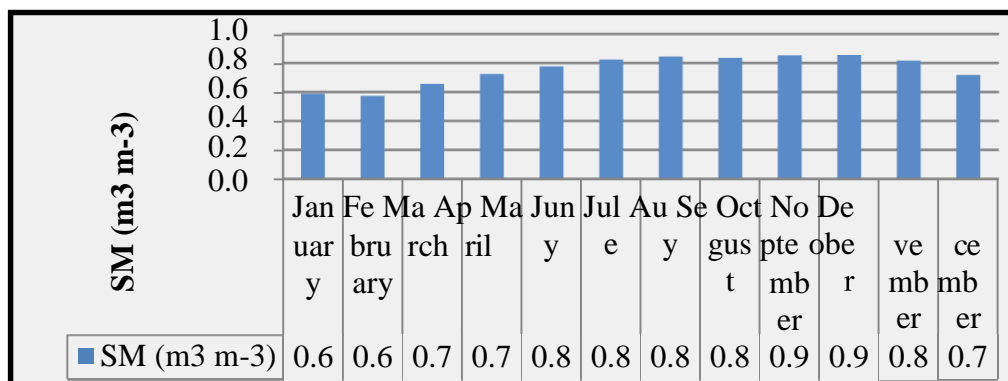


Figure 8 Monthly Pattern of Soil Moisture (0-40cm) in Okada Town
Source: Researchers’ Statistical Analysis (2020)

Besides, 1991/1992 experienced sharp decline in soil moisture amounting to $0.6\text{m}^3/\text{m}^3$ in Nitisols with an obvious increase in soil moisture content observed in 1990/91 with the value of $0.6\text{m}^3/\text{m}^3$ in Okada Town. In

addition, soil moisture exhibited a rising trend in the climatic period with an increment of $0.009\text{m}^3/\text{m}^3$ per annum and 30.7% likelihood of pattern and trend of soil moisture observed in to repeat itself in the future.

THE PATTERNS, TRENDS AND INTERRELATIONSHIPS AMONG ESSENTIAL CLIMATIC VARIABLES IN OKADA TOWN, EDO STATE, NIGERIA

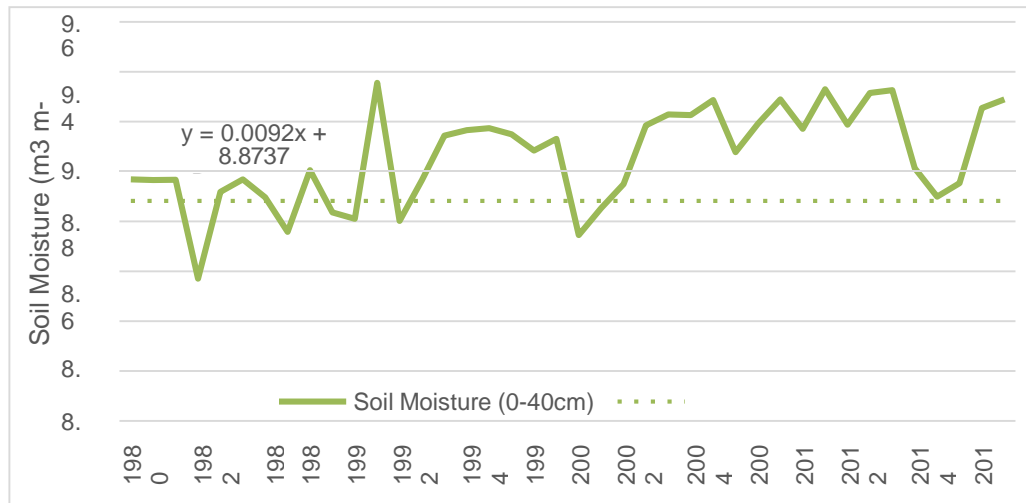


Figure 9 Annual Trends of Soil Moisture (0-40cm) in Okada Town (1980-2019)
Source: Researchers’ Statistical Analysis (2020)

Trends and Patterns of Potential Evapotranspiration in Okada Town

Findings from the 40years climatic period (1980 – 2019) revealed various levels of variability and change

in the trends and patterns of PET in the study area. As shown in Figure 10, the lowest PET value of 3.1mm each was observed in July and August while the highest PET value of 5.2mm was noticed in March.

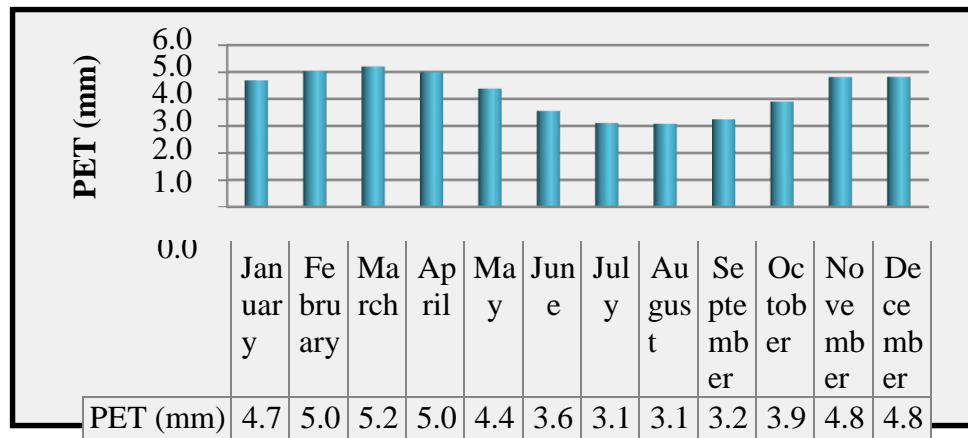


Figure 10 Monthly Pattern of Potential Evapotranspiration in Okada Town
Source: Researchers’ Statistical Analysis (2020)

Annual pattern of PET displayed marked fluctuations in the 40years climatic period with four outstanding peaks in 1988 (52.9mm), 1999 (53.2mm) as well as 2012 and 2017 recording 53.4mm each. A cursory look at Figure 11 shows that 1981 emerged as the year with lowest PET value of 47.6mm. Appealing patterns in the oscillation of PET also displayed a sharp

decline amounting to 3.4mm between 1980/81 and 3.3mm between 2012/13. A corresponding rise of about 2.8mm also occurred between 1987 and 1988 and 2.9mm between 1997 and 1998. On the whole, PET showed a rising trend at annual rate of 0.057mm (R² = 0.233).

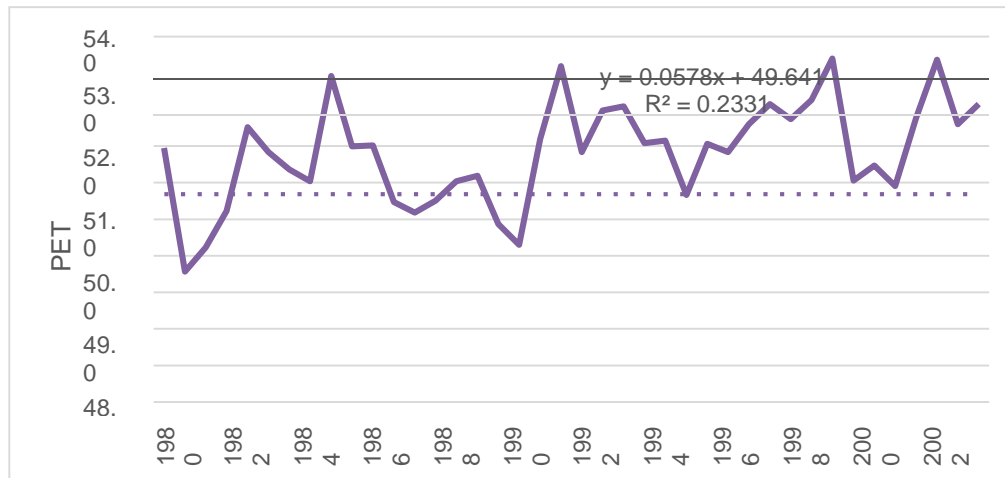


Figure 11 Annual Trends of Potential Evapotranspiration in Okada Town (1980-2019)
Source: Researchers’ Statistical Analysis (2020)

Trends and Patterns of Normalised Difference Vegetation Index in Okada Town

As an important component of climate change studies, the vegetation health in Okada Town was investigated using normalised difference vegetation index (NDVI) which measures the extent of greenness in leaves of crops, trees and plants. Findings from the 40years climatic period (1980 – 2019) revealed various levels

of variability and change in the trends and patterns of NDVI in the study area. As seen in Figure 12, the vegetation is characteristically reduced in the dry season and increased in the wet season in Okada Town. May to July recorded NDVI of 0.7 each with a depression of 0.6 in August and subsequent rise to 0.7 in September and October signalling the end of the rainy season.

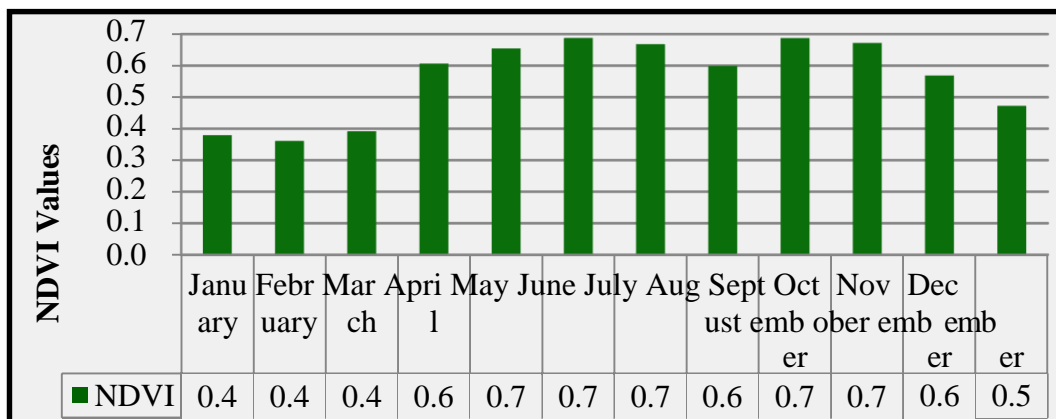


Figure 12 Monthly Pattern of Normalised Difference Vegetation Index in Okada Town
Source: Researchers’ Statistical Analysis (2020)

Annual pattern of NDVI also displayed marked fluctuations in the 40years climatic period with 1987 and 1995 (NDVI= 0.58) and 1999 (NDVI= 0.59) being years with better vegetation performance. In contrast, 1985 and 1994 (NDVI = 0.49 each) were years with poorer vegetation health. A critical look at Figure 13 also shows appealing patterns in the oscillation of

NDVI with a sharp decline amounting to 0.06 between 1999/2000. A corresponding rise of about 0.09 also occurred between 1994 and 1995. In general, NDVI showed a rising trend at annual rate of 0.001 (R² = 0.293).

THE PATTERNS, TRENDS AND INTERRELATIONSHIPS AMONG ESSENTIAL CLIMATIC VARIABLES IN OKADA TOWN, EDO STATE, NIGERIA

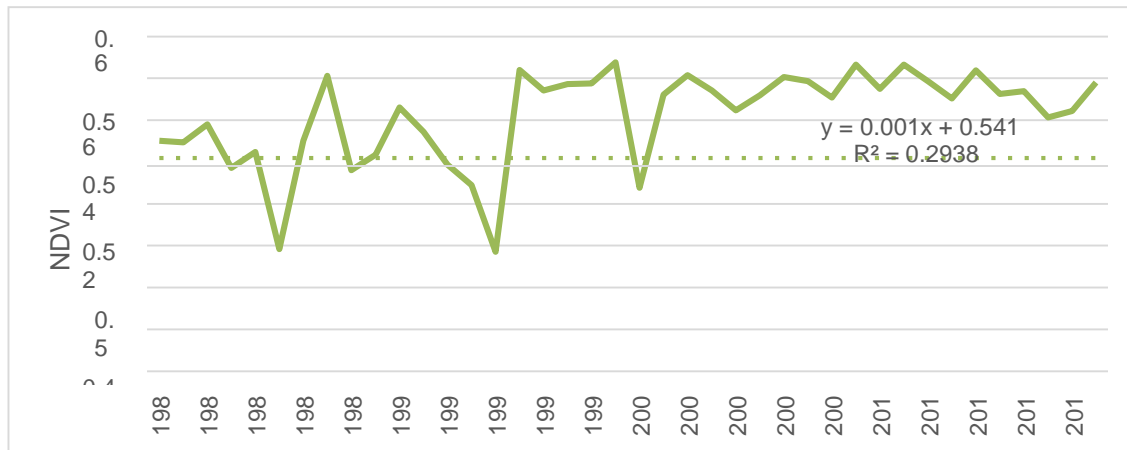


Figure 13 Annual Trends of Normalised Difference Vegetation Index in Okada Town (1980-2019)
Source: Researchers’ Statistical Analysis (2020)

Table 2 ANOVA of ECV between 1980 and 2019 in the Okada Town

ECV		Sum of Squares	df	Mean Square	F	Sig.
Minimum Temperature	Between Groups	2.802	3	0.934	11.277	0.00
	Within Groups	2.982	36	0.083		
	Total	5.784	39			
Maximum Temperature	Between Groups	2.096	3	0.699	8.160	0.00
	Within Groups	3.082	36	0.086		
	Total	5.178	39			
Rainfall	Between Groups	56345.827	3	18781.94	0.705	0.55
	Within Groups	959042.075	36	26640.05		
	Total	1015387.902	39			
Soil Moisture (0-40cm)	Between Groups	0.454	3	0.151	5.370	0.004
	Within Groups	1.014	36	0.028		
	Total	1.468	39			
PET	Between Groups	25.371	3	8.457	5.924	0.002
	Within Groups	51.393	36	1.428		
	Total	76.764	39			
NDVI	Between Groups	0.006	3	0.002	5.402	0.004
	Within Groups	0.014	36	0.000		
	Total	0.020	39			

Source: Researchers’ Statistical Analysis (2020)

Temporal Variations of ECV in Okada Town

In investigating possible temporal variations of ECV in Okada Town, the 40years climatic period (CP) was segmented into four distinct sub-periods each spanning 10years. These include 1980-1989, 1990-1999, 2000-2009 and 2010-2019 as found in previous studies. Analysis of variance (ANOVA) was used to test the differences in their means and the result is presented in Table .2. TMin recorded F-value of 11.277 Between Groups with p-value of 0.00 whereas TMax recorded F-value of 8.160

Between Groups with p-value of 0.00. Also, soil moisture (0-40cm) recorded F-value of 5.370 Between Groups with p-value of 0.004 while PET recorded F-value of 5.924 Between Groups with p-value of 0.002. In addition, NDVI recorded F-value of 5.402 Between Groups with p-value of 0. To further identify the decades where the variation in ECV actually receded, TUKEY test was used and the result is presented in Table 3.

When the mean of TMin in 1980 – 1989 was compared with other decades, the 2nd decade (1990 – 1999) was statistically significant with

THE PATTERNS, TRENDS AND INTERRELATIONSHIPS AMONG ESSENTIAL CLIMATIC VARIABLES IN OKADA TOWN, EDO STATE, NIGERIA

Mean Difference (I-J) of 0.4467 and standard error (SE) of 0.1322 and p-value of 0.009. Also, the 2nd decade (1990 – 1999) was statistically different from 1980 – 1989 (p-value = 0.009), 2000 – 2009 (p-value = 0.002) and 2010 – 2019 (p-value = 0.000). Also, 2000–2009 was statistically different from 1990–1999 (p-value = 0.002) whereas 2010–2019 was statistically different from 1990–1999 (p-value = 0.000). Regarding TMax, the actual decadal variation lies between 1980–1989 and 2010–2019 with mean difference of -0.4936, SE of 0.1278 (p-value = 0.002) while the actual decadal variation lies between 1990 –1999 and 2010 –2019 with mean difference of -0.5859, SE of 0.1315 (p-value = 0.000). The mean of TMax between 2010 and 2019 was also statistically different from 1980–1989 (I-J = 0.4936), SE of 0.1278 (p-value 0.002) as well as from 1990 – 1999 (I-J = 0.5859), SE of 0.1315 (p-value 0.000). Concerning soil moisture (0-40cm), 1980 – 1989 was statistically different from 2010–2019 based on the -0.2909 mean difference, 0.0733 SE (p-values = 0.002. On the other hand, 2010–2019 statistically differed from 1980–1989 based on the mean difference of 0.2909, SE of 0.0733(p-values=0.002). Similarly, PET in 1980 – 1989 differed from 2010 –2019 (p-value = 0.038), 1990–1999 and 2000–2009 (p-value=0.029). Also mean PET observed between 2010- 2019 differed from 1980–1989 (p-value=0.038) and 1990–1999 (p-value =0.004).

Again, the actual temporal variation in NDVI lies between 1980 – 1989 and 1990 - 1999 with statistically significant Mean Difference (I-J) of -0.0261 (p-value = 0.024). The actual temporal variation in PET also lies between 1980 –1989 and 2010–2019 with statistically significant Mean Difference (I-J) of -0.0306 (p-value = 0.005). Comparing the mean NDVI in 2000–2009 with 1980 – 1989 showed statistically significant Mean Difference (I-J) of 0.0261 (p-value = 0.024) while the mean NDVI in 2010 – 2019 was also statistically significant with Mean Difference (I-J) of 0.0306 (p-value = 0.005).

At 95% level of confidence, it could safe to statistically conclude that all the studied ECV excluding rainfall varied with time in Okada Town. This is as a result of marked decade-to-decade variations observed in TMin, TMax, soil moisture, PET and NDV. Rainfall showed no statistical significant decade-to-decade variations due to the fact that all the computed p-values were greater than 0.05 confidence limit specified for this study. Farmers can explore the opportunities offered by the normal pattern of rainfall in Okada Town in their planning farming operations to boost crop yield. Also, with this unchangeable temporal trend in rainfall, flooding and subsequent effects which include destruction of lives and properties can be avoided through good cultural practices and drainage network.

Table 3 Tukey HSD post hoc tests for multiple comparisons

Dependent Variable	(I) Climatic Period	(J) Climatic Period	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Minimum Temperature	1980 - 1989	1990 - 1999	.4467*	.1322	.009	.091	.803
		2000 - 2009	-.0800	.1287	.925	-.427	.267
		2010 - 2019	-.2927	.1257	.111	-.631	.046
	1990 - 1999	1980 - 1989	-.4467*	.1322	.009	-.803	-.091
		2000 - 2009	-.5267*	.1322	.002	-.883	-.171
		2010 - 2019	-.7394*	.1294	.000	-1.088	-.391
	2000 - 2009	1980 - 1989	.0800	.1287	.925	-.267	.427
		1990 - 1999	.5267*	.1322	.002	.171	.883
		2010 - 2019	-.2127	.1257	.343	-.551	.126
	2010 - 2019	1980 - 1989	.2927	.1257	.111	-.046	.631
		1990 - 1999	.7394*	.1294	.000	.391	1.088
		2000 - 2009	.2127	.1257	.343	-.126	.551

Source: Researchers' Statistical Analysis (2020)

* The mean difference is significant at the 0.05 level.

THE PATTERNS, TRENDS AND INTERRELATIONSHIPS AMONG ESSENTIAL CLIMATIC VARIABLES IN OKADA TOWN, EDO STATE, NIGERIA

Table 3 Contd

Dependent Variable	(I) Climatic Period	(J) Climatic Period	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Maximum Temperature	1980 - 1989	1990 - 1999	.0922	.1344	.902	-.270	.454
		2000 - 2009	-.2300	.1309	.310	-.582	.122
		2010 - 2019	-.4936*	.1278	.002	-.838	-.149
	1990 - 1999	1980 - 1989	-.0922	.1344	.902	-.454	.270
		2000 - 2009	-.3222	.1344	.096	-.684	.040
		2010 - 2019	-.5859*	.1315	.000	-.940	-.232
	2000 - 2009	1980 - 1989	.2300	.1309	.310	-.122	.582
		1990 - 1999	.3222	.1344	.096	-.040	.684
		2010 - 2019	-.2636	.1278	.185	-.608	.081
	2010 - 2019	1980 - 1989	.4936*	.1278	.002	.149	.838
		1990 - 1999	.5859*	.1315	.000	.232	.940
		2000 - 2009	.2636	.1278	.185	-.081	.608
Rainfall	1980 - 1989	1990 - 1999	-107.02	74.99	.491	-308.992	94.957
		2000 - 2009	-53.2700	72.99	.884	-249.857	143.317
		2010 - 2019	-35.5400	71.32	.959	-227.607	156.527
	1990 - 1999	1980 - 1989	107.0178	74.99	.491	-94.957	308.992
		2000 - 2009	53.7478	74.99	.890	-148.227	255.722
		2010 - 2019	71.4778	73.36	.765	-126.100	269.055
	2000 - 2009	1980 - 1989	53.2700	72.99	.884	-143.317	249.857
		1990 - 1999	-53.7478	74.99	.890	-255.722	148.227
		2010 - 2019	17.7300	71.32	.995	-174.337	209.797
	2010 - 2019	1980 - 1989	35.5400	71.32	.959	-156.527	227.607
		1990 - 1999	-71.4778	73.36	.765	-269.055	126.100
		2000 - 2009	-17.7300	71.32	.995	-209.797	174.337
Soil Moisture (0-40cm)	1980 - 1989	1990 - 1999	-.1889	.0771	.086	-.397	.019
		2000 - 2009	-.1800	.0751	.096	-.382	.022
		2010 - 2019	-.2909*	.0733	.002	-.488	-.093
	1990 - 1999	1980 - 1989	.1889	.0771	.086	-.019	.397
		2000 - 2009	.0089	.0771	.999	-.199	.217
		2010 - 2019	-.1020	.0754	.537	-.305	.101
	2000 - 2009	1980 - 1989	.1800	.0751	.096	-.022	.382
		1990 - 1999	-.0089	.0771	.999	-.217	.199
		2010 - 2019	-.1109	.0733	.441	-.308	.087
	2010 - 2019	1980 - 1989	.2909*	.0733	.002	.093	.488
		1990 - 1999	.1020	.0754	.537	-.101	.305
		2000 - 2009	.1109	.0733	.441	-.087	.308

*. The mean difference is significant at the 0.05 level.

Source: Researchers' Statistical Analysis (2020)

Table 3 Contd

Dependent Variable	(I) Climatic Period	(J) Climatic Period	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
PET	1980 - 1989	1990 - 1999	.5144	.5490	.785	-.964	1.993
		2000 - 2009	-1.0900	.5343	.193	-2.529	.349
		2010 - 2019	-1.4664*	.5221	.038	-2.872	-.060
	1990 - 1999	1980 - 1989	-.5144	.5490	.785	-1.993	.964
		2000 - 2009	-1.6044*	.5490	.029	-3.083	-.126
		2010 - 2019	-1.9808*	.5370	.004	-3.427	-.534
	2000 - 2009	1980 - 1989	1.0900	.5343	.193	-.349	2.529
		1990 - 1999	1.6044*	.5490	.029	.126	3.083
		2010 - 2019	-.3764	.5221	.888	-1.782	1.030
	2010 - 2019	1980 - 1989	1.4664*	.5221	.038	.060	2.872
		1990 - 1999	1.9808*	.5370	.004	.534	3.427
		2000 - 2009	.3764	.5221	.888	-1.030	1.782
NDVI	1980 - 1989	1990 - 1999	-.0105	.0089	.649	-.035	.014
		2000 - 2009	-.0261*	.0087	.024	-.050	-.003
		2010 - 2019	-.0306*	.0085	.005	-.054	-.008
	1990 - 1999	1980 - 1989	.0105	.0089	.649	-.014	.035
		2000 - 2009	-.0156	.0089	.316	-.040	.008
		2010 - 2019	-.0202	.0088	.115	-.044	.003
	2000 - 2009	1980 - 1989	.0261*	.0087	.024	.003	.050
		1990 - 1999	.0156	.0089	.316	-.008	.040
		2010 - 2019	-.0046	.0085	.949	-.027	.018
	2010 - 2019	1980 - 1989	.0306*	.0085	.005	.008	.054
		1990 - 1999	.0202	.0088	.115	-.003	.044
		2000 - 2009	.0046	.0085	.949	-.018	.027

*. The mean difference is significant at the 0.05 level.

Source: Researchers' Statistical Analysis (2020)

Interrelationships among ECV in Okada Town

The Pearson's Product Moment Correlation (PPMC) at 0.05 and 0.01 *confidence level* was deployed in the evaluation of interrelationships among ECV in Okada Town between 1980 and 2019. The results as seen in Table 4 show that there is a statistical significant relationship between TMin and TMax in Okada Town. This is because of the Pearson Correlation Coefficient (PCC or R) of 0.594 and the two asterisks shows that the correlation is significant at the 0.01 level (2-tailed). By squaring the R to obtain coefficient of multiple determination (CMD or R²) of 0.3528, it can be concluded that 35.3% of the variations in TMin can actually be explained by the variability in TMax.

Inverse relationship existed between TMin and rainfall as exemplified by the negative signs which is also not statistically significant. There is also no statistically significant relationship between TMin and Soil Moisture (0- 40cm) and PET. In contrast, direct relationship existed between TMin and NDVI (R = 0.356) and with R² of 0.1267, 12.8% of vegetation health in Okada Town can be influenced by TMin. In contrast, direct relationship existed between TMin and NDVI (R = 0.356) and with R² of 0.1267, 12.8% of vegetation health in Okada Town can be influenced by TMin.

Table 4 Correlation results of interrelationships among ECV in Okada Town

ECV		Minimum Temperature	Maximum Temperature	Rainfall	Soil Moisture (0-40cm)	PET	NDVI
Minimum Temperature	Pearson Correlation	1					
	Sig. (2-tailed)						
	N	40					
Maximum Temperature	Pearson Correlation	0.594**	1				
	Sig. (2-tailed)	0.000					
	N	40	40				
Rainfall	Pearson Correlation	-0.015	-0.336*	1			
	Sig. (2-tailed)	0.924	0.034				
	N	40	40	40			
Soil Moisture (0-40cm)	Pearson Correlation	0.227	0.071	0.485**	1		
	Sig. (2-tailed)	0.159	0.665	0.002			
	N	40	40	40	40		
PET	Pearson Correlation	0.253	0.188	0.182	0.127	1	
	Sig. (2-tailed)	0.115	0.246	0.261	0.435		
	N	40	40	40	40	40	
NDVI	Pearson Correlation	0.356*	0.347*	0.211	0.444**	0.26	1
	Sig. (2-tailed)	0.024	0.028	0.192	0.004	0.09	
	N	40	40	40	40	40	40

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

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

Source: Researchers' Statistical Analysis (2020)

There is also an indirect relationship between TMax and rainfall based on the R of -0.336 (p -value = 0.034) which is significant at the 0.05 level (2-tailed). This means that the higher the rainfall, the lower the TMax and vice versa. Statistically significant correlation was also noticed between TMax and NDVI ($R = 0.347$) and with R^2 of 0.1204 , 12.4% of vegetation health in Okada Town can be influenced by TMax. Importantly, although relationships existed between TMax and Soil Moisture (0-40cm) ($R = 0.071$) and TMax and PET ($R = 0.188$), these correlation are not statistically significant. These mean weak or negligible relationships between TMax, soil moisture and PET.

In the context of rainfall, it could be seen that the ECV correlates significantly with Soil Moisture (0-40cm) ($R = 0.485$). With the R^2 of 0.2352 , it can be inferred that 23.5% of the variability in soil moisture can be linked to rainfall amount at 99% level of confident. In contrast, weak relationship was noticed between rainfall and PET ($R = 0.182$) and NDVI ($R = 0.211$). These relationships were neither statistically significant at the 0.01 level nor 0.05 level (2-tailed). Thus, in Okada Town, there is little or no influence of PET and NDVI on rainfall pattern and trend.

Also, Soil Moisture (0-40cm) correlates significantly with NDVI ($R = 0.444$) and the correlation is significant at the 0.01 level (2-tailed). The R^2 of 0.1971 point to the fact that 19.7% of the greenness in crops, trees and plants can be determined by the availability of soil moisture at root zone (0-40cm. On the other hand, weak relationship was observed between NDVI and PET ($R = 0.127$) and the correlation was not statistically significant.

CONCLUSION

In this study, the selected ECV for the 40years climatic period (1980 – 2019) depicted various degrees of variability and change in the climate of Okada Town. The upward trends in all the studied ECV is a marked indication that Okada Town is gradually getting warmer than before in recent history.

Also, the oscillatory patterns exhibited by mean annual rainfall trends is a strong pointer that rainfall is highly variable in Okada Town. Abrupt changes in the amount of rainfall have twin implications. First, sudden increases oftentimes result to flooding occasioned by devastating destruction of lives and properties including farmlands, houses and other sources of livelihood as exemplified in the 2012 flooding. Second, sudden decrease in rainfall amount in most cases create water stress situation with its detrimental effects on crops, livestock, humans and the economy.

Statistical significant temporal variations in the ECV also indicate that climate change is seriously threatening Okada Town. The interrelationships among the ECV point to the fact that all the ECV should be monitored in the study area. These therefore, call for total reawakening of consciousness of climate change impacts and evolution of effective adaptation and mitigation strategies in the Okada Town and environs.

The study therefore recommends that since climatic parameters are dynamic, there is need for continued and periodic assessment for better understanding of the trend, patterns and characteristic of climate in the area. Besides, there is need for increased public awareness, particularly among farmers and other relevant stakeholders on the rate at which temperature and other ECV are rising, the variable and changing nature of ECV, the imminent threat to the society and environment as well as opportunities for adaptation and mitigation of the impacts in the area. Incessant bush fire should be checked to safeguard the health of vegetation in Okada Town. Robust environmental and integrated water resources planning and management is also recommended to guarantee sustained livelihood in the area.

The study also recommends the establishment of synoptic meteorological station equipped with modern instruments for ECV monitoring in the area for improved weather forecast, climate assessment, early warnings, disaster preparedness and risk reduction.

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ANALYSIS OF THE SPATIAL PATTERNS OF SECONDARY SCHOOLS IN THE SENATORIAL ZONES OF BENUE STATE, NIGERIA

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Abstract

This research studied the spatial patterns of secondary schools in selected parts of Benue state with the aim of identifying the pattern of distribution of secondary schools and its implications in the state. The objectives of the study were to establish spatial patterns and assess spatial relationships. The study adopted field observation and measurement to obtain the needed data. GIS and inferential statistical techniques were employed to map, visualize and analyze the data. In Logo Local Government Area, the Nearest Neighbour Index (NNI = 0.533139) is higher than the Z-score value (-3.893099). The implication is clustering of schools in the area. In Gboko Local Government Area, the Nearest Neighbour Index (NNI = 0.700016) was higher than the Z-score value (-5.165005). This also implies that the schools in the area are clustered. In Obi Local Government area, the Z-score value (1.191313) was higher than the Nearest Neighbour Index (NNI = 1.146777). This implies that there is a dispersion pattern of schools' distribution in the area. The result showed a randomly distributed pattern of the schools in the area. The distribution turned towards clustering in Logo and Gboko Local Government Areas and towards dispersion in Obi Local Government Area. It is recommended that further research be conducted on the use of GIS for schools mapping and to create a database that can easily be updated at desirable intervals to cover the entire state for effective and efficient decision making.

Keywords: GIS, GPS, Coordinates, Database, Pattern

INTRODUCTION

The study of regional variations in the distribution of social services has captured the interest of geographers, planners and other scientists because of their general interest in the spatial variation of phenomena on the earth's surface (Sani, 2010). These services include; transportation, banking, industrialization, education, commerce, tourism, and hospitality. In this study, education is of major interest among these services. Education is one of the most promising paths for individuals to realize better and more productive lives and as one of the primary drivers of national economic development (Akpan and Njokwu, 2013).

In Benue state, the spatial distribution of public educational facilities has been greatly influenced by political, economic and social factors (Eze, 2010). The resultant effect of these influences is that, the more populated urban centres attract more schools than their less populated rural counterparts. The schools are therefore clustered in the urban centres and dispersed in the rural areas. Consequently, the urban centres are

favoured with educational opportunities at the expense of their rural counterparts.

Regardless of the above, one aspect of access to rural services that remains relatively under-researched in Nigeria at large and Benue State in particular is the distribution and accessibility to secondary schools (Olawole *et al.* 2015; Eze, 2010; Fabiyi and Ogunyenmi, 2015).

Similarly, among the many scholarly works that have been done on secondary schools in Benue state and reviewed for this study, none has been found by the authors to either specifically addressed the spatial distribution of secondary schools in the area using GIS techniques or mapped their spatial locations (Abenga, 1995; Ada, 2005; Tsavga 2011; Odeh, Oguiche & Iyagher, 2015). This has limited the possibility of making significant and valid assessment of the nature and dynamics of the spatial patterns of schools in the area. From the reviewed works, it is apparent that the little or no studies on the spatial pattern of distribution of Secondary schools in Benue state, especially with a GIS focus, have been published. This study

ANALYSIS OF THE SPATIAL PATTERNS OF SECONDARY SCHOOLS IN THE SENATORIAL ZONES OF BENUE STATE, NIGERIA

becomes necessary because of these reasons. Consequently, this study attempts to fill this gap by identifying and mapping the spatial patterns of secondary schools in selected parts of Benue state with the view to identify the pattern of distribution of secondary schools and its implications in the state.

MATERIALS AND METHODS

Study Area

Logo, Gboko and Obi Local Government areas (LGAs) are located in Benue State, which is in the central middle belt of Nigeria. Logo LGA is located on latitude $7^{\circ}40'$ N and longitude $9^{\circ}40'$ E. Gboko LGA is located on latitude $7^{\circ}08'$ N and longitude $8^{\circ}50'$ E; and Obi LGA lies on latitude $7^{\circ}01'$ N and longitude $7^{\circ}41'$ E.

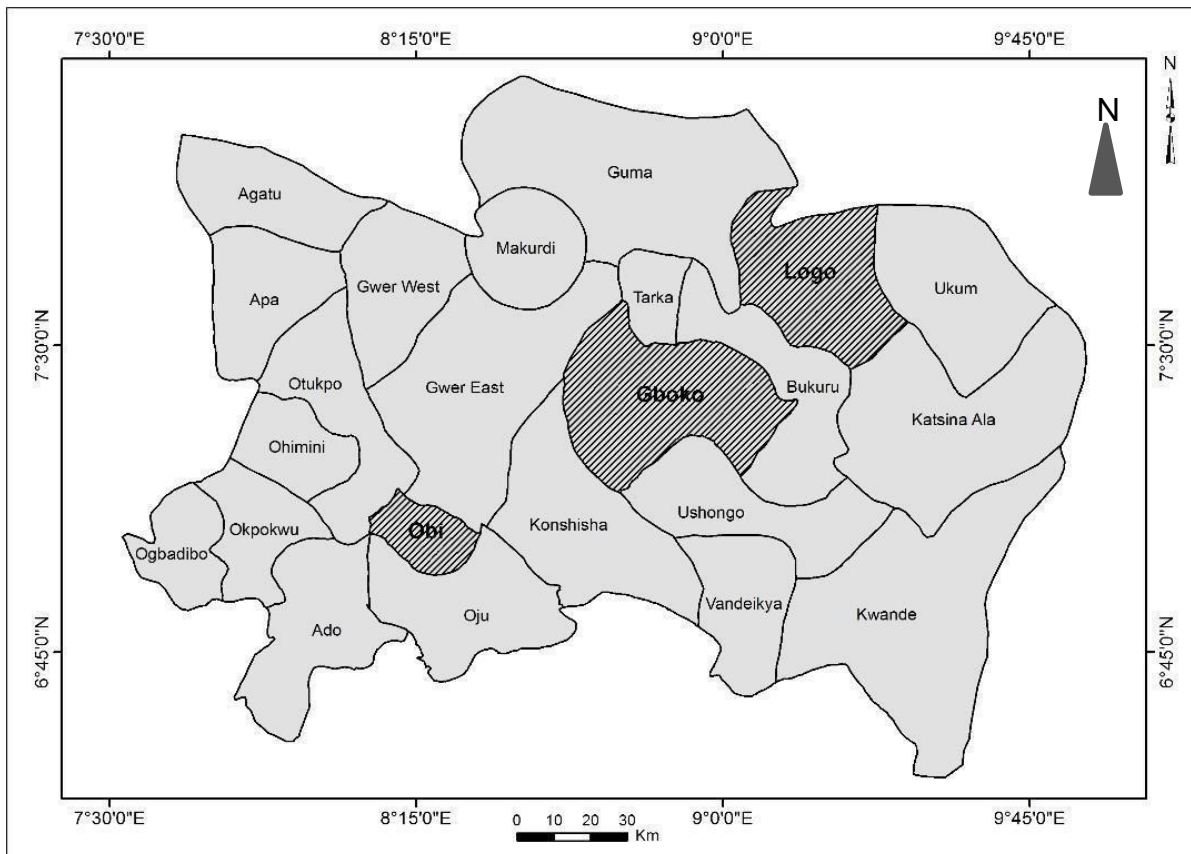


Figure 1 Benue State showing LGAs and the Sampled LGAs

Logo, Gboko and Obi cover land areas of about 1388.908km^2 , 183.405 km^2 and 397.016 km^2 respectively. The climate of the area is of the tropic wet and dry climate (Aw) according to Koppen classification scheme.

The State is made up of built up areas like Gboko with high concentration of people and rural areas like Obi with relatively low concentration of people (Kwaghga, 2006). Dense population exists in Gboko LGA while Logo and Obi LGAs are moderately and less moderately populated respectively. The nature of the land use in the area varies from one part to another. It is

either residential, industrial, commercial, educational, agricultural or open space areas. The heavily built up areas are considered as high density residential areas like Gboko LGA; moderately built up areas are considered as medium density residential areas like Logo LGA and fairly built up areas are low density residential areas like Obi LGA.

Methods of Data Collection

The methods used in this study include field observation, measurement, and interviews. Personal interviews were used to obtain data from

ANALYSIS OF THE SPATIAL PATTERNS OF SECONDARY SCHOOLS IN THE SENATORIAL ZONES OF BENUE STATE, NIGERIA

the concerned government ministries, educational institutions, students, traditional leaders and the inhabitants of the districts. The interview was carried out specifically to get information on secondary schools: their locations, ownership, and registration status with the state's Ministry of Education, and enrolment statistics.

The target population for this study were the secondary schools in the study area. The sampling procedure was multi-staged. First, a stratified sampling technique was used for this study because membership of each stratum was mutually exclusive. Secondly, a simple random sampling technique, used to select one Local Government in each stratum. Thirdly, the stratified random sampling technique was used to

subdivide the Local Government areas into districts. There are three Area Education Zones that cover the 23 LGAs in Benue state: 7 LGAs in Zone A; 7 LGAs in Zone B; and 9 LGAs in Zone C. One LGA was randomly selected from each zone: Logo in Zone A; Gboko in Zone B; and Obi in Zone C. Finally, all the Government owned, grant aided and approved schools in each of these 3 LGAs were engaged for data collection. Thus, 19 schools in Logo LGA, 83 in Gboko LGA and 18 in Obi LGA (table 1) were used in this study. Gboko LGA has a relatively large number of schools probably because it is an urban LGA, with a large population size compared with the other two.

Table 1 Database of secondary schools in the three local government areas

SN	LGA	DISTRICT	NAME OF SCHOOL	CATEGORY	OWNER	X	Y
01	Logo	Mbanym	Govt. Comprehensive Sec	Grant Aided	Government	0539808	0829983
02	Logo	Mbagbev	Govt. Sci & Tech. College	Grant Aided	Government	0527498	0863726
03	Logo	Mbatee	Ugondo Community Sec. Sch	Grant Aided	Community	0537960	0831035
04	Logo	Tombo	Tombo Community Sec. Sch	Grant Aided	Community	0513535	0858930
05	Logo	Mbagbev	Gaambe Tiev Community	Grant Aided	Community	0527192	0862234
06	Logo	Mbavuur	Mbavur Community Sec. Sch	Grant Aided	Community	0536046	0852954
07	Logo	Mbanyam	All Saints Catholic Sec. Sch	Grant Aided	Mission	0537303	0829332
08	Logo	Mbagbev	Unity Sec. Sch	Approved	Individual	0529707	0857688
09	Logo	Mbanyam	NKST sec. sch	Grant Aided	Mission	0538028	0830148
10	Logo	Mbanyam	Voice of the Cross College	Approved	Individual	0538194	0829173
11	Logo	Yonov	No Secondary Schools				
12	Logo	Mbavuur	Imaculate Conception Sec.	Approved	Individual	0534294	0851914
13	Logo	Mbavuur	Gender Foundation College	Approved	Individual	0534059	0852595
14	Logo	Mbagbev	Mandate Sec. Sch.	Approved	Individual	0527247	0862495
15	Logo	Mbagbev	Anyiin Children Sec. Sch	Approved	Community	0527584	0864280
16	Logo	Mbagbev	St. John's Anglican Sec. Sch	Approved	Mission	0526981	0865298
17	Logo	Tswarev/	Tswarev Comprehensive Sec.	Approved	Community	0541776	0867175
18	Logo	Mbagbev	Upsed Grammar Sch	Approved	Individual	0526760	0863038
19	Logo	Tswarev/	Ukemberagya Comm. Sch	Approved	Community	0533518	0865960
20	Logo	Mbaagbev	Prince Victor Sec. Sch	Approved	Individual	0526237	0865340
21	Logo	Nenzev	No Secondary Schools				
22	Logo	Turan	No Secondary Schools				
23	Logo	Mbadyuu	No Secondary Schools				
24	Gboko	Township	Govt. Sec. Sch.	Grant Aided	Government	0501124	0809293
25	Gboko	Township	Govt. Day Sec. Sch. Buter	Grant Aided	Government	0500630	0813281
26	Gboko	Township	Queen of the Rosary Sec Sch.	Grant Aided	Mission	0499714	0810358
27	Gboko	Township	St. Johns Day Sec. Sch.	Grant Aided	Mission	0499677	0810257
28	Gboko	Township	Commercial College	Grant Aided	Individual	0502788	0812203
29	Gboko	Township	W.M Bristow Secondary Sch	Grant Aided	Mission	0500038	0810892
30	Gboko	Township	Gboko High School	Grant Aided	Individual	0500826	0807764
31	Gboko	Township	National College	Grant Aided	Individual	0501883	0812813

**ANALYSIS OF THE SPATIAL PATTERNS OF SECONDARY SCHOOLS IN THE SENATORIAL ZONES OF
BENUE STATE, NIGERIA**

Table 1 Contd

SN	LGA	DISTRICT	NAME OF SCHOOL	CATEGORY	OWNER	X	Y
32	Gboko	Township	Tofi Memorial College	Grant Aided	Individual	0503407	0812440
33	Gboko	Township	Anglican Sec. Sch.	Approved	Mission	0500518	0808943
34	Gboko	Township	Chiandy International Sec.	Approved	Individual	0497796	0811240
35	Gboko	Township	Day Spring Academy	Approved	Individual	0498580	0813152
56	Gboko	Township	Divine Progressive College	Approved	Individual	0496135	0807865
37	Gboko	Township	Excellent International Coll	Approved	Individual	0497914	0809554
38	Gboko	Township	Gboko International College	Approved	Individual	0499553	0812225
39	Gboko	Township	Glory College	Approved	Individual	0497470	0812382
40	Gboko	Township	Great Bethel Int'l College	Approved	Individual	0500981	0812113
41	Gboko	Township	Holy Child Academy	Approved	Individual	0498447	0806329
42	Gboko	Township	Independence Science Coll	Approved	Individual	0497897	0807147
43	Gboko	Township	Kimota Science College	Approved	Individual	0498924	0810134
44	Gboko	Township	Kwaghkohol Royal College	Approved	Individual	0497870	0807907
45	Gboko	Township	Malamin Sec. Sch.	Approved	Individual	0497615	0810607
46	Gboko	Township	Mbayion Comprehensive Coll	Approved	Individual	0497932	0809133
47	Gboko	Township	Mektan International College	Approved	Individual	0501731	0812638
48	Gboko	Township	Mfaterdoo College	Approved	Individual	0498145	0809617
49	Gboko	Township	National Evangelical Mission	Approved	Mission	0498735	0808897
50	Gboko	Township	PA- Andiir Science College	Approved	Individual	0498979	0809900
51	Gboko	Township	Prisons Secondary School	Approved	Government	0499723	0809626
52	Gboko	Township	Rhema International College	Approved	Individual	0501127	0812072
53	Gboko	Township	Rutula Secondary School	Approved	Individual	0497826	0806800
54	Gboko	Township	St. Edward College	Approved	Individual	0501965	0810427
55	Gboko	Township	St. John Model College	Approved	Individual	0498353	0812168
56	Gboko	Township	Unique Secondary school	Approved	Individual	0502000	0807470
57	Gboko	Township	Uplift Secondary School	Approved	Individual	0501102	0810586
58	Gboko	Township	Victory Secondary School	Approved	Individual	0501899	0807767
59	Gboko	Township	Mbayion International Coll	Approved	Individual	0498876	0809431
60	Gboko	Township	Akpuur College Gboko	Approved	Individual	0495812	0808015
61	Gboko	Mbatyu	Mbaakpough Community Sec	Approved	Community	0495499	0822413
62	Gboko	Mbatser	Yion Day Secondary School	Approved	Community	0490770	0816228
63	Gboko	Ukpekpe	Akiishi School Generale Amu	Approved	Individual	0499824	0817557
64	Gboko	Ukpekpe	NKST Secondary School	Approved	Mission	0499656	0817040
65	Gboko	Mbatser	Zenda memorial College	Approved	Individual	0496178	0811873
66	Gboko	Mbatan	Immanuel Model College	Approved	Individual	0493565	0806700
67	Gboko	Ukpekpe	Amua Grammar College	Approved	Individual	0499495	0817744
68	Gboko	Mbatan	Calvary Arrows College	Approved	Mission	0488030	0805660
69	Gboko	Mbatan	El-terald Comprehensive Coll	Approved	Individual	0490147	0805514
70	Gboko	Mbatan	Kings Model College Igyura	Approved	Individual	0488380	0804956
71	Gboko	mbatser	Mbaanyam Commnity Sec.	Approved	Community	0493960	0814449
72	Gboko	Mbatan	Mbamtegh commnty Sec. sch.	Approved	Community	0485292	0813357
73	Gboko	mbatyura	Mbatyura Progressive College	Approved	Community	0496232	0821534
74	Gboko	Mbadim	Mbaanaambe Commty Sec	Grant Aided	Community	0462257	0806686
75	Gboko	Mbaavara	Mbaitav Community Sec	Grant Aided	Community	0477080	0819751
76	Gboko	Mbaanku	Mbasugh Community Sec Sch	Grant Aided	Community	0458943	0816493
77	Gboko	Mbadim	St. Veronica Sec. Sch. Agidi	Grant Aided	Mission	0474356	0807985
78	Gboko	Mbadim	NKST Sec. Sch. Kuhe	Grant Aided	Mission	0476635	0806377
79	Gboko	Mbaanku	Chamagu Sec Sch Tyoado	Approved	Individual	0464907	0824314

**ANALYSIS OF THE SPATIAL PATTERNS OF SECONDARY SCHOOLS IN THE SENATORIAL ZONES OF
BENUE STATE, NIGERIA**

Table 1 Contd

SN	LGA	DISTRICT	NAME OF SCHOOL	CATEGORY	OWNER	X	Y
80	Gboko	Mbadim	Mbatyav Sci. and Tech. Coll.	Approved	Individual	0478610	0806440
81	Gboko	Mbadim	Ngumem College Akpagher	Approved	Individual	0475811	0807647
82	Gboko	Mbaavara	NKST Sec. Sch. Gbemacha	Approved	Mission	0476743	0820405
83	Gboko	Mbaavara	St. Anthony Sec. School	Approved	Mission	0475872	0820245
84	Gboko	Utabar	Yandev Community Sec. Sch.	Grant Aided	Community	0507434	0817138
85	Gboko	Utabar	St. James Junior Seminary	Grant Aided	Mission	0502745	0814816
86	Gboko	Mbaiwar	Mbawar Community Sec.	Approved	Community	0507736	0822477
87	Gboko	Utabar	Kusaki College Yandev	Approved	Individual	0504226	0813290
88	Gboko	Mbakwen	Govt. Secondary School Ikpa	Grant Aided	Government	0474116	0831185
89	Gboko	Mbakwen	Mbatierev community Sec.	Grant Aided	Community	0477710	0831685
90	Gboko	mbakwen	Uavande Community Sec.	Grant Aided	Community	0472826	0840409
91	Gboko	Mbadam	No Secondary Schools				
92	Gboko	Mbakpegh	Ipav Community Sec., Kyu	Grant Aided	Community	0512730	0809710
93	Gboko	Mbakpegh	NKST Sec. Sch. Mkar	Grant Aided	Mission	0505438	0809142
94	Gboko	Mbakpegh	NKST College Mkar	Grant Aided	Mission	0504495	0811084
95	Gboko	Mbakpegh	CDM Academy Mkar	Approved	Mission	0505634	0807564
96	Gboko	Mbakpegh	Creativity Sec. Sch. Meladu	Approved	Individual	0509628	0811080
97	Gboko	Igyorov	Dimtor Sec. Sch. Adewaka	Approved	Community	0516644	0806913
98	Gboko	Mbakpegh	Excelgrace Sec. Sch Akaajime	Approved	Individual	0502615	0809612
99	Gboko	Mbakpegh	Jerusalem Academy Akaajime	Approved	Individual	0502176	0808755
100	Gboko	Mbakpegh	Mkar Model College Mkar	Approved	Individual	0504295	0810718
101	Gboko	Mbakpegh	Graceland Sec. Sch. Akaajime	Approved	Individual	0502250	0809400
102	Gboko	Mbakpegh	Notredam Sec. Sch. Mkar	Approved	Individual	0505012	0808020
103	Gboko	Mbakpegh	Princess Adeja Sec. Sch.	Approved	Individual	0502319	0809842
104	Gboko	Mbakpegh	Sky Gifted Sec. Sch. Mkar	Approved	Individual	0503967	0809650
105	Gboko	Mbakpegh	Takema Memorial Sec. Sch.	Approved	Individual	0503014	0808904
106	Gboko	Mbakpegh	Trinity College Akaajime	Approved	Individual	0502424	0808305
107	Gboko	Mbapegh	Ukough Community Sec. Sch.	Approved	Individual	0516255	0818107
108	Obi	Obarike	St. Joseph Sec. Sch. Ito	Grant Aided	Mission	0425813	0777240
109	Obi	Okwutung	Govt. Girls Sec. Sch. Obarike	Grant Aided	Government	0427545	0777523
110	Obi	Itogo	Itogo Community High Sch. Ek	Approved	Community	0429602	0780668
111	Obi	Itogo	Christ Apostolic Church Sec	Approved	Mission	0430184	0783903
112	Obi	Adiko	Adiko Community Sec. Sch.	Approved	Community	0431396	0773922
113	Obi	Obeko	Adum Community Sec. Sch	Approved	Community	0430421	0767604
114	Obi	Irabi	No Secondary Schools				
115	Obi	Orihi	Soled Sec. School Ohum	Approved	Individual	0426888	0766497
116	Obi	Ogore	Govt. Secondary School Ito	Grant Aided	Government	0426410	0772468
117	Obi	Adum	Methodist High school Adum	Grant Aided	Mission	0422715	0769714
118	Obi	Ikwokwu	Oluwu Onwaji Memorial Sec.	Approved	Individual	0423568	0772504
119	Obi	Ogore	Holy Trinity Anglican Coll	Approved	Mission	0426696	0774413
120	Obi	Obarike	Ede Peter Memorial Academy	Approved	Individual	0425850	0774978
121	Obi	Obarike	De-Patrick Comprehensive	Approved	Individual	0424330	0775420
122	Obi	Odiapa	No Secondary Schools				
123	Obi	Ikwokwu	St. Marks Secondary Sch. Ugba	Grant Aided	Mission	0417165	0776923
124	Obi	Okpokwu	Anglican Secondayr School Ita	Approved	Mission	0413845	0777883
125	Obi	Okpokwu	Emmanuel Hill Top Sec. Sch.	Approved	Individual	0412255	0772347
126	Obi	Okpokwu	Itogo Community High Sch.	Grant Aided	Community	0412893	0780727
127	Obi	Okpokwu	Royal Pride Academy Opirikw	Approved	Individual	0412081	0782907

Source: Researchers' field work

ANALYSIS OF THE SPATIAL PATTERNS OF SECONDARY SCHOOLS IN THE SENATORIAL ZONES OF BENUE STATE, NIGERIA

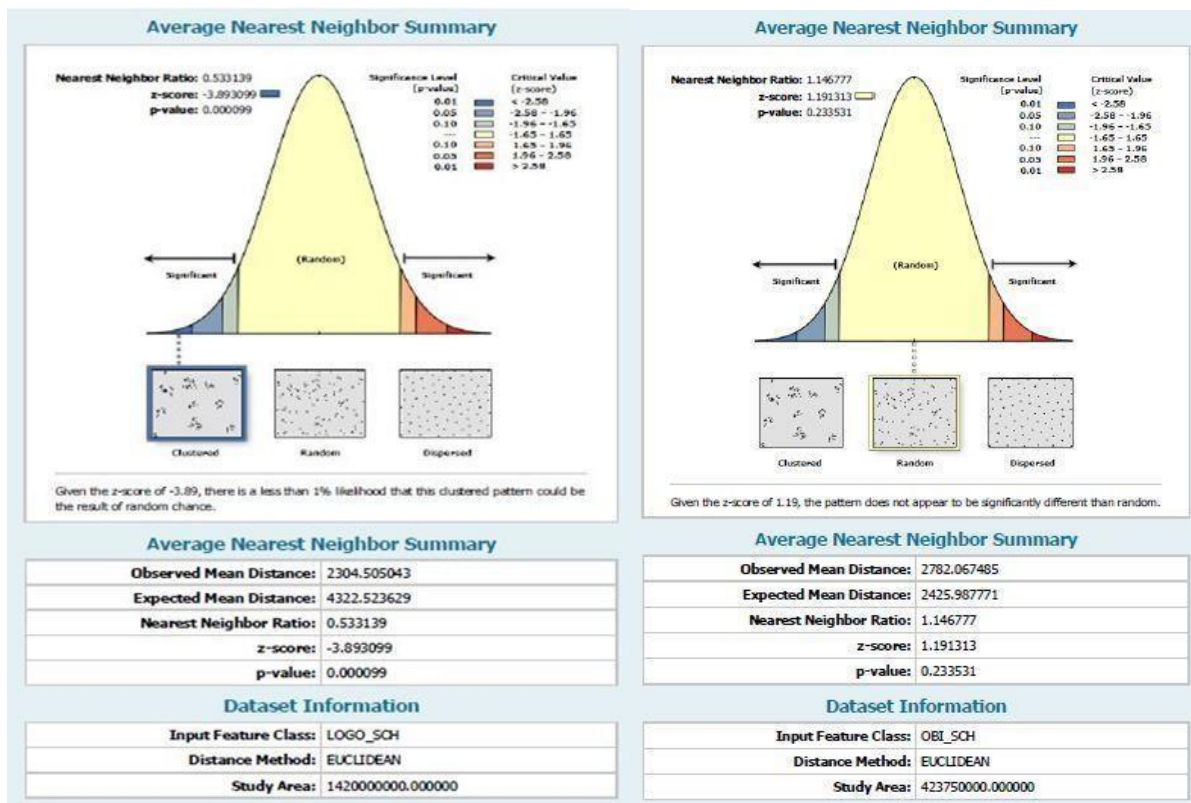
ArcGIS was used to produce map of Benue State showing all the local Government areas. The school coordinates were imported into the maps. The GPS coordinates were further used to create database of the schools by Local government areas. Nearest Neighbour Analysis was done in ArcGIS to establish the pattern of the schools in the areas.

RESULTS AND DISCUSSION

Pattern of Secondary Schools in Logo Local Government Area in Zone A

The GIS analysis carried out identified nineteen (19) secondary schools in Logo Local

Government Area. Proximity analysis was carried out on the secondary schools using the Euclidean distance method. It revealed a range of 2305m (2.305km) to 4323m (4.323km) apart from each other secondary school in the area. The result of the Nearest Neighbour Statistics (NNS = 0.533139) reveals that secondary schools in Logo Local Government Area were randomly distributed (figure 2). The Nearest Neighbor Index implies that the pattern is turning towards clustering. The Nearest Neighbour Index (NNI = 0.533139) is higher than the Z-score value (-3.893099).



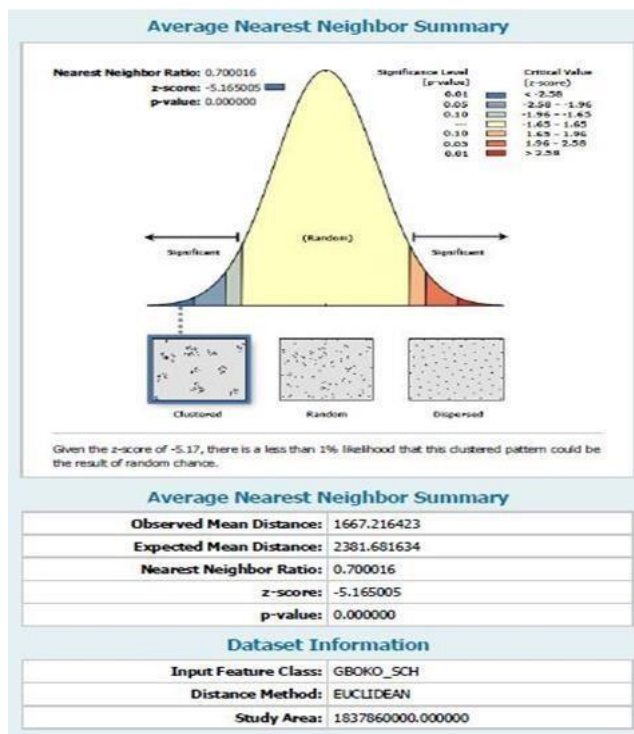


Figure 2 Nearest Neighbour Statistics for Logo, Gboko and Obi LGAs

This confirms that the schools were unevenly distributed. Several reasons can be adduced for this pattern of distribution of secondary schools. This may include the population distribution, relief and even government policies.

Pattern of Secondary Schools in Gboko Local Government Area in Zone B

The GIS analysis carried out identified eighty-three (83) secondary schools in Gboko Local Government Area. Proximity analysis was carried out on the secondary schools using the Euclidean distance method. It revealed an average of 1667m (1.667km) to 2362m (2.383km) apart from each other secondary school in the area. The result of the Nearest Neighbour Statistics (NNS = 0.700016) reveals that secondary schools in Gboko Local Government Area were randomly distributed (figure 2). The Nearest Neighbor Index also indicated that the pattern was turning towards clustering. The Nearest Neighbour Index (NNI = 0.700016) was higher than the Z-score value (- 5.165005), implying an uneven distribution. This

pattern of schools' distribution was observed to have resulted from the influence of some of the major stakeholders to secondary education in the local government area, especially the private individuals and the missions who have many schools located in the urban areas based on their discretion. In the rural areas, it is mostly influenced by the communities and government policies. Other factors that affect the pattern of schools' distribution in the area are population distribution pattern, population size, population structure, especially in the rural areas and government policies.

Pattern of Secondary Schools in Obi Local Government Area in Zone C

The GIS analysis carried out identified eighteen (18) secondary schools in Obi Local Government Area. Proximity analysis was carried out on the secondary schools using the Euclidean distance method. It revealed an average of 2426m (2.426km) to 2782m (2.782km) apart from each other secondary school in the area. The result of the Nearest Neighbour Statistics (NNS = 1.146777) reveals that secondary schools in Obi Local Government Area were randomly

distributed (Figure 2). Nearest Neighbor Index indicated that the pattern tended towards dispersion. The Z-score value (1.191313) was higher than the Nearest Neighbour Index (NNI = 1.146777) showing that the schools were scattered across the area. This pattern of distribution was influenced by the interest of the people in education and development.

The study revealed that the secondary schools were randomly distributed across the Local Government Areas, turning towards clustering in Logo and Gboko Local Government areas. The situation is slightly different in Obi Local Government Area where the distribution turns towards dispersion (Figure.3). This means that most of the available schools were clustered in few specific locations within Logo and Gboko Local Government Areas, leaving the remaining few others dispersed on the wider space especially in Obi LGA.

This was inferred from the results which showed that the secondary schools were generally not evenly distributed and scattered across the area. The implication is that some parts of the Local Government Areas were more favoured by this pattern of distribution than others. For instance, in Logo Local Government Area, Mbagbev district had 42% of the schools, Mbanyam had 21.1% of the schools, while Mbavuur had 15.8% of the schools found in the area. Alternatively, Nenzev, Turan, Mbadyuu, and Yonov had 0% of the schools each. This means the four districts had no school during the study period. In Gboko Local Government area, 43.4% of the 83 schools were found in the township district. The remaining 56.6% of the schools were shared among 12 districts, while one of the districts had no single school. In Obi Local Government Area, Okpokwu had 22.2% of the 18 schools each, Itogo, Ikwokwu, Obarike and Ogore had 11.1% of the schools each. The rest districts had 5.5% of the schools each except Irabi which had 0% of the schools distributed in the area.

Generally, Gboko Local Government area had 69.2% of the total schools sampled, Logo Local Government Area had 15.8% of the total schools sampled while Obi Local Government Area had 15% of the total schools sampled. This implies that Gboko Local Government Area was more favoured by this

pattern of distribution than its rural counterparts. Comparatively, Logo and Gboko Local Government Areas have more similarities in terms of the patterns of spatial distribution of secondary schools than Obi Local Government Area. The random distribution pattern which turned towards clustering was significant in two (Logo and Gboko) out of the three local government areas, consequent of the regional differences brought about by political zonation and tribal differences in the state. One (Obi) out of the three Local Government areas had a dispersed pattern of schools distribution. This shows the variation of the school patterns found in the study area. These varied and heterogeneous patterns of school distribution in the area leads to the uneven nature of school distribution across the area. The Findings conform to prior researches that have identified random pattern of distribution of secondary schools in other parts of Nigeria (Olawole *et al*, 2015).

The study further revealed that there was deficiency in the distribution of secondary schools among the districts (Figure 5). Some districts are over serviced; others are under serviced while others are completely neglected. This indicates that the secondary schools are inadequate and unevenly distributed in the districts. Thus, there is no equity and equality in the patterns of school distribution found in the area. This result is in agreement with the findings of Khalid and Hamdy (2013) in Kuwait which found uneven distribution of schools and lack of schools in many districts. The disparity in spatial patterns of secondary schools have both positive and negative effects on residents' accessibility levels. Positive for the residents of the more favoured locations, like Mbagbev and Mbanyam in Logo LGA and Township in Gboko LGA, who obviously have higher accessibility potentials (Figure 4). In these locations, the favourable conditions of access can attract more students to secondary school. Alternatively, the residents of the disadvantaged locations like Nenzev, Yonov, Turan and Mbadyuu in Logo LGA and Irabi and Odiapa in Obi LGA which do not have secondary schools, will have to trek long distances to access secondary education (Figure 5). This can discourage students, leading to truancy and high dropout rates among the youth in the area. The uneducated youths will be left

ANALYSIS OF THE SPATIAL PATTERNS OF SECONDARY SCHOOLS IN THE SENATORIAL ZONES OF BENUE STATE, NIGERIA

with little or no option than to indulge in social vices and their attendant consequences on the society as a long term effect of the distribution patterns found in the areas.

This result implies that, any further decision to allocate or create new secondary schools in the study area must first favour Obi and Logo Local Government Areas, since Gboko has the highest number of Secondary Schools. To

intensify efforts towards allocation of schools in the Local Government Areas, policies should be made for the government to either create more schools in the Local Government Areas or relocate the existing schools from the over serviced districts to the disadvantaged areas. This is to ensure that there is equity and equality in the distribution of secondary schools across the districts in the Local Government areas.

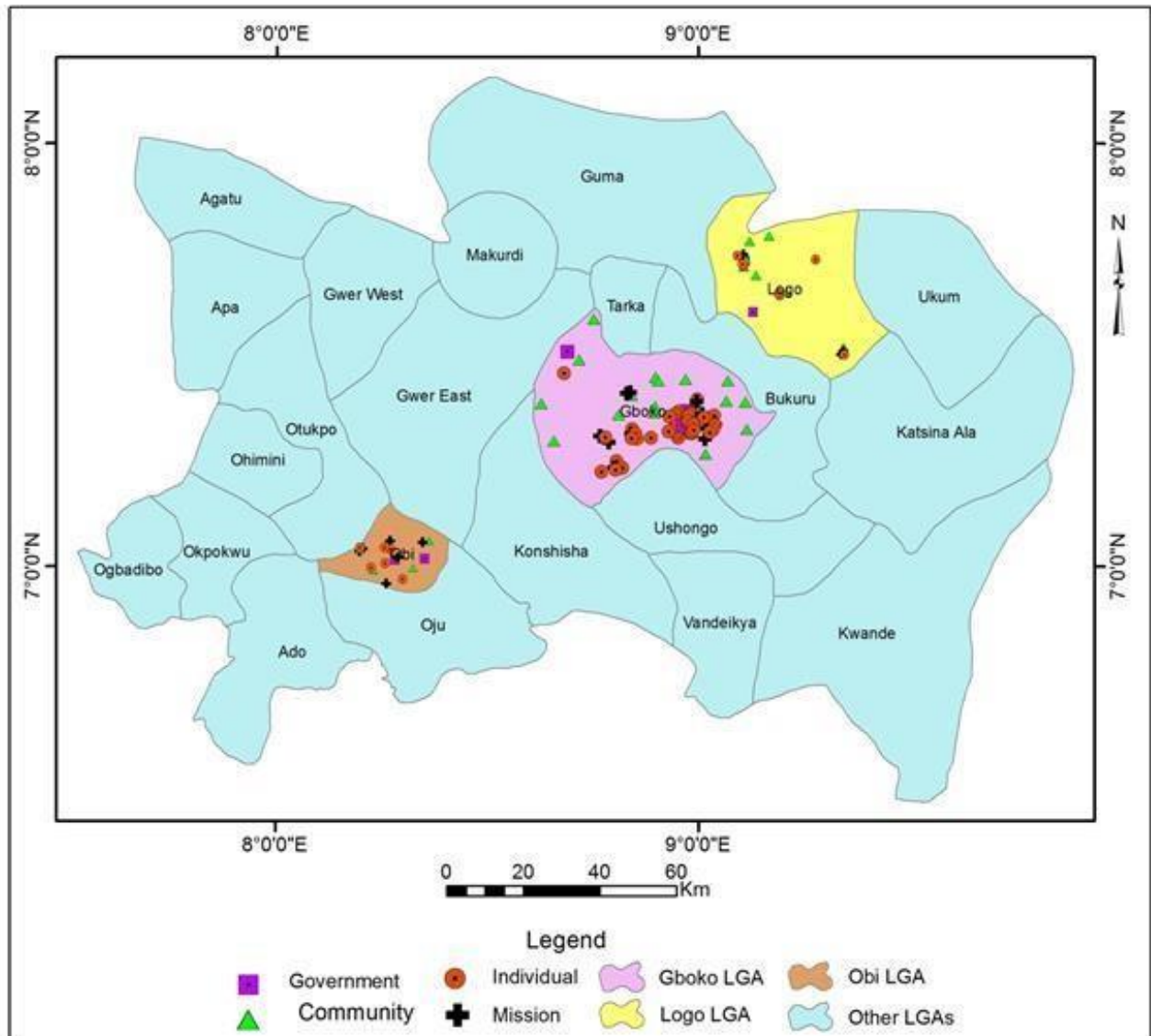


Figure 3 Spatial Patterns of Secondary Schools in Logo, Gboko and Obi LGAs, Benue State

ANALYSIS OF THE SPATIAL PATTERNS OF SECONDARY SCHOOLS IN THE SENATORIAL ZONES OF BENUE STATE, NIGERIA

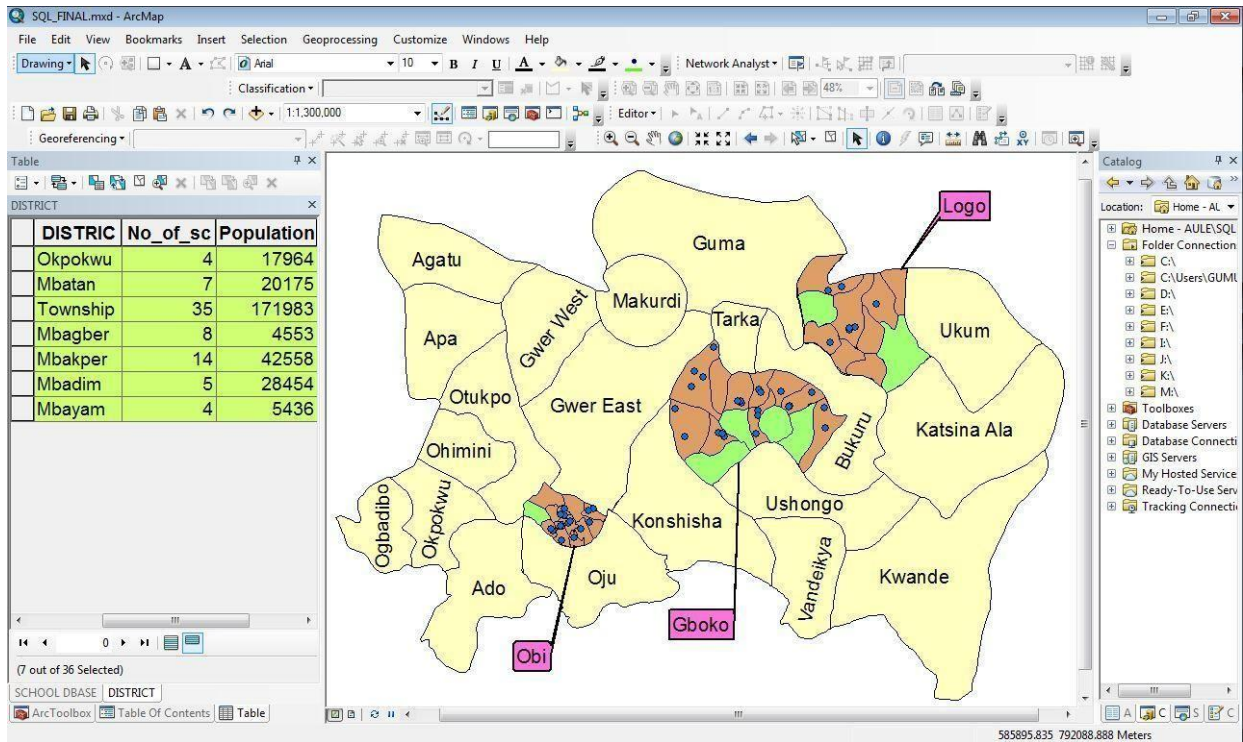


Figure 4 Spatial Query showing all the Districts with more than 3 Secondary Schools

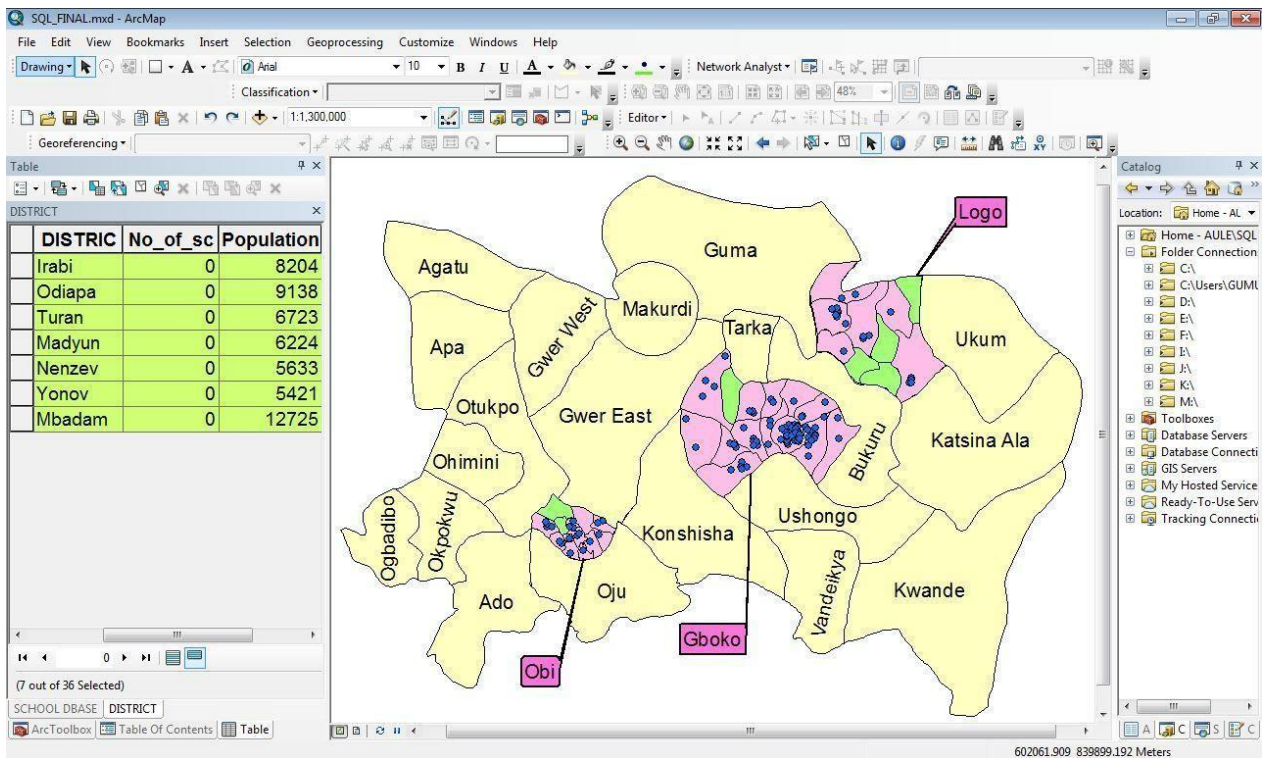


Figure 5 Spatial Query showing all the Districts without Secondary Schools

CONCLUSION

This research has been able to demonstrate the dynamic capabilities of Geographic Information System (GIS) applications and Global Positioning System (GPS) in carrying out spatial analysis. The study has shown how GIS approaches can be used to provide a descriptive analysis of spatial locations and spatial distribution patterns.

The study revealed that the secondary schools in the Selected Local Government Areas of Benue State were unevenly distributed. This implies that most students would find it stressful travelling through long distances to school. This may result to inconsistent school attendance and poor performances. Some students may end up as dropouts, others as perpetual late comers.

Since these patterns have been influenced by: the major stakeholders to secondary school; the interest of the residents in education and development; the settlement patterns obtained in the Local Government Areas; it is recommended that further research be conducted to create an updateable map and database of the schools in the study area, .

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RESIDENTS' PERCEPTION OF THE IMPACT OF FLOOD IN SHIMANKAR RIVER BASIN, SHENDAM LGA OF PLATEAU STATE.

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Abstract

A flood disaster is an unforeseen and sudden event that causes damage to physical infrastructure, destroys lives and properties as well as induces human suffering. This study aimed at assessing the impact of floods on the environment and the livelihood of people in Shimankar River Basin in Shendam Local government Area of Plateau State. To achieve this, relevant data were collected by field observations, interviews, and self-administered questionnaires. A total of 189 respondents were chosen from seven (7) communities residing close to the river channel by probability random sampling. Microsoft excel was employed in creating a database used for descriptive and inferential statistics. The result obtained showed that 73.5% of respondents were self-employed and a little above half of the population (50.8%) were aged between 40 and 59 years. The marital status of the respondents reveals that most were married, with an average monthly income of between ₦25,000 and ₦ 40,000. The finding also revealed evidences that yearly floods has occurred from 2006 to 2016; with 2012 flood year being the worst. The result also revealed that flood impact on livelihood was worst on agrarian-based livelihoods (crop, livestock and Fish farming) while its impact on infrastructures was across all sections except on communication masts. The findings further revealed that 10% of all building types collapsed due to floodings and 50% of the collapsed buildings were of the traditional housing types. Healthwise, Cholera/Diarrhea, Malaria, Typhoid and Bilharziasis with 28%, 17%, 13%, and 10% response, respectively, were at the fore of diseases associated with floods. The study hypothesised that there is no significant difference in the coping strategies adopted by the studied communities. The One Sample t-Test parametric statistics was adopted to test the hypothesis that there is no significant difference in coping strategies adopted by the communities in the river basin. These results confirm the assertion that there is significant difference in the coping strategies with all p-values being less than 0.05 Thus, the null hypothesis that there is not is rejected.

Keywords: Impact, Flood, Perception, River basin

INTRODUCTION

Flood impacts have long been recognized as complex and multifaceted. Floods are perhaps the most frequently occurring natural catastrophic event. Its increasing risk due to climate change in combination with an upsurge in population and urbanization of coastal and riverside cities has made the impact of flooding on people and economic assets even more dramatic in poor and developing countries around the globe (Musolino, Ahmadian, & Falconer, 2020; Olemefore and Obasi, 1999). Floods are environmental hazards largely caused by meteorological factors, but very often induced by man's improper utilization or abuse of the physical environment. They are usually associated with heavy losses to life and property,

misery, hardship, diseases, depression and at times famine (Okorie 2010; Nott 2006).

Flooding is a common environmental problem the world over. It occurs when a body of water moves over and above an area of land that is not normally submerged. Anusha & Bharathi, (2020) defines 'flood' as the temporary covering of land by water that is not normally submerged by water. It is a natural consequence of streamflow in a continually changing environment. Sada (1998) views it as an unusually high rate of discharge, often leading to inundation of land adjacent to streams, and it is usually caused by intense or prolonged rainfall. It is also seen as a hydrological phenomenon that results in a sharp increase in water flow or a rising water level that exceeds the capacity of rivers,

lakes, and reservoirs to accept the water (Zhanga, Yuc, Yud, Sid, Fengd, & Caoa, 2018).

The Third World Water Forum: Poverty and Floods held in March 2003 indicated that in recent years, floods had become more frequent and of increasing severity resulting in loss of life, injury, homelessness, damage to infrastructure and environment as well as impacting on other critical sectors such as education and agriculture. Heavy rains experienced in Nigeria recently have resulted in recurrent flash floods and waterlogging in valleys and low-lying areas within the several river systems that traverse the country. Flooding in Nigeria is generally linked to poor urban planning and climate change; with impacts connected to significant economic losses (mainly through destruction of farmlands, social and developmental infrastructure) and economic disruption (notably in oil exploration in the Niger delta, traffic congestion in many cities, disruption in telecommunication and power supply) (Nkwunonwo, 2016, Ologunorisa 2006).

Floods have benefits but also have many detrimental impacts on land, plants, animals, and people in general. While many people view flooding as having a solely negative effect, positive things can also result in the aftermath of a flood. According to Zhanga et al (2018), floodings often have significant ecological benefits, such as the deposition of rich and fertile sediments in the land adjoining the river and replenishing groundwater. However, when floods cause economic losses or threaten human survival and social development, they are considered to be "disastrous". Chen, (2002), grouped the impacts of flooding into three viz - Immediate & long-term impacts, Tangible & Intangible impacts, and Positive & Negative impacts. These classifications are not entirely independent of each other rather they are inter-dependent or interwoven upon each other.

The immediate impacts of floods include loss of human life, damage to properties, destruction of crops, loss of livestock, and deterioration of health conditions owing to water-borne diseases (Ajayi, 2012). Others are the weakening of structures like houses and bridges leading to the displacement of people, disruption of business, and infrastructures. Damages to infrastructure also cause long-term impacts, such as disruptions to supplies of clean water,

wastewater treatment, electricity, transport, communication, education, and health, and leave communities economically vulnerable (Bunn & Arthington, 2002). Medically, flood impacts directly on both physical and psychological health, with a strong interaction between the two. The physical health impacts of floods include shock and gastrointestinal illnesses (Holmes, 2008). Other health impacts could be immediate, mid-term, and long term, for example, the immediate health impacts of flooding include drowning, injuries, hypothermia, and animal bite; mid-term health impacts could be the evacuation of patients, loss of health workers, and loss of health infrastructures including essential drugs and supplies. Other medium-term impacts include complications of injuries, infected wounds, poisoning, poor mental health, communicable diseases, and starvation. While the long-term health impacts of flooding include chronic Respiratory diseases, disability, poor mental health, and poverty-related diseases as potential legacies (Baxter, 2001).

The immediate environmental impacts of flooding include the destruction of homes, disruption of roads, rail, and communication lines, and loss of crops and agricultural land. Damage to infrastructure causes long-term impacts such as disruption to supplies of clean water, wastewater treatment, electricity, transport, communication, education, and health. Floods disrupt communication links and infrastructures such as power, roads, and bridges thereby affecting the economy in the long term and delayed on-going development initiatives and political processes. Damage to public infrastructure affects a far greater proportion of the population than those whose homes or businesses are directly inundated by the flood. In particular, flood damage to roads, rail networks, and key transport hubs, such as shipping ports, can have significant impacts on regional and national economies. Mirza, Dixit, and Nishat (2003) reported that flood disasters have different impacts on individuals, households, and communities. People cope in different ways. Those who have the capacity after being hit by a disaster emerge faster while those without such capacity sink deeper into the spiral of impoverishment. Coping strategies include actions such as migration from floods affected

RESIDENTS' PERCEPTION OF THE IMPACT OF FLOOD IN SHIMANKAR RIVER BASIN, SHENDAM LGA OF PLATEAU STATE.

areas, flood forecasting, flood insurance of animals and crops, food stockpiling, providing emergency health services, and building flood shelters. These have, however, not been woven systematically into an approach to achieve security from flooding.

Historically, flooding in Nigeria dates back to the early 1950s with coastal and fluvial floods. According to Adebayo & Oruonye (2012), fluvial floods account for the majority of flood threats experienced in locations along the plains adjoining major rivers in the country, including rivers Niger, Benue, Hadeja, and their tributaries. States, mostly affected by fluvial floods are Adamawa, Kano, Niger, Jigawa, Kaduna, Cross River, and Kebbi. Perhaps the worst fluvial flood in Nigeria before the 2012 event was the Kano state flood disaster of 2006 which affected hundreds of thousands of lives with economic loss in millions of US dollars.

Over the years, Plateau state has had its fair share of flood flickers, but of great significance is the floods on different dates in the months of July, August, and September of 2012. These floods were attributed to heavy rainfalls that lasted several hours, causing massive inundations across nine (9) Local Government Areas namely: Jos North, Kanam, Kanke, Langtang South, Mikang, Pankshin, Qua'anpan, Shendam, and Wase. The ravaging floods washed away houses, farmlands, and livestock. It also caused the death of some persons with an unconfirmed record of those missing. Furthermore, infrastructures such as roads, culverts, bridges, and electric poles were submerged and destroyed. A general high magnitude of displacement of persons was recorded during this period across the affected local government areas (SEMA, 2012).

The River Shimankar which traverses through Shendam LGA of Plateau state is one of

such rivers that overtopped its bank in the recent 2012 floods with attendant impacts. Alex, (2013) gave historical records of floodings in the River Shimankar catchment to dates back as early as 1930, the 1950s, 1970s, and 1990s. Dakul, Mwansat, Mafuyai, Baklit, Laka, & Turshak (2018) reported that flood hazards are the foremost environmental problems confronting farmers within the Shimankar River Basin over several centuries. These flood events have over the years impacted on riparian populace thereby causing various influences (both positive and negative) on the people, their livelihoods, and the environment. Therefore, is a need to investigate the impacts of floods in the river basin with a view to proposing possible solutions to curtailing the adverse effect on the people and the environment. The objectives pursued are to identify livelihood types in the basin, ascertain the impacts of floods and the coping mechanism in place in the basin.

MATERIALS AND METHODS

Study Area

The Shimankar river basin is in a generally low-laying severely flood-prone area. Owing to its geographical location, communities within this basin have a limited capacity to regulate hydrological events because they are rural farmers. Shimankar basin is located in the southern part of Plateau State, Nigeria. The basin has several tributaries rising from the extreme south-east of Jos Plateau to the south, the main Shimankar valley runs from chip in the North to the River Benue at Ibi passing through Shendam area. The basin covers parts of Pankshin, Mikang, Langtang south, Shendam, Qu'anpan Local Government Areas of Plateau State (See fig 1 and 2.)

RESIDENTS' PERCEPTION OF THE IMPACT OF FLOOD IN SHIMANKAR RIVER BASIN, SHENDAM LGA OF PLATEAU STATE.

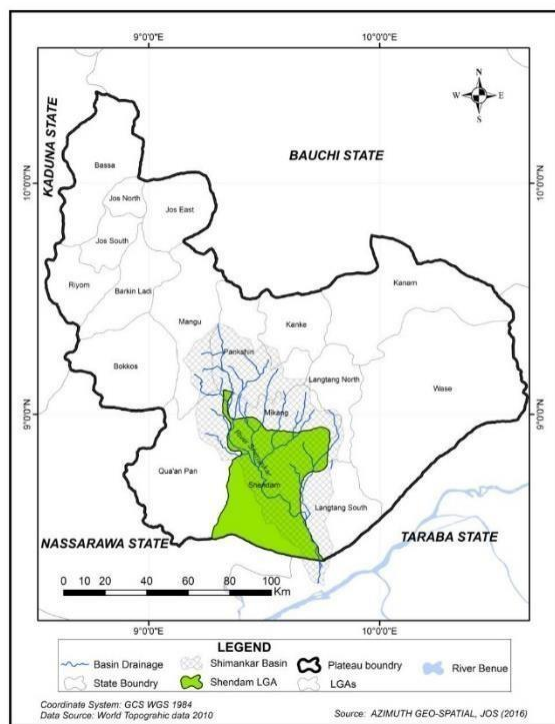


Figure 1 Shimankar Basin, Plateau State

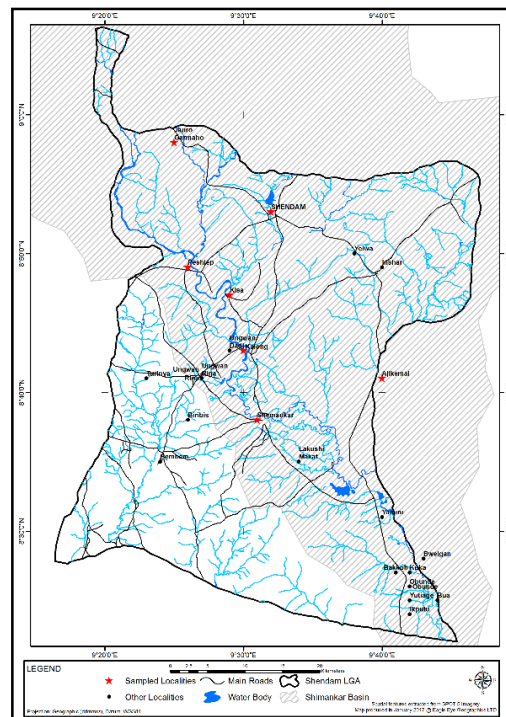


Figure 2 Sampled Communities in Shimankar River Basin, Shendam

Data Collection

To achieve the aim of the study, data was generated using the following; field observation, interview, self-administered questionnaire, and focus group discussion. Seven (7) communities close to the river channel (Jaurogarhamo, Peshiep, Kissakisa, Shendam, Kalong, Shimankar, and Ajikimai) were selected as the study settlements.

A total of 189 copies of a well-structured questionnaire was administered by the researcher with samples chosen by probability a random sampling method. Household heads were the main respondents unless otherwise since they are the main decision-makers in the family and flood impacts are on the entire family and community. The focused group discussion and interview were guided by sets of question checklists of related impacts of flooding on livelihood, physical environment, housing, health facilities, sanitation as well as vulnerable groups and coping strategies. Microsoft excel was employed in creating the database used for descriptive statistics particularly frequency

tables, percentages, and charts while the Chi-square statistical tool was employed to test the stated hypothesis. Satellite imagery of Shimankar River basin was obtained from the remote sensing office in Jos. Also, relevant information relating to flooding was obtained from, journals, textbooks, and the world wide web, as well as unpublished thesis and projects, to support literature.

Sampling Frame

According to Meekyaa (1999), the common rule acceptable to adopt a sample size in any social science research should consist of between 10 to 20 percent of the total population. To this end, a sample size of 15% was adopted for this work. Using the current google earth satellite image for the study communities a total of 1257 buildings were identified, these were assumed to represent a household, a 15% sample size (189 housing forms) was chosen as the sample size. The building count distribution and sample size according to villages are presented in table 1.

Table 1 Distribution of housing forms by communities and sample size

S/N	Settlement	Frequency	Sample size (15%)
1.	Jaurogarhamo	66	10
2.	Peshiep	109	17
3.	Kissakisa	79	12
4.	Shendam	420	63
5.	Kalong	143	21
6.	Shimankar	280	42
7.	Ajikimai	160	24
	Total	1257	189

Source: Field Survey, 2016.

A respondent was selected from each household and given a questionnaire to answer. The adoption of the simple random procedure could be used based on the fact that the population is homogeneous with identical members to represent the entire population regardless of the size of the population.

RESULTS AND DISCUSSION

The study sorts out to ascertain the perception of flood-prone residents in the Shemankar basin on the impacts of floods in the catchment. The impact of floods on the human community is related directly to the location and topography of the area, as well as human demographics and characteristics of the built environment. A hundred percent of the total 189 sample households determined for the study completed the survey. This high percentage response was due to the eagerness of respondents and the resourcefulness of the researcher that allowed for household representatives to respond to the questionnaire on behalf of the household heads where they are not readily available. The result and discussions are as followed:

Sociodemographic Characteristics of Respondents

Socio-demographic characteristics of the respondents including age, gender, and level of educational attainment are presented by descriptive statistics in Table 2. Flood impact depends to a large extent on these variables. The table reveals that no respondent was less than 20 years old, those above 60 years were 20% and between 20-60 years is cumulative of 80%. This distribution is indicative that the sampled respondents were predominantly heads who are

relatively matured in age and therefore, a high possibility of very reliable informed responses. As regards marital status, above 60% of the respondents are married and about 10% are single. This distribution generally shows that there are more married respondents than single, divorced, or widowed and it agrees with the findings of Alex, (2013) that rural household head marital status are mainly married than single, divorced, or widowed. The gender distribution in Shimankar River basin shows that about 80% of respondents are males. This is probably indicative of the fact that in most Nigerian cultures, the men are the primary breadwinners of their households and the decision-makers and agree with the findings of Oluwatayo (2009).

The educational status of respondents will to a great extent determine the perception, vulnerability, and coping strategies that may be adopted by respondents in the catchment. The study found that about half (56.1%) of respondents had obtained secondary education, 22.8% had primary education, 14.3% had no formal education. This distribution reveals that a sizeable number of all the respondents are relatively educated to secondary levels and this could influence their coping and adaptation strategies. Considering the total households occupational types, the results show that households who are self-employed have over 70% of all respondents (with farming having above 60% of the self-employed total); this is expected in a rural setting with primary livelihood type being agrarian and agrees with Babatunde (2008) who states that self-employed is the most remunerative and productive family labor type.

RESIDENTS' PERCEPTION OF THE IMPACT OF FLOOD IN SHIMANKAR RIVER BASIN, SHENDAM LGA OF PLATEAU STATE.

Finally, results on the income distribution of respondents show that 33.3% of the respondents earn an average monthly income of between N25,000 and N 40,000, 23% earn an average monthly income that is less than N18,000, 18.0% have an average monthly income

of between N18,000 and N25,000. However, less than 12% of the respondents earn above N60,000. The income distribution will affect the extent to which respondents' resilience and coping strategy to overcome flood impacts will be harnessed.

Table 2 Demographic characteristics of respondents

Demographics	Frequency	Percentage (%)
Age of Respondent (years)		
Less than 20	00	00.00
21 – 45	86	45.00
46 – 60	66	35.00
Above 60	38	20.00
Total	189	100.00
Marital Status		
Married	120	63.49
Single	20	10.58
Divorced	23	12.17
Widowed	26	13.75
Total	189	100.00
Gender		
Male	152	80.42
Female	37	19.58
Total	189	100.00
Level of Education		
Non-formal	27	14.30
Primary	43	22.80
Secondary	106	56.10
Tertiary	13	6.80
Total	189	100.00
Occupation		
Students	14	7.4
Civil Servant	36	19.1
Self Employed	139	73.5
Total	189	100
Self Employed Types		
Farming	61	44
Trading	34	24
Beer Brewing	27	19
Fishing	17	12
Total	139	100
Monthly Income (₦)		
<18,000	45	23.8
18,000-25,000	34	18.0
26,000-40,000	63	33.3
41,000-60,000	25	13.3
>60,000	22	11.6
Total	189	100

RESIDENTS' PERCEPTION OF THE IMPACT OF FLOOD IN SHIMANKAR RIVER BASIN, SHENDAM LGA OF PLATEAU STATE.

Flood Occurrence: 2006 - 2016

Question asked on flood years in the past 10 years, revealed that each year from 2006 to 2016 had a response count of flood occurrence (Figure 3), however the record for the year 2012 was the highest recording of about 21% of the total response. This is

indicative that respondents experienced floodings in the catchment every year in the past 10 years in at least one location or the other in the catchment; nonetheless, the 2012 event may be adjudged as the most spread and most impactful.

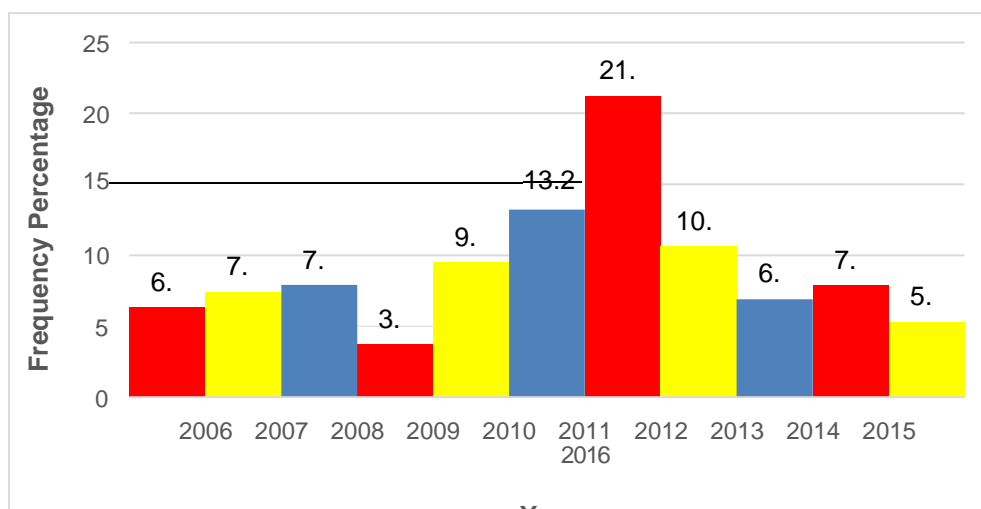


Figure 3 Frequency of Flood Occurrence in Shimankar River Basin (2006 – 2016)
Source: Field Survey, 2016

Causes of Flood in River Shimankar Basin

The causes of floods can be broadly divided into physical, such as climatological forces, and human influences (Nott, 2006). In the Shimankar basin, respondents perception of the cause of floods in table 3 revealed that the highest percentage response of 68.3 % was attributed to heavy rainfalls, about 23% thought it was due to anthropogenic activities (building and dumping of wastes in waterways), while 8% felt it was due to dam collapse. Heavy rainfalls are physical factors (which are climatic) while anthropogenic factors (which are specifically building on water channels and

dumping of refuse in waterways) have worked in combination to cause floods in the study area. It could be argued that despite the high awareness of respondents on the causes of floodings in the basin, their socioeconomic disposition which is mainly tied to traditional land-based livelihoods strategies has largely contributed to their vulnerability to the menace of floods. Hence one can conclude that the occurrence of flooding in the basin is primarily climate-induced due to heavy rainfalls and anthropogenic due to human activities on waterways.

Table 3 Respondents view on cause of flooding

S/N	Cause of Flood	No of Respondents	Percentage (%)
1	Building close to the water channel	20	10.58
2	Blocking water channel with refuse	25	13.23
3	Dam Collapse	15	7.94
4	A high amount of received rainfall	129	68.25
	Total	189	100

Source: Field Survey, 2016.

RESIDENTS' PERCEPTION OF THE IMPACT OF FLOOD IN SHIMANKAR RIVER BASIN, SHENDAM LGA OF PLATEAU STATE.

Impacts of Flooding on Livelihood

Flooding affects various aspects of our lives. It affects our agriculture systems, trade, transport,

and education amongst others. The impacts of flooding on livelihood were investigated and the results obtained are presented in table 4.

Table 4 Impacts of flooding on livelihood

S/N	Livelihood	No. of Respondents	Percentage (%)
1	Crop Farming	35	19
2	Livestock Farming	26	14
3	Beer Production	19	10
4	Fishing	17	9
5	Trading	15	8
6	Civil Servants	10	5
7	Students	8	4
8	No Impacts	59	31
	Total	189	100

Source: Field Survey, 2016

Findings from the study show that cumulatively about 69% of respondents across the study communities reported that floods affect their livelihood types, while only 31% reported otherwise. Livelihoods impacted include Crop Farming, Livestock Farming, Beer Production, Fishing, Trading, Civil Servants, and Students. Remarks made on types of impacts include flooding of farmlands, washing away of farm produce and stocks (animals and fish), flooding market spaces, and hindering students and civil servants from commuting to their respective points. All these affect productivity and lead to colossal losses of investment and properties.

This finding agrees with Dakul et al (2018), who reported that the problem confronting farmers in the river basin is flooding.

Impact of Flooding on Infrastructures

Flooding impacts on physical infrastructures/facilities like roads, schools, hospitals, communication mast, and water supply system in the sampled communities are as shown in figure 4. About 58% of respondents indicated that their culverts, bridges, drainages, and feeder roads were washed away, on the contrary, 41% said these infrastructures were submerged by floods.

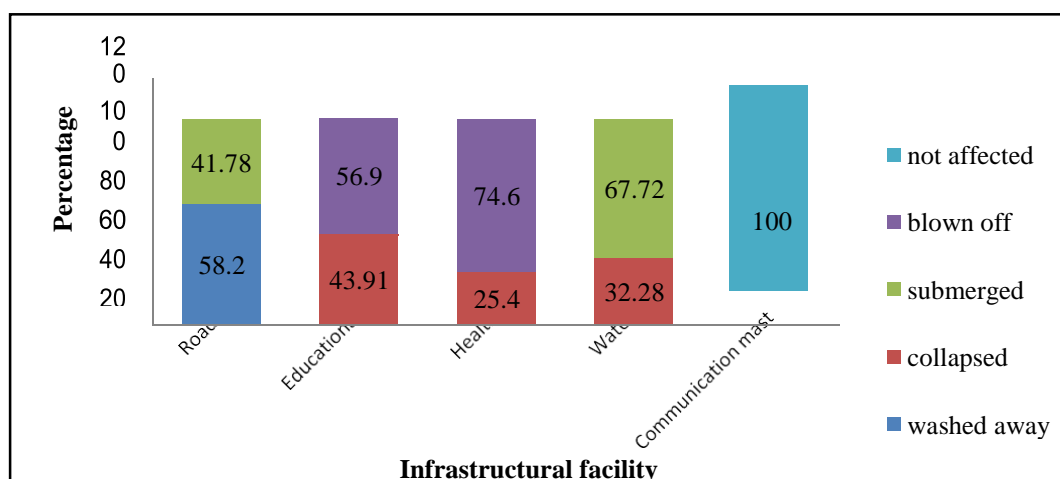


Figure 4 Effect on Infrastructural Facilities

Source: Field Survey, 2016

The implication of this is that evacuation of farm products distribution of

finished goods and passenger flow which all have enormous socioeconomic implications

RESIDENTS' PERCEPTION OF THE IMPACT OF FLOOD IN SHIMANKAR RIVER BASIN, SHENDAM LGA OF PLATEAU STATE.

will be drastically reduces because most of the rural roads that connect the settlements are either washed away or submerged, this agrees with Abubakar, Umar, Barde, and Adamu (2020).

Other infrastructures flooded show that about 74% of the respondents indicated that their health facilities had their rooftops blown-off while 25% had the health building collapsed, 67% said their local wells and other sources of water were submerged by floods while about 33% of the respondents indicated that there different sources of water collapsed

due to the excessive floods. The study further indicated that only communication masts that were in the area did not experience any severe effects of the flood.

Impacts of Flooding on Housing

Question asked on the housing types found in the study area revealed that among the 189 sampled households in the basin, about 60% live in traditional housing type, 25% live in modern housing type while 15% live in houses that have mixed attributes of both traditional and modern (Table 5)

Table 5 Housing types distribution type of respondents in shimankar river basin

S/N	Housing Type	Frequency	Percentage (%)
1	Traditional/Modern	30	15.87
2	Modern	46	24.34
3	Traditional	113	59.79
	Total	189	100

Source: Field Survey, 2016

This finding shows that settlements in the Shimankar River Basin are still very much rural with a large percentage of mud houses and thatched roofs and would be easily affected by floods. Further analysis on the nature of flood on these buildings (table 6) revealed that 9.5% of the respondents indicated that their houses or

part of their buildings had collapsed, 41% responded that their buildings got soaked, 17% said they buildings were stained but 32% said their walls peeled off. Of the total buildings which collapsed, 50% were of the traditional types.

Table 6 Cross tabulation between nature of flood impact and housing type

Housing type	Traditional	Modern	Mixed	Total	%
Collapsed	9	3	6	18	10
Soaked	46	22	10	78	41
Stained	8	20	5	33	17
Walls Peeled off	38	13	9	60	32
Total	101	58	30	189	100
%	53	31	16	100	

Source: Field Survey, 2016

RESIDENTS' PERCEPTION OF THE IMPACT OF FLOOD IN SHIMANKAR RIVER BASIN, SHENDAM LGA OF PLATEAU STATE.

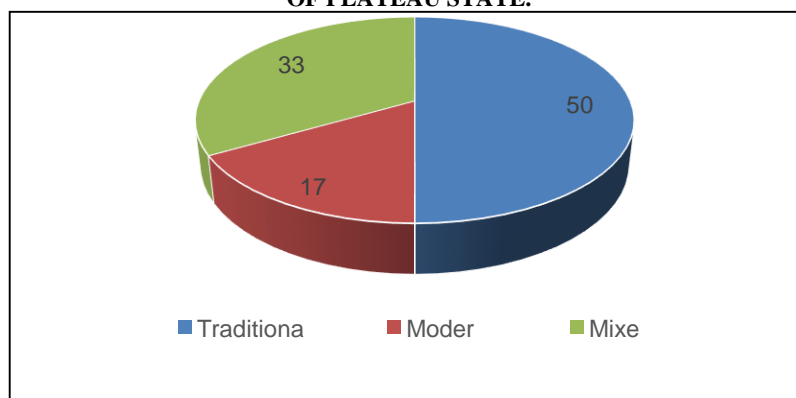


Figure 5 Distribution of Collapsed Building Type

Flooding and Diseases

Respondents were asked to identify at least two common diseases they experienced as a result of flooding in the catchment. The result obtained is summarized in table 7. The study

reveals that Cholera/Diarrhea, Malaria Fever, Typhoid fever and Bilharzia with 28%, 17%, 13%, and 10% response respectively. The least is Schistosomiasis and Rheumatism with 3% each.

Table 7 Distribution of respondents by flood related diseases

SN	Disease	Frequency	Percentage (%)
1	Bilharzia	38	10
2	Cholera/Diarrhea	107	28
3	Cough	21	6
4	Dermatological problems	13	3
5	High Blood Pressure	29	8
6	Malaria Fever	65	17
7	Measles	30	8
8	Rheumatism	13	3
9	Schistosomiasis	13	3
10	Typhoid fever	50	13
	Total	379	100

Source: Field Survey, 2016

This agrees with Du, FitzGerald, Clark & Hou (2010), who alluded to the fact that indirect consequences of floods are those associated with the damage done to the water in the natural and built environment to include infectious diseases. This is also supported by Olanrewaju, Chitakira, Olanrewaju, & Louw, (2019) that the most common waterborne pathogen isolated after floodings causes cholera and watery diarrhea.

Flood Coping Strategies

A survey of the major coping strategies put in place by respondents in the study settlements was conducted and the findings are summarized in table 8. This revealed that about 33% of

respondents got assistance from family and friends, 23% collect loans from cooperatives/banks, while 19% relied on government intervention. About 6% said they had no coping strategies but just to rely on God. This is in tandem with Olanrewaju C, Chitakira, Olanrewaju O, & Louw, (2019) who acknowledged that help from Government and NGOs are meant to be readily available immediately after a flood disaster, but they are often left unattended for a long period.

Testing Hypothesis

It was viewed that communities would exhibit different coping strategies to mitigate against flood effects and so it was hypothesized that there is no significant difference in coping

RESIDENTS' PERCEPTION OF THE IMPACT OF FLOOD IN SHIMANKAR RIVER BASIN, SHENDAM LGA OF PLATEAU STATE.

strategies adopted by the communities in the river basin.

The One Sample t-Test parametric statistics was applied on data in Table 8 and results presented in Table 9. Getting assistance from family and friends produced the highest

mean and standard deviation values of 8.86 and 8.153 respectively. The lowest mean and standard deviation values were recorded on the coping strategy that it was in God's hands, thus there was no need for any strategy.

Table 8 Flood coping strategies at Shimankar catchment area

Community	GAFF	%	USB	%	CL	%	CCD	%	NS	%	GI	%	Total	Total %
Shendam	23	35	13	20	9	14	4	6	1	2	14	21	66	100
Shimankar	18	43	10	24	5	12	2	5	2	5	5	12	42	100
Ajikimai	6	32	7	37	2	11	2	11	2	11	0	0	19	100
Kalong	5	23	4	18	4	18	1	5	1	5	7	32	22	100
Peshiep	4	21	4	21	2	11	2	11	3	16	5	26	19	100
Kissakisa	3	30	3	30	2	20	0	0	0	0	2	20	10	100
Jaurogarhamo	3	27	2	18	2	18	1	9	2	18	2	18	11	100
Basin Total	62	33	43	23	26	14	12	6	11	6	35	19	189	100

GAFF: Getting assistance from family and friends; USB: Use of sandbags; CL: Collect loans; CCD: Construction and cleaning of drainages; NS: No strategy; GI: Govt or NGO intervention
Source: Field Survey, 2016.

Furthermore, the test for differences showed that there was a significant difference in the coping strategies adopted by all the communities in the river basin (GAFF, $P = 0.028 < 0.05$; USB, $P = 0.007 < 0.05$; CL, $P = 0.010 < 0.05$; CCD, $P = 0.011 < 0.05$; NS, $P =$

$0.005 < 0.05$; and GI, $P = 0.029 < 0.05$). These results confirm the assertion that there is significant difference in the coping strategies in all the communities in the river basin. Thus, the null hypothesis that there is not is rejected.

Table 9 One sample t test statistic result

Strategy	N	Mean	Std. Deviation	Std. Error Mean
GAFF	7	8.86	8.153	3.082
USB	7	6.14	4.059	1.534
CL	7	3.71	2.628	.993
CCD	7	1.71	1.254	.474
NS	7	1.57	.976	.369
GI	7	5.00	4.619	1.746

Strategy	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
					Test Value = 0	
GAFF	2.874	6	.028	8.857	1.32	16.40
USB	4.004	6	.007	6.143	2.39	9.90
CL	3.740	6	.010	3.714	1.28	6.14
CCD	3.618	6	.011	1.714	.55	2.87
NS	4.260	6	.005	1.571	.67	2.47
GI	2.864	6	.029	5.000	.73	9.27

RESIDENTS' PERCEPTION OF THE IMPACT OF FLOOD IN SHIMANKAR RIVER BASIN, SHENDAM LGA OF PLATEAU STATE.

CONCLUSION

The study revealed that the settlements studied are predominantly rural and experience persistent floods. The Floods have led to an alteration in livelihood patterns and sources, destruction of infrastructures to include houses, roads, schools, and hospitals, thus affecting the general well-being of the people. A wide range of diseases are being experienced in the area with Diarrhea and Malaria Fever being at the fore, others are Bilharzia, Cholera, Cough, and typhoid fever which are exacerbated from stagnant and polluted aftermath of the floods for drinking water. The nature of housing types in the study puts traditional housing types as predominant and mostly affected by floods. The damage is linked directly to the inundation depth and vulnerability of the building represented the quality of materials the building is made from. All these have in the long run destroyed infrastructures, livelihoods, and increased the poverty levels experienced within the study area. The research also revealed that households cope differently when affected by floods. The current coping strategies being employed by most households are not very effective because they had been using them and yet the situation did not improve.

Sequel to the above findings, some policy considerations for the management of floods' include:

- (1) Government and key stakeholders should engage communities to move permanently to higher grounds with the provision of all the necessary social-amenities, and agriculture support for not less than three (3) years.
- (2) Structural controls to include channelization and earth dams should be considered.
- (3) In the long term, community-based floods early warning systems implemented.
- (4) There is a need for a massive campaign against dumping of refuse in the drainage system.
- (5) Flood policies should be enacted and implemented at community levels.

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ASSESSING SOLID WASTE MANAGEMENT AND ENVIRONMENTAL SUSTAINABILITY IN LOKOJA, NIGERIA

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Abstract

Waste management has become a common issue of discourse among individuals, groups and governments. This study which assessed urban solid waste management in Kogi state with focus on Lokoja urban specifically sought to find out why indiscriminate solid waste disposal/dumps has persisted in Lokoja urban, investigate the measures put in place to curtail the tide and ascertain the extent to which indiscriminate waste disposal affects people's health and environment. Two null hypotheses were formulated and Human Capital Theory was adopted as the theoretical framework. The study used survey design whereby data were collected from the sample considered to be representative of the population. Taro Yameni's formula was applied to reduce the initial population of 195,261 to a smaller researchable size of 399 while data were collected through structured questionnaire. The data collected were presented in tables containing frequencies of the responses and their corresponding percentages. The two hypotheses of the study were tested using chi-square (X^2) statistical tool and the result of the analyses revealed that: there is currently no government approved dumpsites in Lokoja metropolis, most communicable diseases are contracted from dirty environment, among others. The implications are that most households will soon be cut off by flood arising from the blockage of water channels, some streets and roads will be blocked by heaps of wastes and more epidemics will be contracted by the people if nothing urgent was done. The study concluded that, the Kogi State Environmental Protection Agency (KGSEPA) currently have no required manpower, technical skills and competences to curtail the tide of waste and therefore made the following recommendations: Kogi state government should strengthen the already established departments of Environmental in Kogi State polytechnic (KSP) and the School of Health Technology, Iddah, by providing and equipping them with modern waste management equipment for students to be exposed to practical methods of waste management, Government should contract foreign-based private firm through Public-Private-Partnership (PPP) arrangement to establish waste management industry in Kogi state, immediate provision of permanent waste dumpsites by the government, among others.

Keywords: Environment, Sustainability, Waste management, Lokoja

INTRODUCTION

Waste often generated by human beings since time immemorial has continued to be a threatening problem and a growing one that is of major concern to every nation of the world. In Nigeria today, among the pressing environmental and public health issues are the problems of solid waste generation, control and disposal. Although the problem of solid waste disposal is as old as man's existence that is inextricably linked to the generation of waste, the truth is that in many cities, it has become so intractable that even the government is overwhelmed (Jimoh, 2005, Momodu, Dimuna and Dimuna, 2011). Waste in the words of Douglas (2004) is any unwanted and discarded material that arises from the activities of humans and animals on earth. For Onwughara,

Nnorom and Kanno (2010), Urban Solid Waste (USW) covers a broad range of materials including garbage, refuse from factories, commercial refuse, construction and demolition debris, dead animals and abandoned vehicles, food particles, plastics, bottles, polythene material (nylon bag), metallic objects, furniture/wood material, paper and some other unclassified wastes. Rodgers (2011) submits that waste management is a systematic control of the generation, storage, collection, transportation, separation, processing, recovery and disposal of waste. In pre-industrial times, when population was small, waste was disposed on the ground, thrown into water, burnt or thrown into pit where it would turn to compost manure to improve soil fertility. From history, man is believed to have always adopted

dumping, burning, manual recycling and waste minimization as waste management strategies with less than proportionate result in terms of cleaner and healthier environment. One can therefore say that human development or growth has been intrinsically tied to the management of waste, apparently due to its effects on public and environmental health, (Chukwuemeka, Ugwu and Igwegbe, 2012, and Ndinwa, Akpafun and Chukwuma, 2012).

Today, due to rapid industrialization, increase in population and urbanization, the generation, disposal or management of waste has proved to be a major environmental and public health issue. This experience is always so, especially in developing countries like Nigeria where there is lack of or inappropriate strategies for managing wastes. Urban waste management today has become an intractable environmental problem that can be likened to a monster staring everybody on the face. Solid waste dumps apart from its gory sight that destroy the aesthetics (beauty) of the environment have always affected the people's health by decomposing to produce provoking odour or contaminating our drinking water. This no doubt, causes avoidable epidemics. This was what promoted the federal government of Nigeria to promulgate decree 58 for the establishment of Federal Environmental Protection Agency (FEPA) on 30th December, 1988 (Momodu et al (2011). A National Policy on the Environment was also formed to secure for all Nigerians a quality of environment adequate for their health and well-being. He submitted that in spite of the formulation of FEPA and a national environmental policy, the environment has not been adequately protected. It should be recalled that, prior to the creation of Kogi state in 1991, Lokoja urban was faced with myriad of environmental problems ranging from inadequate environmental education and awareness campaign to poor personal and environmental hygiene. Every street was adorned with heaps of refuse while Niger and Benue rivers, in Lokoja urban were converted to dumping arena for domestic wastes and human excreta. It was in response to the foregoing realities in Kogi State upon its creation in 1991 that prompted the government to set up the Kogi State Environmental Protection Agency (KGSEPA) on 6th

December, 1995, to clean, protect and conserve the environment.

While it cannot be denied that for quite some time, Kogi State Environmental Protection Agency(KGSEPA) as a state government agency has always embarked on some routine clearance of wastes, especially in the capital city (daily, weekly and monthly), provision of plastic dustbins for waste collection and evacuation, stationing of waste collection trucks in strategic places within the metropolis and its suburbs, house-to-house sanitary inspection and waste collection, the intractable nature of urban wastes always noticeable in Lokoja urban leaves much to be desired especially as the local government whose constitutional responsibility it is to properly dispose and control these wastes, have been doing nothing. This has been why the commonly repeated experience is a simple transfer of refuse from one point to another in open trucks to some undesignated sites where they are either burnt or buried (Onwughara et al, 2010 and, Nkwede and Nwuzor, 2015).

The problem of solid waste generation, control, especially, disposal or simply, management, has continued to be a threatening global and environmental health issue but more pronounced in developing countries like Nigeria. In fact, Nigeria's major urban centres including Lokoja are today grappling with the problems caused by indiscriminate heaps of solid wastes from the environment. This is despite the continuous government and individual efforts including daily, weekly or monthly environmental sanitation. Waste disposal habit of the people, lack of experienced and skilled manpower, inadequate/lack of modern plant and equipment, among others, militate against any waste management effort/strategy in Nigeria, particularly in Kogi State metropolis (Lokoja urban). The failure of relevant agencies to stem the tide of reckless waste dumping and littering of our capital city and surrounding bushes indicate a clear pattern of non-enforcement or non/poor implementation of existing environmental sanitation laws (Momodu et al 2011). Unfortunately too, the concerned local governments whose constitutional responsibility it is to properly collect and dispose of these wastes (refuse) have either forgotten or consciously neglected their duties.

Residents of Lokoja urban are today apprehensive of epidemic outbreak as refuse takes over the metropolis. Indeed, heaps of refuse have become common sights along major roads, streets, common markets and at bus stops within the state capital prompting residents to express fear that the situation can lead to an avoidable epidemic outbreak if urgent steps were not taken by relevant stakeholders to ameliorate the situation. Although Kogi State government has always claimed to have imported some machines to be used in waste management including promising and paying the contractors on actuality bases, the truth is that such machines/equipment if any, have not been seen to be doing anything especially as there is still no matching manpower skills and intelligence to manipulate them even among the Kogi State Environmental Protection Agency (KGSEPA) staff as the agency is statutorily and structurally deficient in that regard.

Therefore, the persistent increase in the number of indiscriminate solid waste disposal/dumps despite the provision of the customized Kogi State Environmental Protection Agency (KGSEPA) waste bins/stationary trucks which has continued to affect people's health and environment in Lokoja urban without any concrete management strategy in place necessitated this research. The broad objective of the study was to assess waste management in Lokoja urban. Specifically, the study sought to:

- Find out why the number of indiscriminate solid waste disposal/dumps has continued to increase in Lokoja urban despite the provisions of the customized Kogi State Environmental Protection Agency (KGSEPA) waste bins/stationary trucks.
- Investigate measures already put in place to ensure that the Kogi State Environmental Protection Agency (KGSEPA) equipment curtail the tide of indiscriminate solid waste dumps in Lokoja urban.
- Ascertain the extent to which indiscriminate solid waste disposal/dumps have contributed to health complications suffered by the people in Lokoja urban.
- Ascertain the number of ways in which indiscriminate solid waste disposal/dumps affect the Lokoja urban environment.

The Concept of Waste Management

The concept of waste management has attracted a lot of attention from researchers, scholars and the general public. In Nigeria today, the issue is so burning that the government seem to be helpless on the best alternative measure or strategy to be adopted to curtail the tide of waste. This is because, apart from the horror sights that these wastes create in our urban centers, their negative health and environmental consequences (effects) are always far-reaching. "With the advent of industrial revolution, waste management became a critical issue. This was owing to the increase in population and massive shifts in population from rural areas to industrial towns and cities during mid-18th century. There was a consequent increase in industrial and domestic wastes posing threat to human health and environment".

However, the submissions of Chukwuemeka and others that increased urbanizations and industrialization were the major causes of waste management challenges, were vehemently criticized by Adejobi and Olorunnimbe, 2012, Tobore, 2013 and Attah (2013) when they argued that the volume of waste generated do not actually constitute the major environmental problem but rather, the inability of governments, individuals and waste management/disposal agencies to keep up with the task of proper and efficient management of waste. This also is defective in that it lacks specificity on how or where government should concentrate. Waste management simply means the collection, keeping, treatment and disposal of waste in such a way as to render them harmless to human life and the environment in general, Attah (2013). He went further to conceptualize waste management to be the organized and systematic dumping and channeling of waste through or into landfills or pathways to ensure that they are disposed off with attention to acceptable public health and environmental safeguard. He concluded that proper waste management will result in the abatement or total elimination of pollution. Attah understands of waste management to mean a situation where waste is removed in such a way as to avoid its health and environmental harm, has some elements of truth but one-sided.

This is because, disposal or evacuation as his definition suggests, is only an aspect of management. Burning, burying and the likes, reduce the health and environmental effects of waste, but they are not complete management in themselves since waste is said to be managed if apart from the foregoing, it is utilized to serve another purpose or add marginal utility. Rodgers (2011), quoted in Chukwuemeka et al (2012), contends that waste management is a systematic control of generation, storage, collection, transportation, separation, processing, recovery and disposal of solid waste. This definition address critical processes of solid waste management but, it is selective as the only emphasis is on solid waste. It should be noted that other wastes including liquid and gas can be converted or managed to serve valuable uses.

Waste must not always be seen as something that is completely valueless or rubbish that must be discarded, but as something which when properly managed can create wealth. In line with this, Nwude, Igboro, Umar and Okuofu (2006:85), advised that: "Waste should not be regarded as something to be thrown away or disposed off, but as raw material. So, like the biosphere, all wastes generated by industries or consumers should be put back into the industrial economy as much as possible. This is what recycling or management is all about. Sridhar (2006), in agreement with Nwude et al, noted that waste management is at once a technical, cultural and financial problem and so involves various steps including; collection, transportation and recycling. To him, this will help in waste minimization or reduction. It should be noted that waste recycling as a strategy for waste management, will as much as possible guarantee waste to wealth options.

It is timely to point out that waste management is an aspect of environmental management or sustainability which can be interpreted as a conscious and systematic effort by one or more persons acting in concert to produce an aesthetically pleasing, economically viable and physically healthy environment. This may be why Oyediran (1997), defined waste management as the collection, transportation, storage, treatment and disposal of wastes including the after care of the disposal site. It also comprises all

administrative, financial, legal and planning functions, as well as, the physical aspects of solid waste handling. For us, waste management is a calculated, conscious and timely efforts made through variety of measures/techniques or strategies by individuals group(s), agency or government to effectively generate, sort and dispose waste for better uses and still preserve and protect the people's health and environment. Simply put, waste management implies any strategy or method that will nip waste in the bud by eliminating its harmful effects and making it useful to man.

Types of Solid Waste

Solid wastes are classified into different types depending on their sources namely, household generated waste, known as municipal waste. Industrial waste is described as hazardous waste, while waste generated in the hospital is termed infectious waste. Oreyomi (2005) classified solid waste as combustible items such as cartons, boxes, plastic, clothing etc. And non-combustible articles such as cans, ashes, glass, metals, furniture and bathtubs etc. Oreyomi (2005) further observed that garbage denotes waste resulting from growing, handling, preparation and consumption of food. It attracts and breeds flies and other insects, tats and it emits odour. Rubbish comprises of combustible and non-combustible items such as papers, plastic, cans and glass, while industrial wastes are sawdust, paper and iron. Agricultural wastes are wastes originating from agricultural products such as corncob, banana stub, skin and leaves etc.

Efforts towards Waste Management in Nigeria

If there is any problem in which both the government and individuals are tired of, confused and losing sleep about in Nigeria, it is squarely and mainly that of environmental wastes. Nigeria's major urban centers are today fighting to clear mounting heaps of solid wastes from their environments. Nigerian government since independence has been mapping out strategies making different efforts towards curtailing the tides of the ever increasing wastes in its urban centers but with little or no appreciable results. The Nigerian government being aware of the need for high quality urban

environment accordingly made bold attempts at improving urban environmental management. In the first place, Nigeria is committed to a national policy that ensures sustainable development based on proper management of the environment in order to meet the needs of the present and future generations (Federal Republic of Nigeria, 1990). To achieve this laudable objective, the Federal Environmental Protection Agency (FEPA) was established in 1988 and was charged with the responsibility of setting, monitoring and enforcing national environmental quality standards (Madu, 2001). It was also authorized to handle all forms of environmental problems and formulate policies dealing with them (FEPA 1989 cited in Madu, 2001).

FEPA has now been scrapped and its activities incorporated in the Ministry of Environment. Dimuna (2004:132) noted that: Specifically, the national guidelines and standards for environmental pollution and control of 1991 and the pollution abatement in industries and facilities generating waste regulation also of 1991 stipulate guidelines for the design, construction, maintenance and operation of landfill and the requirements for landfill permit. On the other hand, the Environmental Impact Assessment (EIA) decree 86 of 1992 makes it mandatory for new major projects (including waste disposal facilities) to undertake EIA. Some states including Kogi, have implemented the monthly clean up exercises to the later including setting up mobile environmental courts to try defaulters but our urban cities have been overwhelmed by indiscriminate wastes. Kogi state governments through KGSEPA has gone to the extent of contracting some private firms with the mandate of ride of the city of wastes and are being paid on actuality basis. The foregoing are evidences that Nigerian government at all levels have not been sleeping on duty in trying to keep the environment clean. The various planning and policy documents in Nigeria show that sufficient attention has been given to environmental policies and programmes and so, the persistent problem of environmental deterioration in the country must therefore be explained by the wide gap existing between policy goals and achievements. In every state for instance, there are state environmental protection agencies

whose mandate it is to ensure clean and healthy environment for all inhabitants. In Kogi state, the agency is known as the Kogi State Environmental Protection Agency (KGSEPA).

MATERIALS AND METHODS

Study Area

Lokoja is located in the western part of Kogi state of Nigeria surrounded by river Niger and Benue forming confluence from where the name is derived. Lokoja is located in the Guinea savanna zone of Nigeria, within longitude $06^{\circ} 57' E - 06^{\circ} 63' E$ and latitude $07^{\circ} 74' N - 07^{\circ} 79' N$ (Longman, 2000).

The North-east distance of the confluence is about 104 km while from the east to the west; it stretches for about 78 km to Jamata. The confluence covers an area of about 6,400 km² (Oyebanji, 1993). The location of the confluence in Nigeria is within latitude $8^{\circ} 28' E$ and $10^{\circ} 02' E$. Within this area, Lokoja metropolis lies on latitude $9^{\circ} 52' N$ and longitude $8^{\circ} 50' E$,

Lokoja town has two seasons, the wet and the dry seasons, with two maximal rainfalls between April-October and the dry season between November-March. The highest peak of the rain is between July and September. Lokoja area is hot, average daily temperatures range from $24^{\circ} C$ to $36^{\circ} C$. The hottest months are February to April. In the latter month, temperature used to drop to below $24^{\circ} C$ and relative humidity as high as 60%. In the period of cool November to January, temperature drop to $18^{\circ} C$ and rise again to $24^{\circ} C$ during the rainy season around May to September. The average annual rainfall is about 158 cm (1540 mm). The wet season started in April and terminates in October while the dry season lasts from November to March. (Olaniran, 2002).

The vegetation of Lokoja is Guinea savanna type. It is vegetation that made up of scattered deciduous trees and grasses forming the lower stratum. The savanna here is modified by relief thus, the trees are fewer and the grasses are longer than those of the adjoining villages, but the vegetation does not form a true montane plant cover (Adefolalu, 1990). Because of land water cover, over cultivation and grazing, only relics of the original vegetation still remain especially areas far from the city (Adejuwon, 1999).

ASSESSING SOLID WASTE MANAGEMENT AND ENVIRONMENTAL SUSTAINABILITY IN LOKOJA, NIGERIA

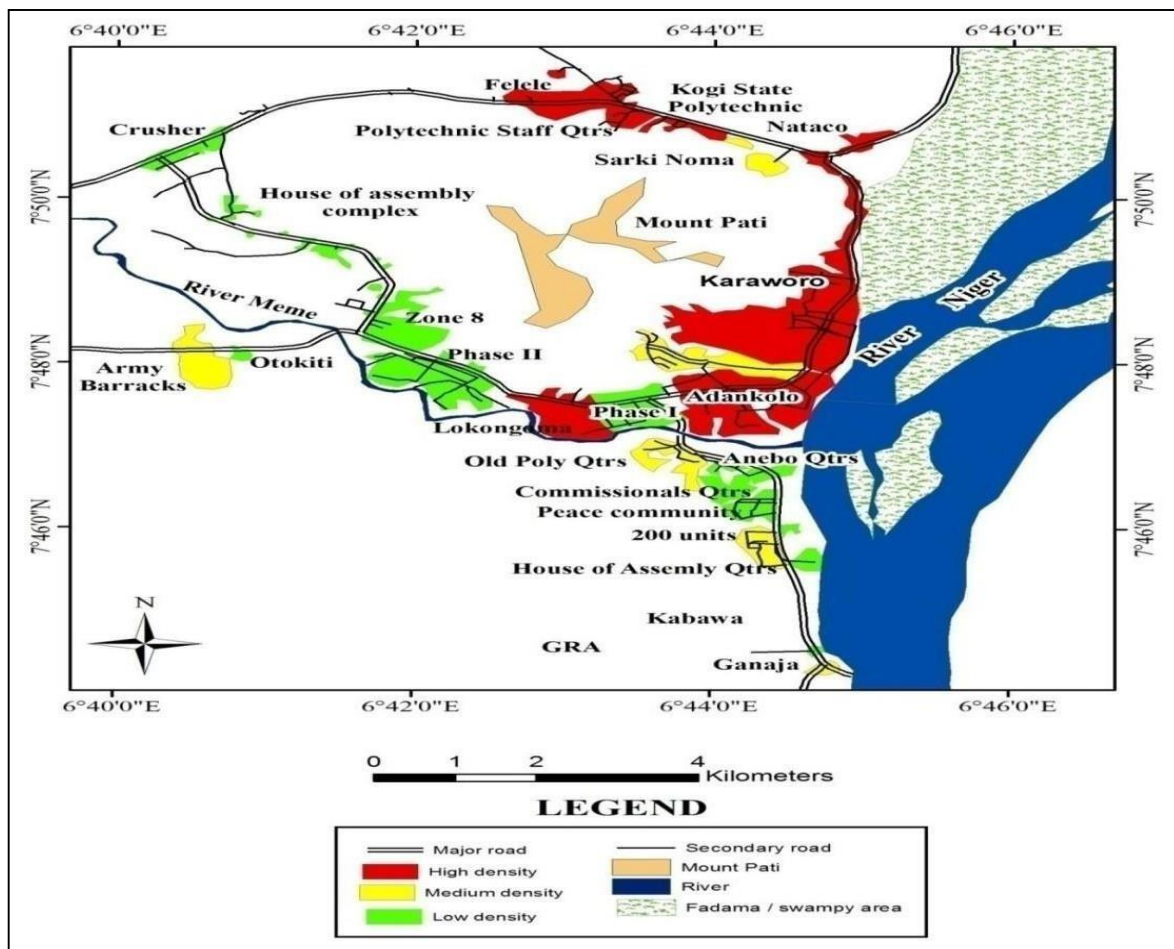


Figure 1 Kogi State showing Lokoja Built-Up Area
Adapted from Ukoje, 2013.

The geology and geomorphology of confluence Lokoja came about through complex processes which are briefly described here; the geology comprises basement complex rocks which have been intruded by igneous and metamorphic rocks. There are older and younger granites. The basalts are made up of older basalts, and newer basalts. According to textural and mineralogical composition, the older granites are divided into three sub-groups, biotite hornblende, porphyritic, biotite which are made of granite and quartz which are mostly non-porphrite and have medium to coarse grains and there are biotite and biotite granite, characterized by fine to medium grain sizes. The latest granites were intruded into Precambrian gneiss during the Jurassic age and because they are more recent than the older basement granites, they are referred to as younger granites (Oyebanji, 1993).

Soils of Lokoja are predominantly zonal tropical ferruginous type, sedimentary along mid-Niger, Alluvial along Niger and Benue, Humus further inland and are characterized by deep chemical weathering profiles as deep as 45m in some places (Faniran, 1994) and 1.5m to 2m thick in other places. The deep weathering profiles can be attributed to periodic high tropical temperature, abundant rainfall and high susceptibility of the rocks to weathering. Lithosols which are a zone soil, occur on the base slopes of the granitic hills and mountains. The lithosols are thin and poorly developed because they are made up of scree, thus, they are of poor agricultural value. There are also vertisols and hydromorphic soils. Vertisols occur along the flood plains or fadama areas. They have high content of swelling clays which crack readily when dry resulting to

Shrinking, and mass movement (Faniran, 1992).

The hydromorphic soils area suborder of intrazonal soils, they are formed under conditions of poor drainage in marshes, swamps areas or flat (Adejuwon and Ekanade, 1998)

Methodology

This study adopted human capital theory as its framework of analysis. Arthur Lewis is said to have begun the idea of human capital when he wrote in 1954 about the economic development with unlimited supplies of labour but it was first discussed by Arthur Cecil Pigou. According to this theory, the principal source of productive capacity or management whether in an economy or organization, rests in the capacity of the people and so, human capital has to do with the stock or a collection of resources - all the knowledge, talents, skills, abilities, experience, intelligence, training, judgment and wisdom possessed individually and collectively by people and which represents a form of wealth which can be used to overcome any challenge and directed to accomplish the goals of the nation or state or a portion thereof. Human capital is directly related to human development and effective and efficient uses of the wealth of nation, and so, where there is human development, the qualitative and quantitative progress of a nation or any part thereof is inevitable. This human resource can be transformed into human capital with effective inputs of education, health and moral values and the transformation of raw human resource into highly productive human resource with these inputs is the process of human capital formation. Madu (2001) argued that human capital development is a sure-bet for solving any human or environmental issue that involves proper exploitation of the physical environment as solutions to human challenges revolve around human development. He stressed that human capital involves the skills, knowledge and intelligence required in tackling technical matters. Since this research was more suggestive than reactive, the theory was applied through identification and suggesting the institutional framework and practical approach that can be used in managing the ever increasing wastes in Lokoja urban center. Although one may want to criticize this theory

by pointing to the difficulty in measuring its key variables and how far their use can guarantee an advance in productivity, the theory was relevant for this study in that it was an avenue to open new vistas in making waste less harmful and more useful through proper management. It also uncovered the reasons for the dismal performance of government even through KGSEPA in waste management. This will surely give room for concerned stakeholders in waste management to fashion out new strategies that would be adopted or adopt the suggested strategies that will nip indiscriminate solid waste disposal in the bud in Lokoja urban.

Also, the study adopted survey research design. This means that some carefully selected people were studied through collecting and analyzing data (primary-structured questionnaire) from them as they were considered to be the representatives of the population. The sample size of the study is 399 and it combined simple random, stratified and purposive sampling techniques. The simple random sampling ensured that every member of the population had equal and independent chance of being selected in the samples studied. Stratified sampling ensured that samples were divided into groups (strata) on the bases of their common characteristics, while purposive sampling ensured that the targeted respondents competently represented each stratum and quickly and objectively too, provided unbiased information about the issue under investigation. The respondents comprised some selected Landlords/caretakers, leaders of markets/traders associations, civil/public servants and carefully selected residents/occupants of the affected areas. In line with these, the researchers applied Bowley's Proportional Allocation Formula to determine the actual number of persons to whom questionnaire were administered in the study area. Data collected in the field were analyzed using frequency distribution tables and simple percentage technique. But, in testing the hypotheses as to achieve the objectives of the study, the researcher used chi-square (χ^2) statistical tool thus:

$$\chi^2 = \frac{\sum (O - E)^2}{E} \quad (1)$$

Where; χ^2 =Chi-square; Σ =Summation;

ASSESSING SOLID WASTE MANAGEMENT AND ENVIRONMENTAL SUSTAINABILITY IN LOKOJA, NIGERIA

Where; χ^2 =Chi-square; Σ =Summation; O = observed frequency; E=expected frequency

Test of Hypothesis:

Ho₁: Lack of clear knowledge and skills to make solid waste useful is not the main reason for the persistent increases in the number of indiscriminate waste dump in Lokoja urban area

Ho₂: The destruction of the aesthetics, blockage of roads and water channels in Lokoja urban area are not caused by heaps of indiscriminate slid wastes dumped

General Decision Rule

If the calculated chi-square (χ^2) value is greater than the critical value, the null hypothesis (H₀) is rejected.

$$Expected\ Freq\ (E) = \frac{Total\ no\ of\ respondents}{No\ of\ response\ options}$$

$$Expected\ Freq\ (E) = \frac{375}{4} = 93.8$$

The Chi-square (χ^2) test was calculated as follows:

The Chi-square (χ^2) test was calculated as follows:

Ho₁:

Table 1 Chi-square (χ^2) table

Observed Freq (O)	Expected Freq (E)	O-E	(O-E) ²	(O-E) ² / E
92	93.8	1.8	3.24	0.04
84	93.8	9.8	96.04	1.02
99	93.8	5.2	27.04	0.29
100	93.8	6.2	38.44	0.41
Total				1.76

Ho₂:

Observed Freq (O)	Expected Freq (E)	O-E	(O-E) ²	(O-E) ² / E
84	93.8	-9.8	96.04	1.02
81	93.8	-12.8	163.84	1.75
100	93.8	6.2	38.44	0.41
110	93.8	16.2	262.44	2.80
Total				5.98

Therefore, the calculated chi-square (χ^2) values are: 1.76, and 5.98 for hypotheses 1 and 2 respectively.

RESULTS AND DISCUSSION

Table 2 shows how often waste management personnel came to evacuate refuse in the area. It revealed that 102 (30.0%) of the respondents stated once in two weeks, 94 (27.5%) of the

respondents reported once in a week, 93 (25.0%) observed that it was once in a month, while 86 (17.5%) of the respondents had not noticed the presence of waste removing equipment in their area. The implication of this is that untimely evacuation of waste in the study area could be partly responsible for health hazards in the area.

Table 2 How often waste management personnel evacuate refuse in the area

Issues	Frequency	Percentage
Once in two weeks	102	30.0
Once in a week	94	25.0
Once in a month	93	27.5
Not notice at all	86	17.5
Total	375	100.0

Source: Author's Fieldwork Report, 2019

ASSESSING SOLID WASTE MANAGEMENT AND ENVIRONMENTAL SUSTAINABILITY IN LOKOJA, NIGERIA

The results on how solid waste disposal sites are managed by waste management personnel showed that 90 (30.0%) observed

burning of solid waste materials, 220 (60.0%) stated by burying, while 65 (10.0%) indicated abandoned solid waste site (See table 3).

Table 3 How the Final Solid Waste Disposal Sites are managed by Waste Management Personnel

Issues	Frequency	Percentage
Burning of waste	90	30.0
Burial of waste	220	60.0
Abandoned the waste	65	10.0
Total	375	100.0

Source: Author's Fieldwork Report, 2019.

The results on how the public could be involved in waste management showed that 65 (15.0%) of the respondents stated payment for service, 135 (50%) reported general environmental sanitation, 45 (5.0%) chose voluntary donation of tippers/lorries for use, 75 (20.0%) stated individual cleaning of

surroundings, while 55 (10.0%) noted environmental awareness of the danger of improper solid waste disposal. This reflected that majority of the people solely depended on the monthly general environmental sanitation to tidy their surroundings.

Table 4 How could the public get involved in waste management

Issues	Frequency	Percentage
Payment for service	65	15.0
General environmental sanitation	135	50.0
Donation of lorries for use	45	5.0
Individual cleaning of surroundings	75	20.0
Environmental awareness	55	10.0
Total	375	100.0

Source: Author's Fieldwork Report, 2019

The findings on the problems of solid waste management agency in the study area showed that 75 (20.0%) of the respondents noted shortage of vehicles, 55 (10.0%) observed shortage of waste containers, 95 (30.0%) of the respondents observed shortage of personnel, 85 (25.0%) of the respondents stated poor funding/encouragement by

Government, while 65 (15.0%) stated lack of dedication to duty (As shown in table 5). This suggested that there is need to increase/improve on the level of facilities and human resources in the Waste Management Board, to ensure their success in their fight against health hazards from solid waste materials in the area.

Table 5 Problems of solid waste management agency in the study area

Issues	Frequency	Percentage
Shortage of vehicles	75	20.0
Shortage of containers	55	10.0
Shortage of personnel	95	30.0
Poor funding by government	85	25.0
Lack of dedication to duty	65	15.0
Total	375	100

Source: Author's Fieldwork Report, 2019

CONCLUSION

In the course of presenting, analyzing and testing the hypotheses formulated for this study, the following findings as summarized were made:

1. There is no government approved permanent waste dumpsites anywhere in Kogi state including Lokoja urban, to serve as final wastes collection points and residents do not help matters through their poor waste disposal habits. The most commonly repeated experience is the simple transfer of wastes from one unapproved site to another.
2. Government through KGSEPA and individuals has not made significant efforts to curtail the tide of indiscriminate solid wastes dumps/disposal in Lokoja urban area.
3. Indiscriminate waste disposal/dumps in Lokoja urban that are not in any way put into any good use (managed), significantly contribute to spreading avoidable communicable and other life threatening diseases such as typhoid, cholera, malarial.
4. KGSEPA as a waste management agency in Kogi state lacks the required modern equipment and technical competence to handle the ever increasing wastes in Lokoja urban center. A situation in which only 4 experts serve in environmental, pollution control and waste management in the Agency is a pointer.
5. The local government (Lokoja LGA) have failed in their constitutional responsibilities of ensuring proper evacuation and disposal of urban solid wastes and Kogi state government currently seem to have no concrete plan to ensure proper waste management.

The findings of this study exposed the devastating effects of urban solid waste in Lokoja as a result of inappropriate and inadequate management. Therefore, both the individuals and the government through KGSEPA have not made appreciable efforts to get and train the required manpower with technical skills and competences that would nip the ever-increasing solid wastes in Lokoja urban in the bud through proper generation, disposal, control, sorting and other management strategies, and should the current state of affairs in handling wastes in Lokoja urban area continue, the resultant negative consequences will have multiplier effects on the present and future inhabitants of the area.

Government is therefore advised to sit up and treat Lokoja urban solid wastes problem with the seriousness it deserves in order to protect the environment and lives of people in the area.

In line with the findings of this study and its implications, the following recommendations were therefore made:

1. Kogi State Government through State polytechnic should as a matter of urgent public importance, strengthen the already established department of Environmental and Public Health in the School of Environmental Technology, of the State Polytechnic (KSP) Lokoja by providing them with modern equipment including machines, for students to be exposed to practical methods of contemporary waste management.
2. Kogi State Government should partner with foreign-based waste management firm under public-private-partnership (PPP) arrangement to commence operation in Lokoja. Such firm should at least be a specialist in any waste management operation including; generation, sorting/separation, recycling and conversion. The firm shall be encouraged to collaborate with KGSEPA staff to complement the manpower needs. The firm apart from serving as a source of revenue to the government will also serve as a training center for Industrial Training (IT) students.
3. Kogi State government should as a matter of urgent public importance, provide permanent waste dumpsites that must be far from markets, schools, churches, commercial and residential areas. This will at least, reduce the dangers of communicable and other life threatening diseases. This should be immediately followed with public enlightenments.
4. The landlords and other inhabitants of the state should be properly represented when planning for any waste minimization or management strategy.
5. Urban and regional planning should be encouraged throughout the state for a livable and aesthetic living environment.
6. Recruitment of more experts in environmental, pollution control and waste management into KGSEPA should be one of the priorities of the current government in Kogi State.

ASSESSING SOLID WASTE MANAGEMENT AND ENVIRONMENTAL SUSTAINABILITY IN LOKOJA,
NIGERIA

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ASSESSMENT OF FLOOD VULNERABILITY IN LOKOJA METROPOLIS, KOGI STATE, NIGERIA

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Abstract

This study assessed flood vulnerability in Lokoja metropolis, Kogi State. The Geographic Information Systems analytical technique was used to assess the flood vulnerability zones of Lokoja metropolis by exploring the benchmark minimum and maximum water level sourced from the National Inland Water Ways Authority (NIWA), Lokoja area office for years 2006 to 2015. Data on Land-use/land-cover and flood vulnerability maps were generated from digitized satellite imageries sourced from Google earth imageries and the Gumbel's frequency distribution method. The study ascertained that the maximum water levels records corresponds with the area extent of flood coverage in Lokoja. The highly and most inundated areas are actually recorded in 2012 with area coverage of 3,638.19 ha, 3,011.2 ha in 2015 and least 1966.05 ha in 2011. By extension, more impact of flooding phenomena were felt more in years 2012, 2015 and less in 2011. Furthermore, the farmlands/ open spaces are most inundated areas e.g. 3,542.13 in 2012, 81.43ha of residential land use, 10.15ha of commercial land use, 4.38ha. of public and industrial 0.1 ha. The agricultural areas, and residential areas are the most vulnerable to high flooding while the industrial areas the least vulnerable. The study therefore recommends the preparation of flood management plan using the mapping of the flood areas done by the study and ensure enforcement by a joint task force that should consists of the Planning Authorities, Ministry of Environment, National Inland Waterways Authority and Ministry of Environment with each a clear cut role in ensuring safer floodplains management.

Keywords: Flood, Land use, Land cover, Inundation, Vulnerability.

INTRODUCTION

Historically, flood plains have served as attractive sites for settlements due to its advantage of fertile land, freshwater supply and transportation. This perceived advantages attracted the beginning of modern settlement (Bue, 1967). In the world today, floods are among the most devastating natural disasters that are responsible for the loss of lives and properties every year (Wang, 1999 and Dilley et-al., 2005). In Nigeria, floods hazard is only second to drought. In terms of the natural hazard directly or indirectly affecting of the 90% of damages resulting from natural hazards (Adeoye et-al. 2009). Floods that occur in Nigeria are as a result of intensive rainfall, drainage blockages and dam failures (Jeb and Aggarwal, 2008). Flood is among the most devastating natural hazards in the world claiming lives and properties more than any other natural phenomena (Ologunorisa, 2006; Alcira and Martha, 1991). In the past decade in Nigeria, thousands of lives and properties worth

millions of Naira have been lost directly or indirectly from flooding every year. In most urban centers of the country most especially in fast growing towns like Gwagwalada town of the Federal Capital Territory, population increase, landscaping in paved areas, streams and channel obstruction due to bad waste disposal and other human activities at floodplains were considered to be the major causes of floods (Ishaya, Ifatimehin and Abaje, 2009). Flooding are common features in Nigeria, and it usually occurs in locations of flat or low- lying terrain, especially cities that have little or poor provision surface drainage system, or where drainages are blocked with municipal waste, refuse and eroded soil sediments (Folorunsho and Awosika, 2001). Adeoye (2009) reported that floods have caused over 10,000 deaths in the United States since 1900. According to Asian Development Bank (2007), floods have affected over nine (9) million people in Bangladesh and about thirty (30) million people in India. With these

characteristics, the occurrence of flood remains unstoppable especially on its destructive consequences on people who reside along its plain. In the United States of America, 80% of disaster occurrences are caused by flood, between the periods of 1988 and 1994 four (4) billion dollars' worth properties are lost annually as a result of flood (Wadsworth 1999). A flood occurrence in many regions of the world are in the increase (Drogue et-al, 2004). It is reported that flood disasters account for about a third of all natural disasters by number and economic losses. This however shows how disastrous flood can be if not checked. Ziervogel (2008) states that, though floods cannot be stopped, but, control of its damaging effects and the vulnerability of risk prone communities is possible.

In recent years, the increase in population and expansion of settlements in flood prone areas has fostered the impact of the floods worldwide. Gilbert (1991) asserted that urban encroachment into floodplain alters the integration of surface- runoff with the main channel, reduces surface water storage and conveyance capabilities, and reduces water quality of receiving waters and adjacent lands, in addition to other secondary effects such as depletion of water resources, cumulative impact on wetlands and pollution of downstream surface waters. Across the globe, floods have posed tremendous danger to people's lives and properties. In Nigeria, the pattern is similar with the rest of world. Flooding in various parts of Nigeria have forced millions of people from their homes, destroyed properties, polluted water resources and increased the risk of diseases (Baiye, 1988; Akinyemi, 1990; Nwaubani, 1991; Edward- Adebisi, 1997). In Kogi State, many urban dwellers reside mostly in relatively low lying areas of Rivers Niger and Benue due to their large resource bases on natural resource. This attraction has led to fast and exponential increase in urban development and other activities in the area. Flooding has been one of the major natural disasters in Kogi, during the disaster lots of lives and properties were lost, inundation of institutions, farmlands, destruction of roads, bridges and especially the major road to gain entrance from southwest into the northern area. Etuvnobe (2011) reported that flooding in Kogi State occurs like wildfire

with ninety communities of over 500, 000 persons including Lokoja displaced from their abodes, and farmlands completely swept away. According to the reports from the Nigeria Emergency Management Agency, NEMA, (2012), five districts, namely, Adankolo/ Kabawa, Sarkin Noma/Galilee, Phase 1– Old Poly quarters, Ganaja and Gadumo of Lokoja were flooded in August and early September, 2012 when River Lagdo burst its banks. Several studies on flood dwelled more on the effects flood on lives and properties, yet there remain lacunas in the subject matter that will foster a strong mechanism towards addressing the problem from the perspective of mapping that forms baseline information for predicting the vulnerability of the flood plains, this is a gap this study attempts to fill in. The study aim is to assess the vulnerability of human settlement along flood plains of Lokoja metropolis via the identification of the causes of flood in Lokoja, mapping of the areas where flooding had occurred and examining the vulnerable areas of flood hazards for the sake of management purposes.

Backdrop of Flooding

Flood is an overflowing or irruption of a great body of water over land not usually submerged (Oxford English Dictionary). It is an extreme weather event naturally caused by rising global temperature which results in heavy downpour, thermal expansion of the ocean and glacier melt, which in turn result in rise in sea level, thereby causing salt water to inundate coastal lands. Flooding is the most common of all environmental hazards and it regularly claims over 20,000 lives per year and adversely affects around 75 million people world-wide (Ologunorisa, 2006; Alcira and Martha, 1991). Previous studies also reported that communications and traffic are interrupted while many land areas are inundated, and industrial plants and commercial establishment are paralyzed during floods. Besides, untold hardship is experienced, especially by the most vulnerable groups (women and school children) whenever there is flood disaster (Oluduro, 1988; Durotoye, 1999; Folorunsho and Awosika, 2001). Flooding is a normal phenomenon that occurs from a river in many catchment areas or drainage outlet). The drainage out let can be a stream or a river, the

wider the catchment area, the more the quantity of runoff getting into the drainage outlet. For instance, the catchment area of River Niger extends far beyond Nigeria; hence it carries the highest volume of water. River Ogun on the other hand extends only into Oyo and Osun States and hence carries smaller volume of water compared with the River Niger. Thus, if the catchment area is large, the inflow into any dam built on the drainage outlet will be heavy and if the inflow is greater than the out flow that the drainage channel can carry, leading to a retention, that forms some reservoir lake and its boundary extending to areas previously dried. Otherwise, there will be an outflow into the adjoining land area. This extension of retained water boundary or the out flow into the adjoining dry land is what is called floods or flooding.

Causes of Flooding in Nigeria

Nwigwe and Emberga (2014) identified that the following causes of flood in Nigeria could be natural as well as human (anthropogenic). The natural cause could be in form of heavy or torrential rains/rainstorm, oceans storms and tidal waves usually along the coast. While, the human causes could be via non-provision of drainage lines or silting of same with solid waste. It could also be via the burst water main pipes, dam burst that results to dam spills. Flooding occurs throughout Nigeria in following forms: Coastal flooding, River flooding, flash floods, urban flooding, Dam burst leaves failures and Dam spills. They further claim that Coastal flooding occurs in the low-lying belt of mangrove and fresh water swamps along the coast river flooding occurs in the flood plains of the larger rivers flash floods are associated with rivers in the inland areas where sudden heavy rains can change them into destructive torrents within a short period. Urban flooding occur in towns located on flat or low lying terrain especially where little or no provision has been made for surface drainage, or where existing drainage has been blocked with municipal waste, refuse and eroded soil sediments, extensive urban flooding is a phenomenon of every rainy session in Lagos, Maiduguri, Aba, Warri, Benin and Ibadan. Virtually every Nigerian is vulnerable to disasters, natural or man-made. Every rainy season, wind gusts arising from tropical storms

claim lives and property worth millions of naira across the country. Flash floods from torrential rains wash away thousands of hectares of farm land. Dam bursts are common following such flood. In August 1988 for instance, 142 people died, 18,000 houses were destroyed and 14,000 farms were swept away. When the Baguada Dam collapsed following a large flood. Urban flooding such as the Ogunpa disaster which claimed over 200 lives and damaged property worth millions of naira in Ibadan, are common occurrence (Edward-Adebisi, 1997). Flood occurrences inhibits economic activities in many towns and cities in the country. Some of the Major roads that link when flooded causes hardship to motorists. When these roads were constructed, the flooding problems were not there, and the companies that constructed the roads probably did not anticipate the problem.

Cause of flooding in Lokoja between 2006 and 2015

The River Niger runs from Guinea through Mali, Benin, Niger and empties into the ocean through Nigeria. The rainy season in West Africa where the River Niger exists is the same, spreading mainly between April and November. The peak of the rainy season is July /August. This peak flow implies that the River Niger runs full all across its length for the rainy season. But the flow also takes time to travel. The peak flow coming from Fouta D'jalou mountain where the River Niger takes its source travels all the way until it arrives in Nigeria. The time it floods Nigeria is, therefore, different from the time the rains fall upstream of its basin. This explains why the River Niger floods Nigeria yearly starting from September and at its peak in November but receding to its lowest discharge of about 500m³/s in May. The authorities managing the Kainji and Shiroro dams would normally open the floodgates only when the peak flow of the River Niger arrives in September in order to ensure adequate impoundment. When the opening of such flood gates coincides with high precipitation in Nigeria, the flooding of the downstream becomes inevitable. And if such opening coincides with discharges due to the opening of floodgates on Lagdo dam on upper River Benue, the flooding is accentuated (NEMA, 2012). The opening of the floodgates of the Kainji, Shiroro on River Niger and Lagdo dams and

their attendant discharges of excess flows coincided with heavy rainfall thus causing the large scale flooding ever recorded in Nigerian history in 2012. Had the floodgates of these dams been opened at various times such that the discharges did not arrive at the confluence in Lokoja simultaneously, the extent of flooding would have been reduced.

Sgarma & Sharma (2002) and Douglas, Gasiorek, and Swaffield (1985) claimed the foregoing issue on causes of floods in Lokoja can briefly be illustrated with some equations. If the catchment area (or drainage basin) available to be A_a , rainfall intensity or storm I , then the quantity of flow available (Q_a) in a drainage basin outlet at any time (t) can be given by:

$$Q_a = 2.78CIA_a \quad (1)$$

(Sgarma & Sharma, 2002: pp. 200-427)

Where C is a constant that depends on surface/soil characteristics of the catchment area, and its values range from 0 to 1 (i.e. $0 < C \leq 1$). The Value of $C=1$ implies non-permeability while $C=0$ implies full permeability or sinking into the ground of all precipitation.

The critical condition for C is when the value approaches unity (i.e. $C=1$). This condition occurs when:

- (1) The ground becomes fully saturated due to past rainfall and can no longer soak any other water,
- (2) When every portion of the catchment area is paved, and
- (3) When the affected area is underlain with impervious rock or clay soil.

On the other hand, if the carrying capacity of a drainage outlet is Q_c , the cross-sectional area of the drainage or river channel is A , slope of the drainage or river bed is S , then

$$Q_c = A[R^{(2/3)} S^{(1/2)}] / n \quad (2)$$

Where R =hydraulic mean radius = wetted perimeter/ sectional area, and n is Manning's constant which depends on surface characteristics of the channel, and S is an exponential power.

Flooding occurs when $-Q_a$ in equation (1) is more than $-Q_c$ in equation (2) or simply put:

$$Q_a > Q_c \quad (3)$$

This can be written as:

$$2.78CIA_a > A[R^{(2/3)} S^{(1/2)}] / n \quad (4)$$

Or

$$I > k(A/A_a) [R^{(2/3)} S^{(1/2)}] \quad (5)$$

Where: $k = 1/(2.78nC)$

Equation (4) provides that if the rainfall intensity is higher than the value on the right hand side, flooding occurs. This can occur due to a sudden increase in rainfall intensity (I) either within a short time frame or over a long time frame. The causes of floods in recent times in China, Russia, America, Africa and Europe have all been associated with high precipitation or rainfall intensity (I) factor.

Similarly from equation (4):

$$A > 2.78nCIA_a / [R^{(2/3)} S^{(1/2)}] \quad (6)$$

It follows from equation (ivb) that if A_a , C , I , or n is high (or their combination is high), then a higher cross-sectional area is required for the same flow. Thus, the excess water above the drainage channel available inundates the surrounding causing ponding and flooding.

The river catchment area of the River Benue basin begins before the Lagdo dam in northern Cameroun and extends westwards up to Lokoja, Kogi State, Nigeria. That of the River Niger starts from the Volta region in

Mali. Thus the catchment area, A_a , is large for both River Niger and River Benue. This is another reason why we have floods. Another condition that can cause flood in Lokoja is when there is a hydraulic jump and energy is dissipated. Upstream of any hydraulic jump is a region of rapid flow and shallow depth while its downstream is an area of sluggish flow with high depth of water. The high depth of water in this case can be taken as flooding. This is

governed by the following equations put forward by Douglas, Gasiorek, and Swaffield (1985: 462-465);

$$D_2 = \frac{1}{2} D_1 [1 + \sqrt{1 + 8v_1^2 / gD_1}] \quad (7)$$

Where: D1 and D2 are conjugate depths upstream and downstream of the hydraulic jump location. For instance, if:

D1 = 2m; v1 = 0.5m/s; g = 9.81m/s²; then D2 = 0.35m.

Thus, relatively shallow depth of approximately 1foot (i.e.0.35m) at the upstream region could generate a depth of 2m in the downstream region. The loss of head associated with any such hydraulic jump is given by:

$$E = (D_1 + v_1^2 / 2g) - (D_2 + v_2^2 / 2g) \quad (8)$$

In examining the terrain traversed by both the R. Benue and R. Niger drainage basins, it is discovered that the most flooded areas occurred in flat areas downstream of sloppy critical flow areas that were associated with energy dissipation (hydraulic jump). In Lokoja, the confluence zone is a spot of hydraulic jump and energy dissipation.

The third condition that can cause flooding occurs when maximum discharges from Lagdo dam, Kainji dam and Shiroro dam coincides with peak rainfall runoff from the adjoining catchment areas. The River Niger is 4,180km long while, the River Benue is about 1,400km long (Douglas, Gasiorex and Swaffield, 1985). If we assume that both Rivers Niger and Benue flow at an average velocity (V) of 1.1m/s, then the time required for a full discharge, T, is governed by:

$$S = VT \quad (9)$$

Where S=distance or length,

V = velocity and T=Time of travel.

From equation (9), we obtain:

$$T = S / V \quad (10)$$

Thus, for River Niger (with distance converted to meters), the time required taken as T1is:

$$T_1 = 4,180 \times 1000 / 1.1 \\ = 3,800,000 \text{ seconds or } 43.98 \text{ days}$$

The peak period of flow from Fouta Djallon, the source of River Niger in Guinea, will arrive in about one and a half months after peak flow begins. And for the River Benue, the time required taken as T2 is:

$$T_2 = 1400 \times 1000 / 1.1 \\ = 1,272,272.3 \text{ seconds or } 14.7 \text{ (15 days)}$$

This shows that the peak flow from the source of the River Benue is about two (2) weeks after the peak flow begins. If the rivers run full in early July, we should expect that higher flow from Lagdo area will arrive at the confluence zone in mid-July while that of the River Niger will arrive in mid-August. During this period of July to August, is the peak of the rainy season. Thus, the opening of floodgates from any dam upstream of confluence point at Lokoja, Kogi State, between July and November will accentuate flooding of the Niger Delta. Such a condition must never be allowed to take place. But in 2012, the floodgates of the Kanji, Shiroro and Lagdo dams coincided with torrential rainfall in the middle and southern parts of Nigeria. That was a human error, and of course a human flooding cause.

From the aforementioned therefore, the following factors can be inferred to be responsible for flooding in Lokoja metropolis: the status of Lokoja as a confluence point/ town fuels the inevitability of flood occurrence, rapid urban sprawl along the floodplains/areas, high rate of precipitation, and the low lying terrain of the metropolis.

MATERIALS AND METHODS

Study Area

Lokoja is the headquarters of Kogi State; it is located between Latitude 7° 45'N to 7° 51'N and Longitude 6° 41'E to 6° 46'E with an area cover of 3,180km² (Britannica Encyclopaedia), it is located between the confluence of Rivers Niger and Benue in Nigeria. It has a population of 195,261 at the 2006 census (NPC, 2006). Lokoja lies in the Koppen Aw-warm continental type (Olatunde and Ukoje, 2016) characterised by tropical wet and dry seasons with a mean annual rainfall of about 1,000mm and Relative Humidity of about 30% (dry season) and 70% (wet season) (Olivera et. al, 1995). Lokoja has a mean annual temperature of 30.7° C with the hottest months of February and March

ASSESSMENT OF FLOOD VULNERABILITY IN LOKOJA METROPOLIS, KOGI STATE, NIGERIA

(Ifatimehin, Ishaya and Ujoh, 2010), the It is underlined by igneous and metamorphic rocks of the basement complexes with a rough terrain and mountainous landscape, forests and valleys, and the soils are generally characterized by a sandy texture overlying a weakly structured clay accumulation (Atoyebi, 2013) with the soils of flood plains of the aforesaid rivers hydromorphic in nature with mixture of alluvial and colluvial deposits (Areola, 2004). The vegetal cover is predominant Guinea or Parkland savanna with tall grasses, shrubs and some trees (Luca, 2012). Lokoja is a cosmopolitan town with mix of various Nigerian ethnic tribes such as Igala, Tiv, Idoma,

Hausa, Egbira, Yoruba, Igbo and Gbagyi just to mention a few (Olatunde and Adejoh, 2017). The people are largely involved in fishing, farming, lumbering and trading activities. The land use is about

556.5 sq. km residential, 1, 510.50 sq.km open spaces (partly farmlands), 467.46 sq. km for roads, 295.74 sq. km water bodies, 73.14 sq. km commercial, 6.36 sq.km industrial, 143.10 sq.km for schools, hospitals, offices and other public uses and 127.20 recreational land use coverage (Lokoja master plan, 2009).

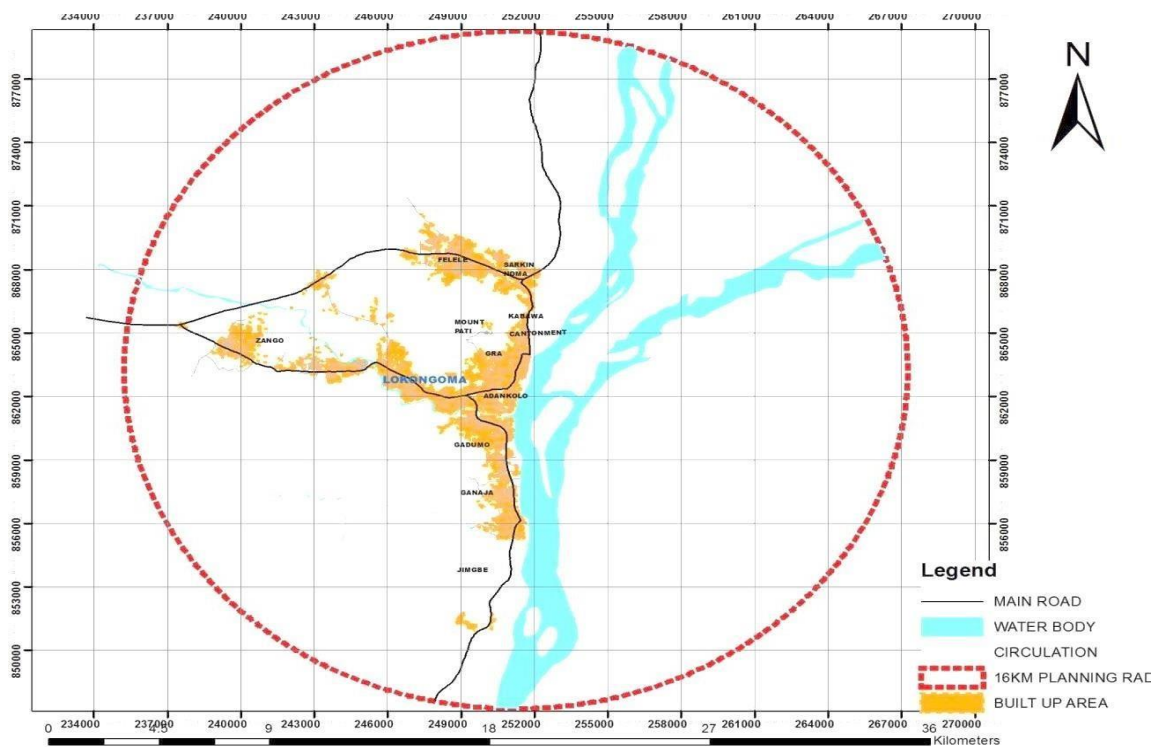


Figure 1 Lokoja Metropolis: 16km Planning Radius.

Source: GIS Analysis by Authors 2016

The study uses Remote Sensing and GIS analysis tool and technique for assessing the flood vulnerability zones of the Lokoja metropolis by exploring the benchmark minimum and maximum water level from the year 2006 to 2015 sourced from the National Inland Water Ways Authority, Lokoja area office. Land-use/land-cover and flood vulnerability maps were generated from digitized satellite imageries sourced from Google earth imageries and the Gumbel's frequency distribution method. The data on

record of flood coverage, yearly discharge record of Niger River, areas affected, contour and Digital Elevation Model (DEM) of the study area were acquired from NIWA as well. Flood vulnerability maps for the study areas were prepared by intersecting/ overlay of the land use map of the floodplains with the flood area polygon for each of the flood event being modeled. This helped in determining the vulnerability and flood risks of the areas, particularly, in terms of the presence or the absence of flooding of a particular return period

ASSESSMENT OF FLOOD VULNERABILITY IN LOKOJA METROPOLIS, KOGI STATE, NIGERIA

as a binary model. Also, record of property/houses lost, farmlands and number of people affected were also collected in the study area from NEMA. The data on water levels on the pattern of flooding from 2006– 2015, from the annual maximum water gauge levels at Adankolo (NIWA Dock Yard) gauge site located in the catchment area analysed via flood frequency analysis and overlay with the Digital Elevation Model with the aid of Arc GIS10.0 Raster Calculator to determine the vulnerable areas and mapping. Descriptive analysis was done on the data collected where necessary.

RESULTS AND DISCUSSION

Flood vulnerability mapping of Lokoja metropolis

Annual maximum water level from 2006-2010

Tables 1a and 1b show the maximum water level from year 2006-2015. Year 2012, had the highest maximum water level height 13.42m, followed by year 2015 with a maximum height of 9.79m, the year with least water level is 2011 with maximum height of 6.65m. this implies that the year with the highest water level seem to be the year that unprecedented inundation was experienced in Lokoja followed by year 2015 when so many houses were submerged, settlements dislodged, farmlands swept off and loss of properties. But year 2011, with the lowest value 6.65m had a minimal experience of inundation and submergence of settlements along the floodplain. This table provides strong baseline information on planning, managing and mapping of vulnerable areas of flooding in the metropolis.

Table 1 Annual water level from 2006 to 2010

ANNUAL WATER LEVEL FOR 10 YEARS RETURN PERIOD															
STATION: Lokoja					RIVER: Niger					MILE: 581.3km					
DATE ESTABLISHED:1914										AREA OF DRAINAGE BASIN:					
ELEVATION OF GAUGE AT ZERO ABOVE DATUM:13.40m															
ELEVATION OF GAUGE AT ZERO ABOVE M.S.L:32.37m															
2006			2007			2008			2009			2010			
Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	
2.32	6.75	3.65	2.26	8.77	4.88	2.84	9.36	4.02	2.11	9.44	3.82	2.05	9.34	4.04	

Table 1 Contd. Annual water level from 2011 to 2015

ANNUAL WATER LEVEL FOR 10 YEARS RETURN PERIOD															
STATION: Lokoja					RIVER: Niger					MILE: 581.3km					
DATE ESTABLISHED:1914										AREA OF DRAINAGE BASIN:					
ELEVATION OF GAUGE AT ZERO ABOVE DATUM:13.40m															
ELEVATION OF GAUGE AT ZERO ABOVE M.S.L:32.37m															
2011			2012			2013			2014			2015			
Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	
2.02	6.65	3.44	1.37	13.42	4.77	2.09	8.22	4.17	2.13	8.75	3.21	2.81	9.79	3.62	

Source: National Inland Waterways Authority, Lokoja Area Office 2015

Pattern of Flooding, 2006-2015

Table 2 shows that the highest water level recorded over the years under study is year 2012 with 13.42m maximum water level, and the least 6.65m in years 2006 and 2011. Between years 2011 and 2012 there was a sharp increase in water level/height meaning an unprecedented inundation in the study area. This water levels height corresponds with

higher inundation of if the increasing land use/ activity areas as shown in figure 2. Less inundated areas were in 2006 and corresponding less development as shown in figure 2. The highly and most inundated areas were actually recorded in 2012 with area coverage of 3,638.19 ha (Plate 3), 3,011.2 ha in 2015 and least 1966.05 ha in 2011 (see plate 2). By extension, more impact of flooding

ASSESSMENT OF FLOOD VULNERABILITY IN LOKOJA METROPOLIS, KOGI STATE, NIGERIA

phenomena should be felt more in years 2012, 2015 and less in 2011. Furthermore, the farmlands/ open spaces are most inundated areas e.g. 3,542.13 in 2012, 81.43ha of residential land use, 10.15ha of commercial land use, 4.38ha. of public and industrial 0.1 ha.

It is worthy to note that, year 2012 was the only year that had the industrial land use inundated. Perhaps, the highest water level recorded within that year. So increase in flooding would affect the industrial hub of the Lokoja metropolis.

Table 2 Pattern of flooding from 2006 –2015 (inundated areas)

YEARS	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Maximum Water	6.65m	8.77m	9.36m	9.44m	9.34m	6.65m	13.42m	8.22m	8.75m	9.79m
Landuse	Area	Area	Area	Area	Area	Area	Area	Area	Area	Area
Residential	39.32	42.34	52.23	59.49	61.01	47.22	81.43	55.34	53.56	65.44
Commercial	4.87	5.33	6.45	6.71	7.6	3.23	10.15	6.92	7.21	8.12
Public	1.34	2.31	3.34	3.41	3.82	2.87	4.38	3.98	3.18	3.83
Industrial	0	0	0	0	0	0	0.1	0	0	0.10
Farmland/	2084.32	2562.12	2662.43	2683.78	2676.12	1912.73	3542.13	2408.43	2518.21	2933.71
TOTAL	2129.85	2612.1	2724.45	2753.39	2748.55	1966.05	3638.19	2474.67	2582.16	3011.2

Source: KSTPDB (2012) and GIS Analysis by Authors, (2016).

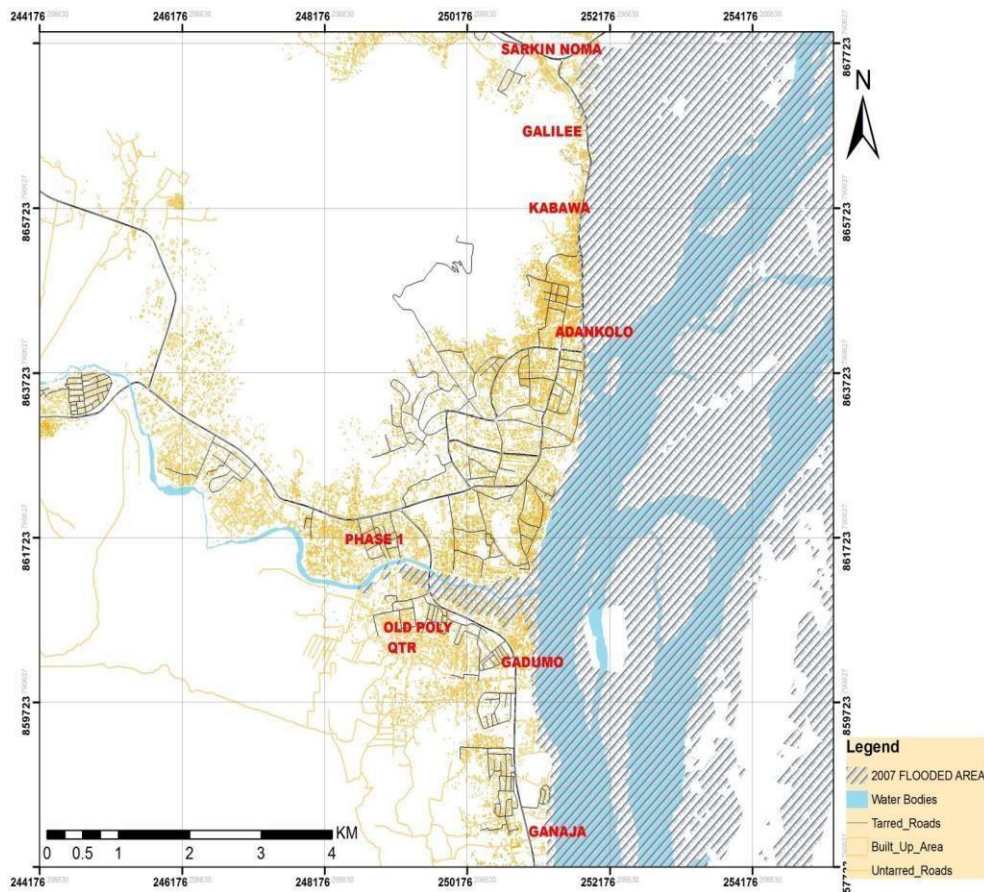


Figure 2 Lokoja Metropolis Flooded Areas in 2006.

ASSESSMENT OF FLOOD VULNERABILITY IN LOKOJA METROPOLIS, KOGI STATE, NIGERIA

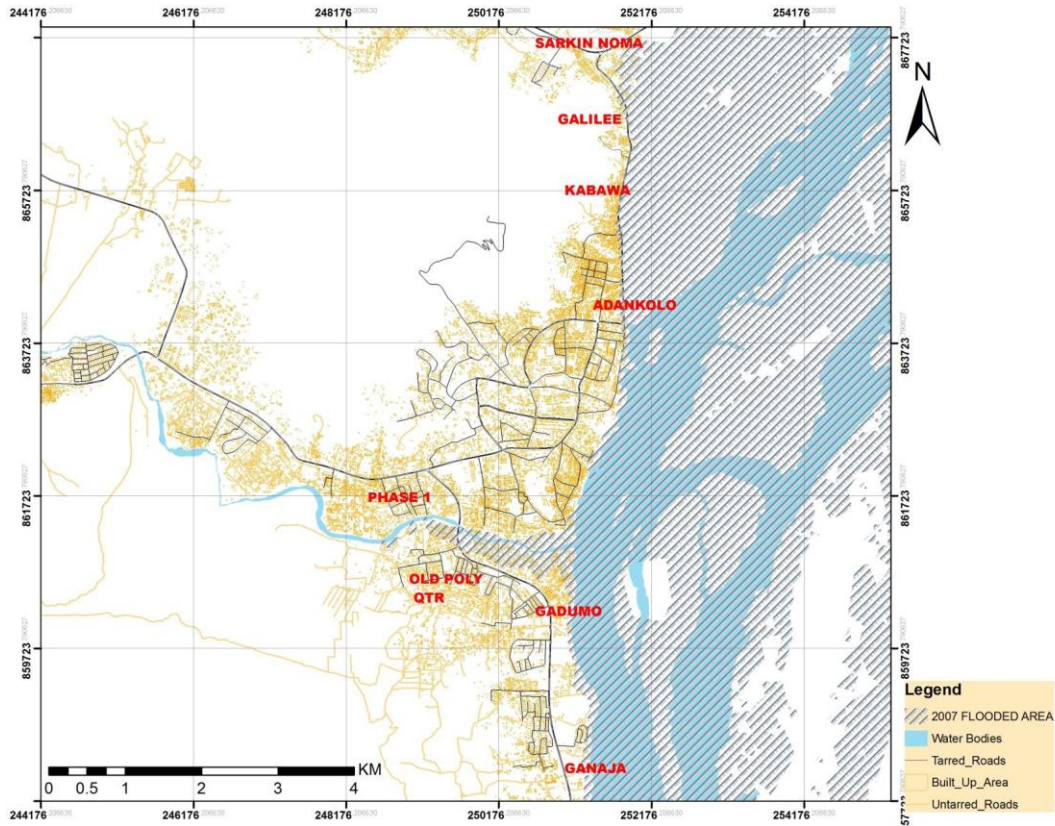


Figure 3 Lokoja Metropolis Flooded Areas in 2007.

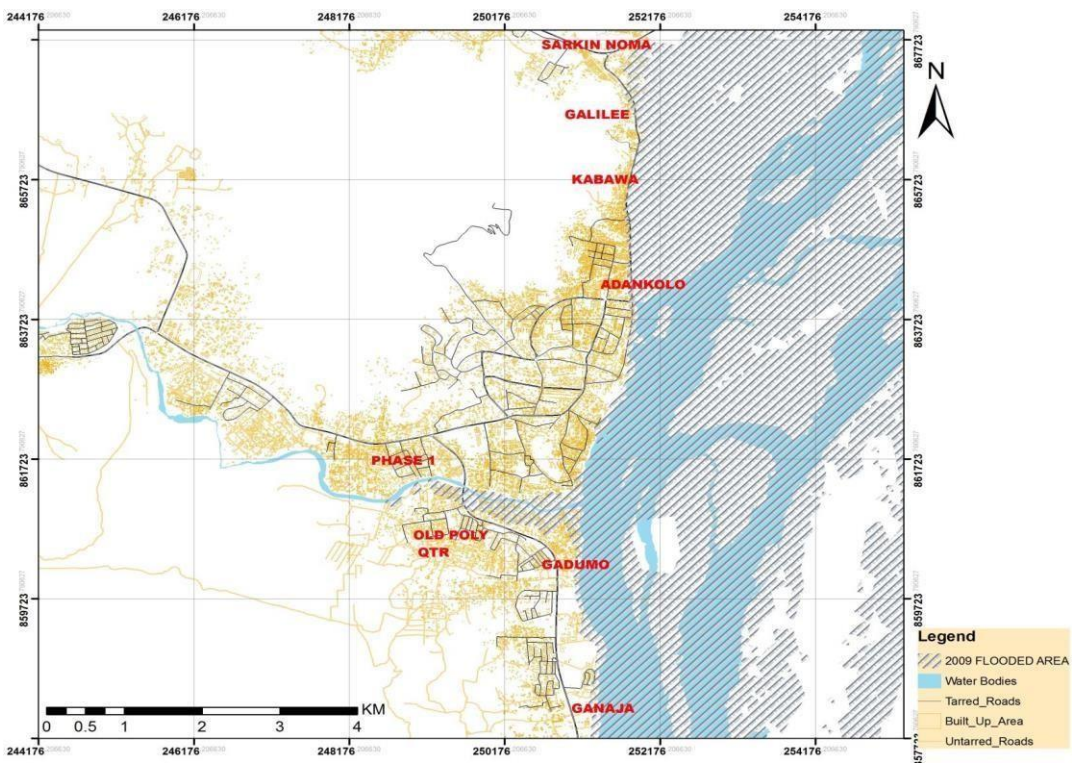


Figure 3 Lokoja Metropolis Flooded Areas in 2009

ASSESSMENT OF FLOOD VULNERABILITY IN LOKOJA METROPOLIS, KOGI STATE, NIGERIA

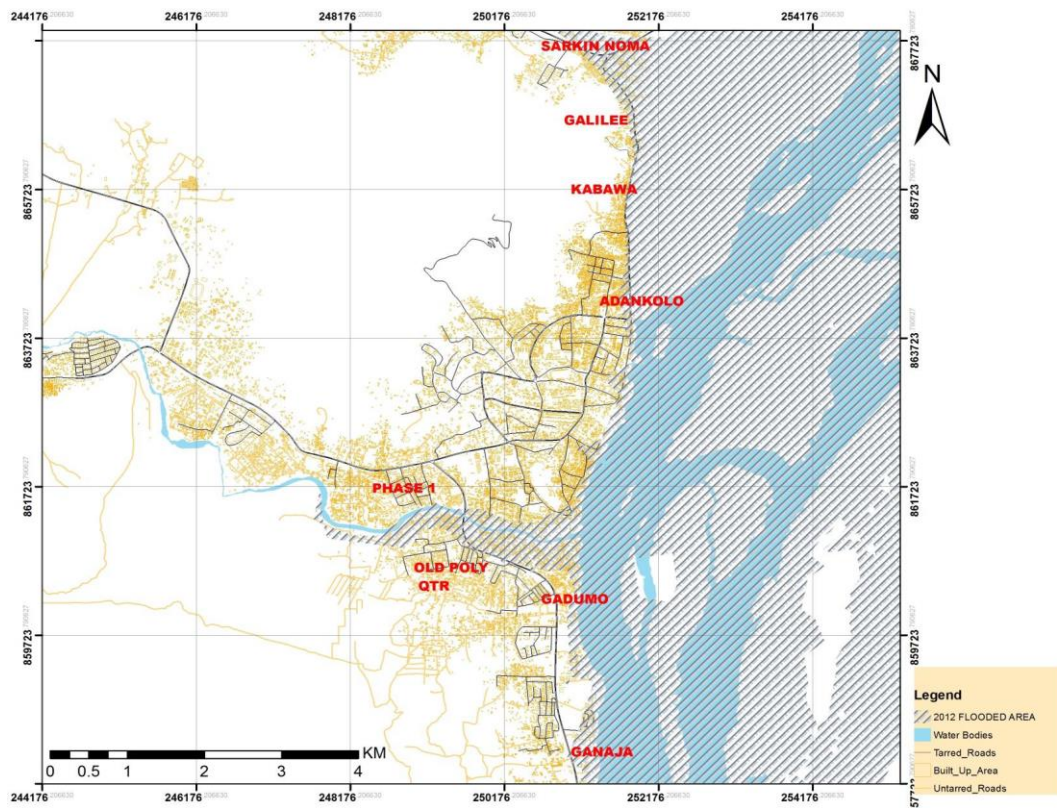


Figure 4 Lokoja Metropolis Flooded Areas in 2012

Structures Affected by the Flood

Table 3 shows that inundated areas are the areas with higher water levels and height in year 2012, year 2015 and the least in 2006. They had structures (property) affected by flood with about 1,792 houses in 2012, followed by 1,434 houses in 2015 and the least

437 houses in 2006 as shown in Table 3. This means whenever the maximum values are recorded area extent of inundation increases, at the same time more properties will be affected, but whenever low values are recorded, the areas shall remain safe from flooding hazards.

Table 3 Structures affected

LOCATION	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Sarkin	201	213	231	236	268	193	345	234	222	276
Kabawa-Adankolo	120	131	143	158	533	385	707	481	457	566
Phase1–oldpolyquarters	15	28	30	39	73	60	112	76	64	90
Gadumo	34	36	42	45	273	201	364	247	231	291
Ganaja	67	71	76	80	192	146	264	178	181	211
TOTAL	437	479	522	558	1339	985	1792	1216	1155	1434

Source: Kogi State Town Planning Board (2012), and GIS Analysis (2016)

ASSESSMENT OF FLOOD VULNERABILITY IN LOKOJA METROPOLIS, KOGI STATE, NIGERIA

Population Affected by the flood

The estimated population affected by the flood varies from one year to another, Table 4, reveals an increasing population at years with higher area extent/ coverage by inundation. The number hitherto, follows the trend of years

2012, 2015 and the least in 2006 with affected population estimates at 15,232 persons, 12,189 persons and 3,715, persons respectively. So the higher the inundated areas the more the likelihood to have many persons affected by the phenomenon.

Table 4 Estimated population affected

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
POPULATION	3715	4072	4437	4743	11382	8373	15232	10330	9818	12189

Source: KSTPDB (2012) and GIS Analysis by Authors (2016)

Flood Vulnerability in Lokoja Metropolis

Table 5 shows that a high vulnerable areas are with more than 8 meters water level gauge, and the areas with the highest coverage are the farmlands/open spaces falls with a land area of 2,754.21 ha, followed by residential land uses with land area/ coverage of 64.23 ha. Commercial 6.79 ha and Public land uses 3.56 ha. Therefore it can be deduced that in the 10 years flood period of 2006-2016 in Lokoja metropolis 2,754.21 hectares of farmland/open

space lies in high hazard zone. By implication, the impact of flooding and proneness of areas to flooding is at an increasing trend, though, with some disparity of vulnerability when compared with the tables 1 and 2 on the maximum water levels recorded in Lokoja. In addition, residential areas susceptibility increases geometrically into the vulnerable conditions with 64.23 hectares of residential land use under higher hazard zone in 10 years flooding (figure 6)

Table 5 Flood vulnerability

Water Level	Land Use					Total	%
	Residential	Commercial	Public	Industrial	Farmland/ Open Space		
< 8m (High Vulnerability)	64.23	6.79	3.36	0	2754.21	2828.59	13.64
8 - 14m (Moderate Vulnerability)	81.43	10.15	4.38	0.23	3756.34	3852.53	18.57
> 14 m (Low Vulnerability)	2619.1	8.12	46.6	0.22	11389.22	14063.26	67.79
Grand Total						20744.38	100

Source: GIS Analysis, 2016

ASSESSMENT OF FLOOD VULNERABILITY IN LOKOJA METROPOLIS, KOGI STATE, NIGERIA

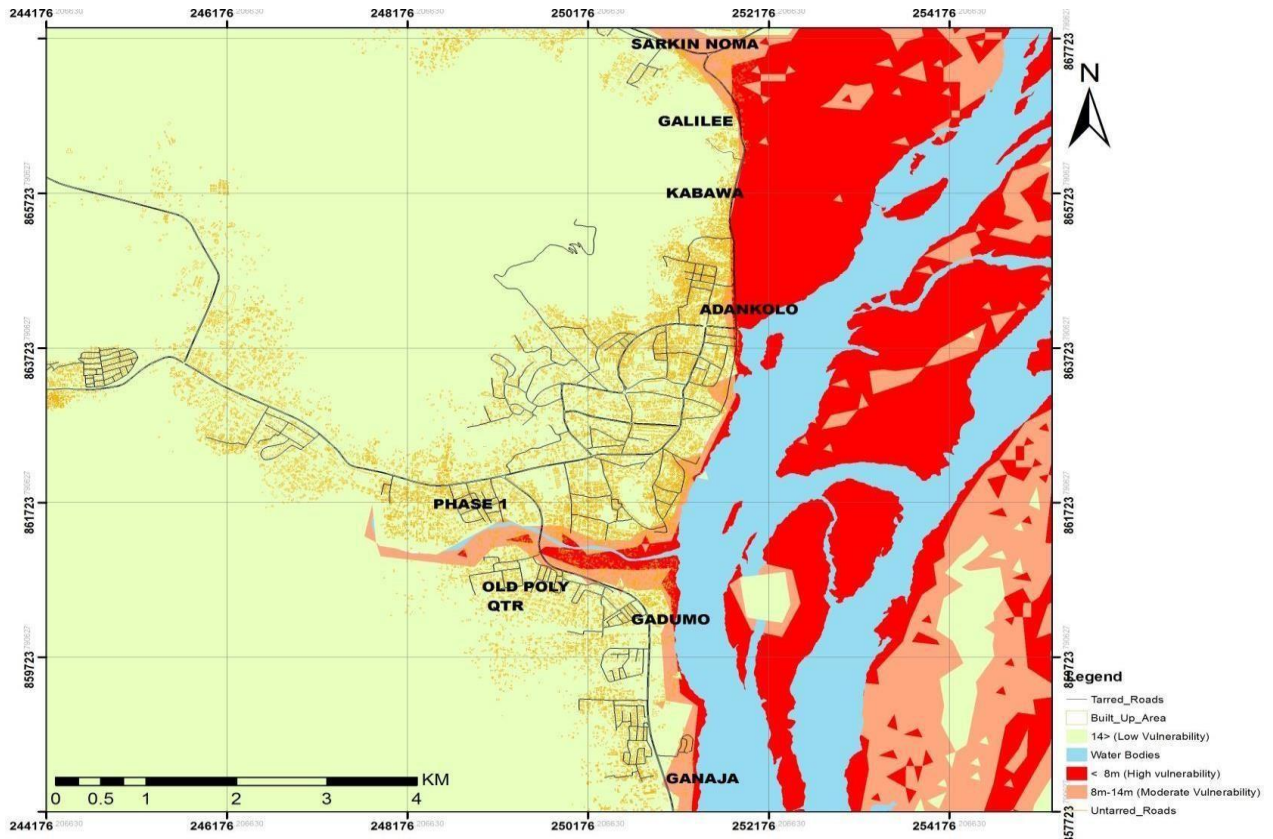


Figure 6 Flood Vulnerable area of Lokoja Metropolis in Ten Years.
Source: Field survey, 2015

CONCLUSION

The study established that flood occurs in Lokoja metropolis and the water levels recorded at the area influences the inundation of areas under the hazard with most houses submerged and the properties destroyed. The study also revealed that the most affected land uses under the threat of flood in the metropolis are the agricultural producing areas meaning threats to food production and subsequently the living areas (residences). The metropolis is really under the threat of flood hazards, which agrees with the initial position of the causes of flooding in the study area as calculated/estimated using Sgarma and Sharma (2002) formulas for an increasing flooding in the area. The study only achieved mapping of the high flood vulnerable areas and areas where flood occurs in ten years in regards to already occurred flood but further studies can explore this technique to simulate the situation and predict areas of flooding effects and vulnerabilities to help policy formulation and management. However, the study provides a strong baseline and benchmark for policy

formulation and management of flood in

Lokoja metropolis. The National Inland Water Authority should collaborate with the Planning Authority, State Emergency Management Authority and the Ministry of Environment to ensure enforcement of standards in relation to setbacks on water ways, and the Government should prepare a flood management plan and risk assessment that will lead to a policy to be jointly enforced by the institutions aforementioned.

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CHARACTERISTICS AND CHALLENGES OF SMALL-SCALE INDUSTRIES IN JOS NORTH LOCAL GOVERNMENT AREA, PLATEAU STATE, NIGERIA

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Abstract

Small-scale industries serve as pivot to socio economic development especially in areas of employment and income generation, self-reliance and reduced dependency. This study focused on the characteristics and challenges of small-scale industries in Jos North Area of Plateau State. It analyzed the nature of ownership, sources of finance, nature of contributions to socio-economic development and challenges faced by small scale industries in the study area. The quota sampling was used to delineate the study area into four industrial zones while the random sampling approach was used to administer a total of 120 copies of questionnaire, 30 in each quota to generate the data which was analyzed using descriptive and inferential statistics. The findings show that most small-scale industries in Jos North are owned by private individuals who have personal savings as a major source of finance and employed less than seven persons. One of the major contributions they have made is the creation of employment opportunities and in encouraging self-reliance. The study also found out that small-scale industries in Jos North face challenges which have limited their growth, such include poor funding and low patronage. Also using Chi-square test at 5% significant level, the study established that there is no significant difference in the types of challenges faced by different types of small-scale industries in the study area. The study therefore recommended that the Public-Private-Participation (PPP) strategy should be adopted to help solve some of the challenges and encourage the growth of small-scale industries sustainably.

Keywords: Small-scale industries, Challenges, Public-Private-Participation

INTRODUCTION

Small-scale industries serve as the bedrock of industrialization, and they form an important sub-sector in the Nigerian economy. They are the springboard for sustainable economic development and a veritable vehicle for the achievement of national micro-economic objective in terms of employment generation at low investment cost and enhancement of skills acquisition and entrepreneurship training. They are labour intensive, capital saving and perceived as the key to Nigeria's economic growth, poverty alleviation and employment generation (Agwu, 2014).

There is no universally accepted definition for small-scale industries, as what constitutes small-scale industry in one country may be considered as a large-scale industry in another. However, there are general operational definitions that are used to identify small-scale industries. Olajide (2008) defined a small-scale industry as a company with a capital base between ₦10,000 and ₦300,000. On the other

hand, The National Council on Industry (1991), as cited by Akinlabi (2008) defined a small scale industry as an industry whose total project cost, excluding cost of land but including working capital, does not exceed five hundred thousand naira (₦ 500,000) and the labour size is not more than ten (10) workers. Aremu and Adeyemi (2011) used the number of employees as a yardstick, indicating that an industry is considered small if it is independently owned, operated and financed, and has fewer than 100 employees. Therefore, this article considers a small-scale industry as an industry that has limited number of employees (not more than twenty (20) workers) and a limited flow of finances and materials

Interest in the role of small and medium scale enterprises (SMEs) in the development process continues to be at the forefront of policy debates in developing countries (Akinlabi et al. 2012). Globally, small-scale industries serve as a tool for empowering citizens and for economic growth. Asia and

CHARACTERISTICS AND CHALLENGES OF SMALL-SCALE INDUSTRIES IN JOS NORTH LOCAL GOVERNMENT AREA, PLATEAU STATE, NIGERIA

North America countries have their economic foundations linked to small-scale industrial development (Schaper, 2002; Wulifan, 2015). In Africa, small-scale industry is the dominant sector and accounts for almost 70% of all the enterprises in rural and urban areas (Uzor, 2004). They contribute to government revenue, increased foreign earnings, wealth creation and employment generation for a stable economy. For instance, it is estimated that small-scale industries employ 22% of the adults in developing countries (Fatai, 2011).

In Nigeria and indeed Plateau State where labour is abundant and capital is scarce, small-scale industries can be set up anywhere to help reduce regional disparities. However, establishing a wide variety of small-scale industries alone is not important, what really matters is their survival and growth. In view of this, Wulifan et al. (2015) noted that small-scale industries are weak in Africa because of small local markets, undeveloped regional integration and very difficult business conditions, which include cumbersome official procedures, poor infrastructure and inadequate financial system. Udechukwu (2003) & Akintunde and Adejuyigbe (2010) observed that poor quality products, inadequate management skills, inadequate social infrastructure, low patronage, poor awareness of the competition and poor pricing methods tend to be the major failings of small-scale manufacturers in Nigeria.

In 1990, the government of Nigeria stepped up her effort to promote the development of small and medium scale enterprises through incentive schemes, including enhanced budgetary allocation for technical assistance programmes, capacity building, enacting favourable economic and fiscal policies, protective laws and direct financial incentives, establishing new lending schemes and credit institutions such as the National Economic Reconstruction Fund (NERFUND), World Bank assisted small scale enterprises loan scheme and the People's Bank of Nigeria (PBN). (Babalola, 1991).

Despite all these programmes by the government targeted at promoting the growth and development of small-scale industries,

most small-scale industrialists are faced with socio-cultural obstacles which include lack of entrepreneurship culture and education, low motivation and lack of confidence as most entrepreneurs believe they cannot make it in the face of competition by bigger companies. Others include technological backwardness of Nigeria, which leads to labour inefficiency, political instability occasioned by civil unrests, political sabotage, local and youth restiveness, thuggery and armed robbery, which create insecurity in the minds of most small-scale entrepreneurs (Aremu & Adeyemi, 2011). There are also managerial problems such as the absence of or poor strategic management skills and attitudes, inability to respond to threatening environmental conditions, lack of clearly defined objectives, lack of delegation, inability to select appropriate equipment and resources and faculty design, implementation and evaluation by small-scale industrialists.

The aforementioned challenges continue to limit the growth and development of small-scale industries in Nigeria. Generally, across the country, similar and other peculiar challenges based on socio-economic and cultural circumstances of regions continue to pose severe limitations on establishment and development of small scale industries. Although various studies have carried out on small scale industries in different parts of the country, none tried to examine the peculiar challenges of small scale industries in Jos North Local Government of Plateau State. It is therefore necessary for a careful study of characteristics and challenges of small-scale industries in Plateau State with a view of making necessary recommendations that would help improve their performance.

MATERIALS AND METHODS

Study Area

Jos North, the study area, is one of the seventeen (17) local government areas (LGAs) that make up Plateau State, and is the state capital. It is located in the North Central geopolitical zone of Nigeria and lies between latitudes 9°53' and 9°58'N of the Equator; and between longitudes 8°51' and 8°58'E of Prime Meridian. (Fig. 1).

CHARACTERISTICS AND CHALLENGES OF SMALL-SCALE INDUSTRIES IN JOS NORTH LOCAL GOVERNMENT AREA, PLATEAU STATE, NIGERIA

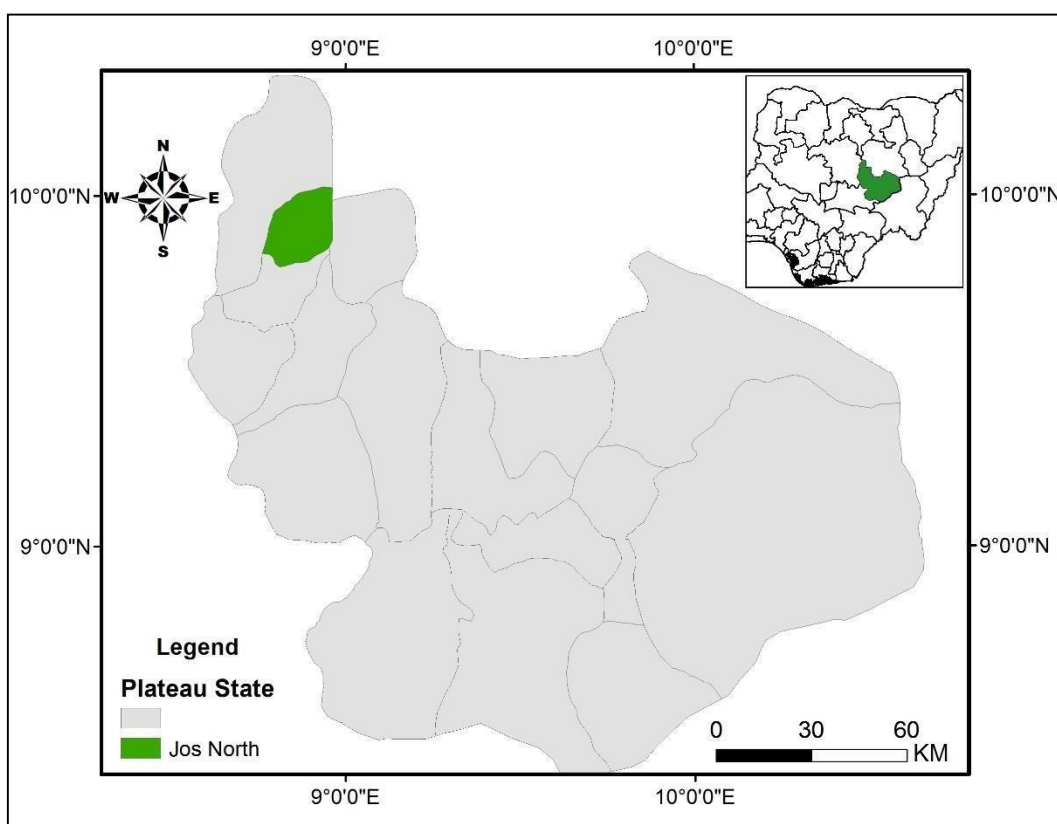


Figure 1 Plateau State showing Jos North LGA (2016)

The population of Jos North LGA was estimated at 519,300 (PIDAN, 2015). The people are noted for farming, mining and civil service occupations. The presence of basic infrastructure like roads, electricity and pipe borne water put in place by the government encourages small-scale industrial activities like wood work, leather works, blacksmithing, cereal processing, block molding, photography, vehicle repairs among others.

Jos North, like much of the Jos Plateau is historically noted for commercial tin mining operation that boomed in the area between 1903 and the 1980s. The growth and development of Jos as one of the prominent cities in Nigeria is tied to the growth and development of tin mining in the area. The mining operation had encouraged the migration of thousands of people from all parts of Nigeria and other parts of the world, who brought different expertise and ideas to bear on many parts of life in the city including social, economic and cultural diversity. Small-scale industries therefore thrived during the mining operations. However, their fortunes dwindled with the fall in tin mining activities in the area, and the austerity

measures that followed the economic recession in the country in the 1980s. Recent impetus has however, helped the establishment, growth and development of small-scale industries again as new economic opportunities present themselves in the face of unemployment and underemployment in the country. In Plateau state, the cosmopolitan nature of Jos North LGA makes it the hub of small-scale industries. The large number and variety of economic opportunities presented by its relative massive population size and the presence of commercial centres and markets such as Delimi market, New market, Farin-Gada market, Terminus market, Satellite market and others encourages growth of small scale industrial production and easy access of products by consumers in Jos.

Data Collection

Data obtained were from primary and secondary sources. The questionnaire and interview were the major instruments of data collection from the respondents. Information from published and unpublished documents, duly acknowledged, were used as the secondary sources of data.

CHARACTERISTICS AND CHALLENGES OF SMALL-SCALE INDUSTRIES IN JOS NORTH LOCAL GOVERNMENT AREA, PLATEAU STATE, NIGERIA

The study adopted quota sampling methods. First, small scale industries in Jos North LGA were classified into four categories: manufacturing, repair and service, cottage and others. The study area (Jos North LGA) was then delineated into four industrial zones namely Gwong, Naraguta, Kabong and Tudun Wada. Each zone contains a number of all types of small scale industries. To ensure adequate spatial coverage of the study area, data was collected from all types of small scale industries in each industrial zone. In each zone, 30 questionnaires were administered to selected small scale industries to ensure that all categories were captured and each type meets a minimum quota of representation. The owners of the industries were the primary target for data collection. However, in the absence of the owner, the most senior employee or apprentice available at the time of survey answered the questions. In total 120 questionnaires were administered, retrieved and used in data analysis.

Data obtained were analyzed through descriptive and inferential statistics. Tables containing frequency and percentage distributions were used along with charts to summarize and describe the socio-economic characteristics of small scale industries and industrialists data while the Chi-square statistical method was employed to test the hypothesis stated as there is no significant difference in the types of challenges faced by different types of small-scale industries in the study area. The chi-square statistical tool was employed because of its robustness and strength of isolating statistically significant factors responsible for observable variation from an assemblage of variables.

RESULTS AND DISCUSSION

Socio-Demographic Characteristics of Respondents

The socio-demographic characteristics of the respondents including age, gender and level of educational achievement are presented in table 1. Growth and development of small-scale industries depend to a large extent on these variables. Table 1 reveals that 70% of respondents are about 45 years old, which reveals that most entrepreneurs are young. This findings shows that most small-scale industries in Jos North are newly established and may

suffer competition from their foreign well established industries. This as explained by Fatai (2011) indicates that young adults engage more in entrepreneurial activities as they strive to provide the basic needs of their immediate families. Also 50% of small-scale industrialists in Jos are married, about 42% are single, while less than 10% comprised of divorced and widowed small-scale industrialist. Though most of the respondents are married, which aligns with the findings of Davuluk (2016) in Jos South LGA. The fact that a large percentage of the respondents are unmarried (42%) confirms the observation that a large number of them are young. The findings on occupation shows that 33.33% are farmers, 25% civil servants, 25% engage in small scale industrial activities/artisans, 16.67% are students. This reveals that a larger percentage of the respondents are farmers which the main occupation of the people of Jos Plateau at large. The 25% engaged in civil service and small-scale industrial activities is because of the presence of Jos North headquarters, and other institutions within the study area and the conducive environment for small-scale industrial activities encourages enables the large proportion of the population to practice. This is affirmed by Obi (2012) who observed that an enabling environment encourages small-scale industries to strive and expand.

From the findings of this study, about 75% of respondents earn more than the current minimum wage of N30,000 a month. Nevertheless, the monthly income of the respondents is generally low since only 16.67% earn above ₦ 90,000 monthly. Davuluk (2016), the higher the income the lesser the desire to maintain a small-scale industry. The data suggests that most small-scale owners may not be able to break out into larger enterprises based only on their current income status.

The gender distribution of small-scale industrialists in Jos North shows that 75% of them were males. This is probably indicative of the fact that in most Nigeria cultures, the men are the bread winners of their households.

Finally, the level of education of small-scale industrialists has implication on the functions, management or operations and the quality of their products. The study found that 83% of respondents are not educated beyond the primary school level. This is likely to pose a

CHARACTERISTICS AND CHALLENGES OF SMALL-SCALE INDUSTRIES IN JOS NORTH LOCAL GOVERNMENT AREA, PLATEAU STATE, NIGERIA

number of problems, chief among which would include the degree of innovations that could be brought to bear on the operations of their businesses, the receptivity and injection of new and modern ideas and technology and the level of financial acumen that may be employed to properly and efficiently manage the necessary resources growth and sustainable development

of the industries. The small scale industrialists stand the risk of losing out in the face of competition from more educationally equipped industrialists. This is affirmed by Joshua (2008), who observed that education increases innovative skills and enables small-scale industrialist to strive better.

Table 1 Demographic characteristics of respondents

Age of Respondent (years)	Frequency	Percentage (%)
Less than 20	30	25.00
21 – 45	54	45.00
46 – 60	24	20.00
Above 60	12	10.00
Total	120	100.00
Marital Status	Frequency	Percentage (%)
Married	60	50.00
Single	50	41.67
Divorced	6	5.00
Widowed	4	3.33
Total	120	100.00
Occupation	Frequency	Percentage (%)
Civil Servant	30	25.00
Farmers	40	33.33
Artisans	30	25.00
Students	20	16.67
Total	120	100.00
Monthly Income	Frequency	Percentage (%)
Less than ₦30,000	30	25.00
₦ 31,000- ₦ 60,000	45	37.50
₦ 61,000- ₦ 90,000	25	20.83
Above ₦ 90,000	20	16.67
Total	120	100.00
Gender	Frequency	Percentage (%)
Male	90	75.00
Female	30	25.00
Total	120	100.00
Level of Education	Frequency	Percentage (%)
Non –Educated	40	33.33
Primary	60	50.00
Secondary	12	10.00
Tertiary	8	6.67
Total	120	100.00

Source: Field Survey, 2016

CHARACTERISTICS AND CHALLENGES OF SMALL-SCALE INDUSTRIES IN JOS NORTH LOCAL GOVERNMENT AREA, PLATEAU STATE, NIGERIA

Characteristics of Small-Scale Industries

The performance or contributions of small-scale industries to socio-economic development is highly dependent on such variables like ownership, finance source, number of employees, and the challenges they face among others.

Types of Small-Scale Industries

The small-scale industries identified in the study area were classified into four on the basis of nature of their products as seen in Table 2.

Table 2 Types of small-scale industries in Jos

Types of Small-Scale Industry	Frequency	Percentage (%)
Manufacturing industry	30	25.00
Repair and service industry	72	60.00
Cottage industry	6	5.00
Others	12	10.00
Total	120	100

Source: Field Survey, 2016

Table 2 shows that 60% of small-scale industries engage in repair of vehicles, electronics, and also service rendering, like hair dressing saloon, computer centres and so on; 25% are manufacturing industries that convert raw materials into finished goods, for example block industry, flour mills, leather industry; 10% fall into a category referred to as “Others” and are largely service providers, for example photographic studio and football viewing centres only 5% are engaged in home-based

production (cottage industry), e.g. pottery industry. As noted by Akintunde and Adejuyigbe (2010) most developing nations engage in manufacturing, repairs and services as well as cottage production at small-scale, which is borne out by this study

Ownership

The nature of ownership of small-scale industry in the study area differs. A survey of this characteristic is summarized in Fig 2.

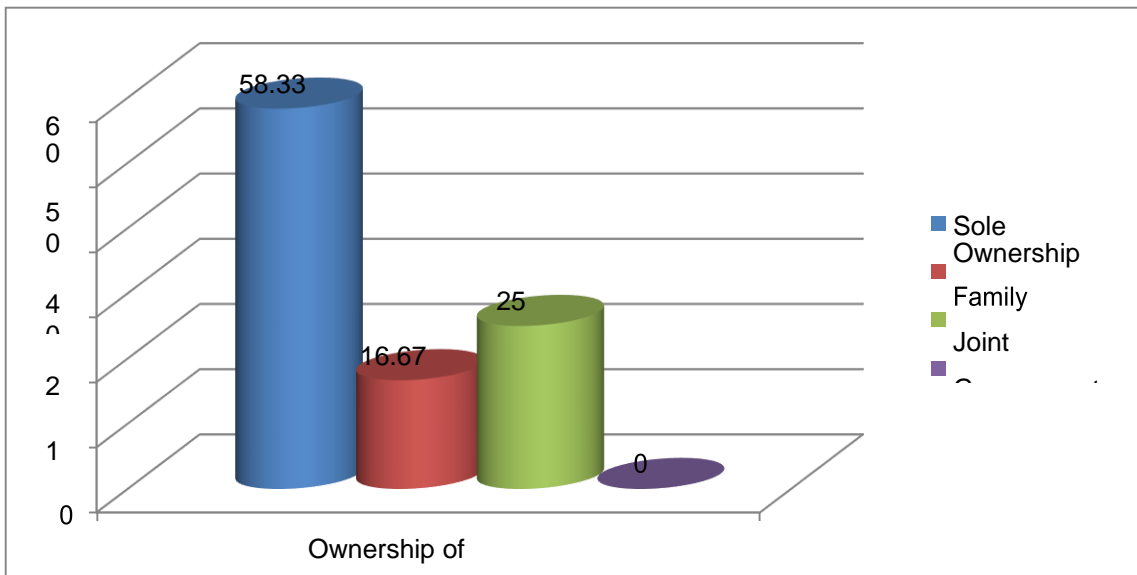


Figure 2 Ownership of Small Scale Industries

CHARACTERISTICS AND CHALLENGES OF SMALL-SCALE INDUSTRIES IN JOS NORTH LOCAL GOVERNMENT AREA, PLATEAU STATE, NIGERIA

Fig.2 shows that most small-scale industries are sole-owned (58.33%) while 25% is based on joint ownership, and 16.67% is based on family ownership. There is no government ownership. This findings agrees with Ugwu (2014), that government generally does not engage in small-scale industrial enterprises rather, they offer financial and infrastructural support to such operators.

Sources of Finance

The establishment of small-scale industry and the quality and quantity of products obtained from them are dependent on the available capital used in such activity. A survey of sources of finance of small scale industrialist is presented in Fig 3

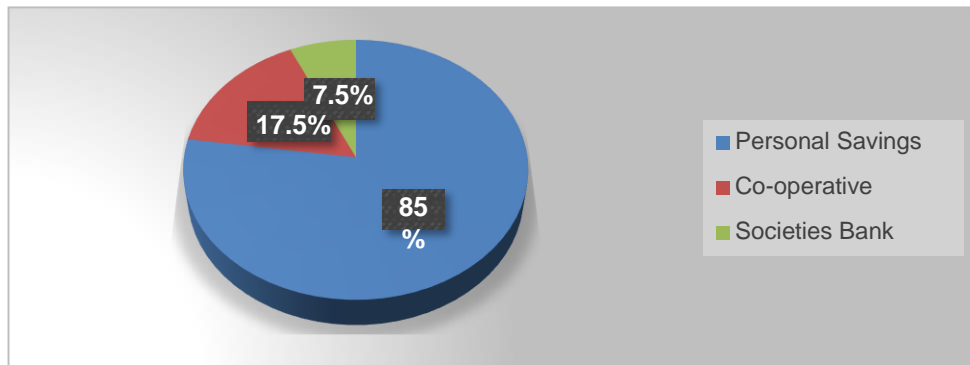


Figure 3 Sources of Finance

Figure 3 shows that 85% small-scale industries source their finance from personal savings. A total of 17.5% was financed by the the help of co-operative societies, and only 7.5% are established from loans gotten from the bank. Ayozie (2011) also found that most small scale industries are established and funded through personal savings of the entrepreneurs. This is instructive in the sense that most personal savings are meagre and would therefore only be enough to establish and start the industries at very small-scales. The

expansion of these industries will depend on the output of the industries, their ability to break even and amass profit for reinvestment.

Number of Employees

The number of employees involved in production of goods and servcies in any small-scale industries is a necessary content to ascertain its performance. The number of employees in small-scale industries is presented in Fig 4.

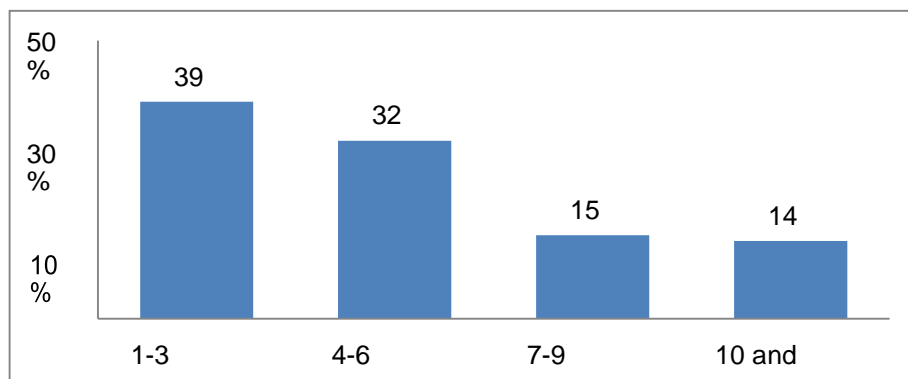


Figure 4 Distribution of Small-Scale Industries by Number of Employees

Figure 4 reveals that most (39.0%) of the small scale industries employ 1 – 3 persons.

32% employ between 4-6 persons. However, those with more than 9 employees constituted

CHARACTERISTICS AND CHALLENGES OF SMALL-SCALE INDUSTRIES IN JOS NORTH LOCAL GOVERNMENT AREA, PLATEAU STATE, NIGERIA

14,9%. Based on this findings, as explained by Aremu and Adeyemi (2011) are small-scale industries in nature with less than 100 employees.

Benefits of Small-Scale Industries

The contributions of small-scale industries to economic development of Jos city were assessed and the result obtained is presented on table 3.

Table 3 Benefits of small-scale industries

Nature of Contribution	Number	Percentage (%)
Employment generation	65	54.17
Self-reliance	30	25.00
Reduced dependency ratio	17	14.17
Revenue generation	8	6.67
Total	120	100

Source: Field Survey, 2016.

Most respondents (54.17%) regarded the small-scale industries as primarily a source of employment. Generally in nearly all the countries of the world, governments and large corporations cannot provide sufficient employment for the teeming population. Since small scale industries do not require large capital base, high degree of educational qualification or high level of expertise, they are easily established and compliment the efforts of government and large corporations in providing employment for a great proportion of the population. As noted by (Fatai, 2011), Small scale industries provide about 22% of employment in developing countries, which translate to millions of people being employed in this sector. In the case of Nigeria, the contribution of small and micro scale industries to employment is even about 60% (Akinlabi et al., 2012). It is not far-fetched therefore to contend that the small and micro scale industries are the backbone of economic activities in Nigeria. This is similarly true of many urban centres in the country.

Self-reliance is another important benefit that small scale industrialists gain from the industry, especially for the owners and entrepreneurs. Twenty-five percent (25%) of respondents regard the small-scale industries principally as a means to achieve self-reliance. For many entrepreneurs, this is an important component of engaging in the industry. It

allows the entrepreneur to dictate their strategy, work at their pace, determine the direction of expansion and investment and essentially chart their path to economic independence and prosperity.

About 14.17% of respondents regarded the small scale industry as a means of reducing dependency on the society through income generation. By engaging in small-scale ventures, employees can now fend for themselves the basic needs of food, clothing and shelter, rather than depending on others. About seven percent (6.7%) of respondents opined that revenue accruing to the government through taxation of small-scale industries is a significant contribution to economic development of Jos North LGA, Plateau State and Nigeria.

Challenges of Small-Scale Industries

Small scale industries all over the world face many challenges at different levels. These include at the startup stage of establishing the industry to its development stage and eventual expansion and transition into larger scales of industrial activity. Data was collected on the major challenges confronting different types of small scale industries. Table 4 presents the summary of the results on some of the most pressing challenges being faced by small scale industries in Jos North LGA, Plateau state.

CHARACTERISTICS AND CHALLENGES OF SMALL-SCALE INDUSTRIES IN JOS NORTH LOCAL GOVERNMENT AREA, PLATEAU STATE, NIGERIA

Table 4 Challenges faced by small scale industries in Jos North LGA

Industry Types	Poor Funding	Low Patronage	Insecurity	Inadequate raw materials	Total
Manufacturing industry	14	10	4	2	30
Repair and service	32	29	5	6	72
Cottage industry	1	2	1	2	06
Others	3	5	2	2	12
Total	50	46	12	12	120
Percentage (%)	41.67	38.33	10.0	10.0	100

Source: Field Survey 2016.

Expectedly, the most important challenge is poor financial base to operate at desired capacity. Nearly forty-two percent (42.7%) of respondents identified poor funding as the major challenge they face. As already determined, most small-scale industries are established and run by funds sourced through personal savings. These are meagre, taking into account the caliber of people engaged in small scale industries in Jos North LGA. Closely following inadequate funding is the problem of poor or low patronage by expected consumers of small scale industrial products. There is much to tie this problem to the challenge of poor funding. First, inadequate funding results into poor products since the production process is generally simple, unsophisticated and limited by a poor resource base to produce finished products of high quality.

For 10% of respondents insecurity is probably the major challenge they are faced with. Jos North LGA has for a long time, until recently, been the focal point of many ethno-religious crises in Plateau State, with attendant violent conflicts that have destroyed many small scale industries in the area. The remaining 10% of respondents are faced with

the problem of access to raw materials which may be closely related to inadequate funds to acquire the required amount of raw materials as input for their business enterprises.

The Chi-square test was employed to determine if there is any significant difference in the types of challenges faced by different types of small scale industries in the study area. The calculated Chi square value is 9.58 while the table value of Chi square at 0.05 level of significance and df at 9 is 12.84. To reject the null hypothesis, the calculated value has to be greater than the table value. Consequently, the study fails to reject the null hypothesis. The implication is that the different types of small scale industries in Jos North LGA face identical types of challenges. Recommendations may then be made to attempt to mitigate these problems and their consequences on the establishment and development of small scale industries in the study area.

Alleviating Challenges

Table 5 presents the recommendations of respondents to the challenges that face small scale industries in Jos North LGA.

Table 5 Respondents' opinions on how to tackle challenges faced by small-scale industries

Possible Solutions	Number	Percentage (%)
Increased government loans/grants	65	54.17
Increased advertisement	23	19.17
Conducive environment	17	14.17
Increased raw materials supply	15	12.50
Total	120	100

Source: Field Survey, 2016.

As expected, most respondents recommend interventions by government that

would provide access to financial resources to invest in their businesses and advertise their

CHARACTERISTICS AND CHALLENGES OF SMALL-SCALE INDUSTRIES IN JOS NORTH LOCAL GOVERNMENT AREA, PLATEAU STATE, NIGERIA

products. Fifty four (54%) require soft loans and grants from government to develop their businesses while 19% opined that increased advertisement may be important to increase patronage of their businesses. These recommendations directly relate to the near-twin major challenges of poor funding and low patronage that the respondents had decried. More funds would help to invest more in their businesses with the potentials for improved quality and increased patronage.

There is also the need for small scale entrepreneurs to liaise with other private individuals who can support and invest in the industry as partners. The entrepreneurs however need to show enterprise to convince private investors to take interest and invest in the businesses. A little more education may help. Technical training, skills development and some more formal education may help the entrepreneurs develop into better managers. The fact that most of them are young means that they are still capable of learning a lot of new ideas and developing new skills. The government may provide such specialized training programmes to certified small scale industrialists. This would boost their access to funding, ideas and investments opportunities for a more productive industrial development.

CONCLUSION

This paper examined the characteristics and challenges of small-scale industries in Jos North LGA, Plateau State. The study revealed that small-scale industries generate employment, revenue and are a source of self-reliance for entrepreneurs. These industries are however, confronted with challenges, important among them being poor funding and low patronage.

The current drive by both the Federal and State government on enabling the medium and small scale industries to become greater contributors in the national and local economies is a welcome development of properly implemented. Cooperatives and soft loans may also be advanced to small scale owners to improve on their productivity. Also, Public-Private-Participation (PPP) strategy should be adopted to help solve some of the challenges and encourage the growth of small-scale industries sustainably.

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PARTICIPATORY SLUMS UPGRADING IN KABONG COMMUNITY IN JOS, NIGERIA

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Abstract

Slums upgrading is a desirable activity in urban areas. It does not only upgrade the status of the area but improves the quality of life of its residents. Kabong community is a neighbourhood in Jos, Nigeria which has a substantial area with slum characteristics. The infrastructural facilities are decayed or deteriorating, the environmental conditions are not palatable and the housing is in squalor conditions. Of recent, however, attempts have been made to upgrade some of these facilities. The government has upgrade a large portion of its inner roadways and electricity has been restored in many portions. This study examines the extent to which residents of the community have participated in this upgrading activities. The study administered 410 questionnaires to residents and had focus group discussions and interviewed the leadership of the community development association in the community. Results indicated that most residents in the community, though aware of the existence of the community development association, are not actively involved in its activities. Only a few pay the annual dues to the association. With the relatively meagre amount of finances available to it, the community development association has renovated the public primary and secondary schools and the primary health care facility situated in the community. They have also provided electric poles and constructed culverts as well as embark on community waste disposal efforts. Individuals in the community have also constructed culverts to lead to their houses or link their sections of the community to other parts. These activities show that the community is becoming more involved in the slum upgrading project of their community. A lot still needs to be done with community mobilization to ensure more commitment of more residents in this activity.

Keywords: Slum upgrading, Public participation, Project services, Community development

INTRODUCTION

The problem of slums in urban centres has subsisted for a long time. Cherry (1970) observed that housing conditions started depleting in quality due to rapid growth in population, increased urban net influx and decline in the national productivity output. Bradbury and Downs (1987) noticed that houses have become spontaneous, dilapidated and severely overcrowded especially in the developing countries. Slums, shacks, squalors, substandard houses and illegal structures started emerging in the urban centres that inhabited crime, appalling environment, diseases and poor hygiene (Timms, 1978). The most enduring physical manifestation of social exclusion in African cities is the proliferation of slums and informal settlements. Arimah (2009) claimed that people who live in slum settlements in the urban areas experience the most deplorable living and environmental conditions.

These dwellers are excluded from participating in social, economic, political and cultural spheres of the city. All this creates a low economic capacity whereby the dwellers that are poor in the first place are made poorer by the various forms of exclusion. UN-HABITAT (2010a) declared that 828 million or 33% of the population of cities in Less Developed Countries (LDC's) resides in slums. Such settlements have life threatening conditions that impose heavy burden on city planners caused by cash-strap with fear and violence (Bloom *et al.*, 2008). These appalling situations probably necessitated the Millennium Development Goals (MDG), Goal 7, which sought to improve the living conditions of at least 100million slum dwellers by 2020 (UN-HABITAT, 2003a).

Currently, many African cities are battling to tackle the problem of slums. UN-HABITAT (2010b) revealed that more than 60% of sub-Saharan African residents dwell in

slums neighbourhoods. The weak political will for planning has resulted to the deterioration of housing conditions and subsequent emergence of mushroom slums areas. Practical Action (2012) iterated that slums are spreading fast and are characterised by poor livelihood, poor service provision and poor security. Slums are growing just as immigrants are increasing, causing growth in slums and the expansion of its formations. Slums have been of great concern based on their conditions, yet the slums dwellers are not always aware of the poor living conditions around them. Migrants strive for urban employment and better livelihoods for themselves and their families but have not been keen on how their urban life may be. Hence, transit abodes are negotiated and the migrants are forced to accept the unpleasant environment. The shortfall in housing provision has continued to increase alongside with alarming increase in poverty.

The World Bank introduced slum upgrading project in Least Developed Countries, which marked a radical change in the official attitude of governments from slum demolition to slum improvement. Cronin and Guthrie (2012) acknowledged that rehabilitation of slums, upgrading infrastructure and housing programmes affect their sustainability. Improvement in the environment involves the aspect of housing, infrastructure, employment and other urban fundamentals still have much to address the “backlog of urban neglect”. It is in this view that Werlin (1999) advocated improvement of the environment, sanitation, security of tenure, access to credit and housing quality.

Nigeria’s population growth has continued to impose great pressure on housing, urban infrastructure, facilities, and employment opportunities. This has resulted to slums emergence at the central sections and the fringes of cities (Agbola, 2006). Hence, many housing structures in major cities have slums presences simultaneously with modern structures (Macpherson, 2014).

The World Bank slum upgrading approach emerged by the propagation of John F. C. Turner and was applied for urban development projects in the 1970’s and 1980’s (Werlin, 1999). Researches undertaken in this regard in Nigeria were on comprehensive urban renewal in slums affected areas of Maroko, Lagos (Agbola & Jinadu 1997; Alagbe 2006;

Gbadegesin 2011; Arimah 2005; and Okpala 1999). These researches view urban renewal in the perspective of complete demolition carried-out without the communal participatory involvement in both the pre and post planning benefits. Turley *et al* (2013) and Walnycki *et al* (2013) reviewed the nature of slum upgrading conducted in cities of developed countries such as Cardiff, Oxford, Harvard, Munich and Birmingham and found that they were conducted without resettling the urban poor. In Nigeria slum residents were dispossessed of their homes. Slum upgrading approach should be community-based. This is the critical issue that this study examines in regards of Kabong area of Jos, Nigeria.

Concept of Participatory Slums Project

Between 2001 and 2004 the United Kingdom Department of International Studies initiated a “*Binding in Partnership*” themed “*Participatory Urban Planning Project*” (BIP-PUP). BIP-PUP project comprised representatives of all stakeholders involving county/local government practitioners and the communities, and were able to identify two major problems confronting residents (Majale, 2008). These problems were economic restrictions in enterprising productivity and the limit of employment creation within small scale enterprises. The project enabled the residents to state their needs with regard to a range of issues defined by problems of inaccessibility to land resources, infrastructure and housing, social services and urban governance (Macpherson, 2014). That is why participation is a crucial means of poverty reduction. It enabled partnership, holistic focusing and project planning amongst stakeholders as an index to improving living conditions.

Participatory Urban Planning Project (PUP) allows for residents to be included in decision making processes. Another advantage includes the alleviation of individual sectoral weaknesses by taking advantage of other sectoral strengths (Otiso, 2003). Thus it fosters efficiency and allows for resources to be distributed during decision making process. This highlights why participation of slum dwellers in decisionmaking, inspite of their poor economic and intellectual bases, is vital to poverty reduction (Sen, 1999).

The relationship existing between public, private and civic society has become

PARTICIPATORY SLUMS UPGRADING IN KABONG COMMUNITY IN JOS, NIGERIA

salient to the successes of slums upgrading. According to Majale (2009) participation allows harnessing of local human capital and artisan skills in the construction/implementation stage. Beneficiaries developed resilient, unique and exploded applicable strategies for the survival of their needs for durable, viable and affordable shelter. Locatelli and Nugent (2009) stressed

that this was shared amongst development practitioners and local government personnel who have the resources to scale up or advocate these methods. Or at the very least, the human capital could be able to shed light on community issues that were previously neglected or unknown to the development practitioners and government officials, as seen in figure 1.

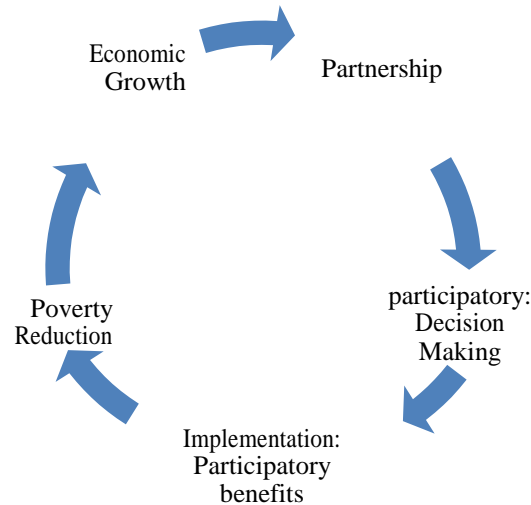


Figure 1 Slums Upgrading Participatory Cycle
Source: Macpherson, 2014; 89

Figure 1 explains the community involvement in the actualisation of slums upgrading in cities. The five basic tenets of economic growth, partnership, participatory, decision making, implementation; participatory benefit and resultant urban poverty reduction are the highlighted. Economic growth indices centre on employment, income, rent and access to land by the affected migrants vis-a-vis the occupants. Partnerships involve collaboration with relevant organisations on the conceived burden to achieve targeted objectives. Partnerships open-up spectrum of stakeholders to ensure the execution from the on-set to the off-set in project assurance that includes collaboration, sensitisation, discussion and construction. By this act a reliable and formidable planning perception changes the orientation of project plan to the beneficiaries. Participatory role can be the democratic activities undertaken such as collaboration, voting and provision of the housing units. This shifts the urban poverty reduction impact that result from accomplishment of Slum Upgrading Programme (SUP).

Participation is unlikely to guarantee a means of poverty reduction and slum sustainability. Top-Down planning has emphasised on restricted understanding of poverty reduction as realistic in African cities (Mansuri & Rao, 2013). It does not take into account the fact of housing multifaceted problems in socioeconomic, political, environmental and heritage transformation. Therefore, appropriate government reform ought to be community-based as its results to a realistic sustainable poverty reduction (Cox & Negi, 2010). Arandel and Wetteberg (2012) noticed that local communities are egalitarian in nature with different interest and capabilities, all these factors must be captured in both the planning design and implementation. The Kisongo community presented and utilised many local organisations such as NGO, churches and the traditional leaders, which were able to keep check on the development of BIB-PUP projects (Majale, 2008) Hence in implementing participatory upgrading programmes, strong local organisations must be

coherent and active in tackling social issues and resolving conflict.

Overview of Slum Upgrading Features

This consists of physical, social, economic, organisational and environmental improvements within the slum neighbourhood and its associated appalling conditions. These projects enumerated by Field and Kermer (2006; 12) include:-

- i. Regularising security of tenure through property mapping, titling and registration
- ii. Installing or improving basic infrastructure, including water, waste collection, storm drainage, electricity, security lighting, and public telephones
- iii. Removal or mitigation of environmental hazards
- iv. Providing incentives for community management and maintenance
- v. Constructing or rehabilitating community facilities such as nurseries, health posts, community centres, market and court.
- vi. Home improvement materials, new construction and expansion of the existing structures which includes cement, roofing sheet, housing design, and others to cope with changes in family size, improved income status and environment
- vii. Improving access social support programmes to address community issues such as crime control and substance abuse,
- viii. Enhancement of income-earning opportunities through training and micro credit.

Many interventions bundle these services and provisions, so it is critical for evaluators to have an understanding of each project component (Bamberger *et al*, 1882 and, Bamberger and Eleanor, 1986). Furthermore in many cases, subprojects grow out of initial interventions such that evaluators must monitor with keen interest/concern the objective of the project as it expands its services and programmes components. To do so, Ghafur (2001) and Kapoor *et al* (2004) suggest that evaluators should conduct in depth interviews with central and field level project administrators at the start of the process as opposed to relying on intervention blueprints.

Slum Upgrading Paradigm

Slum upgrading fundamental has experienced a gradual shift in the past 30 years in Africa (UNDP, 2003; and, Gulyani & Bassett, 2007):

- a) It has shifted from an intervention in housing to focus on access to infrastructures and services.
- b) The scale and the scope have changed; from multi-sectoral projects that involve social and economic objectives to modest specified projects composed of fewer objectives on a particular sector.
- c) Difference in the inherited planning tradition of former colonial masters also explained the incidences of slums; authority of British colonies maintained zero tolerance policy towards slums.

Colonial planning regulations still form the basis for urban development in Africa. Teddal and Ray (2001) observed that the British had low tolerance towards slums to the extent of demolition and resettlement as observed in Ghana, Kenya, Nigeria, Zambia and Zimbabwe. Payne (2005) acknowledged the bureaucratic regulatory framework governing the delivery of planned landuse in urban area is affected by both residential and land ownership. The standard procedures and regulations, made planned land unaffordable and unavailable to low income households leading to the development of informal settlements. The provision of urban infrastructure can better the lives of slum dwellers. Arimah (2009, 14) illustrated that the effect of infrastructure may be examined in three variables: "percentage of paved roads, the numbers of telephones mainline per 1000 people, and the public expenditure on health as a percentage of GDP". The first two variables are measurement of the stock of the existing infrastructure. The third variable is a proxy measurement of infrastructural expenditure and investment.

MATERIALS AND METHOD

Study Area

Kabong is located in the NW of Jos , Nigeria, which is situated between Latitudes 09^o 55' E and Longitude 08^o 54' N. It has an elevation of about 1400 metres above sea level (Ofune, 1981). The total annual rainfall is 2,476 mm. The mean temperature is about 22^o C. The vegetation is the Montane type made of shrub, herb and grasses.

Some areas within Kabong, such as Rock Haven, Angwan Alheri and Utan were

PARTICIPATORY SLUMS UPGRADING IN KABONG COMMUNITY IN JOS, NIGERIA

planned, due to the influence of missionary residents. Today some patches of these areas have haphazard unapproved built structures. The central area of the district has a modern market of over 200 shops with bank, court, police station, parking bay and malls and 2 spotted local markets in the west and the east of the area respectively. Kabong has some reputed secondary and mission colleges in the nursery, primary and secondary levels. It has a catholic convent, many churches, a modern stadium, the city graveyard, hotels and many bars.

Data Collection Methods

This involves the Focus Group Discussion

(FGD) and questionnaire administration.

Focus Group Discussion (FGD) approach

There is always a variety of ideas when stakeholders are assembled to discuss the slum upgrading issues existing in an area. The diverse ideas explored the various perceptions and orientation of pressure groups in the slum upgrading project. The research methodology is based on focus group discussion (FGD) technique. There were 4 FGD workshops undertaken. Table 1 showed the nature of the stakeholders invited to start the first phase of the FGD.

Table 1 Stakeholders composition and their number

S/No	Stakeholders	Number
1	Ward Head or Representative	1
2	Slum residents	8
3	Church leaders	3
4	Hotel/Restaurant	2
5	Planning authority	1
	Total	15

Questionnaire administration

This is structured into 2 sections: socioeconomic characteristics and the community-based effects of SUP. The socioeconomic characteristics included age, sex, marital status, occupation, income and house location, while the community-based

participation included strength of Community Association (CA), project services, organisational provision and an evaluation of services provision/benefits derived. A total of 410 questionnaires were administered based on stratified random sampling to the slum dwellers in these areas.

Table 2 Kabong neighbourhood areas

S/N	Slum-prone	Areas	Type
1	Yes	Kabong CBD, Yow and Angwan Suya,	3
2	No	Utan,	2
3	No	Rock Haven	1
		Total	6

Grade: 1 – Planned area, 2 – Fairly Planned area and 3 - Unplanned area

The researcher recruited and trained 4 field assistants. Questionnaires were administered to

residents of these neighbourhood areas for a period of 8 consecutive days.

RESULTS AND DISCUSSION
Socioeconomic Characteristics of Respondents

This affects socioeconomic characteristics and the community compositional set-up for projects. The socioeconomic characteristics

considered in this research include income and occupations of residents. Ranges of income levels per month were also collected and presented in table 3.

Table 3 Income level per month

Income monthly range	Freq	Percent
0-25,000	105	25.61
25,001-50,000	85	20.73
50,001-75,000	72	17.56
75,001-100,000	66	16.10
100,001-125,000	43	10.49
125,001-150,000	18	04.39
>150,001	21	05.12
Total	410	100

Table 3 shows that about 70% earned above the income minimum wage of N30,000 per month. About 20% of respondents earned N100,000 and above. About 95% of the respondents, however, earn less than N150,000 per month. In the current dispensation of high

inflation, the statistics indicate a low income earning power for most residents of the neighbourhood. The other socioeconomic characteristic is the occupation of resident respondents (Table 4).

Table 4 Occupation of residents

S/N	Occupation	Freq.	Percent
1	Artisan	75	18.29
2	Trading	120	29.27
3	Farming	42	10.24
4	Civil servant	122	29.76
5	Retired	40	09.76
6	Professional	11	02.68
	Total	410	100

Table 4 showed high proportion of traders and civil servants who together make up nearly 60% of the respondents. There is also a sizeable number of artisans (18%) in the community. This may explain the low income status of most residents in the neighbourhood (Table 3). Most of the civil servants are low cadre and most of the traders are equally petty traders or shop owners who are into retail servicing. These groups earn only enough income for sustenance. Professionals make up only a small fraction (2.68%) of the respondents. Most of them live in Rockhaven

quarters of the neighbourhood, which is the upscale section of the community

Community Association

The neighbourhood has a community development association (CDA), which has the responsibility of representing the community's needs to the government and acts as the platform for self-help community development efforts, security and safety concerns. It is also the liaison between the community and the security outfits. However, not all residents appear to be active in its deliberations (Figure 2)

PARTICIPATORY SLUMS UPGRADING IN KABONG COMMUNITY IN JOS, NIGERIA

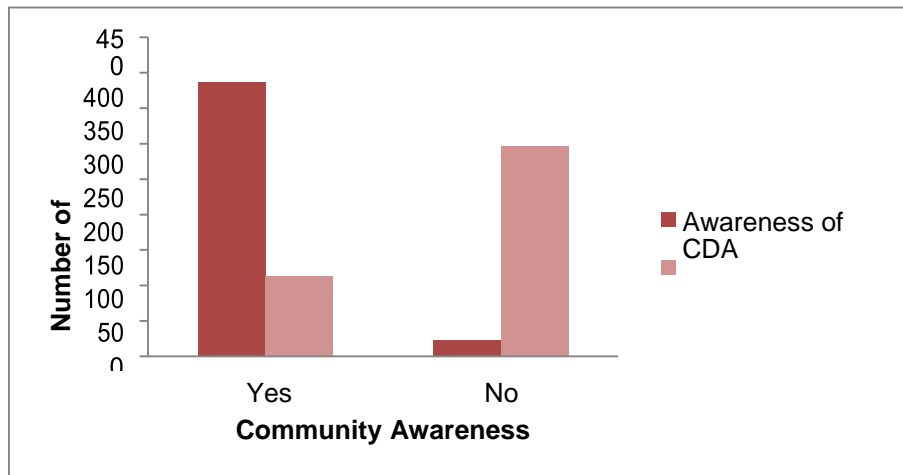


Figure 2 Community Association Awareness

In Figure 2, 387 respondents with a proportion of 94.39% were aware of the existence of the Kabong Community Development Association in the neighbourhood while 23 respondents with a proportion of 5.61% were not aware of its existence. In the subsequent related inquiry 297 respondents with 72.44% had never attended any meeting held by CDA while 113 respondents with a proportion of 27.56% attended and participated in the programmes. Apparently, many residents have a carefree concern and nonchalant attitude towards the association. This has many implications for participation in community development

efforts. Although many of the respondents claimed they remitted their dues to the association despite the fact that did not attend any meetings, their active involvement in the association would have been a more welcome development. Many respondents however indicated that they attended meetings especially when there were issues of security concerns in the community or in Jos town. At such meetings, they explained, more credible information and updates are obtained from officials of the association who have better access to security and community information than most residents have.

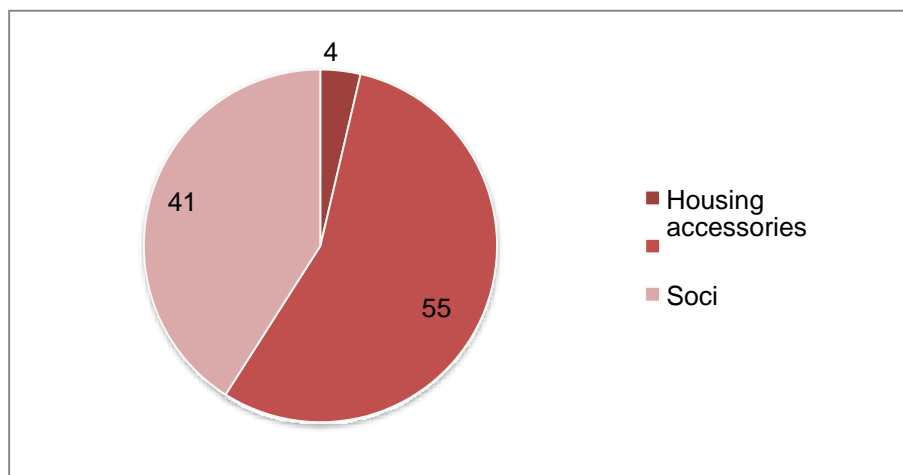


Figure 3 Project Services Needs in the Community

The provision of project services (PS) is vital to community livability. Project services

consist of infrastructural services (IS), social services (SS) and housing accessories.

PARTICIPATORY SLUMS UPGRADING IN KABONG COMMUNITY IN JOS, NIGERIA

Infrastructural services include bridges, tarred roads, culverts, tap/pipe-borne water and electricity, among others; while social services include clinics, schools, markets, churches clubs and parks/gardens and open spaces. Housing accessories include woods, sand, stone, zinc sheets, windows/doors and rods.

Figure 3 showed that 227 respondents (55.37%) identified infrastructural services as the most pressing project services needed in the community, while social services had 168 respondents (40.97%) and the least is housing accessories with 15 respondents (3.66%). This exhibited the greatest need for slum upgrading because the IS and the SS had a sum of 96.34%. In the community, IS were more needed as they

are required in everyday life and living of residents. They would provide better livelihood and confer higher quality of life as well. For example, the water, roads and electricity are needed at all times by the people for domestic and commercial uses. These are among the primary human needs. It is when IS are available that SS can be utilised. Housing accessories are individualized services provided, mostly, by the people themselves for their own needs. Individual preferences and affordability are important considerations.

Figure 4 presents the results of the respondents' perception of responsibilities for the provision of project services in the community.

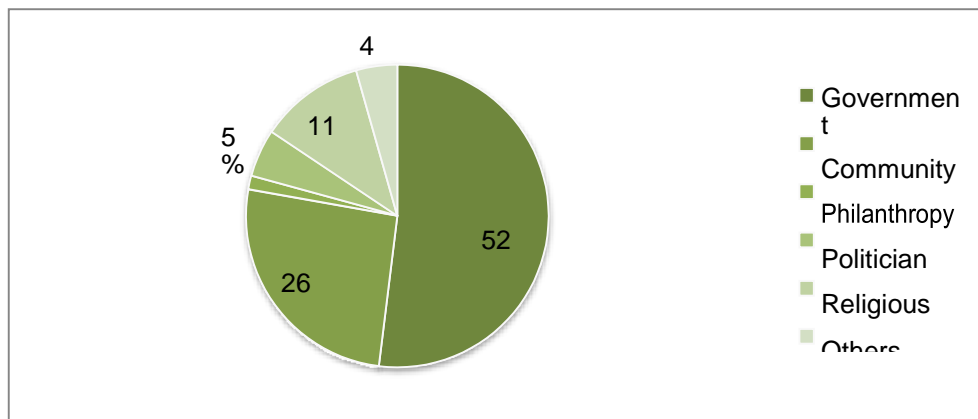


Figure 4 Organisational Provision of Project Services in Community.

Most respondents indicated that the government has the greatest responsibility to provide project services in the neighbourhood (213 respondents) (51.95%), while the community-based association had 106 respondents (25.85%) and religious bodies had 46 respondents (11.22%). The least is philanthropy with 6 respondents (1.46%).

Community Upgrading Effort

Anecdotal evidence suggests that the neighbourhood of Kabong has a population that exceeds 50,000 people. However, only 1,200 (0.024%) are actively registered members of the community development association. Indeed, the high rate of artisans, traders and civil servants (77.12%) as residents of the

neighbourhood indicate the poor/handicap financial conditions of residents, which will affect the strength of the CDA. Most of them live on daily wages therefore they leave their homes early and return late from work even on weekends. Attendance at community meetings therefore is not regular for most of them. The association, however, still needed to keep to its responsibility of intervening to provide essential services that the community may need, even in the face of strained financial resources. The study examined the project services in the community, their agency that provided the project services, the status of the project and whether it has been upgraded or not (Table 6).

PARTICIPATORY SLUMS UPGRADING IN KABONG COMMUNITY IN JOS, NIGERIA

Table 6 Infrastructural provision

S/N	Infrastructure	Financier	Type	Status	Remark
1	Road	G ¹	42.6km	Constructed 28km Renovated 14km	Upgraded
2	Water supply	G ¹	>300,000Ltrs	Constructed	Upgraded
3	Electricity	G/C	National grit	Constructed	Not upgraded
4	Telephone	PO	Antennas	Constructed	Not Upgraded
5	Culvert and cutter	C/R	7 culverts, >500m	Resident Constructed	Upgraded
6	Bridges	G ¹	3	Constructed	Upgraded

C – Community G¹ – State Government
 PO – Private Organisation R – Residents

Table 6 detailed the IS provided in the neighbourhood. The government is the largest benefactor of the community having provided the most essential services (roads, bridges, water and electricity). The community provided culverts and some of the electricity poles require to run the grid in some parts of the community. The telecommunication antennae were provided by private telecommunication providers. The community also assisted in providing land to the government and private organizations at ceiling discount rates to facilitate provision of project services. Land being under the control of the community is provided no matter its size for governments services (state and local) because of the need for basic services in the community. The

community cooperate to curtail the erosion if government did not intervene immediately. The IS provides a multiplier effect to urban development and residents of community. It is the infrastructure that enable the upsurge in liveability and personal economic status, which are important to bringing out the community out of its slum predicaments. The SS is detailed in Table 7.

Table 7 shows that community has upgraded markets and schools (both public primary and secondary schools). The modern market has more than 360 stalls within its premises, with a police post, a bank with Automated Teller Machines (ATM) and a market administrative office. The open market has only 125 stalls but has 2 ATMs.

Table 7 Social amenities/services provision

S/N	Social services	Financier	Type	Status	Remark
1	Market	G ^{1,2} ,C	3	Community gave land (>6 Hactares)	Upgraded
2	Schools-	G ^{1,2} , C	1 Primary 1 secondary	Community gave land (>7 Hactares)	Upgraded
3	PHC	G ² ,C	1, >4	Not functional	Not Upgraded
4	Court	G ¹	1	Functional	Not Upgraded
5	Bank	Co	1	Functional	Upgraded
6	Police post	Po	2	Functional	Upgraded
7	Fast food	PB	1	Not functional	Upgraded
8	Refuse	C/G ¹ /R		Poor dustbins adherence, Flithy central collection	Not Upgraded

C – Community CO – Corporate organisation
 G¹ – State Government G² – Local Government
 PB – Private Businesses Pol - Politicians
 PO – Public organisation R – Residents

CONCLUSION

It is this upgrading principle that is key in transforming shelter, environment and

liveability conditions in urban planning. The Kabong community development association has done quite a bit to uplift the living

PARTICIPATORY SLUMS UPGRADING IN KABONG COMMUNITY IN JOS, NIGERIA

conditions of the neighbourhood. As an association, it has provided and upgraded several project services in the community including markets, schools, primary health centre and refuse disposal activities and constructed culverts, paid for and installed electricity poles for the benefit of the community. As an association, the CDA appears to be fully involved in upgrading the slum conditions of the neighbourhood. Residents have also provided culverts that lead to their homes or even that link parts of the community to other sections.

However, there are several challenges to greater achievement of its goals. First is the challenge of a large urban area, most part of it with slum conditions. This is an intimidating feat to challenge by the association on its own. Most of the infrastructure demanded to uplift the status of the community are capital intensive and out of the reach of a community association to finance. Consequently, there is need for government intervention. Secondly, most of the area is occupied by people of low income status who live on daily wages. Their levels of participation and contribution to the association is therefore weak. The association does not have enough people mobilized to respond to active individual participation in community project efforts. There is either a lukewarm attitude being exhibited by most residents towards the association or they are unable to fulfil their commitments to the association as a result of other more pressing personal needs. With a low and inactive membership and low financial base, there is only so much the community association can do. Within the context of these and other problems being faced by the association, it may not be only a charitable pronouncement to assert that the community, led by its association, is involved in upgrading the slum status of the community through its project services and its partnership with the government and private organizations to also provide services to the community that would help alleviate its living conditions and therefore its standard of living and quality of life.

There is still much to be done to bring the neighbourhood out of its slum conditions and there is still room for greater community participation. One of the major challenges that the community association needs to undertake presently to surmount some of its challenges is

to initiate and sustain a deliberate sensitization and orientation campaign to mobilize the mass of its community towards more proactive participation in community activities and development.

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WOMEN INVOLVEMENT IN STONE QUARRYING ACTIVITIES IN JALINGO, TARABA STATE, NIGERIA

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Abstract

The debate as to whether women provide a bulk of unpaid care and domestic work is not in doubt but the fact that they contribute largely to informal economy is underreported. Mining activities help to generate fund for those involved in it especially now that an almost permanent increase in poverty has compelled people to seek alternative livelihoods. The aim of this study is to investigate the involvement of women in quarrying activities in Jalingo, Taraba state, Nigeria. Simple random sampling was used to arrive at 186 respondents out of about 400 women involved in the quarrying industry, which takes place in four different wards in Jalingo local government area. A structured questionnaire was the instrument of data collection. All the questionnaires administered were accurately filled in and returned. The results indicated about 43% of respondents fall between the ages of 36-45 years and only about 5% falling between of 26 years and below. It was also discovered that about 51% of respondents earn between N2000 to N4000 of Nigeria currency daily while about 20% of respondents earn N5000 and above daily. The result also shows that there is no significant relationship between local quarry and women livelihood in Jalingo but there existed statistically significant relationship between age and daily earnings $r(184) = .546, P = .000$. It was recommended that Introduction grant schemes such as survival fund for small-scale quarry operations could come together under one umbrella. This move would make banks and other financial institutions more willing to give them loans as credible and creditworthy entity; this will create better opportunities for diversification of livelihood incomes and assets that will promote positive livelihood outcomes.

Keywords: Informal economy, Livelihood, Quarry mines, Stone quarrying

INTRODUCTION

The female adult gender referred to as women are gradually taking very important place in the economy of the world and the adult women of the developing countries are not left behind as they gradually found in all facet of economic endeavors, as opined by Aminur-Rahman (2013), women are sensitively talking about gaining control over their lives, and participating in making the decisions that affect them in home and community. Stone quarrying is one very important economic activity that women are involved in even though it is time consuming and highly labor intensive it is a land use which involves extraction of non-fuel and non-metal minerals from rocks (Ukpong, 2012). It is usually done by open-cast method using rock drills, explosion of dynamite among other methods. According to Kitula (2006), quarrying has environmental and health effects. And the Nigerian Minerals and Mining Acts 2007 defines quarrying as the extraction of aggregate stones dimensions, laterite, sand, and clay mineral from any location in Nigeria. The operations in stone quarrying, whether small or

large-scale, are inherently disruptive to the environment, producing enormous quantities of waste that can have harmful impacts for decades as a result of inappropriate and wasteful working practices and rehabilitation measures (Sati, 2015). The degradation of environment due to stone quarrying activities has put forth questions as to whether or not the mining activities should be continued (Nartey, et al. 2012; Sati, 2015). It has been revealed that 4 million people died yearly from acute respiratory problems in developing countries, for the most part being aggravated by environmental pollution emanating from quarrying, sandblasting and emission of dangerous chemicals (Nartey 2009; Langer, 2012). But it has been noted in rural Africa that the dependence on agricultural output could no longer provide year round security in terms of finance due to continuous decline in farm yields (Asante, Abass & Afriye 2001). This is not surprising since most of the rural farmers are subject to varying degrees of uncertainty due to climate variability and postproduction loss (Cooper, et al 2008). This has compelled over

500 million people in developing countries to engage in occupations such as small-scale surface mining and quarrying for survival (Wang, 2012). The formal sectors in developing countries have very little potential in terms of job creation the informal sector such as stone quarrying has become an attractive alternative for achieving livelihood (Ibrahim, 2012; Asante, Abass & Afriye, 2014). Indeed, women and girls bear an unequal burden of unpaid domestic responsibilities and are overrepresented in informal and precarious jobs. Women also possess inherent agency and knowledge that is overlooked by policy-makers as they form and implement poverty reduction plans. Development interventions continue to be based on the idea that men are breadwinners and women are dependents. The global population growth and urbanization is very alarming and Nigeria is part of the alarming population growth which could have resulted to more pressure and exploitation on natural resources. This has forced over 500 million people in developing countries to employ in occupations such as small-scale surface mining and quarrying for survival (Wang et al, 2010). This includes increasing number of women in local quarrying as a means of livelihood support in the country which is posing a threat to the resources and physical environmental. Many people in rural area consider non-farming activities as pre-occupation. Several factors account for this. In most societies, gender norms define women's role as largely relegated to the home, as mother and caretaker, and men's role as responsible for productive activities outside the home. These norms influence institutional policies and laws that define women's and men's access to productive resources such as education, employment, land and credit. Ample evidence shows that girls and women are more disadvantaged than boys and men in their access to these valued productive resources. There is also an evidence to show that the responsibilities of women and the challenges they face within poor households and communities are different from those of men. Persistent gender inequality and differences in women's and men's roles greatly influence the causes, experiences and consequences of women's poverty. Policies and programs to alleviate poverty must, therefore, take account of gender inequality and gender differences to effectively address the needs and

constraints of both poor women and men. In most cases it has been revealed that possible over dependence on agricultural output could no longer provide year round food and revenue security because of continuous decline in farm yields due to recent security threats such as kidnappings, inter-tribal wars, incidences of herdsmen and farmers clashes and cases of Boko Haram terrorism. This is not surprising since most of the rural farmers are subject to varying degrees of uncertainty due to climate change. It is for this reason that diversification of rural income has become common among those who wish to live, at least, an average life. Since non-agricultural activities in many instances yield as much returns as subsistence farming the only option for those without access to productive farmlands is to subject the natural environment to other activities such as artisanal, sandblasting, stone extraction and small-scale mining.

Despite the large numbers of women working in local quarry, there is need to study the impact of local quarry as a means of livelihood support for women in Jalingo Local Government Area. This gap of looking at the primitive way of stone quarrying and how women get involved to contribute to family needs is very vital and form the main aim of this study.

MATERIALS AND METHODOLOGY

Study Area

Jalingo Local Government Area is roughly located between latitudes 8° 47'-9° 01'N and longitudes 11° 09' to 11° 30'E. It is bounded to the North by Lau Local Government Area, to the East by Yorro Local Government Area, to the South and West by Ardo-Kola Local Government Area. It has a total land area of about 195km². Jalingo LGA has a population of 139,845 people with a projected growth rate of 3% per annum (Shawulu et al, 2008). It has a projected population of 165,774 in 2014 (Oruonye, 2014).

The relief of Jalingo LGA consists of undulating plain interspersed with mountain ranges. This compact massif of rock outcrops (mountains) extends from Kona area through the border between Jalingo and Lau LGAs down to Yorro and Ardo Kola LGAs in a circular form to Gongon area, thus given a periscopic semi-circle shape that is almost like a shield to Jalingo town. Jalingo metropolis is

drained by two major rivers Mayogwoi and Lamurde, which take their source from the mountain ranges in Yorro LGA and empty their contents into the Benue River System at Tau village. The valley of River Lamurde is dotted with ox-bow lakes which are as a result of depositional activities. Jalingo LGA has tropical continental type of climate characterized by well-marked wet and dry season. The wet season usually begins around April and ends in October. The dry season begins in November and ends in March. The LGA has a mean annual rainfall of about 1,200 mm and an annual mean temperature of about 29°C. Relative humidity ranges between 60-70 per cent during the wet season to about 35-45% in the dry season. Jalingo is located within the northern guinea savanna zone characterized by grasses interspersed with tall trees and shrubs. Some of the trees include locust bean, sheabutter, eucalyptus, baobab and silk cotton tree. The major ethnic groups of Jalingo LGA are the Fulani, Jibu Kona and Mumuye, while other ethnic groups such as Hausa, Jenjo, Wurkum and Nyandang are also found. Hausa language is widely spoken as a medium of communication for social and economic interactions. Jalingo environment is populated by mostly yam farmers because of the relief of Jalingo LGA that consists of undulating plain interspersed with mountain ranges and the compact massif of rock outcrops (mountains) extending from Kona area through the border between Jalingo and Lau LGAs down to Yorro and Ardo Kola LGAs in a circular form to Gongon area, thus given a periscopic semi-circle shape that is almost like a shield to Jalingo town. Jalingo metropolis is drained by two major rivers Mayogwoi and Lamurde which also allows for dry season farming.

Research Design and Methods

This study followed a single-round survey design which Fisher (1991) and Cleland (1990) found to be useful in descriptive and exploratory studies. This study aimed at

investigating the level of women involvement in stone quarrying with respect to benefits and problems. The study used a mixed method of qualitative and quantitative research design. This enables the researchers to answer the questions raised as clear as possible at the same time dealing with the logical problems raised.

Since there are no registered figures from the state government on the population of women involved in local quarrying, the estimated number of quarry workers, both males and females was obtained from the local mine quarry owners association, which they believe is not very consistent because some women are more or less part time workers. The quarry mining sites in these areas are allocated to quarry operators based on leases, which could cover a reasonable land mass, and the leases are mapped out in what they call pits for individual quarry operators. The mining sites are considered the property of the federal government and not individuals because all mining activities is on the exclusive list of the Federal Government (FMMP, 1970).

Sample Procedure and Size.

The research adopted two sampling techniques and these are purposive and simple random sampling. Jalingo has ten (10) wards out of which four (4) wards were purposely sampled because these wards are the wards where quarrying activities is concentrated a table is presented below showing the number of women involved in quarrying per ward and the number sampled using Krejcie and Morgan table of random selection. Based on the population of the operators, the sample size for this study is 186, randomly picked from the quarrying sites. About 190 questionnaires was produced and administered and 186 were adequately filled and returned back to the researcher.

Methods of Data Analysis

Correlation analysis was used ascertain the level of statistically significant relationship that exist between age, daily and monthly earnings of respondents at a rejection level of P=.000 of the null hypothesis. An acceptance level of P=.251 was made for the null hypothesis ascertaining a significant relationship between age and daily earnings. The formula used for data analysis is as follows:

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \quad (1)$$

x=age of respondents

y=daily earnings of respondents

y²=monthly earnings of respondents

Table 1 Showing sampled population

Name of Centre	Number of Operators	Numbers Sampled
Dinyavoh (Kona Ward)	200	103
Kona Garu (Kona ward)	35	18
Rafin zurfi (Turaki A)	52	27
Turaki B	73	38
Total	360	186

Source: researchers field survey 2020

RESULTS AND DISCUSSION

This section presents the results of the analyzed data collected through field survey carried out and discussions on the results. The variables analyzed in the study include demographic characteristics of

women participating in quarrying activities, the amount of earnings of women in quarry mines, the frequency of visits to the quarry sites for stone quarrying by women and their level of satisfaction with the earnings from quarrying activities.

Table 2 Socio-demographic characteristics of respondents

Response	Frequency	Percentage (%)
Age		
25 & Below	9	4.8
26 - 35 years	29	15.6
36 - 45 years	79	42.5
46 - 55 years	49	26.3
56 & Above	20	10.8
Educational Qualification		
None	86	46.2
Primary	73	39.2
Secondary	23	12.4
Tertiary	4	2.2
Religion		
Christianity	147	79.0
Islam	34	18.3
ATR	5	2.7
Marital Status		
Single	6	3.2
Married	152	81.7
Divorced/Separated	6	3.2
Widowed	22	11.8

Source: Field work, 2020

Table 2 shows the socio-demographic characteristics of the respondents for the study. The result reveals that majority of the respondents were within the age bracket of 36 – 45 (42.5%), followed by those in the age bracket of 46 – 55 (26.3%) and 26 – 35 (15.6%), while 10.8% and 4.8% are accounted for by

those in the age categories 56+ and less than 26 respectively. This shows that majority of the women involved in quarry activities are matured. On the educational qualification of the respondents, the result shows that majority (46.2%) of the respondents have no formal education.

WOMEN INVOLVEMENT IN STONE QUARRYING ACTIVITIES IN JALINGO, TARABA STATE, NIGERIA

Table 3 Earnings in stone quarry mines

Variable Class	Frequency	Percentage
Daily Earnings (₦)		
<1,000	53	28.5
2,000 – 4,000	95	51.1
5,000 & Above	38	20.4
Monthly Earnings (₦)		
<11,000	4	2.2
11,000 - 20,000	21	11.3
21,000 - 30,000	61	32.8
31,000 - 40,000	83	44.6
41,000 - 50,000	17	9.1

Source: researcher’s field survey 2020

Table 4 Danger of stone quarrying

Quarry work is low paid and highly dangerous	Frequency	Percentage
Yes	172	92.5
No	14	7.5

Source: Field work, 2020

Table 5 Frequency of participation in quarry activities

Response	Frequency	Percentage (%)
Time women start quarry work		
7am	89	47.8
8am	18	9.7
Not defined	79	42.5
Time women close from quarry		
5pm	11	5.9
6pm	36	19.4
Not defined time	139	74.7
No. of hours at quarry sites per day		
8hrs	23	12.4
9hrs	9	4.8
No defined hours	154	82.8
Do quarry workers get break		
Yes	186	100
Duration of break		
1 hr	159	85.5
2hrs	27	14.5
Situations where women work at night		
No	186	100

Source: Field work, 2020

On the other hand, 39.2% of the respondents completed primary education. Based on religious inclination, the result found

that nearly four-fifth (79%) of the respondents are Christians, 18.3% Muslims, and 2.7% of the respondents are adherents of the Africa

WOMEN INVOLVEMENT IN STONE QUARRYING ACTIVITIES IN JALINGO, TARABA STATE, NIGERIA

traditional religions. The marital status of the respondents shows that majority (81.7%) are married, 11.8% are widowed, 3.2% are single or yet to marry. Since majority is married, it is safe to assume that they have children and have needs to cater for them. This explains in part why the respondents have to engage in stone quarrying to complement the efforts of their husbands.

Table 3 shows respondents' earnings from quarry activities. The data show that most of the respondents (51.1%) claimed daily income of between ₦2, 000 and ₦4, 000. Only a few respondents (20.4%) earn 5,000 or more daily. Based on monthly income, the table further reveals that majority (44.6%) of respondents earn between ₦31, 000 – ₦40,000 followed by those who are earning between ₦21,000 – ₦30,000 (32.8%) and ₦11,000– ₦20,000 (11.3%). Comparatively only few respondents earn ₦41,000 – ₦50,000 (9.1%) and ₦1,000 – ₦10,000 (2.2%).

The result presented in table 5 shows the frequency of quarry activities among the respondents. The result shows 47.8% of the respondent start work at stone quarry sites by 7:00 a.m, followed by 42.5% who have no defined time for start of work in the morning at quarry sites, 9.7% starts work at 8a.m daily. Respondents' view on time of closure from quarry sites revealed that majority (74.7%) do not have any defined time of closure, 5.9% and 19.4% close by 5pm and 6pm respectively daily. The results on number of hours women work at stone quarry sites shows that majority (82.8%) of them do not have defined hours of work. 12.4% close at after 8 hours of work while 4.8% spent 9 hours at work. Workers at the stone quarry sites usually observe break time. Nearly nine-tenth (85.5%) observe one hour while the remaining 14.5% take 2 hours off-work rest.

Table 6 Use of earnings from quarry activities on household

Statement	SA	A	D	SD	Mean	S.D	Decision
I use the money I realize from quarry activities to buy food for the family	136	50	-	-	3.73	.44	Ac ept
The money I realize from quarrying is only for my personal use	-	10	169	7	2.02	.30	Reject
The money from quarrying activities is used for my children school fees	19	160	5	2	3.05	.41	Accept
The money realized from quarrying activities is used when anyone is sick in the house	114	69	-	3	3.59	.52	Accept
I use the money from quarrying activities to establish business	33	124	22	7	2.98	.67	Accept
The money from quarrying activities is used to buy clothing for my children and I	83	99	4	-	3.42	.54	Accept
My daily contribution and local bank is achieved through the money from quarrying activities	78	108	-	-	3.42	.49	Accept
The money I realize from quarrying activities is used in settlement of debts	37	89	52	8	2.83	.79	Ac ept
Most of the financial needs of the family is met through the money I realize from quarrying activities	103	79	4	-	3.53	.54	Ac ept
The money I earn from quarrying activities is not enough but to some extent, it solves my family problems	110	70	6	-	3.56	.56	Ac ept
Average Mean & S.D.					3.213	.53	

Source: Field work, 2020

WOMEN INVOLVEMENT IN STONE QUARRYING ACTIVITIES IN JALINGO, TARABA STATE, NIGERIA

Table 6 shows responses of respondents on use of earnings from stone quarrying activities on their households. The results with an average mean of 3.213 and standard deviation of .53 which is above the decision mean shows that women use the earnings from quarry activities to solve most of their household problems. The table shows that among the household problems women use earning from quarry activities on include feeding, children's school fees, treatment of

sick family members, establishment of small business, clothing for self and children, daily contribution and savings, settlement of debts, financial needs of the family, and solving other family problems. From the foregoing most of the decisions shows accept except the question about using of earnings for personal purpose that the decision show reject, this suggest that women's earnings from stone quarry activities is able to solve their household problems.

Table 7 Correlation analysis between age, daily and monthly earning

		Age	Monthly Earnings	Daily Earnings
Pearson Correlation	Age	1.000	.049	.546
	Monthly Earnings	.049	1.000	.091
	Daily Earnings	.546	.091	1.000
Sig. (1-tailed)	Age	.	.251	.000
	Monthly Earnings	.251	.	.109
	Daily Earnings	.000	.109	.
N	Age	186	186	186
	Monthly Earnings	186	186	186
	Daily Earnings	186	186	186

Source: researcher's field survey 2020

A simple linear regression was computed to predict the relationship between Age of women, daily earnings and monthly earnings. A statistically significant relationship was found between age and daily earnings $r(184) = .546$, $P = .000$ therefore, we reject the null hypothesis. But, there was no statistically

significant relationship discovered between age and monthly earnings $r(184) = .049$, $P = .251$ to that end we accept the null hypothesis. There was a positively large association between age and daily earning ($r = .546$) while positively very weak or none association existed between age and monthly earning ($r = .049$).

Table 8 Showing correlation analysis between educational qualification, daily and monthly earning.

Correlations		Educational Qualification	Monthly Earnings	Daily Earnings
Pearson Correlation	Educational Qualification	1.000	-.119	-.206
	Monthly Earnings	-.119	1.000	.091
	Daily Earnings	-.206	.091	1.000
Sig. (1-tailed)	Educational Qualification	.	.053	.002
	Monthly Earnings	.053	.	.109
	Daily Earnings	.002	.109	.
N	Educational Qualification	186	186	186
	Monthly Earnings	186	186	186
	Daily Earnings	186	186	186

Source: Researcher's field survey 2020

WOMEN INVOLVEMENT IN STONE QUARRYING ACTIVITIES IN JALINGO, TARABA STATE, NIGERIA

A statistically significant relationship was found between educational qualification and daily earnings $r(184) = -.206$; $P = .002$. But the relationship between educational qualification and monthly earnings is more complex: $r(184) = -.119$, $P = .053$. The p-value of 0.053 is slightly non-significant ($\alpha = 0.05$).

The result presented in table 2 revealed that majority (43%) of the respondents are within the age bracket of 36–45, only few (5%) were below 25 years age bracket. This implies that most of the women involved in quarry activities are matured. Most of the respondents have no formal education. A good percentage of them have primary education as their highest level of education. Only few respondents have secondary and tertiary education respectively. Based on religious inclination, majority of the women involved in quarry activities in the study area are Christians. Only few are Muslims and adherents of the African traditional religions. Based on the marital status of the respondents, majority of the respondents are married. On the other end, few are widowed, single or divorced/separated respectively.

Table 3 presents findings on respondents' earnings from quarry activities. The result shows that most (51%) of the respondents earn daily income between ₦2,000 and ₦4,000. Fewer (20%) earn ₦5,000 or more daily this amount of money earned is very small considering the present economy of Nigeria. This is similar to the finding of Wang et al, 2010 where he discovered that most surface mining are done in small scale for taking care of survivals

Table 4 presented a finding based on respondents perception of dangers associated, with stone quarry mines, where nine-tenth (92.5%) complained of low pay and the risks involved. This finding tallied with the discovery of Nartey (2009) and Langer (2012).

The result presented in Table 5 shows the frequency of quarry activities among the respondents. The result shows that most women (48%) working in quarry mines start work at quarry sites by 7:00 a.m., while others do not have any defined time for start of work in the morning. On the time of closure from quarry sites, the finding reveals that most women do not have any defined time of closure from quarry sites. Few either close by 5pm or 6pm respectively. Most of the women working at

quarry sites do not have defined hours of work. Some spend eight hours (8hrs) or nine hours (9hrs) depending on their strength or other activities they have to attend to. Women working at quarry sites do have breaks in between working hours. The duration of this break varies. Most of the women reported that they do spend just one hour (1hr) break during work. The women reported that there are no situations where they have to work at quarry sites in the night.

The findings presented in table 6 shows that women use the earnings from quarry activities to solve their household problems. The household problems on which women use earning from quarry activities include household feeding, children's school fees, treatment, establishment of businesses, clothing for self and children, savings, settlement of debts, financial needs of the family, and solving other family problems. This implies that earning of women from quarry activities is capable of solving their household problems.

A Pearson product moment correlation coefficient was conducted to evaluate the null hypothesis that there is no significant relationship between local quarry and women livelihood support in Jalingo. Preliminary analysis show that in table 7 there existed statistically significant relationship between age and daily earnings $r(184) = .546$, $P = .000$ therefore the null hypothesis is rejected but, there was no statistically significant relationship discovered between age and monthly earnings $r(184) = .049$, $P = .251$ in this case the null hypothesis is accepted. There was a positively large association between age and daily earning ($r = .546$) this implies that age of the women engaged in quarrying determine their livelihood support.

There was negatively weak association between educational qualification, daily earning ($r = -.206$) and monthly earning ($r = .049$) this imply that as the educational status of women increases they leave business for better business. Religion and marital status of women engaged in quarrying have nothing or little do with the livelihood support of women but their educational qualification has.

CONCLUSION

Quarrying provides some employment levels and generates some income for the women of the selected areas in Jalingo. The majority of

the people studied, however, are engaged in small-scale operations. With inadequate financial capital and simple hand-made tools, small-scale stone quarrying does not generate returns to commensurate the efforts and time spent. Consequently, income from the sector is meager.

The quarrying operation in its current form is environmentally unsustainable. Land degradation is widespread, posing a severe threat to food security. Quarry mine dust concentration coupled with the physical nature of the quarrying process creates negative health consequences.

Based on the findings, the study recommends the following:

(1) In order to control and reduce the extent of environmental damage caused by the quarry industry, the Ministry of Environment and Ministry of Mineral Resources must enforce its environmental regulations, seeing to it that all those involved in quarrying operations have, as a matter of priority, the protection of the integrity of the environment.

(2) Introduction of grants schemes such as survival fund, small-scale quarry operations could come together under one umbrella. This move would make banks and other financial institutions more willing to give them loans as credible and creditworthy entity; this will create better opportunities for diversification of livelihood incomes and assets that will promote positive livelihood outcomes.

(3) Further study should be conducted on quarry workers' exit strategy in terms of savings and future business plans. Studies should be conducted on the effects of crude instruments and protective gears on quarry workers.

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ASSESSMENT OF ACCESS TO DOMESTIC WATER SUPPLY SOURCES IN GYEL DISTRICT OF JOS, PLATEAU STATE, NIGERIA

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Abstract

Access to clean potable water and good sanitation facilities is a great problem for many households in Nigeria. The issue is particularly very severe in most parts of northern Nigeria with few households having access to safe drinking water and adequate sanitation. This is responsible for high incidences of waterborne diseases, threats to livelihoods of many poor households, and a contributor to low levels of school enrollment, especially among girls. This study therefore seeks to determine the distribution pattern and its effects on the level of user accessibility to domestic water supply sources in Gyel district of Jos South LGA Plateau State, Nigeria. The research utilized the Satellite data, coordinates of various sources of domestic water and their attributes, population data and a structured questionnaire and photographs from field in determining the locations, density and proximity of water supply projects to their target users. ArcGIS 10.3 tool was used in determining the density and proximity, mapping and Geo-processing, while SPSS and Microsoft software were used for the Statistical analysis. Findings showed that hand dug wells had the highest number among the public water sources and 60% of the respondents depends on it as their primary source of domestic water supply. The pattern of the distribution of water supply facilities were clustered around the city centre and well planned cadastral area, this exerts serious pressure on access to water sources especially on those within the unplanned and newly developed area as only 32% of the respondents had access to the public domestic water sources. Most of the built-up areas which constituted the households fall within the basic access level while the thinly occupied areas fall within no-access level where the basic standard for domestic water usage are not met, 71% of the respondents asserted that there was a problem of water scarcity as a result of distance (no proximity) and longer travel time, inconsistency of supply and seasonal effects. The study recommended the provision of more domestic water sources in unserved districts by the Plateau State Water Board (PSWB), private sector and individuals, the Jos Metropolitan Development Board (JMDB).

Keywords: Accessibility, Water supply, Domestic sources, Water demand

INTRODUCTION

Nigeria is a party to the United Nations Declaration of the Right to Water, which entitles everyone living in Nigeria to sufficient, affordable, safe and acceptable water for personal and domestic uses. While 75% of the urban population is served by improved water supply, often people will collect water from vendors and carry water a good distance after collecting it in containers. In rural areas, only about 42% of households have access to safe water. Thus, Nigeria was not able to meet the MDG target of 75% coverage for improved drinking-water and 63% coverage for access to

sanitation facilities by the year 2015. As a step towards addressing equity in access to WASH services, the human right to water and sanitation services is recognized in legislation and Nigeria has a universal access for all policy. However, funds are reported to be largely directed to urban areas and drinking-water services, whereas the number of unserved is mainly for sanitation services and in rural areas (GLAAS, 2014; Felix and Olusola, 2016).

According to Eneh (2007) like many developing countries, access to potable water is a common problem in Nigeria. Indeed, many lives are lost annually

ASSESSMENT OF ACCESS TO DOMESTIC WATER SUPPLY SOURCES IN GYEL DISTRICT OF JOS, PLATEAU STATE, NIGERIA

to waterborne diseases arising from unmitigated poor access to safe drinking water. Statistics show that 36% of urban dwellers and 61% of rural dwellers are totally unserved safe water. Public stand post is accessible to only 21% of urban dwellers and 8% of rural masses. Protected dug well is available to only 7% of urban dwellers, while 17% of rural dwellers have access to it. Borehole water pump is available to 7% of urban dwellers and 11% of rural inhabitants. One State in Nigeria is heavily infested with 2,647 cases of guinea worm, and yet another State with 1,843 cases. Access to potable water is perceived as the greatest problem to 28% of households and 24% of communities (Eneh, 2007).

There are social, environmental and economic benefits of investing in water supply projects and services, beneficial to the government, individuals, households as well as the environment. The benefits from improved water supply include the time saved in fetching water, cost savings on non-incremental water consumption, reduced incidence of water borne diseases, flood control, employment opportunities, decreased distance to water source, and increase in water consumption per capita and time and travel costs, among others (Ali, 2018).

According to Meride and Ayenew (2016), it is not only water quality but also water quantity that is important in achieving health improvements. Quantity is dependent on accessibility. The benefits of improved water supply and sanitation are many, including prevention of disease, improved basic health care, better nutrition, increased quantity and access to water, reduction in time and effort required for water collection, promotion of economic activity, strengthening of community organization, improvements in housing, and generally improved quality of life (Ali, 2018). According to Meride and Ayenew (2016) the need for domestic water supplies for basic health protection exceeds the minimum quantity required for consumption (drinking

and cooking). Additional volumes are required for maintaining food and personal hygiene through hand and food washing, bathing and laundry. Poor hygiene may in part be caused by a lack of sufficient quantity of domestic water supply which depends on the level of accessibility and efficiency of the existing facilities, in this case accessibility plays key role in domestic water supply.

According to Ilaboya, et al (2014), access revolves around distance and time indices. These indicators show four (4) paramount levels of accessibility; No access, for the worst scenario; Basic access; Intermediate access and Optimal access all on the basis of time and distance. Dinka (2018) sees accessibility as the balance between the demand for and the supply of consumer services over a geographic space, and narrowing or bridging the gap between geographic spaces is all about the significance of transport. Integrating Geographic Information System database can provide utility managers reliable and scientific support decision making on water distribution network management and rehabilitation (Soakodan *et al.*, 2011).

This study therefore determines the existing distribution pattern and its effects on the level of user accessibility to domestic water supply facilities and sources in the Gyel district of Jos South LGA, Plateau State, Nigeria.

MATERIALS AND METHODS

Study Area

The study area (Gyel District) is located between Latitude 9° 46'0" N and 9° 52'0"N, north of the equator and Longitude 8°48'0"E and 8°52'0"E and is relatively bounded in the North by Tudun wada and Holwshe in Jos North LGA, while in the South by Vom district, West by Bassa LGA and in the East by Dadin kowa, Whytt and Rahol Kanang respectively, in Jos South Local Government Area of Plateau State which covers the total land area of 81.9km/sq approximately.

ASSESSMENT OF ACCESS TO DOMESTIC WATER SUPPLY SOURCES IN GYEL DISTRICT OF JOS, PLATEAU STATE, NIGERIA

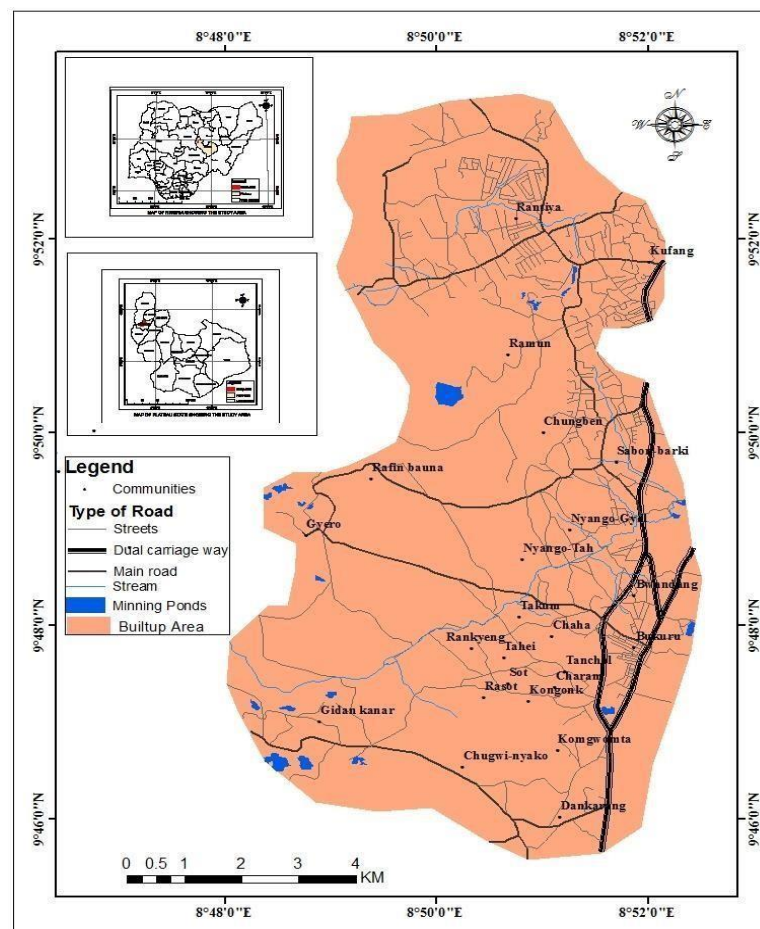


Figure 1 Map showing Gyel District
Source: Modified from Quickbird Satellite Image, 2019

Ojo, Gbuyiro and Okoloye (2004) asserted that the influence of the oscillation of the Inter Tropical Discontinuity (ITD) is completely modified by the high altitude of the Plateau. The area has more cold weather than most parts of Nigeria on the same latitude. It is characterised with an average monthly temperatures range between 21–25 °C, these cooler temperatures have made it a semi-temperate like area. It receives about 1,400 millimetres rainfall annually between April and October with the precipitation arising from both convectional and orographic sources, owing to the location of the area (Omada, 2018).

Gyel district is an area of younger granites intruded into the older basement complex rocks which covers the entire locality and other neighbouring localities. These younger granites are thought to be about 160 million years old and created unusual scenery of Jos. There are numerous hilly rocks with

gentle slopes, characterized by a long period of weathering and erosion (Omada, 2018).

According to Omada (2018), two soil types can readily be identified at the superficial level. These are the sandy loam and grey loam soils. Most soils are stony, fertile and hard to work on for the agriculturalist. This seems to result from the washing away of the top soil by denudation processes. The major soil is characterized by tropical ferruginous soils, which comprises of hills rock outcrops containing younger granite rocks extensively intruded into the older basement complex rocks characterized by a long period of weathering and erosion

Omosho (2007) asserted that the average elevation of the Jos Plateau is about 1150 meters above mean sea level and the highest peak on the Shere hills which is about 1777 meters above sea level. However, the area is dominated by relief average altitude of

**ASSESSMENT OF ACCESS TO DOMESTIC WATER SUPPLY SOURCES IN GYEL DISTRICT OF JOS,
PLATEAU STATE, NIGERIA**

1,217m, with depressions which pave way for drainages adjoining the plain area.

Also according to Omada (2018), the drainage pattern on the area is in a radial pattern where the many rivers and streams diverge from the top of the plateau and flow away to different directions. Some of them drain into Rivers Ganawuri and Kaduna

The population of the area was 145,750 from 2006 population census conducted, it comprises 24 communities mostly dominated by the Berom, Hausa, Yoruba, Ibo and other minor tribes from within and outside plateau state which most of them are Christians combined with the Muslims. The area is known for vegetable farming, animal grazing; rock quarrying, tin mining and marketing, (Ali, 2018).

Nature, Types and Sources of Data

This study utilized both the primary and secondary data sources. Different types of data for the research work were obtained from many sources. Field work was undertaken to determine the coordinate of Public Reservoirs, hand dug well, water supply pipes network, bore holes, Photographs of the current situation of water supply sources and water hydrants and this was complimented by information from Plateau State Water Board, Jos. Quick bird satellite image (0.6 m resolution) of 2015 and Population Data on the other hand were gotten from National Centre for Remote Sensing and National Population Commission, Jos respectively. Structured questionnaire were used in generating the statistical data from the respondents.

Method and Data Pre-Processing

This include geo-referencing, delineating the study area using the data collected to create of geo-database and feature classes which were digitized into map format used for the spatial analysis. All the maps acquired were properly geo-referenced in ArcGIS software and Geo-corrected to a common Projection System (UTM, Clarke 1880), and to a common Geo-TIFF data format. The maps were also geo-coded to a common resolution with the quick bird satellite image at a resolution of 0.6m to ensure both compatibility and data standard. A shape file was created in ArcGIS to delineate the boundary of the study area and to show the

extent of features necessary for the research analysis.

Sampling Technique and Size Determination

Stratified random sampling technique was adopted for the administering of the questionnaire for the study, a total number of three hundred and eighty-four (384) questionnaires were administered, in which the entire 24 communities within the study area covering both the urban and rural areas were randomly and proportionally represented with the total population of 145,750, using the formula by Krejcie and Morgan (1970);

$$n^1/n \times N = N^1/N \times Q \quad (1)$$

Where n^1 : Sampled population for individual community

n : Sum total for the population of the whole sampled communities

N^1 : Sampled proportion for individual community

N : Proportion of sample size (100%)

Q : Total Questionnaire Administered

During the field work, 384 questionnaires were distributed to households and 263 retrieved, personal observation was also undertaken to gain more insight on domestic water supply facilities in the area. GPS receiver was used to collect the coordinates of various water facilities and digital camera for photographing. The coordinates of pipe-borne taps, hand dug wells, boreholes, reservoirs and water supply pipes were determined and transferred into excel sheet and imported to ArcGIS 10.3 environment to create the geo-database (Omada, 2018).

ArcGIS 10.3 version was used to create a file geo-database for this research work, which consist of Built-up area, Road network, water supply pipe network, public reservoir, taps, boreholes, hand dug well, water hydrant, stream and ponds feature classes within Gyel district area and their necessary attributes such as location, diameter, condition, function and distance covered which was conceptually organized. Integrated approach was used to achieve the objectives which includes both the GIS and Statistical analyses.

Density analysis determined the pattern of distribution of public hand dug wells and

ASSESSMENT OF ACCESS TO DOMESTIC WATER SUPPLY SOURCES IN GYEL DISTRICT OF JOS, PLATEAU STATE, NIGERIA

boreholes and line density for the distribution of water supply pipes. This was also used to describe the pattern of domestic water source distribution and concentration showing the area of high, moderate and low concentration within the study area. Proximity analysis was used to depict four levels of accessibility which includes; optimum, intermediate, basic and no-access levels were on the following distance interval 1-30m, 30-100m, 100-1000m and 1000m above to analyse the level of accessibility to domestic water sources by the residents of the study area.

The statistical analysis includes the results from administered structured questionnaires, The statistical packages for

social science (SPSS) is used to compute simple percentage and statistical diagram for the source, pattern and level of accessibility to domestic water supply source in the study area.

RESULTS AND DISCUSSION

This section dwells on the reasons (problems) of inaccessibility to domestic water supply facilities, locations, density and solutions to problems of access to domestic water supply.

Reasons for Inaccessibility to Domestic Water Sources and Solution

There are diverse reasons of inaccessibility to water supply projects in Gyel District by most residents as shown in Figure 3.

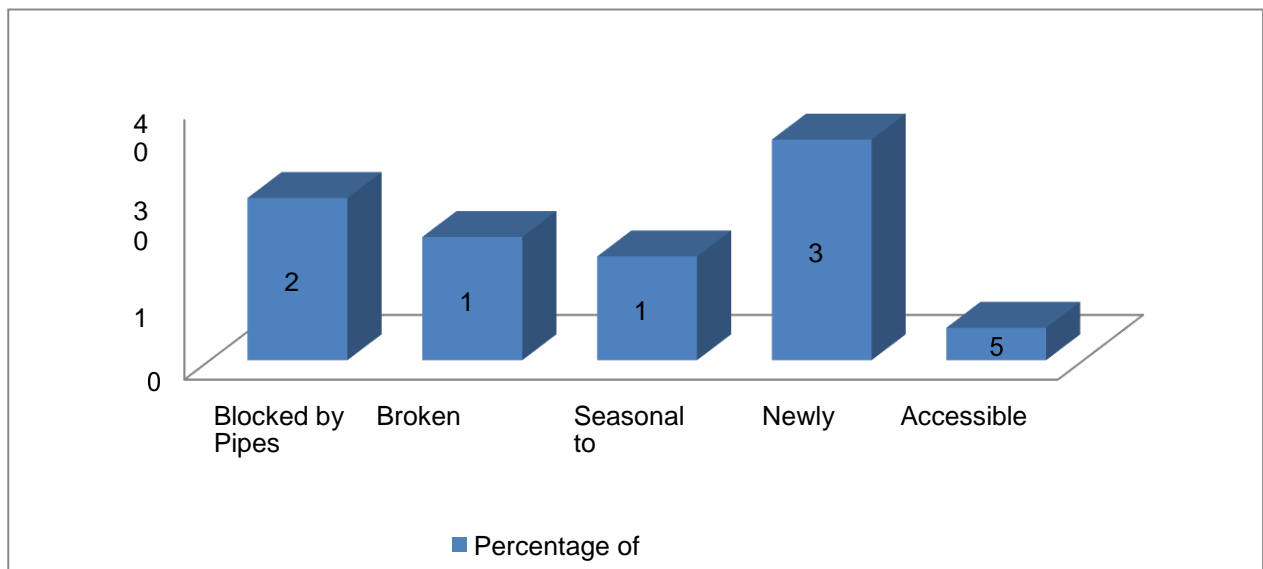


Figure 3 Reasons for Inaccessibility (Problems) to Water Supply Sources
Source: Field survey, 2019

Reasons for difficulty in accessing water supply facilities include blockages of public water sources by houses as a result of unplanned cadastral layout, broken water supply pipes which were not noticed to be replaced by water board management, effect of seasons on the water source most especially the well, boreholes and stream during dry season and newly extended built-up area (Figure 3). Plate 1 also show that the domestic water users are clustered along the road with water supply sources around Bukuru low-cost and Kufang area, this finding is inconsistent with that of MacDonald, Dochartaigh and Welle (2009)

who mapped water and sanitation in Ethiopia and found that water supply failures in this region were that of the reduced yield of the aquifer and deep seated water level during the dry season. Also similar to the findings by George, George and Jacob (2010) inaccessibility of water services in Kisumu municipality which revealed that the proportion of households with access to piped water supply within a distance of 200m is 77.1%, only 65.6% of the basic water requirements of the residents are met and that only 25% of the households access the minimum recommended 50 l/c/d.

**ASSESSMENT OF ACCESS TO DOMESTIC WATER SUPPLY SOURCES IN GYEL DISTRICT OF JOS,
PLATEAU STATE, NIGERIA**

Table 1 Possible solutions to poor access to water supply infrastructure

Solution to the reasons	Number of respondents	Percentage
Sinking Boreholes	60	23
Laying of water supply pipes	103	39
Digging wells	88	33
Buying from water supply vendors	12	5
Total	263	100

Source: Field Survey, 2019

Table 1 shows the possible solutions suggested by the respondents to solve the problem of domestic water supply in the area. Extension of water supply pipes will widely solve this problem especially for the newly extended area, followed by digging wells and others.

Accessibility to Domestic Water Supply Sources

There are diverse sources of domestic water supply in the area. These include; drilled boreholes equipped with hand pumps, collection tanks and protected springs as well as concrete lined wells, surface flowing rivers and streams, lakes, shallow wells, deep wells and pipe borne water (Carter, *et al.*, 2005; Felix and Olusola, 2016).

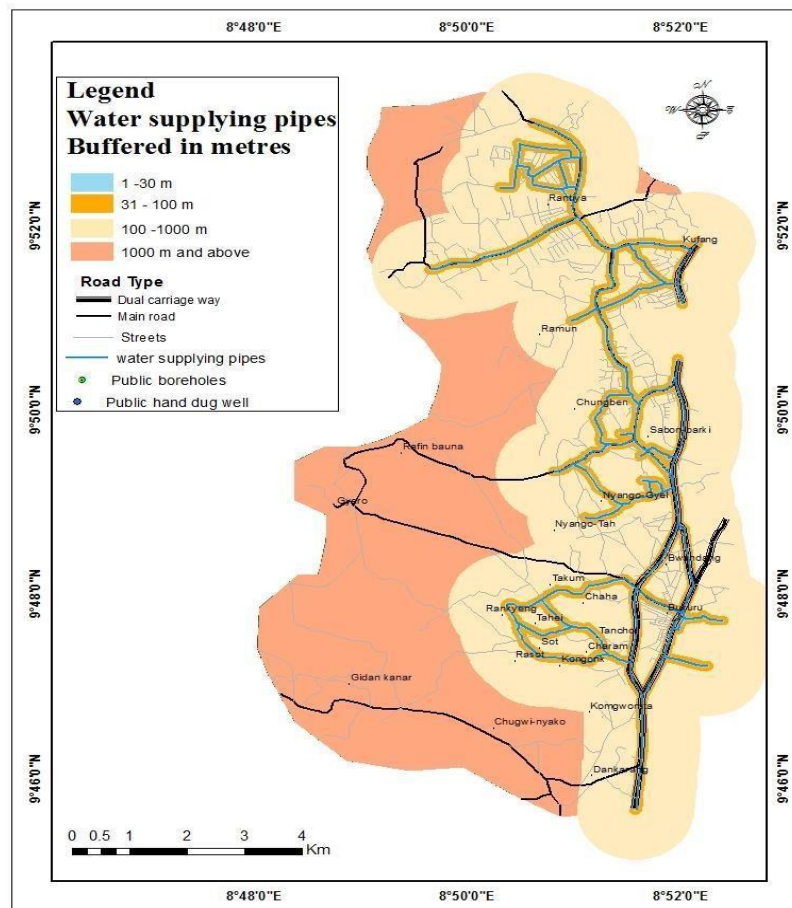


Figure 4 Multiple Ring Buffer Map of Public Water Supplying Pipe

ASSESSMENT OF ACCESS TO DOMESTIC WATER SUPPLY SOURCES IN GYEL DISTRICT OF JOS, PLATEAU STATE, NIGERIA

Access to domestic water sources in Gyel District

The proximity analysis techniques used include the multiple ring buffer, with the standard of distance 1-30,31-100,100-1000 and 1000 meters above, depicting the four level of accessibility which are; optimum, intermediate, basic and no-access, which were used on the various public water supply sources in the study area, as shown in Figures 4,5,6,7,8, show the

following results respectively. This results agrees with that of Chia, Ijir, Iwar and Nduluen (2014).

Regularity of pipe-borne water supply from the source

The regularity of pipe-borne water supply also affects access to domestic water supply in the study area as shown in Figure 4 and Table 2.

Table 2 Regularity of pipe-borne water

Regularity of pipe-borne water source	Number of respondents	Percentage
Everyday	3	17
Once in three days	5	28
Once in a week	6	33
Once a month and beyond	4	22
Total	18	100

Source: Field Survey, 2019

Table 2 shows that of 18 respondents that had access to pipe-borne water supply it were only 17% of the sampled households have access to domestic water supply on daily, This was as a result of irregular supply from the stations coupled with the problem of pipe

damaged due to construction activities especially road construction and illegal connections and natural factor such as weakening and rusting of pipe material which were not replaced in time by the water board service.

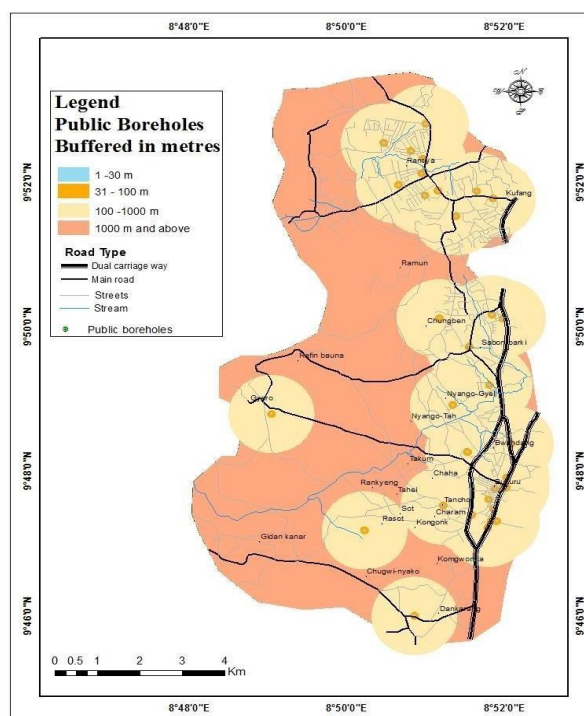


Figure 5 Multiple Ring Buffer Map of Public Boreholes
Source: GIS LAB, NCRS, Jos

ASSESSMENT OF ACCESS TO DOMESTIC WATER SUPPLY SOURCES IN GYEL DISTRICT OF JOS, PLATEAU STATE, NIGERIA

Figure 5 shows the spatial distribution of drilled boreholes and their level of accessibility within the built-up area, large area falls within the level of no-access which takes

them more than 1000 metres to reach the source, likewise the hand dug wells, streams and ponds as shown in Figures 6, 7 and 8.

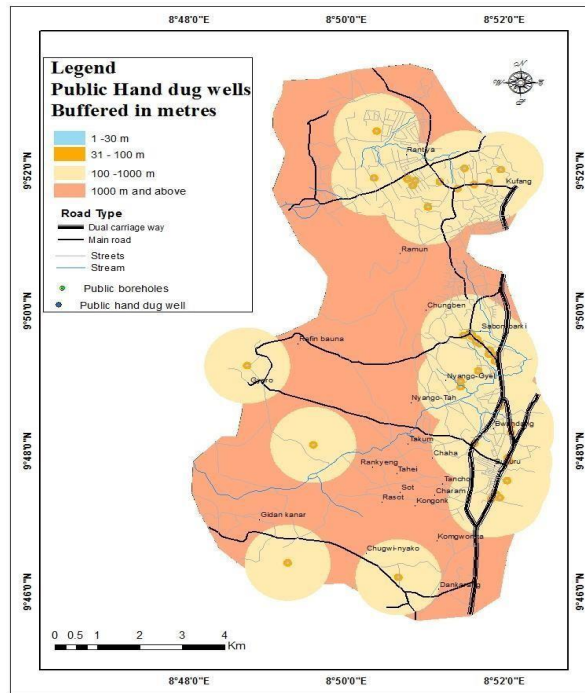


Figure 6 Multiple Ring Buffer Map of Public Hand Dug Well

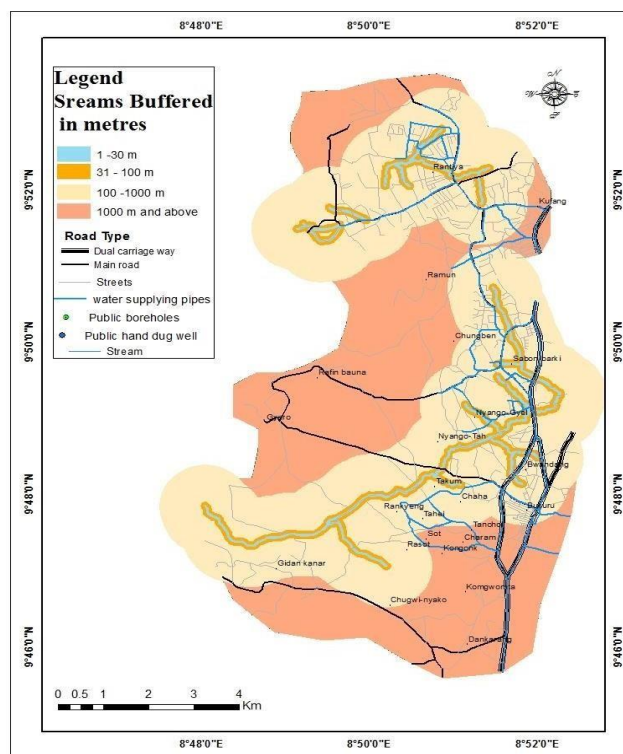


Figure 7 Multiple Ring Buffer Map of Streams in the Area

ASSESSMENT OF ACCESS TO DOMESTIC WATER SUPPLY SOURCES IN GYEL DISTRICT OF JOS, PLATEAU STATE, NIGERIA

Availability of Wells, Boreholes and Streams

Availability of ground water such as well, boreholes and stream sometimes were affected

by seasonal variation as the aquifer goes down in the dry season and also no runoffs from rainfall this can be seen in Table 3.

Table 3 Availability of well, borehole, stream

Water availability	Number of respondents	Percentage
Throughout the year	135	55
Seasonal	106	43
Not at all	4	2
Total	245	100

Source: Field Survey, 2019

Seasonal influence is a threat to domestic water source in this study area as the quantity reduce during the dry season thereby leading domestic water scarcity in the area and this supported that of Odafivwotu and Abel (2014) whose findings revealed that the quantity of water supply was inadequate and the distances to sources of major water supply

reduces during dry season. This has been revealed earlier by MacDonald, Dochartaigh and Welle (2009) which mapped water and sanitation in Ethiopia and found that water supply reduced deep seated water level during the dry season, in addition to the streams Figure 8 shows the distribution of mining ponds as they are also useful in domestic water supply.

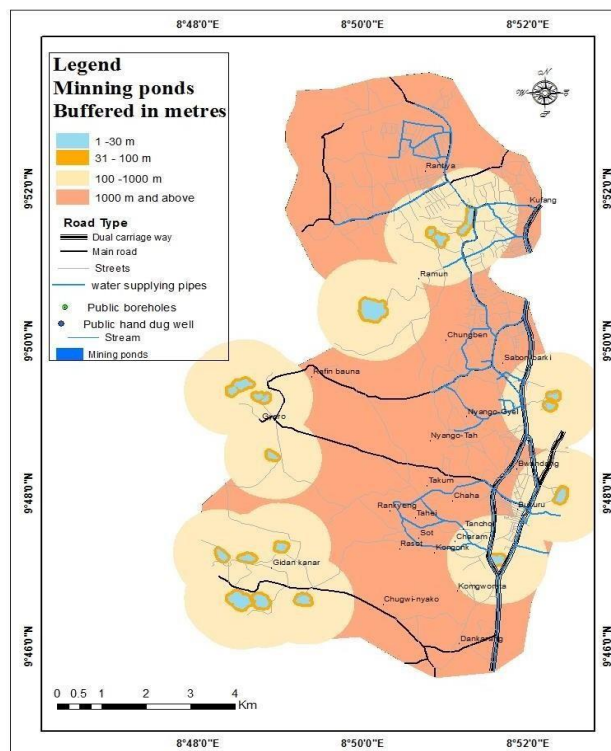


Figure 8 Multiple Ring Buffer Map of Ponds in the Study Area

Using multiple ring buffer analysis of the location of various sources of domestic water supply from Figures 4, 5, 6, 7 and 8, have shown that most percentages of the households were within distance of basic access and no-

access level of accessibility. This is similar to the findings by George and Jacob (2010) in accessibility of water services in Kisumu municipality which revealed that the proportion of households with access to piped water supply

**ASSESSMENT OF ACCESS TO DOMESTIC WATER SUPPLY SOURCES IN GYEL DISTRICT OF JOS,
PLATEAU STATE, NIGERIA**

within a distance of 200m was 77.1%, Only 65.6% of the basic water requirements of the residents were met and that only 25% of the households access the minimum recommended 50 l/c/d. Also MacDonald, Dochartaigh and Welle (2009) mapped water and sanitation in Ethiopia and found that low income households

and low levels of investment in water infrastructure are related to reduced access to water services.

Access to public domestic water supply

The result of access to public water source in the study area is show in Figure 9.

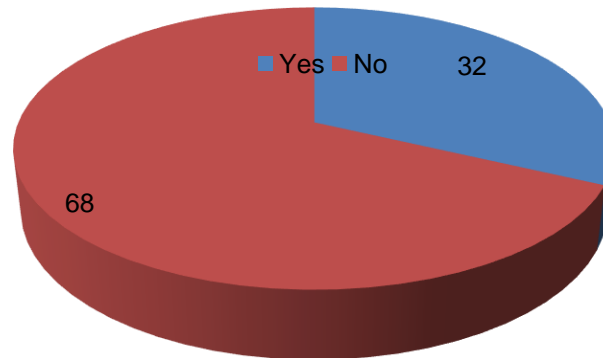


Figure 9 Access to Public Water Supply
Source: Field Survey, 2019

In the area only few people had access to the public water source which is just 32% of the population in the area.

CONCLUSION

The application of spatial analytical tools such as density and proximity analysis using GIS with the aid of Satellite, Global Positioning and population data is important in spatial analysis of access to domestic water supply. It can identify and map patterns of water sources distribution and examine the effects on accessibility in terms of distance and time travelled to water sources.

In determining the spatial distribution of most public water supply sources (facilities) and their level of accessibility within the built-up areas, a large area falls within the level of no-access which takes the residents more than 1000 metres to reach. The hand dug wells, boreholes, streams and ponds are also inaccessible to lowest income households and low levels of investment in water infrastructure also reduce access to water services in the area.

The study therefore recommends the following:

(1) Encourage the provision of more domestic water sources by the Plateau State Water Board, private sector and individual households to boost water supply. Also create awareness on the importance of various sources of domestic water supply as they complement each other especially during dry season in the area.

(2) The Jos Metropolitan Development Board should ensure that built-up areas adopt town planning standard rules to ease laying of water supply pipes and other public water supply facility extensions, especially in the developing built-up areas.

(3) Plateau State Water Board, Jos should engage in periodic pipeline extension services to be able to cover the newly developed areas, regular replacement of damaged facilities to enhance the supply of water in the area.

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EFFECTS OF POULTRY DROPPINGS APPLICATION ON SELECTED PROPERTIES OF LATERITIC SOILS DERIVED FROM BASALTS ON THE JOS PLATEAU, NIGERIA

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Abstract

One of the greatest challenges confronting farmers on the Jos Plateau, as in other parts of the tropics, is soil fertility maintenance. In addition, lateritization the tropical soil forming process, has resulted into soils with very low inherent fertility. The high cost of chemical fertilizers has necessitated farmers to seek alternative sources of fertilizer material and poultry droppings application has found wide acceptance. This research was carried out to study the effects of poultry manure on selected soil properties on a lateritized basalt in Bokkos L.G.A. of Plateau State. Soils samples were collected from an area of highly ferruginized soils, not cultivated and where there has not been application of poultry manure and from two farms where the farmers had been applying poultry manure for over 10 years. A total of 3 profile pits were dug and 16 soil samples collected. Results of physical and chemical analyses showed that water content was higher for soils with poultry manure application with 18 and 20% and 28 and 16% for surface and subsurface horizons compared to 8 and 10% for soils without poultry droppings application respectively. The organic matter content for the surface soils with poultry droppings application were higher with values of 3.42 and 1.36% and 3.92 and 1.42% compared to 0.75 and 0.60% for soils without poultry droppings application. Another positive effect was found in the total nitrogen content of the soils. While it was 0.350 and 0.245 cmol/kg and 0.245 and 0.280 cmol/kg soils with poultry droppings application, it was 0.210 and 0.140 cmol/kg for those without. Exchangeable Mg content was also higher for soils with poultry droppings application. Results of t test confirmed significant differences in contents of total nitrogen and organic matter between the two groups of soils. The study has shown that poultry droppings application is capable of building up the organic matter levels and general fertility of soils. The practice of liming was recommended to maximize the benefits of the high organic matter content of the soils in view of the generally low pH values obtained.

Keywords: Lateritized basalts, Poultry droppings, Soil properties, Jos Plateau

INTRODUCTION

One of the greatest challenges faced by local small holder farmers is soil fertility maintenance (Galadima et al, 2018). It has been observed that continual cultivation with inappropriate farming methods has resulted in severe decline in soil nutrients and organic matter thus posing a threat to agricultural production in sub-Saharan Africa. Inorganic fertilizer utilization by farmers has proven unsustainable due to high cost. This assertion applies to the Jos Plateau of Nigeria where the application of inorganic fertilizers has continued to decline.

Lateritization is a tropical pedogenic process that produces soils in which the horizons are dominated by iron and aluminium oxides, are reddish to dark reddish brown in colour and are

generally infertile and unproductive especially where natural vegetation has been cleared. Lawal et al (200) describe lateritic soils as products of highly weathered material under tropical and subtropical condition, rich in secondary oxides of iron and aluminium or both and which are void of bases and primary minerals. They further assert that their agricultural values depend largely on the thickness of overlying surface material with those having concretionary layers below 50cm depth being moderately productive for paddy and other cereal crops. In terms of their physical properties and nutrient content, Raychaudhuri (1980) observed that the highly weathered lateritic soils were mostly rated poor for agriculture because of their compacted B-horizon which inhibits root penetration with relatively

EFFECTS OF POULTRY DROPPINGS APPLICATION ON SELECTED PROPERTIES OF LATERITIC SOILS DERIVED FROM BASALTS ON THE JOS PLATEAU, NIGERIA

low moisture. In agreement with this assertion, Ansa et al (2019) having reviewed the physical and chemical properties of lateritic soils stated that they have very low potential for arable and economic crop production while Seghal et al (1998) observed that surface crusting, poor inherent fertility, P-fixation, aluminium toxicity, soil erosion among others are the major constraints in these soils.

The lateritic soils occupy extensive areas of land on the Jos Plateau and they are found irrespective of soil parent materials, to form lateritic capping of many granitic and basaltic hill crests as well as ironstone gravels on the surfaces of various middle and lower foot slopes and gently undulating slopes (Olowolafe and Kazeem, 2007). Lateritic soils are now widely utilized in the study area for crop cultivation, grazing and constructional purposes. According to Olowolafe (1995), the total area affected by lateritization in the basaltic landscape is 16,952 ha (i.e. about 22% of the Jos Plateau area). Due to shortage of prime agricultural land, farmers have been forced to move into marginal lands such as those affected by lateritization to cultivate them in order to produce much needed food crops particularly in the basaltic areas. Because of the low fertility of such land's farmers have had to improvise on ways of increasing and maintaining soil fertility in order to productively make use of the land and one such method that has found great acceptance among the farmers in the study area is the use of poultry droppings as fertilizer material.

The Jos Plateau is a predominantly agricultural area and is nationally noted for the production of Irish potatoes and various types of vegetables. Agricultural production in the area is becoming more intensive with all year-round production taking advantage of the numerous mining ponds left behind after a long period of tin mining as well as the perennial streams in the area to supply water for irrigation farming. Studies have shown that soils on the Jos Plateau are generally low in nutrient reserves and that this is one of the major constraints to crop production (Olowolafe, 2003, 2004, 2008). With the high cost of chemical fertilizers that has made crop production uneconomical, farmers in the study

area have looked for alternative means of augmenting soil fertility and one of the methods that have gained popularity is the use of poultry droppings.

The poultry industry has grown quite rapidly on the Jos Plateau with both large scale farms as well as small holdings sometimes in the homes of individuals. There is hardly any street that one passes through without a poultry farm at the back of a few homes and so the material is not in short supply. Many studies have been conducted to show the positive effects of poultry droppings on soil properties. According to Mandal et al (2013) composted poultry droppings contain several plant macronutrients and micronutrients and enhance soil fertility, organic matter, and tilth. They have further noted that the labile form of phosphorus increased following long-term sequential application of poultry litter. Davis et al (2017) have given the nutrient content of poultry litter of various types but those relevant to the study area are stock piled broiler and layer droppings. The values are nitrogen 36, ammonium 8, phosphorus 80 and potassium 34 lb/ton for broiler droppings while those for layers are nitrogen 38, ammonium 18, phosphorus 56 and potassium 30 lb/ton. It is therefore not surprising that farmers in the study area have adopted the use of poultry droppings as an alternative to chemical fertilizers. Soremi et al (2017) reported a significant increase in different P fractions such as organic P, residual and reductant soluble P with application over a two-year period. They also reported a significant decrease in occluded P in the soils. Bakayoko et al (2009) reported an increase in organic matter content of a sandy Ferralitic soil from 0.46 to 2.8%, CEC from 1.27 to 12.75 me:100g and base saturation from 47 to 80% with poultry manure treatment.

Literature search has revealed that no study has been conducted on soils formed on lateritized basalts on the Jos Plateau where farmers have been using poultry droppings as fertilizer material for a considerable period of time. This study was therefore conducted to study the effects of poultry droppings application on

EFFECTS OF POULTRY DROPPINGS APPLICATION ON SELECTED PROPERTIES OF LATERITIC SOILS DERIVED FROM BASALTS ON THE JOS PLATEAU, NIGERIA

lateritized basalts on the Jos Plateau to assess their effects on selected soil properties.

MATERIALS AND METHODS

Study Area

The Jos Plateau is found in central Nigeria with a latitudinal and longitudinal extent of between $8^{\circ}30'N$ and $10^{\circ}30'N$ and of $8^{\circ}20'E$ and $9^{\circ}30'E$ with total land area of about $9,400\text{km}^2$. The Plateau has an average elevation of about 1,250m above mean sea level and is over 600m above the surrounding plains. It experiences the Aw climate (Koppen's classification) characterized by

alternate wet and dry season. The main influences on the climate are the altitude of the area and the movement of the Intertropical Discontinuity (ITD). The mean annual rainfall is about 1,260mm lasting from April to October with the single maximum occurring between July and August when the moist tropical maritime air mass dominates the airspace while dry conditions persist between November and March with the tropical continental air mass moving in from the north east. Mean annual temperature is about $22^{\circ}C$.

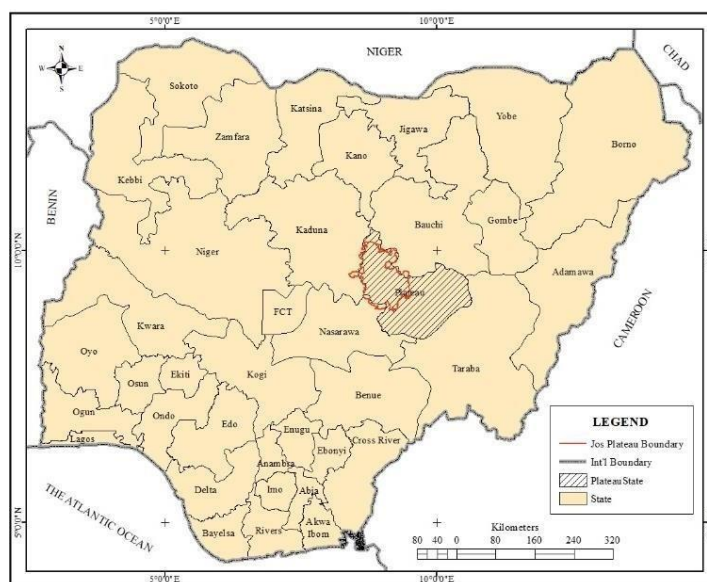


Figure 1 Nigeria showing the Jos Plateau region

The vegetation is composed of open woodland and tall grasses characteristic of the northern Guinea Savanna but has been much altered due human activities like agriculture and tin mining (Keay, 1953). The geology of the area is made up of Precambrian basement complex rocks (migmatites, gneiss and older granites), the Jurassic younger granites (biotite- granites), the tertiary and quaternary volcanic rocks (basalts, pumice, lava flows and ash deposits) (Macleod et al, 1971). The varied geological and topographic features of the Jos Plateau have given rise to a variety of soil types.

Olowolafe and Dung (2000) have stated that the most prominent include Entisols, Inceptisols, Alfisols and Ultisols. Some of the soil parent materials have undergone lateritization as a result of high temperature and high seasonal rainfall (Macleod et al, 1971). The dominant soil type in the studied area are Ultisols developed under wet/dry conditions (Ustults). They are characterized with abundant plinthites in the horizons resulting into the dominant reddish colour that was observed.

EFFECTS OF POULTRY DROPPINGS APPLICATION ON SELECTED PROPERTIES OF LATERITIC SOILS DERIVED FROM BASALTS ON THE JOS PLATEAU, NIGERIA

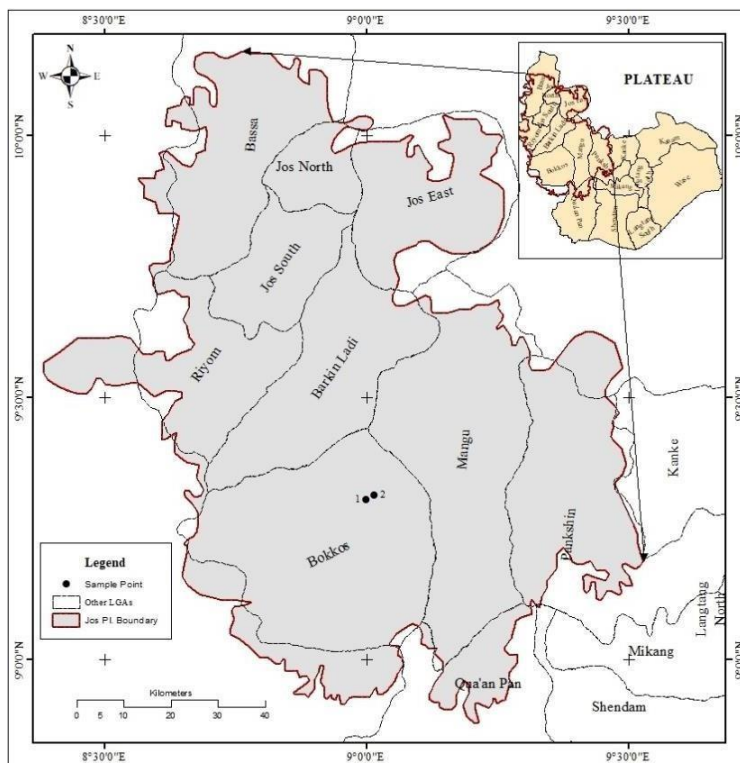


Figure 2 Jos Plateau Region

Data Collection

The study was conducted in an area of extensively lateritized basalts to the north of Bokkos town in the south-central part of the Jos Plateau. Soil samples were collected from three areas with the first being highly ferruginised and having abundant lateritic concretions on the surface and was not cultivated but given to rough grazing. The other two areas of sampling were cultivated with the addition of poultry droppings practiced for over ten years. The farmers usually broadcast the poultry droppings over the land in March to allow it to ferment before ploughing was done. Some bags of the poultry droppings are kept in the open and allowed to ferment and are later applied to the growing crops. Three profile pits were dug one was in the uncultivated area and served as the control while pits two and three were sited on a farm on the upper- and lower-foot slopes based on the local topography. Five samples were collected each from pits 1 and 2 and six from pit 3 giving a total of sixteen.

Soil profile pit description was based on the FAO (2006) method. Soil samples were collected from the identified horizons, air dried and passed through a 2mm sieve. **Particle size distribution** was determined using the hydrometer method (Bouyoucos, 1981). **Soil pH** was determined in a 1:2.5 soil to water suspension using a pH meter. **Organic carbon** was determined by wet oxidation method (Nelson and Sommers, 1982). **Total Nitrogen** was done by the Macro-Kjeldahl method and **available P** by Bray-1 method (Bray and Kurtz, 1945). **Exchangeable bases** were extracted with neutral IM NH₄OAc at a soil solution ratio of 1:10 and measured by flame photometry. Magnesium was determined with an atomic absorption spectrophotometer. **Exchangeable acidity** was determined by titration method (Maclean, 1982).

RESULTS AND DISCUSSION

The results of analysis on the soil samples are presented in table 1. All the soils studied, for the profiles with and without poultry droppings

EFFECTS OF POULTRY DROPPINGS APPLICATION ON SELECTED PROPERTIES OF LATERITIC SOILS DERIVED FROM BASALTS ON THE JOS PLATEAU, NIGERIA

application, were either sandy loam or sandy clay loam in terms of their texture. The percentage water content at the surface was least for profile pit 1 (the control) with 8 and 10% for the surface and subsurface horizons while it was 18 and 20% and 28 and 16% respectively for soils around profile pits 2 and 3. This is consistent with field observation where it was found that soils around profile pit 1 was highly ferruginised with abundant lateritic concretions while soils around profile pit 3 were poorly drained. The appreciably higher water content of the soils in profile pits 2 and 3 may be attributed to the higher organic matter content of these soils compared to those of profile pit 1. This is further borne out by the result of t test (at 0.05) which gave a significance of 0.014 indicating that difference in water content between the two groups of soils was significant. Baur and Black, (1994), Doran and Parkin, (1994) and Weil and Magdoff (2004) have reported on the importance of organic matter in water retention and availability in soil. Brady and Weil (1996) have observed that the water content causes soil particles to swell and shrink, to adhere to each other and to form structural aggregates. Higher water content of soils with application of poultry droppings have also been reported by Agbede et al (2017). Ewulo et al (2008) observed a reduction in soil bulk density and increase in soil moisture content with increase in poultry manure addition. They attributed this to the increased organic matter content and its mulching effect, improved moisture retention and water acceptance as a result of improved soil structure and microporosity.

Soil bulk density figures showed that soils around profile pit two at the surface soil was the highest (2.09g/cm^3) while it was 1.7g/cm^3 and 1.8g/cm^3 respectively for profile pits 1 and 3. In general, the bulk density values for the soils were high compared to those of basalts in Kerang area of the Jos Plateau (Galadima, 2018). This may be attributed to the much more weathered and lateritized status of the soils under study. The uneven spread of the poultry droppings as well as the rate of application by the farmers may have resulted in the site of the profile pits having had less applied.

Onyegbule and Asawalam (2015) and Duruigbo et al (2007) reported lower acidity with increasing poultry droppings application. They have cited the ability of organic manure to increase soil pH due to the presence of basic cations contained in poultry manure. However, the results in this study did not show any significant variation in pH for all the soils particularly at the soil surface. This may be attributed to leaching of basic cations in view of the higher pH values in the lower horizons of the profile pits 2 and 3. The available phosphorus for the soils was generally very low especially at the surface (Landon, 1991) with values of between 3.50 and 5.25ppm. The uncultivated soils around profile pit one (1) had higher values of available phosphorus at the surface and subsurface soils compared with the soils with poultry droppings application. This is in contrast to what has been reported by Soremi et al (2017)b and Onyegbule and Asawalam (2015). Soremi et al (2017)b reported an increase in total P from 504.40 to 555.16mg kg⁻¹ in the first cycle and from 182.59 to 283.08 mg kg⁻¹ in the second cycle of their study. Onyegbule and Asawalam (2015) also reported an increase in available P from 16.9 mg/kg to 32.8mg/kg with application of 25 t/ha of poultry manure. The lower content of available P in the soils with poultry droppings application could be attributed to the high uptake of phosphorus by plants despite the higher rate of mineralization of the organic phosphorus. In addition, the higher content of the nutrient in the lower horizons particularly for profile pit 2 indicates downward movement through leaching. Total nitrogen content for the soils showed appreciable difference between soils with and those without poultry droppings application with values of 0.210 and 0.140, 0.350 and 0.245 and 0.245 and 0.280 cmol/kg respectively for the three profiles at the surface and subsurface. This may be attributed to the increased microbial activities which could have resulted in enhanced decomposition of the organic forms of N. This is in agreement with Uwah et al (2014) and Bakayoko et al (2009) who reported higher nitrogen content of soils with application of poultry droppings.

EFFECTS OF POULTRY DROPPINGS APPLICATION ON SELECTED PROPERTIES OF LATERITIC SOILS DERIVED FROM BASALTS ON THE JOS PLATEAU, NIGERIA

Table 1 Physical and chemical properties of the soils

S/No	H	Particle size distribution (%)			TC	% WC	g/cm ³ BD	H ₂ O pH	% OM	TN	ppm AP	Ca	Mg	cmol/kg		EA	CEC
		Clay	Silt	Sand										K	Na		
Profile pit 1: Area without poultry droppings application																	
1	A	10	18	72	SL	8	1.70	5.40	0.75	0.210	5.25	6.60	2.76	0.26	0.58	1.40	11.80
2	B1	20	16	64	SL	10	1.40	5.60	0.60	0.140	8.75	5.00	1.98	0.23	0.75	1.20	10.40
3	B2	24	12	64	SCL	20	1.62	6.11	0.21	0.245	3.50	3.30	0.58	0.11	0.81	0.80	7.90
4	B3	24	12	64	SL	23	1.70	5.70	0.26	0.175	1.75	3.70	0.79	0.18	0.80	1.00	9.60
5	C	24	14	62	SL	28	1.55	5.40	0.36	0.105	3.50	3.60	1.86	0.12	0.78	1.40	9.90
Profile pit 2: Area with poultry droppings application																	
6	Ap1	18	12	70	SL	18	2.09	5.40	3.42	0.350	4.03	5.80	3.42	0.14	0.10	0.60	12.5
7	A2	28	12	60	SCL	20	1.26	5.50	1.36	0.245	3.50	7.40	4.26	0.08	0.14	0.60	14.1
8	B1	30	18	52	SCL	21	1.81	5.70	1.31	0.350	8.40	5.40	2.54	0.09	0.16	0.80	17.7
9	B2	28	16	56	SCL	22	1.64	5.70	0.26	0.210	21.7	5.40	3.06	0.09	0.15	0.60	20.0
10	C	32	14	54	SCL	27	1.74	5.80	0.41	0.175	12.43	11.00	5.10	0.08	0.15	0.40	19.0
Profile pit 3: Area with poultry droppings application																	
11	Ap1	12	28	60	SL	28	1.80	5.62	3.92	0.245	3.50	6.50	3.20	0.23	0.72	1.40	11.20
12	A2	18	22	60	SL	16	1.65	5.70	1.47	0.280	1.75	4.20	1.32	0.14	0.73	1.80	9.20
13	B1	18	18	64	SL	21	1.57	5.80	1.47	0.175	6.13	5.80	0.86	0.21	0.70	2.80	10.50
14	B2	20	18	62	SL	19	1.71	5.91	0.76	0.140	2.63	5.60	2.68	0.24	0.77	3.00	14.40
15	B3	24	14	62	SCL	20	1.67	6.04	0.26	0.105	1.75	3.70	0.56	0.41	1.04	2.40	11.70
16	C	20	18	62	SL	27	1.60	6.02	0.29	0.105	3.50	4.40	2.42	0.43	0.74	1.80	12.20

H= Horizon, TC= Textural classes, WC= Water content, BD= Bulk density

Table 2 Result of t test at 0.05%

	f	sig.	t
Water content	7.838	0.014	1.286
Organic matter	7.300	0.022	1.817

Researchers have reported the positive influence of poultry manure on organic matter and exchangeable bases content of soils (Uwah et al, 2014, Bakayogo et al, 2009, Soremi et al, 2017b and Kobierski et al, 2017). Ca content of the soils at the surface do not vary much (6.60, 5.80 and 6.50 cmol/kg respectively) but the higher values in the lower horizons of the soils with poultry droppings application (11.0, 4.40) indicates the downward movement of the nutrient with the finer fraction. For Mg there is an appreciably higher content of the nutrient in soils with poultry droppings with values of 3.42 and 4.26 cmol/kg (pit 2) and 3.20 and 1.32 cmol/kg (pit 3) compared to 2.76 and 1.98 cmol/kg for the soils without poultry droppings (pit 1) in the surface and sub surface horizons respectively. The content of exchangeable K showed a slight decrease at the surface for profile pits two (2) and three (3) compared to the control (0.26 to 0.14 and 0.23cmol/kg). This may be attributed to K fixation and leaching in pit three (3) in view of the much higher content in the bottom horizons. CEC values for the soils were only slightly higher for the soils with the application of poultry manure at the surface but were higher in the lower horizons (11.8 cmol/kg compared to 12.5 and 11.20 cmol/kg). Soremi et al (2017b) have stated that poultry manure is a rich source of exchangeable cations and that their reduced content could be attributed to their uptake by crops. This will be true of the soils under study as the areas of poultry droppings application were under continuous cultivation with two crops of Irish potatoes annually and sometimes intercropped with maize all of which are heavy consumers of soil nutrients. Organic matter content of the soils showed a sharp contrast between soils around profile pit one (1) where there was no cultivation and no addition of poultry droppings and those around pits two (2) and three (3) where the farmers have been

applying the fertilizer material for a very long period of time.

The organic matter contents of the surface and subsurface horizons were 0.75 and 0.60% while those for soils with poultry droppings application were 3.42 and 1.36% and 3.92 and 1.47% respectively. Profile distribution pattern showed a decline down the profile for all but while organic matter content was generally very low (for tropical soils, <5%) for soils around pit one (1), the first three horizons for pit two (2) and three (3) had much higher amounts. This pattern may be explained by the fact that consistently farmers apply the poultry droppings on the surface before ploughing and over time it accumulates in the surface and subsurface horizons compared to the lower horizons which have very low content. The organic matter content for the soils around profile pit one (1) is rated very low while those for pits two (2) and three (3) are rated medium to high (Landon, 1991). t test conducted (at 0.05) gave a significance of 0.022 indicating that the difference in OM content for the two groups of soil was significant. The results are in agreement with Kobierski et al (2017), Onyegbule and Asawalam (2015), and Soremi et al (2017) who have all reported significant increases in soil organic matter with application of poultry droppings.

CONCLUSION

The data obtained shows that poultry droppings can be effectively used to manage lateritized soils to make them more productive. Though the farmers applied the material purely as fertilizer for higher yields, the beneficial effect goes beyond adding to the fertility of the soils to changing the total soil environment. The higher organic matter content seems to have resulted into slightly lower acidity, higher organic matter, N, Mg, Na and CEC content for the soils. The residual effect of poultry droppings application

will ensure higher yields for the farmers and other benefits that come with higher organic matter content such as good tilth and higher moisture retention. The presence of organic material on the surface tends to maintain a level of productivity of the lateritized soils because removal of vegetation cover results into hardening of the surface and formation of lateritic crusts. The advantage of building up the organic matter levels of such soils is summed up by Walsh and McDonnell (2012) who have stated that soil that is chemically and biologically fertile but which cannot physically support crop development will not fulfill its agronomic potential and that soil productivity is therefore determined by a combination of organic matter's influence on chemical, physical and biological properties of the soil.

The fertility status of the soils is quite high but could be even better if other management practices like liming are introduced. The CECs of the soils could be much higher than they are if liming is done to reduce acidity. Murphy (2014) has stated that when pH of soils falls below 5.0 many of the organic acids which make up the soil organic matter are not dissociated and so do not display a negative charge leading to low CEC while the best pH for increased CEC from organic matter is 6.0. The fear of shortage of poultry droppings for supply to farms does not exist for now based on the author's observation that more people are engaging in poultry farming.

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**EFFECTS OF POULTRY DROPPINGS APPLICATION ON SELECTED PROPERTIES OF LATERITIC SOILS
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ERODIBILITY OF SOIL IN ANGWAN RIMI, ZANGO KATAF LOCAL GOVERNMENT AREA, KADUNA STATE, NIGERIA

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Abstract

The Soil is a vital component of the environment and serve as a medium for many biological and other non-biological activities on agricultural farms. The aim was to assess the erodibility indices of soils under different agricultural land. Four farmlands of Ginger, Beans, Maize and Fallow land were selected at a distance of 130km apart. The study plot size ranges between 1036m² to 8640m² and a total of 12 soil samples were collected at a depth of 0-10cm. Three (3) samples from each site were collected and analyzed for pH, electric conductivity, particle size distribution, organic carbon, exchangeable acidity and bases (exch. Na, Ca, and K) using standard laboratory procedures. Result showed that Clay Ratio (CR) did not significantly vary with the agricultural land uses, likewise mean value of clay ratio across the farmlands was found to be 9.92%. This result imply that there was loose soil structure and high susceptibility of the soils to erosion; the Maize farm had clay ratio of 68.07% and Ginger farm have 61.95% implying an unstable structure and erosion risk while the mean values of beans farm and fallow land implied lesser susceptibility to erosion with 59.18% and 59.95% respectively. Communal tree planting (re-vegetation), use of organic manure, farming across the slopes, crop rotation and grass fallowing are proffered solution.

Keywords: Erodibility, Farmland, Organic, Particles size, Soil

INTRODUCTION

Soil is a very important component of the environment and a primary medium for many biological and other non biological activities mainly agricultural, infrastructural construction and many more. Therefore it is very imperative to study and protect soil in relation to its diverse importance (Nam *et al.*, 2003). Soil in different location of the world deserve considerable attention because soils are subject to natural and human induced erosion forces.

Very little amount of soil is loss when erosion occurs naturally without human influence with relatively little or no significant adverse impact whereas erosion become more apparent and severe with higher significant adverse impacts as a result of anthropogenic activities. Studies in Nigeria observed that as the population of the country increases rapidly, pressure is mounted on the country's soil to produce enough food to meet the requirement of the ever increasing population Yang *et. a.,l* (2007). There is also more pressure on soil for construction materials as demand for development and construction of houses, roads, bridges and other infrastructures increases. These increasing

demands for food and infrastructures made it necessary for the population to subject the soil into more agricultural practices (overcultivation) and over exploitation of the construction materials for development as such leads to degradation of soil structure, fertility and quality as well as increasing soil contamination and aggravating soil erosion (Deivid *et al.*, 2003).

Deivid *et al* (2003) noted that Soil erosion amounts to reduction of soil quality and fertility among other problems such as development of gullies and badlands, destruction of good roads and hindering transportation are linked to agents of denudation such as water, wind and less importantly ice. Water erosion is a more complicated process involving impacts from precipitation, detachment and subsequent transportation of the detached soil. Water erosion generally depend on erodibility of the soil surface, deposition and kinetic energy of water flow over land surface. This implies that soils prone to detachment and over land transportation can be eroded with ease.

Soil erodibility is an important index and a major factor in evaluating soil sensitivity to erosion. It is defined as the susceptibility of soils

to erosional processes (Igwe, 2003; Fu *et al.*, 2014); Bagarello *et al.*, 2012 and Feraira *et al.*, 2015). The term denotes the inherent susceptibility or vulnerability of soil to detachment, transportation and deposition by rain fall, run off, wind and ice. Soil erodibility is a complex concept that is influenced by many factors such as soil properties and human activities. Soil properties tend to determine the vulnerability of the soil aggregates and particles to detachment, disintegration, entrainment and their subsequent transportation (Keli, *et al.*; 2002 and Chem *et al.*, 2013), terrain (Wang *et al.*, 2012), climate(Hussein *et al.*, 2013; Sanchis *et al.*, 2015) vegetation (Sepheveda Lozada *et al.*, 2009), land use (Cerda *et al.*, 1998; Tang *et al.*, 2016), soil texture and aggregation, share strength, infiltration capacity, permeability, organic content, chemical content, soil profile, detaching and transportation force.

Similarly, important soil characteristics, properties and their corresponding qualities with respect to erodibility have been outlined by Edward (1961) as follows; texture, permeability,

nature of clay, infiltration, water holding capacity, soil structure, detachability, organic matter content, ease with which particles moves, thickness of significant layers degree of consolidation or cementation of soil particles impacts on erodibility status of soils. Loose particles aggregates will be prone to detachment and transportation by agent of denudation and ease with which excess water can leave the soil. These factors influence soil susceptibility to erosion. However, Salako (2003) in his work observed the research conducted in Nigeria by Aina, 1980; Obi and Salako, 1989 agree that rainfall erosivity in the tropics can be linked to intensity, amount and sizes of rain drops.

MATERIALS AND METHODS

Study Area.

Zangon Kataf Local Government Area (LGA) of Kaduna State, Nigeria lies between latitudes 9° 25'N and 10° 20'N and longitude 7° 45'E and 8° 40'E, with a total land area of about 5,625km² and density of 167.0/km² (Abaje *et al.*, 2009) (Fig 1). The area of study is Angwan Rimi area.

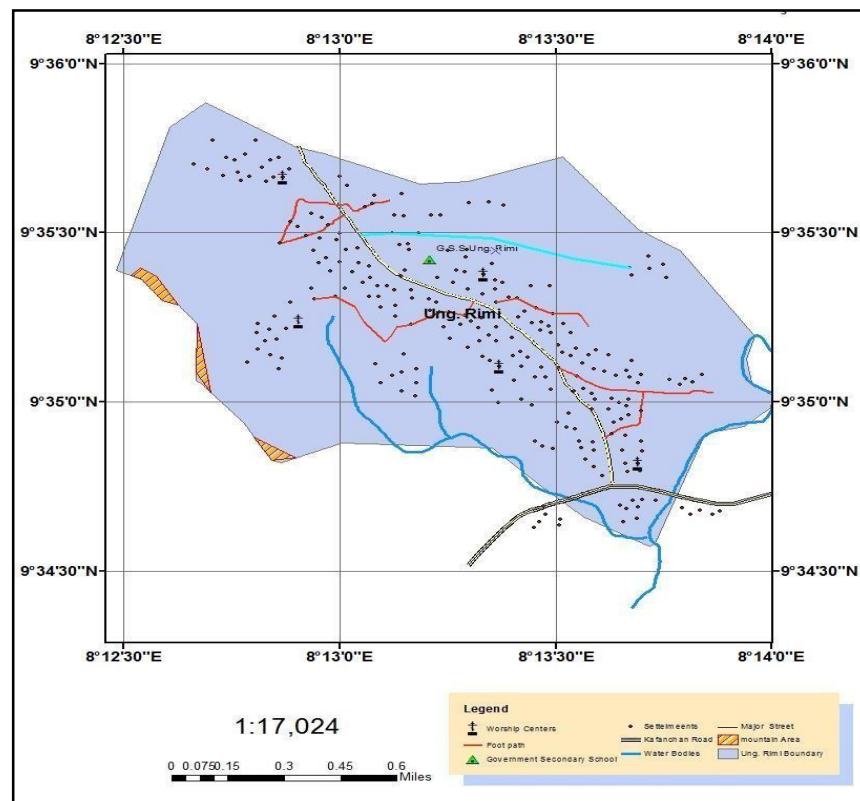


Figure 1 Angwan Rimi, Zangon Kataf, Kaduna State (Study area).

Geology

The bedrock geology of Zangon Kataf Local Government, Kaduna State is predominantly metamorphic rocks of the Nigerian Basement Complex consisting of biotic gneisses and older granites; young granites and batholiths are evident. Deep chemical weathering and fluvial erosion, influenced by the bio-climatic nature of the environment, have developed characteristic high undulating plains with subdivided interfluves (Oluyori *et al.*, 2016).

Climate and Vegetation.

The study area is located in the middle belt of Nigeria, Zango – Kataf LGA is located within the tropical continental climate (Koppen's AW) with two distinct seasons –wet and dry. A typical Tropical Continental climate with distinct seasonal regimes oscillating between cool to hot dry and humid to wet Rainfall occurs between the months of April to October with a peak in August. The mean annual rainfall is about 1800mm, the mean monthly temperature at 25⁰c, while the relative humidity is about 62%, (Hussein *et al.*, 2013). Generally, the soils are typical red brown to red yellow tropical ferruginous soils which is related to the climate, vegetation and topography of the study area, likewise The soils in the upland areas are rich in red clay and sand but poor in organic matter. Clay and sandy soils are also found at the banks of the rivers. The relief of the area is relatively flat and undulating (Abaji, Ati and Ishaya 2009).

The vegetation type found in the study area is Southern Guinea Savanna type characterized by thick woodlands, tall grasses and herbs with riparian forest along streams and river banks (Igwe, 2003 and Udo, 1981).

Population and Economic Activities.

According to National Population Census (2006) the Local Government had a population size of 318,991. However, the National Bureau of Statistics (2012) estimated the projected population size of 370,615 by the year 2011. Average population density of the Local Government is about 76 persons per squares kilometer. The sex ratio of this population (NPC, 2006) stood at: 162,047 males to 156,944 females (approximately 50.8: 49.2). The structure of the

population indicates that a higher proportion are children and youths who constitute about 65% of the entire population, a relative low middle and old age group. About 70% of the total population are farmers, engaged in at least one form of subsistence farming, cultivation of cash crops especially ginger and rearing of animals. The most cultivated crops are mostly yam, maize, ginger, beans and cocoyam (Abaji, Ati and Ishaya 2009).

Methods of Data Collection and Analysis.

Five various methods were applied in the experiment on soil erodibility. Measurement of soil physiochemical properties (water and wind erosion research), measurement by scouring experiment, simulated rainfall experiment, plot experiment (water erosion research), wind tunnel experiment (wind erosion research). Likewise soil erosion models and nomogram were also used to calculate soil erodibility, adopting Song Yang *et al.*, (2007) method.

Data Requirement

Primary data required on soil physiochemical properties that are known to have influence on soil erodibility in the study area are:

1. Physical properties of the soil under study; physical soil properties such as; Bulk density, porosity, soil moisture content, soil aggregate stability and particle size distribution.
2. The chemical properties of the soil under study; soil ph, soil organic carbon, soil organic matter, exchangeable acidity, exchangeable bases and effective cat ion exchange capacity.

Experimental Design

Site Selection and Sample Collection.

The farmlands under study were selected using purposive and sample random sampling technique for sample collection and laboratory analysis. Four farm lands under different cropping systems showing moderate to catastrophic erosion problem were selected. The agricultural land uses were selected based on dominant crops cultivated and three soil samples were taken from each of the four farmlands (beans, maize, ginger and fallow land) at different points (10m distance between each point) and at a depth of 0cm to 15cm. The distance between

the selected farmlands are not equally distributed, however, the distance between beans and maize farm is 130km and between ginger farm and fallow land is 150km. Similarly, the total area for the different farm lands under study are not equal, the largest is the maize farm which have 8640m², beans farm have total area of 2400m², fallow land have 1800m² and ginger farm have 1036m² respectively.

Laboratory Analysis of Soil Samples

Laboratory analysis of soil samples were conducted in soil Laboratory. Standard laboratory procedures were followed throughout the analysis to determine the following soil physiochemical characteristics that affects soil erodibility

Particle size distribution

Particle size distribution was determined by hydrometer method as described by Gee and Bauder (1986). Clay, silt and sand were determined by dispersing the soil sample in calgon (hexametaphosphate) solution. The dispersed sample is to be shaken on a reciprocating shaker after which particle size distribution is determined with aid of Boyoucou hydrometer at 40 seconds (clay + silt) and 2 hours (clay only) interval. The textural classes were determined with the aid of USDA textural triangle.

$$C = R - RL + (0.36T) \tag{1}$$

where: C = corrected hydrometer reading (g/l)
 R = hydrometer reading (g/l)
 RL = Blank reading (g/l)
 T = temperature of the suspension (°C)

$$\%Clay = \dots\dots\dots \times \dots\dots\dots \tag{2}$$

$$\%Silt = \dots\dots\dots - \%Clay \tag{3}$$

$$\%Sand = 100 - (\%Clay + \%Silt) \tag{4}$$

Organic Carbon

Soil organic carbon was analyzed by wet oxidation method of Walkey- Black (Nelson and Sommer, 1986). One gram of air dried, less than 2 mm soil were placed in 250 ml flask. 10 ml of 1N Potassium dichromate (K₂Cr₂O₇) solution

will pipette into the flask and swirled gently for soil dispersion.

Soil pH

Soil pH will be determine electrometrically using a pH meter with a glass electrode, after equilibrating for 30 minutes (Jurinak, 1978).

Electrical conductivity (EC)

The EC (1:2.5) soil/ water ratio extract will be determined using a direct EC meter at room temperature. Results will be expressed in micromhos cm⁻¹ and thereafter converted to decisiemens per meter (dsm⁻¹) will be adjusted to that of 25°C, using the appropriate factors (US Salinity Lab. Staff, 1954).

Soil Nitrogen (TN)

Total Nitrogen (N) was determined by Kjeldahl method (Bremner, 1982), a wet oxidation method which involves digestion of the soil sample to convert N to ammonium (NH₄) and determination of the NH₄ in the digest by titration.

Cation exchange capacity (CEC)

The CEC values was measured using ammonium acetate (1N NH₄OAC) at pH 7 as described by Rhoades and Thomas (1982).

Exchangeable Bases (EB)

Soils was analyzed for Ca, Mg, K and Na, following the extraction with 1N ammonium acetate (1N NH₄OAC) at pH 7, using 1:10 soil/solution ratio. Na⁺ and K⁺ in filtered extracts will be determined with a Gallen Kamp Flame Analyzer while Ca²⁺ and Mg²⁺ are determined by a Palkin-Elmer Model 290B atomic absorption spectrophotometer (Chapman, 1965).

Determination of erodibility index.

The erodibility indices and values of the study soils was determined by the use of the formulation suggested by Boyoucou (1935). The clay ratio proposed by Bouyoucos (1935) is a measure of the amount binding due to clay. When clay ratio decreases with increase in depth. This may be interpreted to mean that the binding influence of clay and hence the resistance of the soils to erosion increased with increase in depth. Higher clay ratio here indicates lower binding

influence due to clay and therefore greater susceptibility to erosion. The formula is given as:

$$\text{Clay ratio} = \frac{\% \text{ silt} + \% \text{ sand}}{\% \text{ clay}} \quad (5)$$

RESULTS AND DISCUSSION
Soil Physiochemical Parameters

Soil organic matter and porosity

The soil of the study area have a considerable amount of organic matter whose mean values ranges from 3.35 for fallow land as the highest and 1.53 as the lowest in beans farm, ginger farm have 2.25 and maize farm have 2.19 respectively. The mean result shows that mean percentage of Soil Organic Matter is 1.42%, this mean result is considered to be slightly moderate as similar result of 1.41% obtained by Oluyori (2016) work on assessment of some soil erodibility indices on agricultural land uses in Fdan kagoma area of Jema'a local government area, Kaduna state, northern nigeriia and 1.01% obtained by Mgbanyi's (2011) work on rates of soil wash on miniature badlands and bare surface in the FCT with the obtained soil texture of Sandy Loam (S.L) on this study, low organic matter does not encourage soil aggregation and thus poor soil structure making it prone to particle detachment and entrainment. This is as a result of influence

of exposure to physical stresses as observed by Bryan (2000). These stresses are linked to human activities which involve vegetation change, alteration of organic inputs, and physical disruption of the soil, which transforms soil climate and organic decomposition rates. These were noticed in the study area, and the results further show other effects such as influence of bush burning (Giovannini et al., 1958; Fernandez et al., 1997) and animal trampling (Steffens et al., 2008) which significantly change aggregation characteristics by reducing organic material or precipitating hydrophobic substances which temporarily "water-proof" aggregates.

Porosity across the land uses is highest with 33.09 in ginger farm and beans farm record the lowest value with 9.00, fallow land has porosity mean of 14.92 and maize farm has 19.75 respectively (Table 1).

Soil bulk density and particle density.

The soils in all the farm lands generally have low mean values of Bulk Density and Perticle size (Table 1). The farm land with highest value for B.D is maize farm with 1.44; fallow land is 1.40; beans farm have 1.36; and the lowest is ginger farm with 1.31. While P.D on the other hand is highest in beans farm with mean value of 1.50, maize farm have 1.44, ginger farm have 1.33 and fallow land is the lowest with 1.30.

Table 1 Soil physiochemical properties under different agricultural land uses

PARAMETERS	Fallow land	Giger Farm	Maize Farm	Beans Farm
Organic Carbon	2.19	1.3	1.21	0.92
Nitrogen	0.19	0.18	0.19	0.12
Potassium	0.8	0.18	0.31	0.23
Sodium	0.68	0.29	0.35	0.27
Magnesium	2.16	1.32	1.2	0.94
Bulk Density	1.4	1.31	1.44	1.36
Particle Size Density	1.3	1.33	1.44	1.5
Soil PH	6.44	6.38	6.46	5.98
Organic Matter	3.35	2.25	2.19	1.53
Phosphorus	8.22	32.3	41.2	25.43
Calcium	8	5.06	6.3	3.51
Cation Ex. Capacity	11	7.41	8.86	5.32
Porosity	14.92	33.09	19.75	9

Particle size distribution (sand %, clay % and silt)

The textural soil of all the agricultural uses are generally classified as Sandy Loam (S.L) Percentage mean of sand, clay and silt was found to be 58.00%, 15.00% and 27.00% for fallow land respectively. The mean of sand, clay and silt to be 59.00%, 13.00% and 28.00% for ginger farm, mean of sand, clay and silt to be 57.33%, 16.66% and 26.66% for beans farm and mean of sand,

clay and silt to be 66.00%, 10.66% and 22.66% for maize farm respectively. The result implies that clay is highest in beans farm and lowest in maize farm. the farmlands under examination generally have low silt content. silt is highest in fallow land and lowest in ginger farm whereas Maize farm have the highest mean value of sand, in contrast beans farm have the lowest sand value across the farmlands examined (Fig 2).

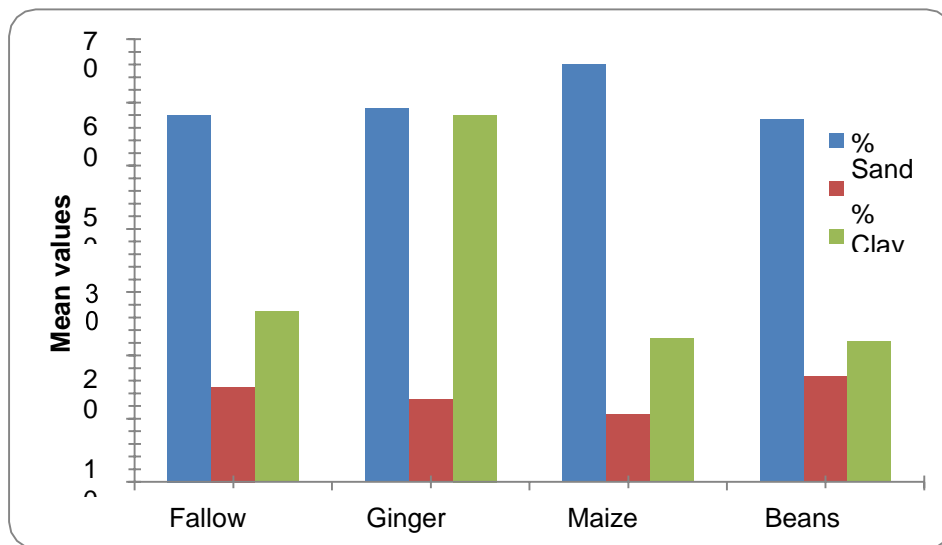


Figure 2 Particle Size Distribution across the Farmlands Under Study

Soil pH and exchangeable acidity

The soils in all the plots of agricultural land uses under study have acidic reaction below neutral pH value of 7, mean Average pH values were generally low in the beans farm with 5.98 while the highest mean value is in the maize farm with 6.46. Exchangeable acidity on the other hand have the same value of 0.40 across the different agricultural uses under study.

Effective cation exchange capacity and phosphorus

General mean values in the distribution shows that there is low exchange capacities across the farmlands under study. The highest value (11.00) is obtained in fallow land, maize farm have 8.86 while ginger farm contain 7.41 and the lowest is the beans farm with 5.32. Available phosphorus which is very essential for improving plant

resistance to disease is found in an appreciable amount, table four shows the result of available phosphorus obtained in the samples collected. Mean values of phosphorus in fallow land, ginger, maize and beans farms are 8.22 MgKg⁻¹, 32.20 MgKg⁻¹, 41.26 MgKg⁻¹ and 25.43 MgKg⁻¹ respectively. Highest value is found in maize farm while the lowest value is found in beans farm.

Total nitrogen and magnesium

Results of analysis from soil sample show that Nitrogen content is more in fallow land (0.29), maize farm is 0.19, Ginger farm 0.18 and the least is in beans farm 0.12. Similarly, magnesium is more in fallow land (2.16), maize farm is 1.70, Ginger farm IS 1.32 and beans farm is the least with 0.94 (Figure 3).

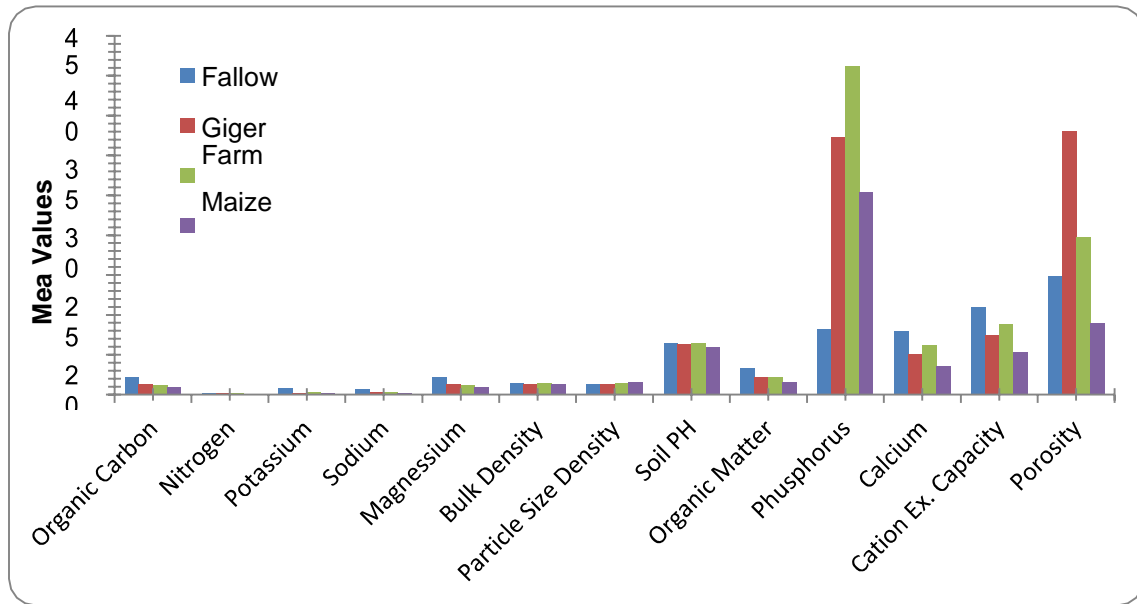


Figure 3 Soil Physiochemical Properties Under Different Agricultural Land Uses

Sodium and calcium

Results indicated that the mean values of calcium is higher than values of sodium obtained across the farmlands under study. However, sodium and calcium were found more in fallow land and maize farm. Fallow land has 8.00 calcium and 0.69 sodium, maize ‘farm has 6.30 calcium and 0.35 sodium, Ginger farm has 5.06 calcium and 0.29 sodium and finally the least is beans farm which contains 3.51 calcium and 0.27 sodium.

Potassium

Potassium content was found generally to be low across the farmland under study. The highest value is obtained in fallow land (0.80) while the lowest is obtained in ginger farm (0.18). Maize farm have 0.31 and beans farm have 0.23

respectively. Maize farm contain more of phosphorus among all the physiochemical soil properties under study

Clay Ratio Index (Erodibility Value)

Finding revealed that the fallow land and beans farm are more resistant to soil erosion than the maize and Ginger farm land. The decrease in Clay Ratio in soils reflects the increase of resistance to erosion. Higher clay ratio here indicates lower binding influence due to clay and therefore greater susceptibility to erosion. However, the maize farm is most susceptible to erosion with clay ratio of (68.07) while the Beans and fallow land are the least susceptible to erosion with clay ratio of 59.95 and 59.18 respectively (Figure 4).

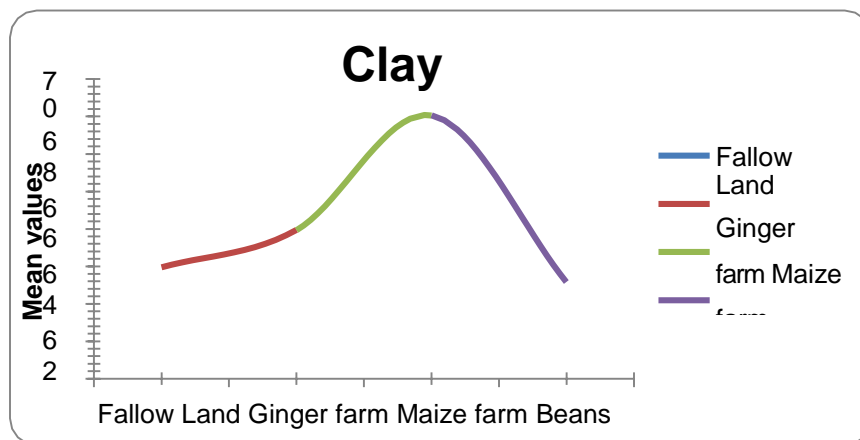


Figure 4 Mean Plot for Clay Ratio

The result shows an existing relationship between clay ratio and soil erodibility index. Soil with larger clay ratio are more vulnerable to water erosion due to lack of stability of the soil particle. Soil texture with large particles are resistant to transport because of the greater force required to entrain them and fine particles are resistant to

detachment because of their cohesiveness (Figure 5). The least resistant particles are silts and fine sands. Thus, soils with silt content above 40 percent are highly erodible. While the textural soil of Angwan Rimi is generally classified as Sandy Loam (SL).



Figure 5 Erodibility Indices under Different Farmland Uses

The result obtained from this study showed that mean value of clay ratio of the farmlands under study is 9.92 which is lower than 11.8 that was obtained by Oluyori et al (2016) that assessed some soil erodibility indices on agricultural land uses in Fadan Kagoma area of Jema'a Local Government. This is higher than mean value of 7.87 obtained by Oluyori and Mgbanyi's (2014) work on soil aggregate stability and erodibility in

different gully sites in parts of Kaduna and more higher than the mean value of 2.31 obtained by Mgbanyi (2011) in the FCT badlands; However, in contrast to this findings, textural structure of the soil under study varies with the findings of Oluyori and Mgbanyi (2014) who worked on soil aggregates stability and erodibility in different gully sites in parts of Kaduna State especially parts of Zaria with the aim to provide

'quantitative information on the variation of some soil properties and their interaction with eroding agents and how this affects soil erosion on the sites, they found that Soil particle size distribution in all the gully sites show soil textural classes of silt loam, sandy loam, sandy loam and sandy clay loam at Guga, Saye, Kubanni and Yashi gully sites respectively and the results show there is a significant variation of clay, silt, sand, clay ratio and aggregate stability with gully sites at 0.05 levels of significance.

Pearson's correlation matrices that describe the interrelationships and similarities between the physiochemical soil properties of the agricultural land uses under study (fallow land, maize farm, ginger farm and beans farm). There is a strong positive correlation between the physiochemical properties of the farm lands under study where the values imply that soil physiochemical properties are highly correlated at 95% probability level and with N-1 degree of freedom. however, soil physiochemical properties of fallow land and beans farm show the least similarities with value of (0.57) and the similarities between soil physiochemical properties of beans farm and maize farm is near perfect with is the highest (0.98).

Similarly, the result of correlation analysis of variables of soil particle size distribution (clay, sand and silt) and clay ration (erodibility) indices shows a positive strong relationship between percent of sand and clay ratio (0.99), where as percent of clay showed high negative correlation with clay ratio (- 0.94) and the correlation between percent of silt and clay ratio was highly negatively low. Correlation between percent of sand to percent of clay is highly negatively poor (-0.90) and between sand and silt is low (-0.22).

According to the results obtained, there is no significant difference (variation) in the levels of soil erodibility indices (Clay Ratio), percent of sand, percent of silt, and soil organic matter among the agricultural land uses at 0.05 level of significance level. However, other soil physiochemical properties such as potassium, magnesium, nitrogen, sodium, organic matter, calcium, phosphorus, clay, effective cation exchange capacity, porosity, bulk density and particle size density all showed that there is significant difference among the agricultural land

uses at 0.5 level of significance. This result is similar to the work of Oluyori et al (2016) that assessed some soil erodibility indices of agricultural land uses in Fadan Kagoma they found that erodibility indices (clay ratio) amongst and between agricultural land use types did not significantly vary with the agricultural land uses. In contrast to the result obtained in this study, similar attempts were made to compare the erodibility of different land uses and gully sites. Oluyori, Nenadi R. and Lazarus, James (2016) assessed soil aggregate stability and erodibility in different gully sites in parts of Zaria, Kaduna State, Nigeria. Their results showed that there is a significant variation of clay, silt, sand, clay ratio and aggregate stability with gully sites at 0.05 levels of significance. Ezeabasili et al (2014) also assessed Relative erodibilities of some soils from Anambra basin where Some properties of soils relevant to their erodibilities was studied in twelve locations where severe gully erosion were observed, result of clay ratio obtained were generally low ranging from 0.21 to 24.64% implying high resistance to erosion.

CONCLUSION

The results obtained from this study showed that the soils of Angwan Rimi are generally highly susceptible and vulnerable to erosion compared to global results. Among other factors, this may for a larger extent come as a result of human activities that are responsible for destroying vegetation cover and continuously degrading the physiochemical properties of soil that affects soil structure, share strength and aggregates stability. The most vulnerable is the soil under maize cultivation and the least vulnerable is the soil under beans cultivation.

Result from correlation analysis implies that there is a highly positive relationship between the soil physiochemical properties across the farmlands under study. The highest similarity was obtained between the properties of maize farm and beans farm. However, there exist a negative similarity between soil particle size distribution of the soil under study. Generally, there is a positive relationship between percent of sand and clay ratio, a negative one between clay and clay ratio and a negative low relationship between silt and clay ratio. It is therefore concluded that the relationships observed among

the soil characteristics and soil erodibility could not have occurred by chance, thus erodibility is significantly influenced by soil characteristics.

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EXPLORING BURN SEVERITY OF SEASONAL FIRE IN YANKARI NATIONAL PARK, NIGERIA, USING LANDSAT DATA

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Abstract

Fire is generally used as an environmental management tool around the world but it also has devastating impacts on biodiversity and may cause drastic changes to carbon, energy and water fluxes. Although parks and games reserves are demarcated and protected from undue human influences such as fires, fires have continued to impact these protected areas. In many developing countries with poor data collection capacities, the use of Remote Sensing technologies offers a credible solution to monitoring the health of the environment. In this paper we apply the normalized difference burn ratio (dNBR) to Landsat 5 images for the dry season months to explore burn severity of fire in Yankari Games Reserve in Northern Central Nigeria. The games reserve is one of the most popular and well-known reserves in the West African sub-region. Results suggest that fires are started at the edges of the park, where many settlements are now established and spread towards the central area, which shows less severity probably as efforts are made to combat it. This pattern of spread may be responsible for the observed distribution of wildlife in the reserves in the dry season, with large concentrations at the center of the reserves. This has implications for policy at several levels including restrictions on settlements and farming activities within or near the reserve.

Keywords: Fire, Burn severity, NDVI, dNBR, Wildlife, Livestock

INTRODUCTION

Since the last century, the protection, preservation and conservation of environmental resources have become important endeavors of human efforts to achieve sustainable development. Understanding the tremendous influence of human activities in shaping the structure and function of the natural environment therefore has become central to environmental resources management. One of the most important factors that have significantly impacted the earth's physical and social systems, ecosystem and its environmental resources is fire (Eriksen, 2007; Malmstrom, 2010; Chuvieco, Mouillot, van der Werf, Miguel, Tanase, Koutsias, García, Yebra, Padilla, Gitas, Heil, Hawbaker & Giglio, 2019).

Over the course of human evolution and development, fire has played significant roles in the stability of human societies and their ability to domesticate and dominate their environment (Smith & Tunison, 1992; MacGregor, 2006). Fires help ecosystems maintain their vitality and

sustainability (MacGregor, 2006), and have therefore become an important environmental resources management tool. Fire has been deliberately set to burn selected areas to achieve environmental management goals (Wakimoto, 1989; Parson & Botti, 1996; Parson, 2000) such as a reduction in the accumulated fuel loads that energize wild and accidental fires, promote regeneration of natural vegetative cover, improve wildlife habitat, and general sustainability in the ecosystem (Pyne, 1996).

Periodic low-intensity fires have been acknowledged to maintain certain forest types that would have been altered by occasional wildfire. Similarly, other ecosystems have not indicated any signs of long-term effects from infrequent, high-intensity fires (Heinselman, 1981; Kilgore, 1981; Smith & Tunison, 1992). In the savanna regions, fire consumes the litter which suffocates the grasses and reduces shading by killing young woody plants thereby exposing the grasses to more light (Geerling, 1985). This position has been partly supported by NCF and

WWF (1987), which posited that annual fires set at beginning of the growing season after the first rains would encourage development of open grasslands that may be beneficial for annual grasses but harmful to perennial grasses if the frequency of fire is high.

In developing countries like Nigeria, the employment of fire as a tool for preparing land for agricultural cultivation is well-known and documented. As human population and settlements grow, an increase in the frequency of fire burns has exerted a commensurate amount of pressure on the ecosystem (Geerling, 1985), especially since most of the population relies on agriculture and the environment for their livelihood (Abdullahi, Sanusi, Abdul & Sawa, 2009). Environmental resources are depleted as more forests are cut and grasslands are burnt to provide land both for settlement and agricultural cultivation. The wanton and uncontrolled use of fire however have had devastating consequences on environmental resources as drastic changes to carbon, energy and water fluxes are induced at the local scales thereby influencing species richness, the structure and composition of plant and animal habitats and communities, the amount of biomass and loss of biodiversity (Eriksen, 2007; Turshak, 2010; Picotte & Robertson, 2011; Veraverbeke, Willem, Stefaan, Ruben & Rudi, 2012). Consequently, the demarcation and management of protected areas has evolved into an important proactive strategy to conserve biodiversity in the ecosystem and manage the ubiquitous anthropogenic factors that have threatened the environment over time.

In Nigeria, many parks and game reserves have been demarcated and commissioned to safeguard and protect the environment from undue human influences and encourage the preservation of the natural environmental ecosystem. Understanding the governing principles and processes that influence ecosystems and the factors that threaten to unbalance the system is necessary to developing intervention measures to mitigate threats and conserve the protected areas. This requires a proactive ecosystem monitoring and surveillance system that would equip the managers with the necessary data and information to make informed decisions on intervention measures and mechanisms. Fire incidents are known to be a

notorious presence in many of these parks and game reserves. Information on areas critically affected by fire that is accurate and up to date is important to discern the drivers of fire activity and how they affect biogeochemical factors, climate and air quality. They also aid effective management of fire (Chuvieco et al., 2019)

Developments in technology, especially Remote Sensing and GIS, provide both the platform and capability to monitor and manage vast areas of environmental resources in a timely manner. Furthermore, the employment of satellite remote sensing methods to measure and monitor burn incidences, severity and areas is less expensive than ground monitoring. It also allows for quick updating of information (Picotte & Robertson, 2011) for better environmental management. Remote sensing techniques have provided a reliable means for estimating both temporal and spatial dimensions of fire risk. Unfortunately, these resources (Remote Sensing and GIS capabilities) are still underemployed in Nigeria for environmental resources management. This study explores the use of satellite remote sensing technology to measure fire severity in the Yankari Games Reserve, one of the most popular game reserve in the West African sub-region. The study demonstrates the potentials of remote sensing technology for environmental resources management in developing countries where data for such purposes are generally scarce and unreliable.

Remote sensing techniques have been used to monitor fire regimes in several studies especially when the affected area has a complex topography, with steep slopes and inaccessible areas (Escuin, Navarro & Fernandez, 2008), as is the case with Yankari Games Reserve. The use of remote sensing technique is made possible by the fact that after the fire, a series of spectral changes takes place due to the fire consuming the vegetation, destroying the chlorophyll, leaving the soil bare, charring the roots and altering the soil's moisture. The reduction in chlorophyll results in an increase in the visible region of the electromagnetic spectrum and in a diminution in the near infra-red region (Escuin, Navarro & Fernandez, 2008). These changes are conspicuous and relatively easy to identify and monitor and therefore allows for the determination of the severity of fire incidences.

EXPLORING BURN SEVERITY OF SEASONAL FIRE IN YANKARI NATIONAL PARK, NIGERIA, USING LANDSAT DATA

Fire severity is the degree of change in the soil and vegetation caused by fire (Escuin, Navarro & Fernandez, 2008). It has been used to describe both aboveground and belowground impacts of fire intensity, which is an important factor in seasonal and sometimes long term land cover change. Detecting changes in landscape characteristics resulting from fire severity is an important research area especially in the savanna regions of Africa where bush fires are incessant as a result of farming practices and other activities that involve bush burning such as hunting and the management of parks and games reserves. It is clear, for example, that the severity of burns to organic soil layer has direct bearing with carbon emissions and post-fire carbon sequestration, the potential of the vegetation to recover and the structure and function of the ecosystem post-fire (French, Graham, Whitman & Bourgeau-Chavez, 2021).

Fada (2015) reported that except for a fire report (Green, 1986) and a fire management plan (Green & Amance, 1987) no studies have been undertaken on fire incidences and severity in the Yankari Games Reserve. Using MODIS Active Fire and burnt area products downloaded for a fourteen year period (2000-2014), she calculated that 94% of the Games Reserves area exhibited fire scars. She, however, did not examine burn severity, which is important to understanding vegetation recovery and regrowth with attendant implications for conservation and management of the reserves. For example, Pourreza, Hosseini, Sinegani, Matinzadeh and Alavai (2014) asserted that high severity fires negatively affect plant species abundance and richness. Murphy, Vidal, Smith, Hallagan, Broder, Rowland and Cepero (2018) have also provided evidence that fire severity has significant negative impact on plant quality. These have important bearings on conservation and management of both the vegetation and wildlife in the reserves. Unfortunately, such studies in the Yankari Games Reserves are not available. It is probable that the fact that field studies of fire incidents and severity are expensive to carry out, especially for a large area like the Yankari Games Reserves contributes to the dearth of research work in his area. Alternative methods that are more cost-effective may help in this regard.

This paper explores the employment of remote sensing techniques using Landsat data to estimate burn severity in the Yankari reserves, which may be significant in two ways. First, Landsat data are easy to acquire. They can readily be downloaded from several websites, e.g., the United States Geological Survey (USGS) website (<http://glovis.usgs.gov/>), for free. Second, it provides a more pragmatic choice to detect severity of burned areas in a timely and much wider scale of coverage than field sketches allowed. It should be quickly acknowledged that the methods advanced in the paper are no substitute for actual rigorous ground work and field studies. However, they provide a guide towards identifying where emphasis and priority on data collection work may be placed to save time, effort, energy and financial costs.

MATERIALS AND METHODS

Study Area

Yankari Games Reserve lies in the southern part of the Sudan Savanna. It is composed of savanna grassland with well-developed patches of woodland. It is also a region of rolling hills, mostly between 200m and 400m above mean sea level. It falls within the latitudes 9° 34' N and 10° 05' N and longitudes 10° 10' and 10° 50' E, lying in the south-central area of Bauchi state in central Nigeria (Fig 1). It covers an area of about 2,244 sq. km (866 sq. miles), with an elevation range between 150 and 700 m above mean sea level. The vegetation is composed mainly of combretaceous trees and shrubs, *Azelia*, *Anogeissus* and *Detarium* savanna woodlands. Along the Gaji river, which bisects the reserve, is vegetation typical of the forest ecosystem. This consists of evergreen swamp and riparian forest (Green & Amanche, 1987). Annual rainfall in the park is between 900 mm and 1,000 mm. The rainy season is from May to September. Temperatures range between 18 ° C and 38 ° C. During the dry season, the Harmattan wind blows from the Sahara, often bringing dusty skies and night temperatures fall as low as 12 ° C. The hottest period falls in March and April, when temperatures can rise above 40 ° C in the day (Geerling, 1973). The vegetation is dried in the dry season and most of the reserve is devastated by fire (Fada, 2015).

EXPLORING BURN SEVERITY OF SEASONAL FIRE IN YANKARI NATIONAL PARK, NIGERIA, USING LANDSAT DATA

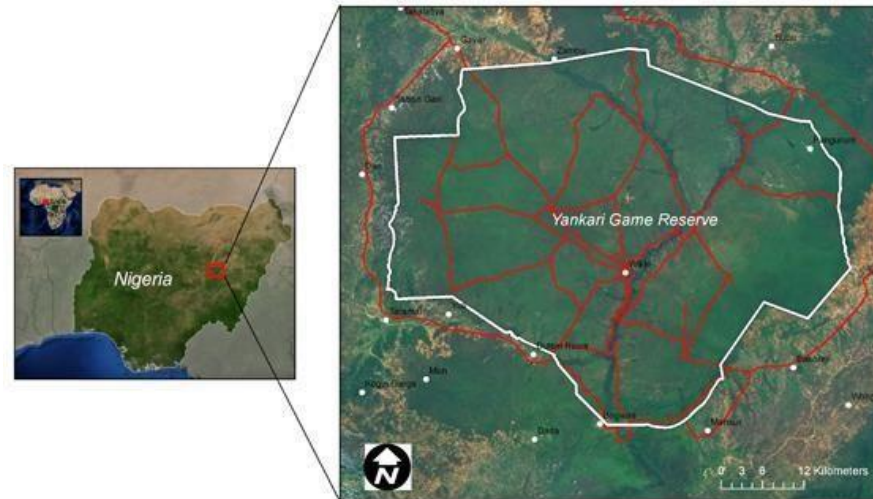


Figure 1 Yankari National Park in Central Nigeria

Source: http://www.fieldtripearth.org/media_image.xml?object_id=3188&file_id=8172

The savanna has both dry and rainy seasons. Seasonal fires play a vital role in the savanna's biodiversity. Goldammer & de Ronde (2004) identified lightning and humans to be responsible for starting fires, but were quick to observe that the share of fires caused by human intervention is rapidly increasing. Fire is used by pastoralists to stimulate grass growth for livestock while subsistence farmers also use fire to remove unwanted biomass when clearing agricultural lands and to eliminate unused crop residue after harvest. In the Yankari, as in most forest reserves and national parks across the region, fire is set by the Rangers (Fada, 2015) for environmental management purposes.

Fires are commonly used as an environmental management tool in the Sudan and Guinea savanna zones. Annual fires set early in the growing season after the first rains, with trees sprouting but grass still dormant, will result in more open grassland after a few years, as woody plants are killed off. This may be good for grazing species, but harmful to perennial grasses if done on a yearly basis (NCF & WWF 1987). Turshak (2010) observed during a study of mammals and primates of the Yankari Game Reserve that the whole reserve is burnt annually. The fire regime seems to be carried out haphazardly and is usually set between November and February of every year.

Fire is a widespread seasonal phenomenon in the African continent. In the savanna grassland region it is estimated that 168 million hectares are burnt annually, which is about 17% of the total land base and accounts for the burning of 37% of dry matter globally (Goldammer & de Ronde, 2004). Savanna fires account for 50% of this total with the remainder caused by the burning of fuel wood, agricultural residues, slash and burn agriculture, and from land clearing.

Acquisition of adequate Landsat TM or ETM+ scenes

Five Landsat 5 TM scenes for October, November, December 1986 and January and March 1987, were acquired from the USGS website. The choice of the dates for the acquisition of the images were based on availability of the images and the fact that the fires in Yankari games reserve usually occur between November and February of every year. There was no Landsat 5 image available for the month of February.

Procedure for Data Analysis

Data preprocessing

Indices derived from LANDSAT bands are among the techniques used to estimate the ratios and normalized differences as well as pre-/post-

EXPLORING BURN SEVERITY OF SEASONAL FIRE IN YANKARI NATIONAL PARK, NIGERIA, USING LANDSAT DATA

fire temporal differences in vegetation. These indices include the normalized difference vegetation index (NDVI) and the difference normalized burn ratio (dNBR). Several studies have demonstrated the relationship between pre-/post-fire NBR difference (dNBR) and fire severity (Key & Benson, 1999; Wagtendonk, Root & Key, 2004; Cooke, Fule & Crouse, 2005; Kokaly, Rockwell, Haire & King, 2007).

The normalized difference burn ratio (dNBR) was applied to Landsat 5 images for the dry season months to monitor the severity of fire in Yankari Games Reserve during the 1986-87 dry season months. The results were then compared to NDVI changes for the same time

period. The dry season in this region in Nigeria starts from October and ends around March. The month of April normally marks the beginning of the rainy season.

First, the data was processed by converting the image from DN to reflectivity by the atmospheric correction method, COST, (Chavez, 1996) for both pre-fire and post-fire images to enable comparisons in severity levels between the corresponding NBR and NDVI indices and also between the NBRpost and NDVIpost values.

The model by Chavez (1996), used to transform data to reflectance is represented as:

$$model = \frac{((-2.8890805 + (0.0602353 * n1_tm_or(1) - 0.15 * PI * 0.9932554)))^2}{195.7 * (\frac{PI}{180} * (90 - 52.21))^2} \quad (1)$$

This model is a combination of several inputs, which include converting each minimum

DN value to an at-satellite minimum spectral radiance value using the following equation:

$$L_{\lambda,min} = LMIN_{\lambda} + QCAL * (LMAX_{\lambda} - LMIN_{\lambda}) / QCALMAX \quad (2)$$

Where QCAL is minimum DN, QCALMAX = 255 and constants , LMAX_λ as given in Chandretal.(2009).

The theoretical radiance of a dark object assumed to have a reflectance of 1% by Chander et al. (2009) is computed for each band as follows:

$$L_{\lambda,1\%} = 0.01 * d^2 * \frac{Cos^2 \theta}{n * ESUN_{\lambda}} \quad (3)$$

Where ESUN_λ = mean solar exoatmospheric spectral irradiance from d is the sun-earth distance and theta is the solar zenith angle (90-sun elevation).

A haze correction is computed using the computed dark object values (Chavez 1996):

$$L_{\lambda,haze} = L_{\lambda,min} - L_{\lambda,1\%} \quad (4)$$

The fundamental radiance to reflectance (ρ) equation (Chavez 1996) is:

$$\rho = \pi * d^2 * L_{\lambda,sat} - L_{\lambda,haze} \quad (5)$$

Indices of burn severity:

- (i) NBRpre: NBR corresponding to the scene before the fire
- (ii) NBRpost: NBR corresponding to the scene after the fire
- (iii) NDVIpre: NDVI corresponding to the scene before the fire
- (iv) NDVIpost: NDVI corresponding to the scene after the fire
- (v) dNBR = NBRpre - NBRpost
- (vi) dNDVI = NDVIpre - NDVIpost

Because November usually marks the beginning of the fire-setting season in the reserve (Turshak, 2010; Fada, 2015) the study adopts October 1986 as the pre-fire scene, while the remaining months (November, December, January and March) in the season are post fire.

Processing the Landsat Data

Monthly NDVI

NDVI is a vegetation index used to measure and monitor plant growth (vigor), vegetation cover, and biomass production obtained from satellite images. It is the ratio of the difference between

EXPLORING BURN SEVERITY OF SEASONAL FIRE IN YANKARI NATIONAL PARK, NIGERIA, USING LANDSAT DATA

the near infrared band (band 4) and the red band (band 3) and the sum of the bands.

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \quad (6)$$

Normalized Difference Burn Ratio

The normalized difference burn ratio which gives the indication of the severity level of the burn is generated as follows:

- a) Generate an NBR image of each of the scenes, i.e. pre- and post-fire. NBR is given as the ratio of the

difference between the near infrared band (band 4) and the mid infrared band (band 7) and the sum of the bands:

$$NBR = \frac{(NIR - MIR)}{(NIR + MIR)} \quad (7)$$

- b) Generate the difference (Δ) for NBR, given as (Bourgeau-Chavez, Grelik, Billmire, Jenkins, Kasischke & Turetsky, 2020):

$$dNBR = NBR_{pre} - NBR_{post} \quad (8)$$

The fire severity level is based on the following scale of the dNBR range:

Table 1 Fire severity levels for dNBR ranges

Severity Level description	dNBR range
Enhanced Regrowth, High	-500 to -251
Enhanced Regrowth, Low	-250 to -101
Unburned	-100 to +99
Low Severity	+100 to +269
Moderate-low Severity	+270 to +439
Moderate-high Severity	+440 to +659
High Severity	+660 to +1300+

Bands 3, 4 and 7 are analyzed because they are the bands that are relevant for the study. Bands 3 and 4 are used to calculate changes in the NDVI of the park while band 7 is useful for analyzing the normalized burnt ratio for the vegetation.

RESULTS AND DISCUSSION

Reflectance of Bands 3, 4 and 7

Fig. 2 shows maps of the reflectance values for the bands for the dry season months of October 1986 to March 1987. The maps show increase in the area with high reflectance in band 7. In figure 3 the box plots show changes in reflectance values of bands 3, 4 and 7 over the months. The month of Oct 1986 shows higher values of band

3 with an average reflectance value of almost 0.4 and a max of about 0.7. There is also higher reflectance in band 4 than band 7. The average reflectance in band 4 is almost 0.4 but the max reflectance in this band is 0.6.

Normalized Difference Vegetation Index

The result of the NDVI analysis shows that NDVI values are very high in the month of October with about 65% of the area of the park having NDVI values of between 0.4 and 0.5. As the dry season progresses the NDVI reduces drastically such that in March 1987 more than 80% of the area of the park has NDVI value of 0. The NDVI values for each month are shown in figs 4 and 5.

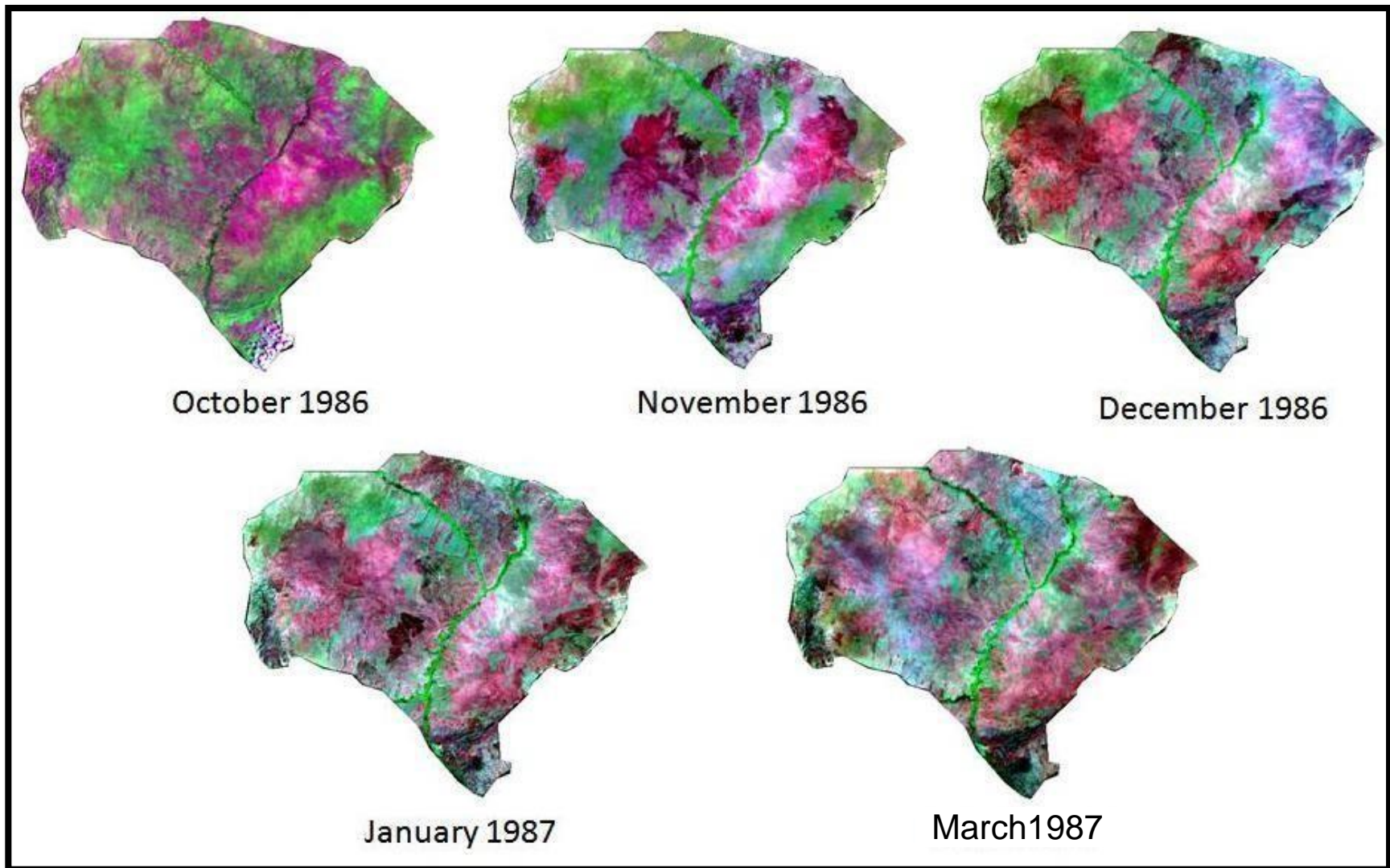


Figure 2 Reflectance Maps for Bands 3, 4 and 7 for the Study Area

EXPLORING BURN SEVERITY OF SEASONAL FIRE IN YANKARI NATIONAL PARK, NIGERIA, USING LANDSAT DATA

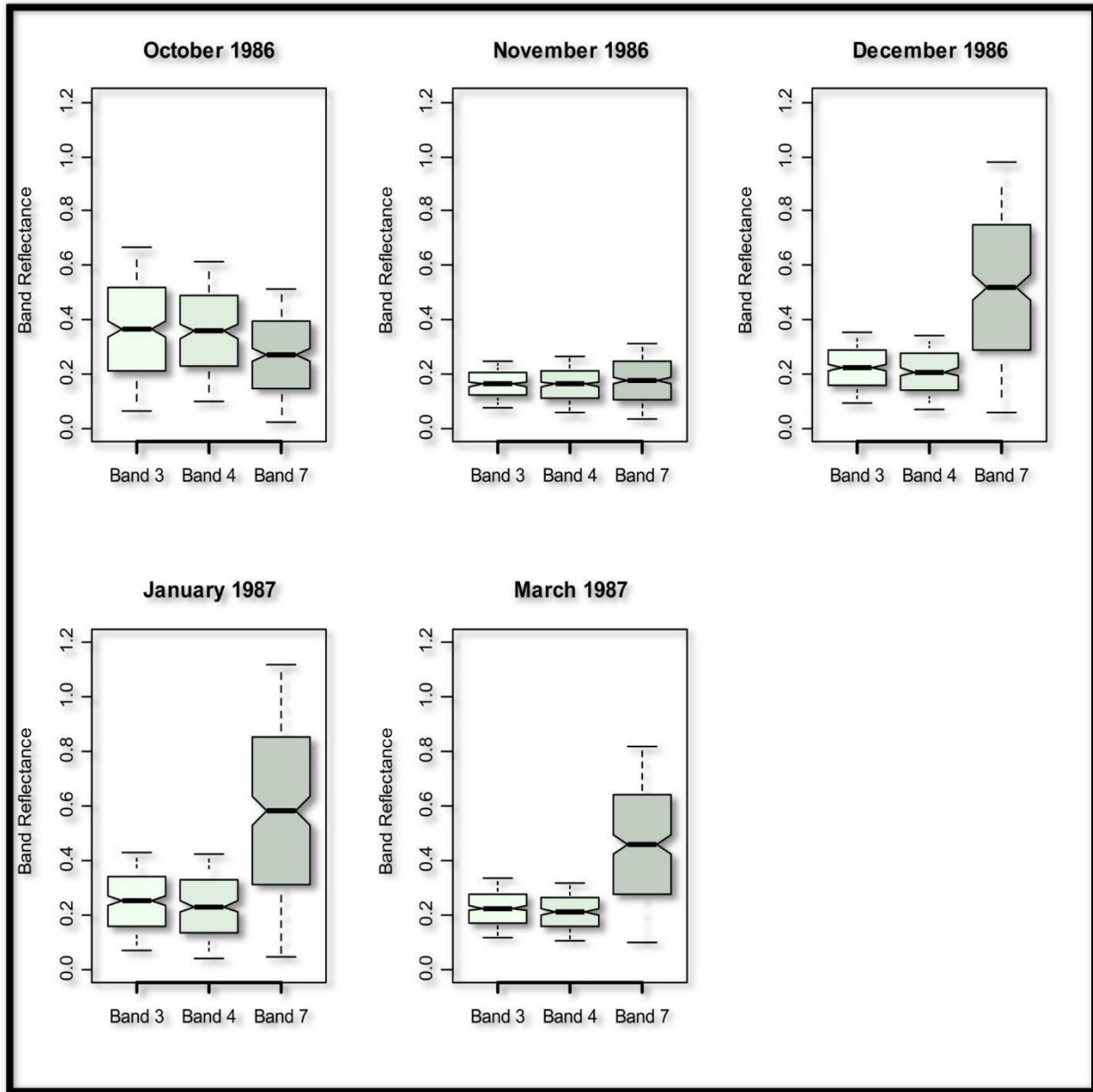


Figure 3 Box Plots Showing Changes in Reflectance Values of Bands 3, 4 and 7 over the Season

EXPLORING BURN SEVERITY OF SEASONAL FIRE IN YANKARI NATIONAL PARK, NIGERIA, USING LANDSAT DATA

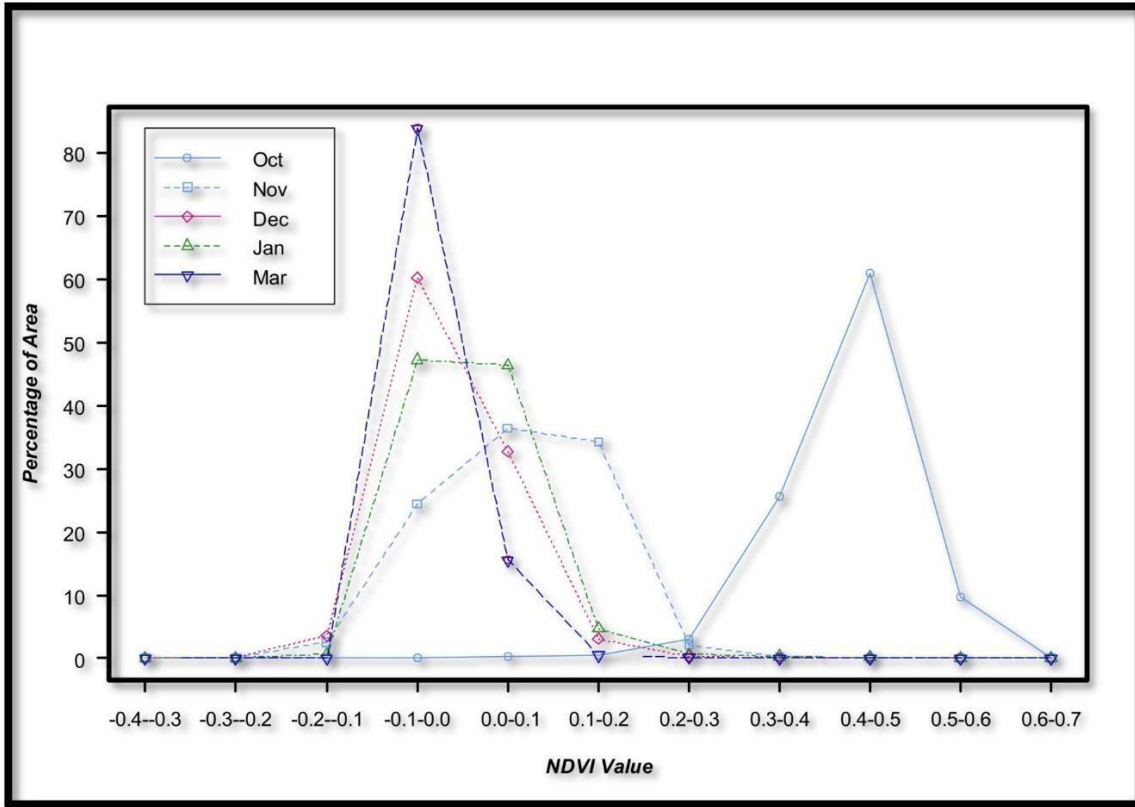


Figure 4 Plot of Percentage Area of Monthly NDVI Values

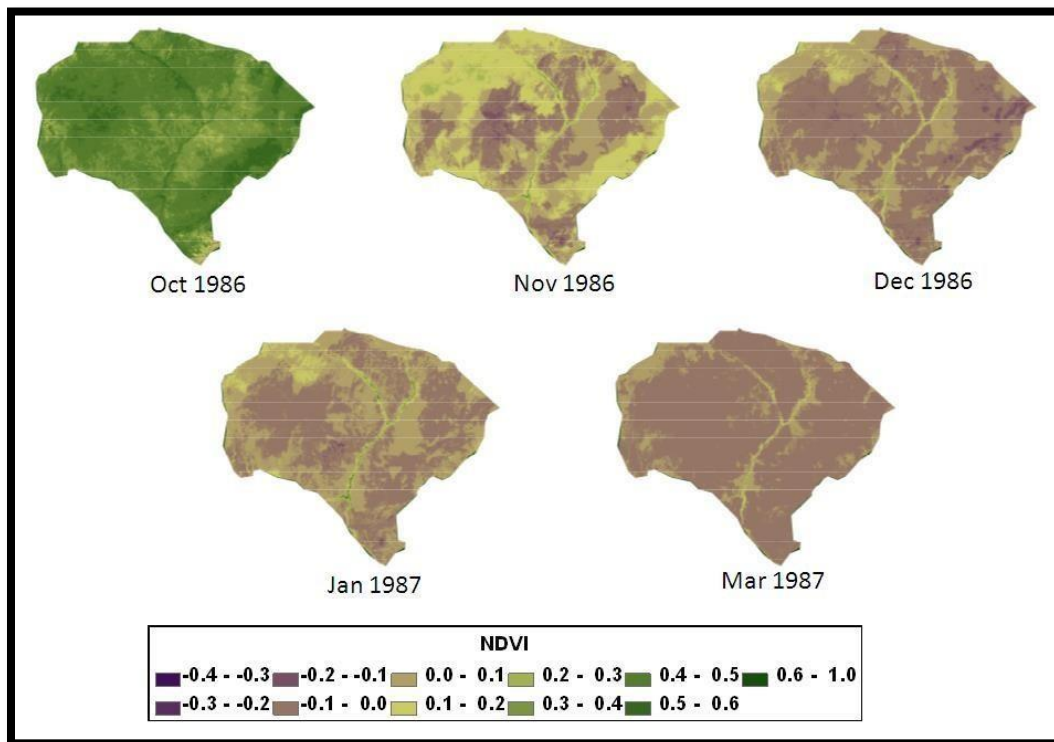


Figure 5 Monthly NDVI Maps

Normalized Difference Burn Ratio

The normalized difference burn ratio for the park between the months of October and March are shown in figures 6 and 7. As shown in equation 8, the normalized difference burn ratio is the difference between the pre- and post-fire normalized burn ratios. In this analysis it is the

difference between the NBR for the month of October and the other months, given that the fire season starts in November. The maps on figure 6 show that fires started at the edges, and spread towards the central area, which shows less severity as the fire weakens over time or efforts are made to combat it.

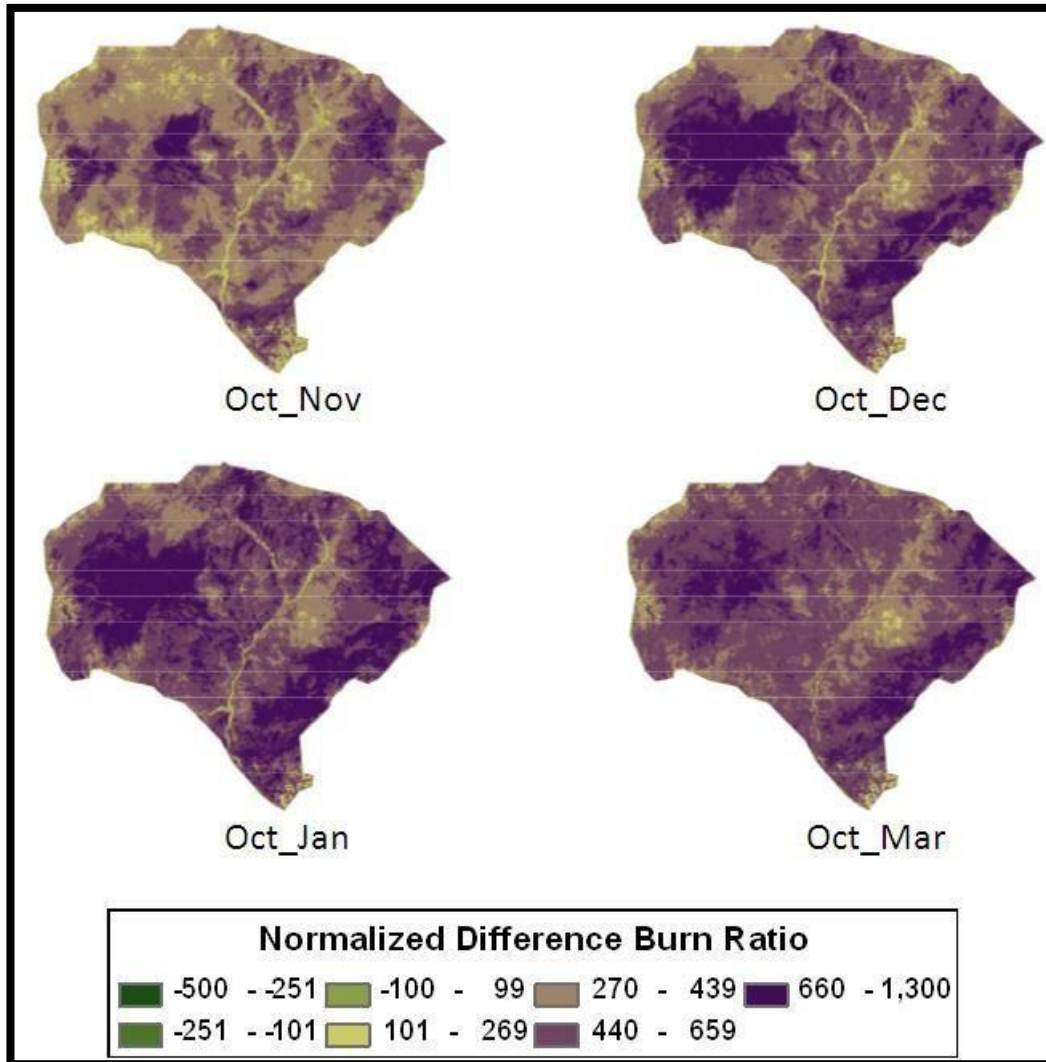


Figure 6 Normalized Difference Burn Ratio (dNBR) Maps over the Season

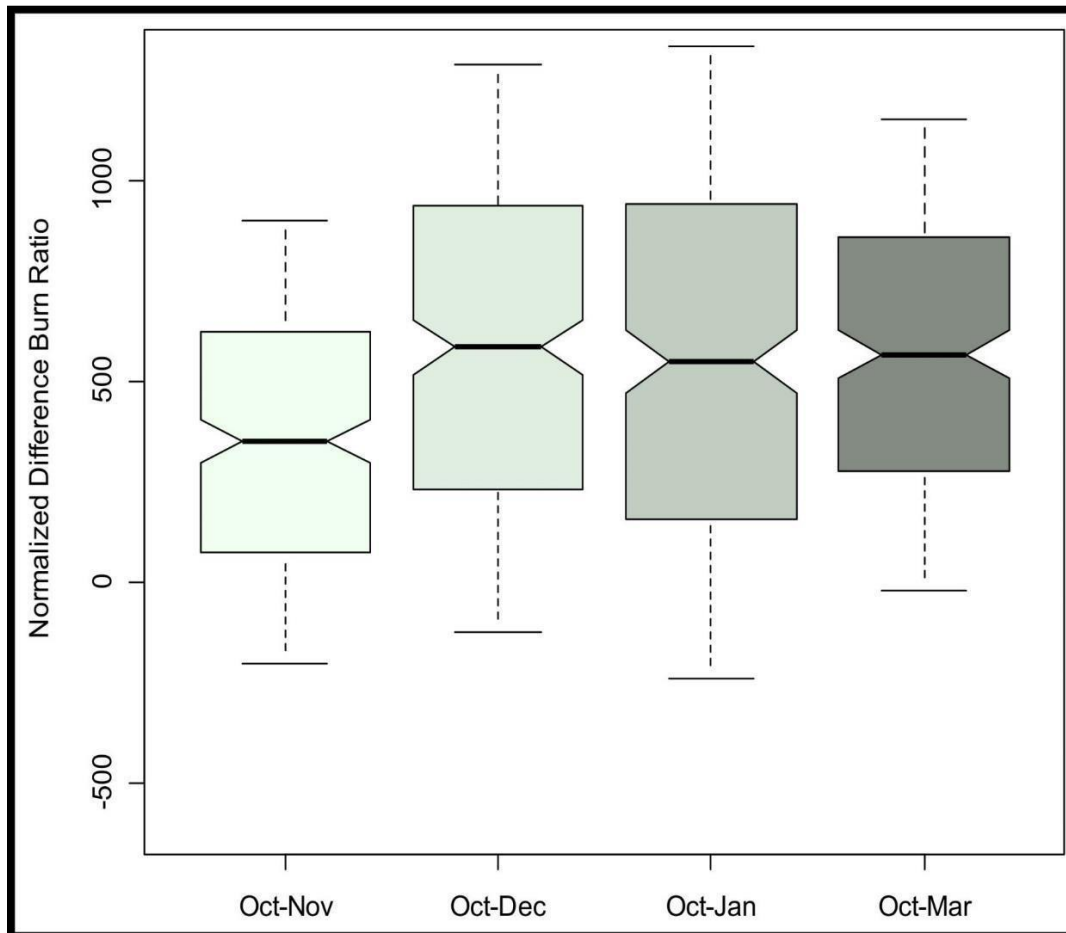


Figure 7 Normalized Difference Burn Ratio October 1986 - March 1987

Fada (2015) also noted that since the periphery of reserve areas are less protected and usually heavily inhabited, illegal fires could easily start from the edges of the reserves. This pattern of spread may have contributed to the observed distribution of wildlife in the reserves in the dry season (April 29 – May 2), with large concentrations around the Gaji River at the center of the reserves (Bergl, Dunn, Haruna, Mshelbwala & Nyanganji, 2011). In contrast, Omondi, Mayienda, Mshelbwala and Massalatchi (2006) reported a much wider spread of wildlife population in Yankari Games Reserve during the rainy season (July).

Generally, the area along the length of the river possesses the most robust vegetation during the dry season because of the abundance of water resources. It is natural therefore for most wildlife to congregate along the river and be found there because of abundance of food resources as well. However, there may be several

wildlife species that would prefer the open grassland or periphery areas away from the river for predatory reasons. The non-availability of vegetation at the fringes due to fire burns precludes this choice and forces these animals into unfriendly territories. And if so (pattern of spread from edges to center) we could speculate on arson by poachers being probably responsible as it is common to have fires started for hunting purposes, to frighten animals out of hiding thereby exposing them. There are settlements and farmsteads at the perimeter of the reserve as well and these people may be responsible for starting some of the fires either accidentally or for farming purposes as well – the peak being in January may well serve both purposes because that is the farmland preparation period and the hunting season since farm work is completed.

Mohammed (2010) reported an increase in the number of settlements at the periphery of the reserves due to an increasing number of

EXPLORING BURN SEVERITY OF SEASONAL FIRE IN YANKARI NATIONAL PARK, NIGERIA, USING LANDSAT DATA

internally displaced persons (IDP) due to the serious security threats in the region. This situation has the potentials to exacerbate the problem. For example, Toepfer (2005) observed that large numbers of fires in reserves in the Congo were started by internally displaced persons (IDPs) who had settled around the reserves and wanted to prepare land for farming activities. Umar, Abdullahi, Ezra and Auwalu (2015) reported that over 80% of residents of communities adjoining Yankari Games Reserves are farmers. The potential and risks of starting a fire for land preparation purposes is therefore high. Arhyel, Daful and Ezeamaka (2019) concluded from their study of vegetation community composition in the reserve that there has been a decreasing trend in land cover in the reserve due principally to anthropogenic

activities. The implications for conservation of the reserve therefore appear grim if no proactive measures are taken to stop these practices.

By the month of January the only parts left without the effect of fire in Yankari Park are the riparian zones of the Gaji River and its tributaries. This finding agrees with Fada (2013) who reported that more than 90% of the reserve has been affected by fire between 2000 and 2014. Apparently, this trend has been ongoing for much longer than this period as suggested by the findings of this study. Also Estes, Knapp, Skinner, Miller and Preisler (2017) stated that in fire incidents, riparian and higher elevation forest areas burn less frequently than other sections, which agrees with this study. Figures 8a-8d show the areas (in sq. kms) of the park under various categories of burn severity.

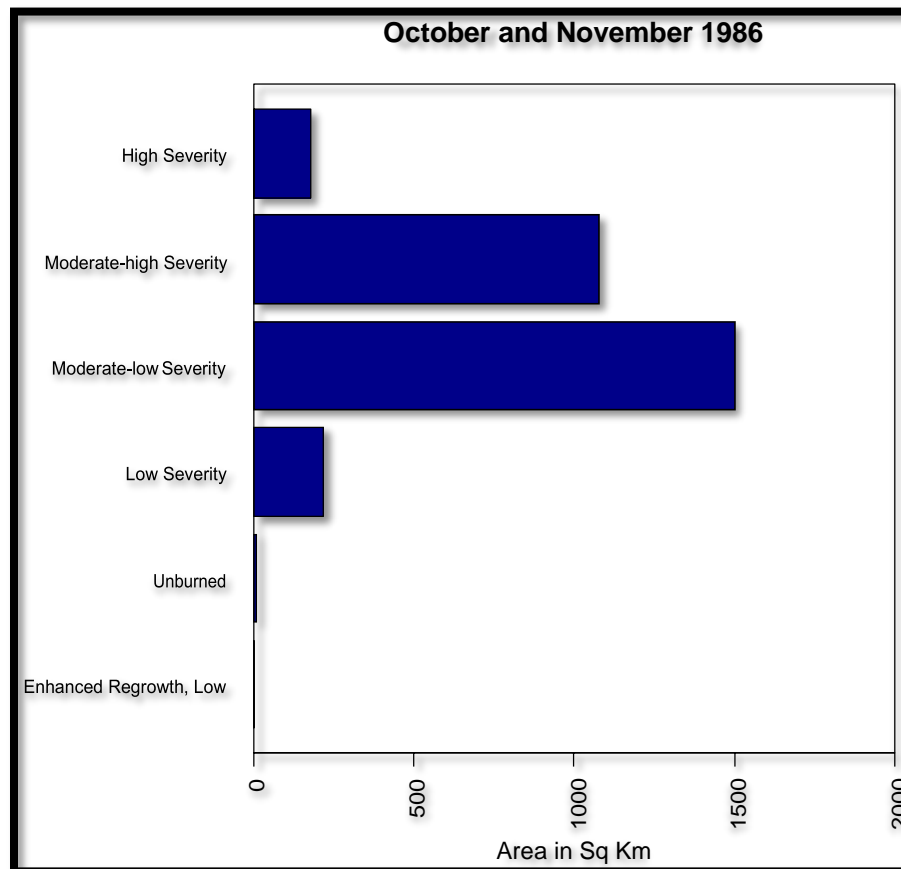


Figure 8a

EXPLORING BURN SEVERITY OF SEASONAL FIRE IN YANKARI NATIONAL PARK, NIGERIA, USING LANDSAT DATA

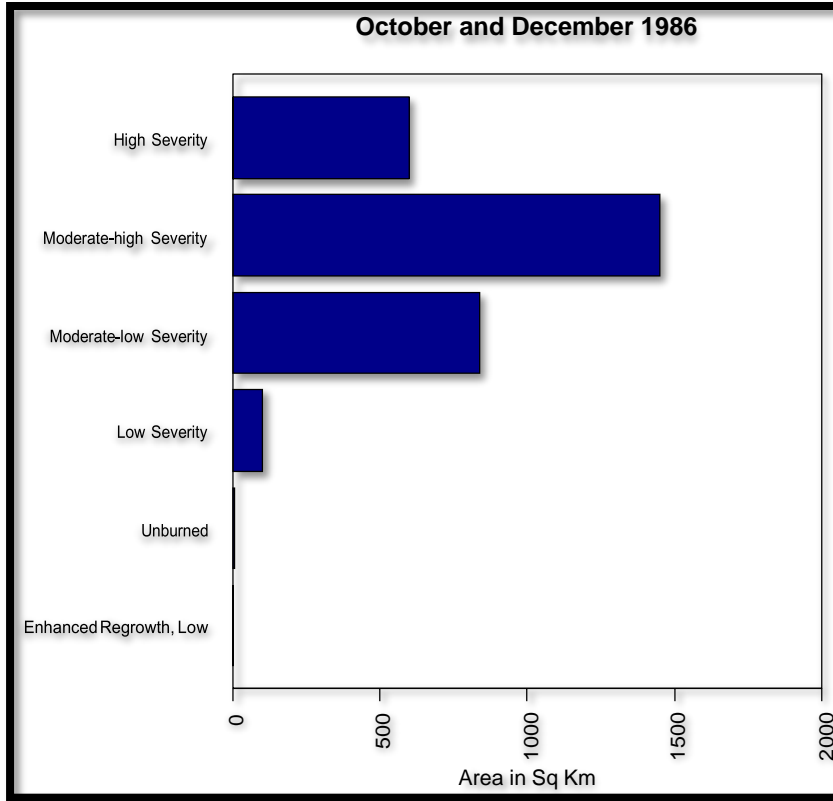


Figure 8b

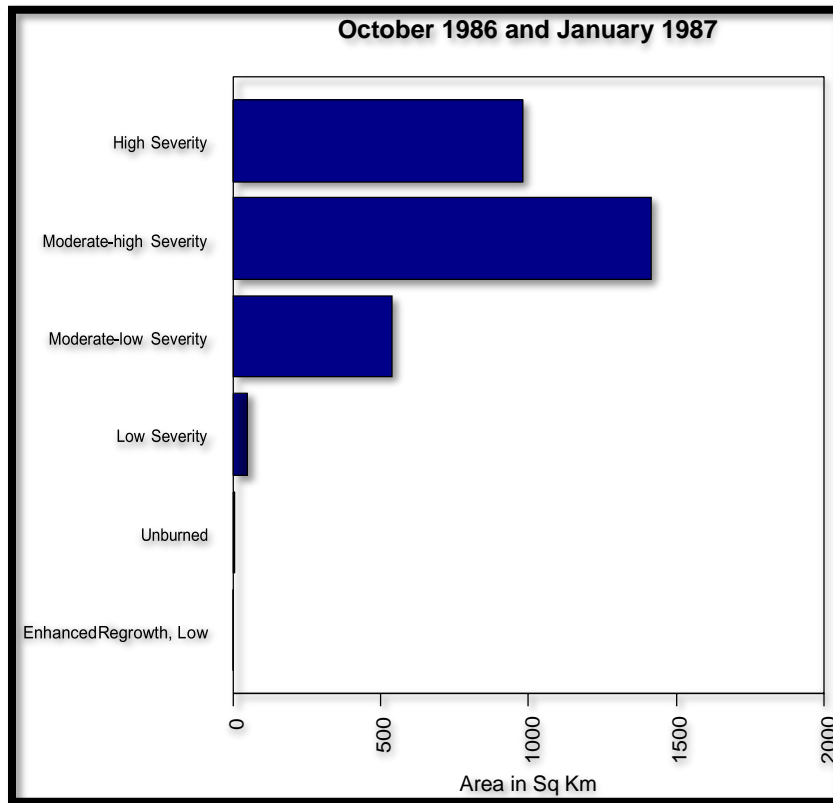


Figure 8c

EXPLORING BURN SEVERITY OF SEASONAL FIRE IN YANKARI NATIONAL PARK, NIGERIA, USING LANDSAT DATA

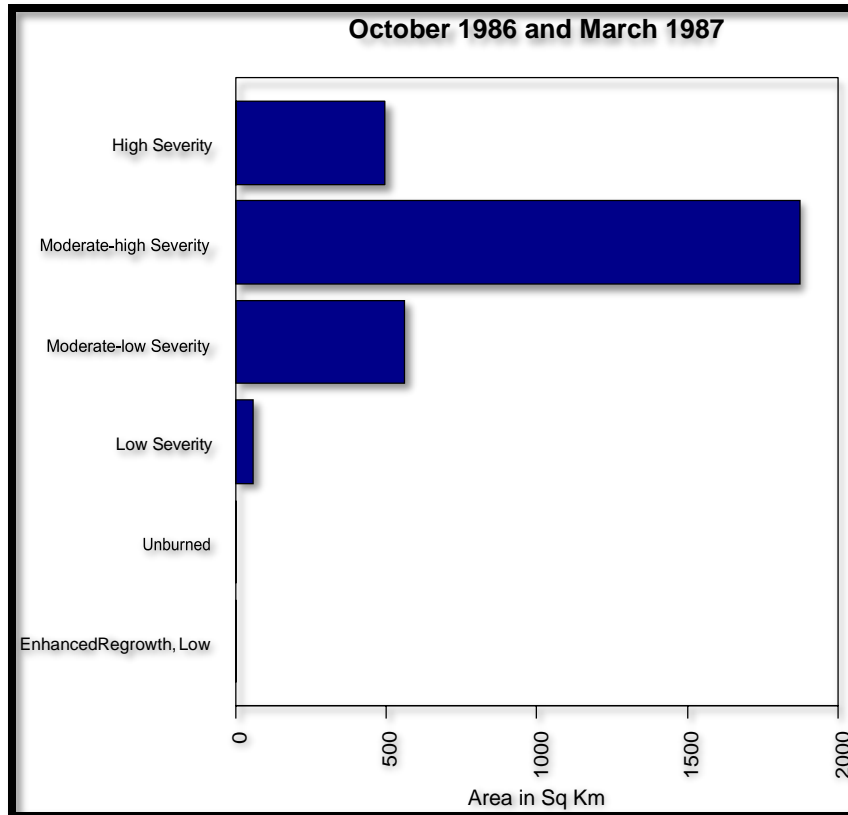


Figure 8d
Figures 8a-8d Barplots showing severity of burn (dNBR)

In November, about 1500 square kilometers (sq. km) of the park is under moderate to low burn severity and about 1100 sq. km is under moderate to high severity. As little as about 100 sq. km is under high severity. In December the area under High burn severity increases to about 600 sq. km, moderate to high severity increases to about 1500 sq. km while the moderate to low severity level decreases to about 900 sq. km. Fig. 8 shows that close to 1000 sq. km of the park is severely burnt in the month of January, with over 1500 sq. km with moderate to high level of burn severity. Almost no part of the park is left unburned except the riparian areas. In the month of March, there are no forest fires and probably some regrowth which show most of the area (about 1900 sq. km) as moderate to high severity of burn.

Bergl, Dunn, Haruna, Mshelbwala and Nyanganji (2011) reported that the west and eastern part of the reserve are dominated by *Azzeria* savanna woodland and combretaceous shrub savanna vegetation types (Geerling 1973; Green & Amance 1987; Abdullahi, 2011). These

roughly coincide with areas of severe fire burns (see Fig. 6). The reported incursion of large numbers of domesticated livestock into the reserves during this period (the dry season) by nomads poses additional problems to the herds of wildlife in the reserves. With considerably less vegetation due to fire burns, there is additional competition for the remaining vegetation from livestock. Cattle are currently by far the largest livestock population in the reserve (Nyanganji, Saidu, Hensche l& Dunn, 2012; Arhyel, Daful & Ezeamaka, 2019). This has the potentials to increase food stress, overgrazing and consequently instability in food reserves for the wildlife in the reserve. Risks of wildlife contracting diseases such as rinderpest from livestock are also real. Namathe and Lamorde (1983) and Mohammed, Shehu, Adamu and Saleh (2010) reported significant loss of herbivorous wildlife due to rinderpest in the 1980s. The fact that the most affected wildlife species were herbivores lends credence to the fear that contacts with livestock, which are also

EXPLORING BURN SEVERITY OF SEASONAL FIRE IN YANKARI NATIONAL PARK, NIGERIA, USING LANDSAT DATA

herbivores, could have resulted into the near purge of some species. For example, according to Mohammed, Shehu, Adamu and Saleh (2010) only 25 buffalos survived the epizootic outbreak of rinderpest in the reserve in the 1983/84 season.

The use of fire to encourage growth of annual grasses has been well-documented. However, excessive employment of fire to boost annual grasses endanger perennial grasses and woody plants, which are important sources of food for many wildlife such as the elephants. The loss of these plant covers also expose the land to erosion and eventual degradation with serious consequences for sustainable food production for wildlife in the reserves (Mohammed, Shehu, Adamu & Saleh, 2010). These concerns have generated discussions on the necessity to employ fire as a tool to boost annual grasses in the reserves (Abdullahi, Sanusi, Abdul & Sawa, 2009).

CONCLUSION

Fire severity describes how fire intensity affects ecosystem following wild or regulated fires as is the case in Yankari Games reserves in Nigeria. The use of Landsat images and normalized difference burn ratio in this study provides useful information on the severity of fire in this forest that otherwise would not be possible through field work.

The study has tracked the intensity and severity of fire and the burn severity using the dNBR index and this capacity provides the prospects for predicting the impacts (positive or negative) such as soil erosion due to exposure or response of natural vegetation and the resultant effect on wild life. Describing ecosystem response would best be done quantitatively. Detailed experimental onsite studies would be needed to achieve this. Though many biotic and abiotic factors are involved in the relationship between fire intensity and ecosystem response, it is clear that forest fires are an important factor in ecosystem changes in the dry season in the game reserve.

It is important to understand the growth and development of fires in the reserve, the implications and its extent to be able to control it

and its impacts. The application of remote sensing techniques provides a bird's eyeview of the reserve in ways that no other method can equal. This exploratory examination provides inkling of the variety of use to which remotely sensed data and its application can potentially bring to game reserve conservation in countries with limited data by highlighting the areas of severe fire intensities, the probable sources and therefore factors that may have generated fire incidents and especially, the probable degree of impacted areas by fire.

There are also several policy implications that suggest themselves even at this level of exploration. The results indicate that human settlements and activities both within and around the games reserve are important sources of fires in the park. In many instances these fires are generally uncontrolled and may have devastating impacts on biodiversity and wildlife. Legislation should include strict restrictions on human settlements and activities within and near the games reserves. This is vital to sustained protection, preservation and conservation of both plant and animal diversity in the park. Equipped and modern fire service stations should be established in strategic locations throughout the park and charged with the responsibility to combat and control unintended fires. With adequate training, the fire fighters may be charged with any environmental management efforts that require a controlled fire as tool. The necessity to be proactive in fire management in the games reserve is borne out of the near regularity with which uncontrolled fires occur in the park and their long term impacts on plant and animal diversity.

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**EXPLORING BURN SEVERITY OF SEASONAL FIRE IN YANKARI NATIONAL PARK, NIGERIA, USING
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