International Journal of Agriculture and Environmental Research

ISSN: 2455-6939

Volume:05, Issue:03 "May-June 2019"

CHARACTERIZATION AND CLASSIFICATION OF SOILS PROXIMAL TO BENUE RIVER IN MAKURDI, NORTH CENTRAL NIGERIA

*Osujieke, D.N., Imadojemu, P.E., Onwu, C.A. and Ashiekaa, H.T.

[1]Department of Soil Science and Land Resources Management,
Federal University Wukari, PMB 1020 Wukari, Taraba State.

*Correspondence Author

ABSTRACT

The study was to characterize and classify soils of Makurdi proximal to River Benue in North Central, Nigeria. Two soil profile pits were dug, described and sampled base on horizon differentiation for laboratory analyses. Data generated were analyzed statistically using the coefficient of variation (CV) and correlation. The textural classes of horizons of the pedons were predominantly sandy clay loam, sandy loam, and clay loam. Sand fraction had a mean of 550 g/kg in pedon 1 and 470 g/kg in pedon 2. Organic carbon ranged from ≥1.5 g/kg ≤18.8 g/kg in pedon 1 and ≥0.80 g/kg ≤7.00 g/kg in pedon 2 while base saturation had a mean of 42.81 % and 42.75 % in pedons 1 and 2, respectively. The CV indicated that sand, pH(H_2O), and total exchangeable acidity had low variability (≥0.00 % ≤11.78 %) while organic carbon and available phosphorus had high variability (≥56.58 % ≤115.32 %) among the horizons of the pedons. However, clay correlated positively (r= 0.405, r= 0.223, r= 0.530) with organic carbon, effective cation exchange capacity and base saturation. Hence, the soils were classified as Psammentic Hapludults (Haplic Fluvisols) for pedon 1 and Arenic Kandiudults (Dystric Arenosols) for pedon 2 using USDA soil taxonomy and correlated with world reference base classification system.

Keywords: characterization, classification, horizon, pedon, survey

INTRODUCTION

There is an emerging trend of environmental degradation and decline in agricultural productivity and such demands for information on soils as a means to sustain and improve our environmental quality and agricultural production. Agricultural development as an alternative to improve the economic activity in Nigeria demands for soil experimental data in Nigeria, which can be determined through soil characterization. Hence, Nigerians depend on soil medium for their agricultural practices. Soil characterization provides the basic information necessary to create

ISSN: 2455-6939

Volume:05, Issue:03 "May-June 2019"

suitable soil classification schemes, and evaluate soil fertility in order to unravel some unique soil problems in an ecosystem (Lekwa *et al.*, 2004).

The integration of soil characterization, soil classification, and soil mapping provides a powerful resource for the benefit of mankind especially in the area of food and nutrient security and environmental sustainability. Thus, Ogunkunle, (2005) opined that soil characterization provides the information that enables users to understand the physical, chemical, mineralogical and microbiological properties of the soils they depend on to grow crops, sustain forests and grasslands as well as support homes and social structures. Soil characterization data are been required for proper classification of the soil and it also enables other scientists to group the soils in their classification systems. Soil characterization is a major building block for understanding the soil, classifying it and getting the best understanding of the environment (Esu, 2005). However, soil characterization serves as a basis for more detailed evaluation of the soil as well as gathers preliminary information on nutrient, physical or other limitations needed to produce a capability class (Eswaran, 1977).

Soil classification helps to organize our knowledge, facilitates the pedotransfer technology from one place to another and helps to compare soil properties to determine their suitability. Soil classification systems organize soil variability into useful groupings that can be identified by a field investigation and documented in soil survey activities to promote effective resource management and technology transfer (Ahukaemere *et al.*, 2017). Many soil classification systems have been developed over years for a better understanding of our soil characteristics for the purpose of extrapolation of research results to localities of need and also to enhance pedotransfer technology. The most popular soil classification systems in the world are; USDA soil classification system and FAO/WRB (World Reference Base) classification system.

Owing to the fact that Makurdi district is an agrarian community main town of Benue State (Makurdi, Benue Riverbank) and not much study has been done on the soils of the area, characterization and classification will help reveal information that could be useful in the management and use of the soils in a sustainable manner. Hence, this study was aimed at the characterizing and the classifying of soils proximal to Benue River in Makurdi North-central Nigeria.

MATERIALS AND METHODS

Study Area

The study site was located in Makurdi (Fig 1) the capital of Benue state of Nigeria. The study area lies between latitude 7° 40′ N and 7° 53′ N of the equator and between longitude 8° 22′ E and 8° 35′ E of the Greenwich meridian. Makurdi is located on the banks of Benue River, a

ISSN: 2455-6939

Volume:05, Issue:03 "May-June 2019"

major tributary of the Niger River. Climatically, Makurdi falls within the tropical, subhumid, wet and dry climate which has two distinct seasons, namely wet season and dry season. The wet season starts from April and lasts till October; while the dry season starts in November and lasts till March. Rainfall ranges from 775 mm to 1792 mm, with a mean annual value of 1190 mm. The mean annual temperature range was 20.8 ^{o}C to 22.8 ^{o}C while mean Monthly Relative humidity in Makurdi varies between 43 % in January to 81 % in July-August period (NIMET, 2015).

Geology of the Study Area

It has been shown that the formation comprised of three zones: the lower Makurdi sandstone; the upper Makurdi sandstone and the Wadata limestone (Agbede and Smart, 2007).

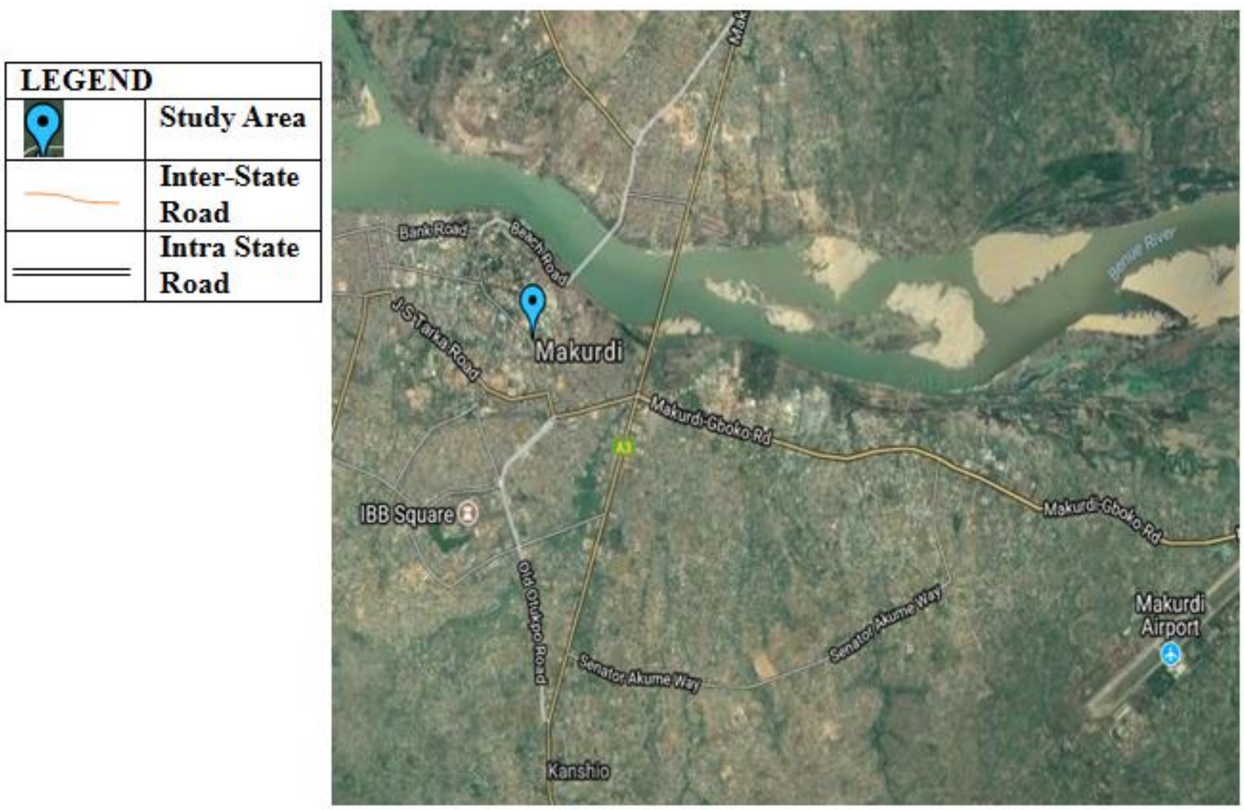

Fig. 1: Location map of the study area (Google Imagery, 2018)

ISSN: 2455-6939

Volume:05, Issue:03 "May-June 2019"

Vegetation

Makurdi falls within the Guinea Savannah belt of Nigeria. The Guinea Savannah belt is a transitional vegetation zone separating the forested belt of southern Nigeria from the true savannah of the north. It is characterized by a mixture of tall grasses and trees of average height.

Field Work

A reconnaissance survey of the area was carried out and free survey technique was used to align two different profile pits along the banks of the study area. The profile pits were described and samples collected following the guidelines of Schoeneberger *et al.* (2012). Soil colour was determined using the Munsel colour chart (Munsel, 1994).

Laboratory Analysis

Soil samples were analyzed using the standard procedure as described by Soil Survey Staff, (2014a).

Statistical Analysis

The generated data were analyzed using the coefficient of variation as described by Wilding *et al.* (1994) to determine the variation among horizons of the pedons while the relationship among soil properties was determined using correlation. The Gen Stat statistical software version 8.1 was used in performing the analyses.

Soil Classification

The soil was classified according to the USDA soil taxonomy (Soil Survey Staff, 2014b) and correlated with the world reference Base (WRB) IUSS Working Group WRB (2015) soil classification system.

RESULTS AND DISCUSSION

The soil morphological characteristics of the studied pedons were shown in Table 1. All the horizons were well drained. The studied pedons had subangular blocky (SBK) structure in all the horizons. Soil consistency at moist status indicated that the horizons of the pedons were firm except for the AB horizon of pedon 1 that was friable. Thangasamy *et al*. (2005) reported that the variation of clay content influences the soil consistency. The soil of the studied sites can easily be cultivated mechanically at appropriate moisture content. The colour matrix as determined when moist in pedon 1 was light reddish brown 2.5YR 7/4, pinkish gray 5YR 7/2, reddish yellow 5YR 7/6 and black 10YR 2/1 in horizons A, AB, Bt1 and Bt2, respectively.

ISSN: 2455-6939

Volume:05, Issue:03 "May-June 2019"

Table 1: Soil morphological properties of the studied sites

Hori	Depth (cm)	Colour (moist)	TC	Structure	Consistency (moist)	Root	Drainage
		PEDON 1					
A	0 – 22	2.5YR 7/4 light reddish brown	SCL	SBK	Firm	Vf1	WD
AB	22 – 58	5YR 7/2 pinkish gray	SL	SBK	Friable	C1	WD
Bt	58 – 68	5YR 7/6 reddish yellow	SCL	SBK	Firm	M12	WD
Bw	68 – 75	10YR 2/1 black	SCL	SBK	Firm	Vf1	WD
		PEDON 2					
A	0 – 24	10YR 6/8 brownish yellow	SCL	SBK	Firm	C1	WD
AB	24 – 46	7.5YR 8/6 reddish yellow	SCL	SBK	Firm	Vf1	WD
Bt_1	46 – 59	5YR 7/4 reddish yellow	CL	SBK	Firm	C12	WD
Bt_2	59 – 86	10YR 6/4 light yellow brown	CL	SBK	Firm	M2	WD

TC= textural class, SCL= sandy clay loam, CL= clayey loam, SL= sandy loam. Structure: SBK= subangular blocky. Root: M= many, C= common, VF= very few, 1= fine, 2= medium, WD= well drained

Furthermore, pedon 2 had a colour matrix of brownish yellow 5YR 7/6, reddish yellow 7.5YR 8/6, reddish yellow 5YR 7/4 and light yellow brown 10YR 6/4 in horizons A, AB, Bt1, and Bt2. The observable changes in the soil colour matrix in the various pedons could be associated with drainage condition, available iron oxides, and organic matter. This is in conformity with the findings of Osujieke *et al.* (2016) in soil of south east Nigeria. However, the textural class of the pedons generally appears more sandy in composition with a fewer clay and loamy concentration. The textural class was sandy clay loam (SCL) in the A, Bt1 and Bt2 horizons and sandy loam (SL) at AB horizon in pedon 1. The result in Table 1 also showed a textural range of sandy clay loam (SCL) at the A and AB horizons and clayey loam (CL) at Bt1 and Bt2 horizons of pedon 2. The textural class could be attributed to soil formation factors. Generally, soil texture does not change within a relatively short time (Brady and Weil, 1999) hence, the parent material that give rises to a particular soil has a significant influence on its texture (Nnaji *et al.*, 2002). The soils of

ISSN: 2455-6939

Volume:05, Issue:03 "May-June 2019"

the study area developed from sandstone and quartzite parent material. Such parent materials are capable of impacting coarse texture to the soil.

The result of the soil physical properties (Table 2) shows that sand fraction ranged from 490 – 640 g/kg in pedon 1 and 440 – 490 g/kg in pedon 2. The sand fraction decreased with an increasing soil depth in pedon 2 while it had no definite sequence with soil depth in pedon 1. The coefficient of variation indicated that sand fraction had a moderate variability (20.72 %) and low variability (10.68 %) in pedon 1 and pedon 2 respectively. The variability can be attributed to runoff effect and eluviations process. The sandiness of Makurdi soil was due to a combination of sandy parent material (sandstone) and tropical climate. These factors influence the pedogenesis and properties of soils (Onweremadu *et al.*, 2011 and Wang *et al.*, 2001). However, sandy soil encourages high infiltration which in-turn promotes leaching of plant nutrients. Silt fraction had a mean of 189 g/kg with moderate variability (26.91 %) in pedon 1 and 224 g/kg with low variability (7.78 %) in pedon 2. Silt fraction increased with an increasing soil depth in pedon 1 while it had no specific trend of increase in pedon 2. The Pedons have silt clay ratio greater than 0.15, hence it indicates the formation of a well-developed pedon. This is in concurrence with the findings of Abate *et al.* (2014) that soils with low silt-clay ratio are at an advanced stage of development and as such confirmed the existence of material translocation in the pedons. Also, soils with low silt clay ratio possess no potential for degradation and vulnerability. This confirms with the findings of Lal, (2004).

Table 2: Soil physical properties of the studied sites

Horizon	Depth (cm)	Sand →	Silt g/kg	← Clay	SCR	TC
			PEDON 1			
A	0 – 22	520	149	331	0.45	SCL
AB	22 – 58	640	169	191	0.89	SL
Bt	58 – 68	490	199	311	0.64	SCL
Bw	68 – 75	550	239	211	1.13	SCL
Mean		**550**	**189**	**261**	**0.78**	
CV		**11.78**	**20.72**	**26.91**	**38.09**	
Ranking		**LV**	**MV**	**MV**	**HV**	
			PEDON 2			
A	0 – 24	490	199	311	0.64	SCL
AB	24 – 46	480	249	271	0.92	SCL
Bt_1	46 – 59	470	209	321	0.65	CL
Bt_2	59 – 86	440	239	321	0.75	CL

ISSN: 2455-6939

Volume:05, Issue:03 "May-June 2019"

Mean	**470**	**224**	**306**	**0.74**
CV	**4.60**	**2.38**	**7.78**	**17.55**
Ranking	**LV**	**LV**	**LV**	**MV**

SCR= silt clay ratio, TC= textural class, SCL= sandy clay loam, CL= clayey loam, SL= sandy loam. Structure, CV= coefficient of variation, < 15= low variability (LV), ≥15≤35= moderate variability (MV), > 35= high variability (HV)

However, the clay fraction ranged from 211 g/kg – 331 g/kg (mean= 261 g/kg) in pedon 1 and 271 g/kg -321 g/kg (mean= 306 g/kg) in pedon 2. Clay had no definite sequence of increase with soil depth in pedons 1 and 2. The clay increase with increasing profile depth was in concurrence with the findings of Osujieke *et al.* (2017) on tropical soil which is usually underlain by clay-enriched subsoil (argillic horizons). Also, Nuga *et al.* (2008) opined that higher clay content as observed in most subsurface horizons in the pedons can be attributed to illuviation and faunal activities taking place in the area. Clay fraction recorded high variability (38.09 %) in pedon 1 and moderate variability (17.55 %) in pedon 2. The variability recorded can be attributed to fine particle deposition as well as eluviation-illuviation processes that occur within the soil profile. This is in conformity to the works of Chikezie *et al.* (2009) and Malgwi, (2001).

The soil chemical properties as indicated in Table 3 shows that soil pH(H_2O) were moderate - strongly acidic according to the ratings of Chude *et al.*, (2011). Soil pH(H_2O) had means of 5.39 in pedon 1 and 5.25 in pedon 2. This is an indication that the pedon 2 is least acidic. However, soil pH had low variability (≥4.73 % ≤9.75 %) in pedon 1 and 2. This may be attributed to the inherent properties of the parent material (sandstone) from which the soils are derived. The pH level of the surface horizon may be associated with the influence of organic matter through biogenetic cycling of bases. Organic carbon and total nitrogen were low when compared with the ratings of Chude *et al.* (2011) and Esu, (1991). The low organic carbon and total nitrogen could be attributed to crop removal, crop residue removal, volatilization as a result of a high oxidation. This conforms to the findings of Osujieke *et al,* (2017) on tropical soils. Organic carbon had high variation (≥83.11 % ≤115.32 %) while total nitrogen had low variation (≥2.96 % ≤7.99 %) in both pedons. The variation could be attributed to the removal of plant residue and the rate of decomposition and mineralization. However, Idoga, (2014) have made similar reports on soils of Northern Nigeria. Organic carbon and total nitrogen decreased down the pedons which may be associated with the availability of organic materials with a high concentration on the surface horizon and drainage pattern of the soil. The result (Table 3) shows that Na was predominant over other exchangeable cations (Ca, Mg, K). The exchangeable bases of the pedons were very low for Ca, very low for Mg, moderate for K, and high for Na when compared with the ratings of Landon (1991). These reveal that with exception of Na, other basic cations should be improved. The higher content of available Na may be associated with capillary movement of water from the water table to the surface as suggested by Malgwi, (2001). Effective cation exchange capacity

ISSN: 2455-6939

Volume:05, Issue:03 "May-June 2019"

(ECEC) had a mean of 9.12 cmol/kg in pedon 1 and 6.19 cmol/kg in pedon 2. The ECEC was low when compared to the ratings of Landon, (1991). The ECEC of soils is dependent on the amount of clay and organic matter. This is in conformity with the findings of Brady and Weil, (2002). The variability among the pedon can be attributed to runoff, and seepage effect on the level of cation concentration in the soil as suggest by Ukpong, (2000).

ISSN: 2455-6939

Volume:05, Issue:03 "May-June 2019"

Table 3: Soil chemical properties of the studied sites

Horizon	Depth (cm)	pH (H_2O)	OC → g/kg	TN ←	Av.P (mg/kg)	Ca →	Mg	K	Na cmol/kg	TEA ←	ECEC	BS (%)
					PEDON 1							
A	0 – 22	4.75	18.8	1.4	1.41	0.92	0.15	2.100	6.45	5.00	14.62	65.80
AB	22 – 58	5.20	3.5	1.6	1.52	0.92	0.16	0.034	1.25	5.00	7.36	32.07
Bt	58 – 68	5.65	3.9	1.6	0.70	0.91	0.16	0.037	1.68	4.59	7.38	37.81
Bw	68 – 75	5.95	1.5	2.5	0.35	0.87	0.19	0.019	1.46	4.60	7.14	35.57
Mean		**5.39**	**6.9**	**1.6**	**0.99**	**0.91**	**0.17**	**0.55**	**2.71**	**4.33**	**9.12**	**42.81**
CV		**9.75**	**115.32**	**7.99**	**56.58**	**2.63**	**10.50**	**189.05**	**92.23**	**4.88**	**40.16**	**36.22**
Ranking		**LV**	**HV**	**LV**	**HV**	**LV**	**LV**	**HV**	**HV**	**LV**	**HV**	**HV**
					PEDON 2							
A	0 – 24	4.90	7.00	2.0	0.12	0.53	0.12	1.04	2.15	3.30	7.14	53.78
AB	24 – 46	5.25	1.80	2.0	0.59	0.52	0.12	0.29	1.20	3.50	6.22	43.73
Bt_1	46 – 59	5.40	3.50	1.9	0.35	0.52	0.12	0.27	1.29	3.50	5.70	38.60
Bt_2	59 – 86	5.45	0.80	1.9	1.17	0.56	0.12	0.26	1.29	3.70	5.70	34.91
Mean		**5.25**	**3.30**	**2.0**	**0.56**	**0.53**	**0.12**	**0.41**	**1.48**	**3.50**	**6.19**	**42.75**
CV		**4.73**	**83.11**	**2.96**	**80.93**	**3.56**	**0.00**	**108.01**	**30.15**	**4.67**	**10.97**	**19.16**
Ranking		**LV**	**HV**	**LV**	**HV**	**LV**	**LV**	**HV**	**MV**	**LV**	**LV**	**MV**

OC= organic carbon, TN= total nitrogen, Av.P= available phosphorus, TEA= total exchangeable acidity, ECEC= effective cation exchange capacity, BS= base saturation, CV= coefficient of variation, < 15= low variability (LV), ≥15≤35= moderate variability (MV), > 35= high variability (HV)

ISSN: 2455-6939

Volume:05, Issue:03 "May-June 2019"

Base saturation (BS) as indicated in the result showed that pedons 1 and 2 had a mean of 42.81 % and 42.75 % respectively. The base saturation was low to moderate according to the rating of Landon, (1991). However, Soil Survey Staff, (2014b) opined that soils with base saturation of less than 50 % are dystric in nature and as such low in basic cations.

The correlation matrix as indicated in Table 4 showed that organic carbon correlated positively (r= 0.346, r= 0.361, r= 0.043, r= 0.395, r= 0.953) with available phosphorus, Calcium, Magnesium, total exchangeable acidity and effective cation exchange capacity while it had a highly significant positive correlation (r= 0.958, r= 0.977, r= 0.898, p= 0.01) with K, Na and base saturation. Clay fraction correlated positively (r= 0.141, r= 0.472, r= 0.401, r= 0.223) with total nitrogen, K, Na and effective cation exchange capacity while it correlated negatively (r= -0.134, r= -0.407, r= -0.620, r= -0.423) with available phosphorus, Ca, Mg and total exchangeable acidity. Also, pH correlated negatively and significantly (r= -0.726, r= -0.773, p= 0.05) with organic carbon and base saturation. However, the positive correlation implies that increase in one soil property increases the other while, negative correlation implies that increase in one soil property decreases the other and vice versa.

Table 4: Correlation matrix of the studied soil properties

	Sand	Silt	Clay	SCR	pH	OC	TN	Av.P	Ca	Mg	K	Na	TEA	ECEC	BS
	→ g/kg ←				(H_2O)	→ g/kg ←		(mg/kg)	→ cmol/kg ←						(%)
Sand	1														
Silt	-0.490	1													
Clay	-0.822*	-0.093	1												
SCR	0.366	0.627	-0.827*	1											
pH	-0.027	0.625	-0.377	0.666	1										
OC	-0.093	-0.782*	0.405	-0.709*	-0.726*	1									
TN	-0.535	0.721*	0.141	0.246	0.077	-0.602	1								
Av.P	0.419	-0.528	-0.134	-0.199	-0.307	0.346	-0.636	1							
Ca	0.683	-0.572	-0.407	0.037	0.140	0.361	-0.933**	0.516	1						
Mg	0.651	-0.190	-0.620	0.435	0.494	0.043	-0.69	0.162	0.868**	1					
K	-0.052	-0.632	0.472	-0.679*	-0.800*	0.958**	-0.366	0.185	0.123	-0.136	1				
Na	0.040	-0.685	0.401	-0.638	-0.629	0.977**	-0.638	0.393	0.394	0.107	0.934**	1			
TEA	0.714*	-0.602	-0.423	-0.032	-0.069	0.395	-0.952**	0.651	0.979**	0.814	0.157	0.438	1		
ECEC	0.227	-0.738*	0.223	-0.530	-0.565	0.953	-0.761*	0.477	0.564	0.277	0.869**	0.976**	0.606	1	
BS	-0.177	-0.502	0.530	-0.657	-0.773*	0.898**	-0.236	0.032	0.016	-0.207	0.976**	0.873**	0.023	0.794*	1

SCR= silt clay ratio, OC= organic carbon, TN= total nitrogen, Av.P= available phosphorus, TEA= total exchangeable acidity, ECEC= effective cation exchange capacity, BS= base saturation

ISSN: 2455-6939

Volume:05, Issue:03 "May-June 2019"

Taxonomic Classification of Soils

The soils of the study sites were classified using USDA soil taxonomy and world reference base (WRB) systems of soil classification. According to the USDA soil taxonomy, the study sites had isohyperthermic temperature and ustic moisture regimes. The pedon 1 had a light-coloured epipedon and simple horizon development which qualified it as an Inceptisols. Considering the soil moisture regime it falls under the suborder Ustepts. Ustepts are mainly the more or less freely drained Inceptisols of subhumid to semiarid regions. They have an ustic moisture regime (moisture is limited, but available, during portions of the raining season) (Soil Survey Staff, 2015). The pedon 1 has a base saturation (by NH_4OAc) of less than 60 percent in all horizons at a depth between 25 and 75 cm from the mineral soil surface as such considered as Dystrustepts (Soil Survey Staff, 2014b). Dystrustepts are the acid ustepts with low base saturation and relatively low natural fertility. Some properties include steeper soils been shallow to root limiting bedrock or a dense, compact layer (Soil Survey Staff, 2015). This classified pedon 1 under the USDA soil taxonomy sub group as Typic Dystrustepts (Dystric Cambisols). The pedon 2 had a base saturation above 35 % and argillic horizon which qualified it as an Alfisols. Considering the soil moisture regime they fall under the suborder Ustalfs. However, the pedon 2 has a kandic horizon (very low ECEC) in which clay content does not decrease significantly and as such considered as Kandiustalfs (Soil Survey Staff, 2014b). Hence, pedon 2 was classified under the USDA soil taxonomy sub group as Typic Kandiustalfs (Dystric Planosols)

CONCLUSION

The result showed that the pedons had subangular blocky structure, predominantly firm inconsistence and well drained in all the horizons. The physiochemical properties of the pedons varied with both depth and horizons. The particle size distribution indicated that sand particle dominated other fractions of the fine earth material. This can be associated with the underlain parent materials (lithology) of the study area. Silt-clay ratio was generally low in all the pedons, which indicated an advanced stage of weathering. The soil pH(H_2O) were moderate – strongly acidic in all the pedons examined. The base saturation was moderate in pedons 1 and 2. Organic carbon was generally low in both pedons and decreased down the profile. The exchangeable acidic cations dominated in ECEC in all the horizons. However, irrespective of the difference in both the physical and chemical properties yet the coefficient of variation showed that sand fraction and pH(H_2O) had low variability while organic carbon and total nitrogen had high variation among the horizons of the studied pedons. After the profile description and examination of the soil properties. Pedon 1 and pedon 2 were classified as Typic Dystrustepts (Dystric Cambisols) and Typic Kandiustalfs (Dystric Planosols), respectively. However, for sustainable crop production, there is the need for adoption of improved soil management

ISSN: 2455-6939

Volume:05, Issue:03 "May-June 2019"

practices such as mulching, conservation tillage and incorporation of organic materials in the soils of the area that will effectively minimize erosion, enhance and maintain soil quality and productivity.

REFERENCES

Abate, N.A., Kibebew, K., Heluf, G. and Abayneh, E. (2014). Characterization and classification of soils along the toposequence at the Wadla Delanta Massif, North Central Highlands of Ethiopia. *Journal of Ecology and Natural Environment*. Vol. 6(9): 304 – 320.

Agbede, I.O. and Smart, P. (2007). Geotechnical properties of Makurdi shale and effects on foundations. *Nigerian Journal of Technology*, Vol. 26 (2): 63 – 73.

Ahukaemere, C. M, Obi, C.I. Ndukwu, B.N and Nwamadi, N. J. (2017). Characterization and Classification of Soils Of Egbema in Imo State, South-Eastern Nigeria. *FUTO Journals Series* Vol. 2(1): 41 – 47.

Brady, N. C. and Weil, R.R. (2002). The Nature and Properties of Soils, 13th edition. Prentice-Hall, Upper Saddle River, NJ, USA.

Brady, N.C. and Weil, R.R. (1999). The nature and properties of soils. 12th edition. Prentice-Hall Inc.

Chikezie, A., Eswaran, H., Asawalam, D.O., and Ano, A.O. (2009). Characterization of the benchmark soils of contrasting parent materials in Abia State, Southeastern Nigeria. *Global Journal of Pure and Applied Sciences.* 16(1): 23 – 29.

Chude, V.O., Malgwi, W.B., Amapu, I.Y. and Ano, A.O. (2011). Manual on Soil Fertility Assessment. Federal Fertilizer Department. FAO and National Programme on Food Security, Abuja, Nigeria. 62.

Esu, I.E. (2005). Characterization, classification and management problems of the major soil orders in Nigeria. The 26th Inaugural Lecture of the University of Calabar, Nigeria 66.

Eswaran, H. (1977). Soil Analysis for Soil Surveys. In: Soil Resource Inventories. A proceeding of a workshop held at Cornell University, Ithaca, USA. Pp 315-324

Fasina, A.S., Aruleba, J.O., Omolayo, F.O., Omotosho, S.O., Shittu, O.S. and Okusami, T. A. (2005). Properties and classification of five soils formed on granitic parent material of humid southwestern Nigeria. *Nigerian Journal of Soil Science*, 15 (2): 21 – 29.

ISSN: 2455-6939

Volume:05, Issue:03 "May-June 2019"

Idoga, S. (2014). Soil and urban land use planning: a case study of Markudi urban centre, Benue State of Nigeria. *Nigerian Journal of Soil Science.* Vol. 24(1): 51-58.

IUSS Working Group WRB. (2015). World Reference Base for Soil Resources 2014, update 2015 International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106. FAO, Rome.

Lal, R. (2004). Methods and guidelines for assessing sustainability use of soil and water resources in the tropics. Soil management support service technical monograph No 21: 1 – 78.

Landon, J.R. (Ed) (1991). Booker tropical soil manual: A Handbook for soil survey and Agricultural land Evaluation in the tropics and subtropics, Longman Scientific and Technical, Essex, New York. 474p.

Lekwa, M.U., Anene, B.O. and Lekwa, G. (2004).Chemical and Morphological Soil Characteristics in Drainage Toposequence in Southeastern Nigeria. In Ojeniyi, S.O., Ano, A.O., Awasalam, D.O. and Chukwu, G.O. (Ed) Land Degradation, Agricultural Productivity and rural poverty, environmental implications proceedings of the 28th Annual Conference of the Soil Science Society of Nigeria, held at National Root Crops Research Institute, Umudike, Abia State. 4th – 7th Nov. 2003, Pp 316 – 322.

Malgwi, W.B., Ojanuga, A.G., Chude, D.O., Kparmwang, T. and Raji, B.A. (2000). Morphological and physical properties of some soils of Samaru, Zaria, *Nigeria Journal of Soil Research.* 1:58 – 64.

Malgwi, W.B., Ojanuga, A.G., Chude, D.O., Kparmwang, T. and Raji, B.A. (2000). Morphological and physical properties of some soils of Samaru, Zaria, *Nigeria Journal of Soil Research.* 1: 58 – 64.

Munsell (1994). Munsell soil colour charts. Macbeth Division of Kollmorgen Instruments Corporation New Windsor, NY USA.

NIMET (Nigerian Meteorological Agency), (2015). Climate Weather and Water Information, for Sustainable Development and Safety

Nnaji, G.U., Asadu, C.L.A. and Mbagwu, J.S.C. (2002). Evaluation of physicochemical properties of soils under selected agricultural land utilization types. *Agro Science,* 3: 27-33.

Nuga, B.O., Eluwa, N.C., and Akinbola, G.E. (2008). Characterization and classification of soils along a toposequence in Ikwuano local govt. areas of Abia state Nigeria: *Electronic Journal of Environment, Agriculture and Food Chemistry*. Pp 2779 –2788

Onweremadu, E.U., Okuwa, J.A., Njoku, J.D. and Ufot, U.O. (2011). Soil nitrogen forms distribution in isohyperthermic Kandiudults of Central southeastern Nigeria. *Nigeria Journal for Agriculture, Food and Environment.* 7(2): 52-56

Osujieke, D.N., Imadojemu, P.E., Ndukwu, B.N. and Okeke, O.M. (2017). Properties of Soils in relation to Soil depth, Land-use and Landscape position on Soils of Ikeduru Area of Imo State, Southeastern Nigeria. *International Journal of Agriculture and Rural Development.* Vol. 20(2): 3132-3149.

Osujieke, D.N., Ahukaemere, C.M., Imadojemu, P.E., Ndukwu, B.N., Obi, C.I., Obasi, S.N. and Nnabuihe, E.C. (2016). Morphological Properties of Soils of Three Different Toposequences Underlain by Dissimilar Lithologies in Imo State South-East Nigeria. Proceedings of 50th Annual Conference of Agricultural Society of Nigeria. Pp.1037-1041

Schoeneberger, P.J., D.A. Wysocki, E.C. Benham, and Soil Survey Staff. (2012). Field book for describing and sampling soils, Version 3.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE.

Soil Survey Staff. (2014a). Soil Survey Field and Laboratory Methods Manual. Soil Survey Investigations Report No. 51, Version 2.0. R. Burt and Soil Survey Staff (ed.). U.S. Department of Agriculture, Natural Resources Conservation Service.

Soil Survey Staff, (2014b). Keys to Soil Taxonomy. 12th Ed. USDA-NRCS, Washington D.C.

Soil Survey Staff. (2015). Illustrated guide to soil taxonomy, version 2. U.S. Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center, Lincoln, Nebraska.

Thangasamy, A., Naidu, M. V. S., Ramavatharam, N. and Raghava Reddy, C., (2005): Characterization, classification and evaluation of soil resources in Sivagiri Micro-watershed of Chittoor district in Andhra Pradesh for sustainable land use Planning: *Journal of Indian Society of Soil Science,* 53: 11–21.

Ukpong, I.E. (2000). Ecological classification of Nigeria mangroves using soil nutrient gradient analysis. *Wetlands Ecology and Management,* 8: 263 – 272.

Uponi, J.J. and Adeoye, G.O. (2000). "Soil testing, and plant analysis: an overview". In: Akoroda, M.O. (ed.) Agronomy in Nigeria, Department of Agronomy, University of Ibadan, Pp. 174 – 182.

Wang, J., Fu, B., Qui, Y. and Chen, L. (2001). Soil nutrients in relation to land-use and landscape position in the semi-arid small catchment on the Loess Plateau in China. *Journal of Arid Environment*, 48: 537 – 550.

Wilding, L.P., Bouma, J. and Boss, D.W. (1994). Impact of spatial variability on interpretative modeling. In: Quantitative modeling of soil forming processes. Bryant, R.B. and Amold, R.W. SSSA. Special Publication. No.39: 61.

