Nigerian Journal of Soil Science
journal homepage:www.soilsjournalnigeria.com

Characterization and Classification of Soils of Jalingo Metropolis, North-east, Nigeria

*[1]Osujieke, D.N., [2]Obasi, N.S., [1]Imadojemu, P.E., [1]Ekawa, M and [1]Angyu, M.D.

[1]*Department of Soil Science and Land Resources Management, Federal University Wukari, PMB 1020 Wukari, Taraba State Nigeria.*
[2]*Department of Crop and Soil Science, National Open University of Nigeria, Faculty of Agriculture Kaduna, Kaduna State Nigeria*

ARTICLE INFO

Article history:
Received:28th June, *2018*
Received in revised form: 30th July, 2018
Accepted: 2nd August, 2018
Available online: 1st December, 2018

Keywords:
Characterization, Classification
Horizon, Jalingo
pedons, variation.

***Corresponding Author's* e-mail Address:**
bigdonax@yahoo.com;
+2348030877200

https://doi.org/10.36265/njss.2018.280209
ISSN-1597-4488 ©publishingrealtime.

ABSTRACT

The study was aimed at the characterizing and the classifying of soils of Jalingo metropolis in Taraba State, North-East Nigeria. Profile pit was dug on each of the three different sites of the study area as identified using free survey. The profile pits were described and sampled bases on horizon differentiation for laboratory analyses. A total of 10 samples were collected. Data generated were analyzed using descriptive statistics to determine their coefficient of variation. The result indicated that the horizons were mostly reddish when moist at different contrasting level. The textural classes were mostly loamy sand while the sub-angular blocky structure was observed in the entire subsurface horizons. The horizons of the pedons were well drained. Sand fraction had means of 826.80 g/kg, 816.80 g/kg and 766.8 g/kg for pedons 1, 2, and 3 respectively. Clay fraction increased in an increasing soil depth which formed an argillic horizon. Sand fraction, bulk density and particle density recorded low variation (≥0 % ≤5.22 %) in among the pedons. Soil pH(H_2O) had a mean of 6.40 in pedon 1, 6.43 in pedon 2 and 6.41 in pedon 3. Organic carbon ranged from ≥2.0 g/kg ≤0.43 g/kg while cation exchange capacity ranged from ≥4.58 cmol/kg ≤5.01 cmol/kg among the pedons. The percent base saturation had a mean of 66.6 %, 65.1 % and 66 % in pedon 1, 2 and 3. Hence, pedons 1 and 2 were classified as Grossarenic Kandiustalfs (Arenic Lixisols), while pedon 3 was classified as Arenic Kandiustalfs (Loamic Lixisols) according to USDA soil taxonomy and correlated with world reference base.

1. Introduction

The need for more information about the soil as a means for its sustainable use and proper conservation has continuously demanded soil characterization. Soil, as the dominant medium for agricultural production and also, for diversification of Nigeria's economy through agriculture has called for much demand on experimental soil data which has led to many requests on soil characterization. Soil characterization provides the fundamental information necessary to create functional soil classification schemes, and assess soil fertility to resolve some unique soil problems in an ecosystem (Lekwa *et al.,* 2004). Characterizing the soils is a significant indicator of the soil's capacity to produce safe and nutritious food, enhance human and animal health, and overcome degradation processes (Schoenholtza *et al*., 2000).

Different soils possess different properties due to differences in morphological, physical, chemical and mineralogical properties (Ukut *et al*., 2014). Soil characterization deals with the separation of soils into groups of similar morphological properties such as colour, texture, structure, consistency, roots; physical properties such as sand, silt, clay, bulk density, porosity; chemical properties such as pH, organic matter content, total nitrogen, available phosphorus, exchangeable cations. Characterization of soils is essential for decision making concerning crop productivity and the determination of the intrinsic potential of the soils to resist degradation by raindrops and runoff (Schoenholtza *et al*., 2000). It is through precise measurement and full understanding of the nature and properties of soils, as well as proper management of the nutrient and moisture requirements that one can elevate the inherent capability of the soils towards the establishment of various land-use types. In order to evaluate the quality of our natural resources and their potential to produce food, fodder, fiber and resistance to erosion, detailed information on soil properties is required. The relevance of soil classification can be seen in the determination of the best possible use and management of soils. Soil characterization and classification contribute to the alleviation of the adverse effect of soil diversity and aid precision agriculture, land use planning and management (Ogunkunle, 1986).

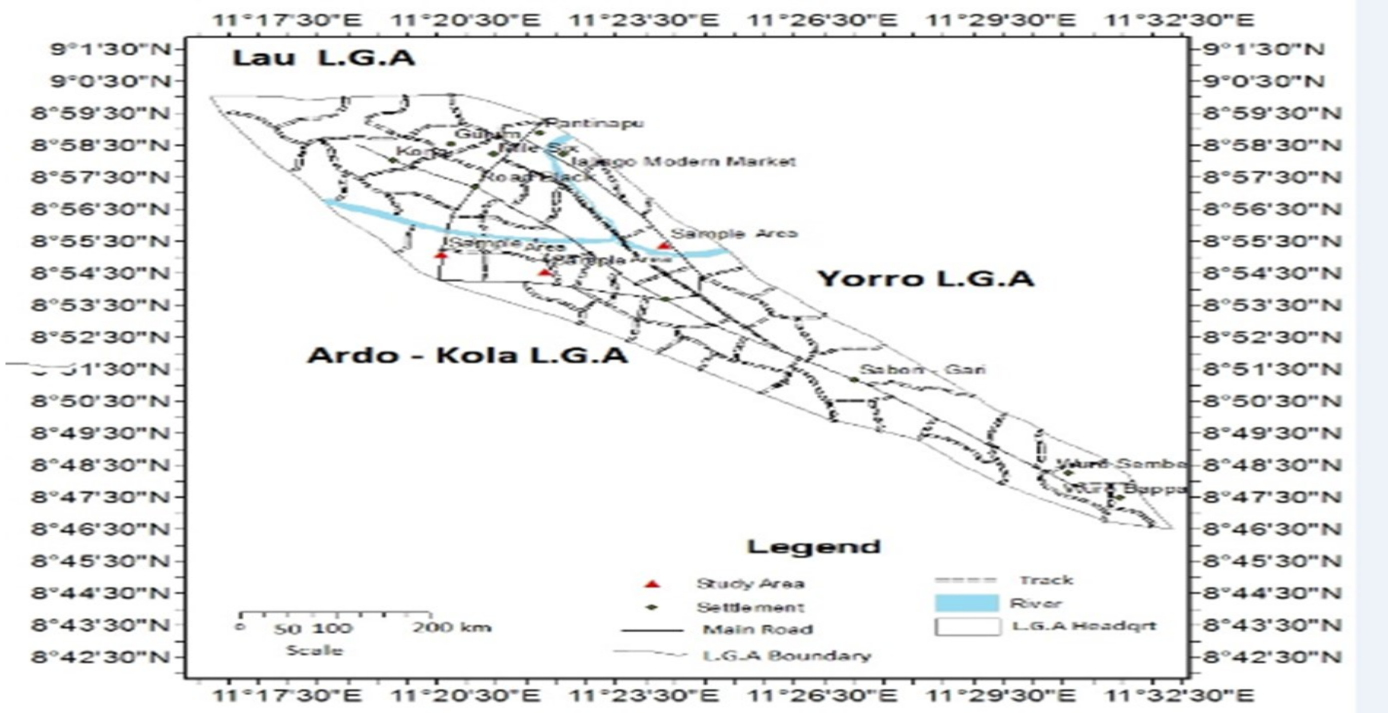
This research work will provide information on the properties and nature of soils of the study area and how these properties influence characterization and classification of the resulting soils. The study will also provide the information needed for the adequate production of crops to guarantee food and nutrient security and sustainable agriculture. Because not much research has been done on the soils of Jalingo, this study aimed at producing information that could be useful in the management and sustainable use of soil. Hence, this study was to characterize and classify the soils of Jalingo Metropolis.

2.0 Materials and Methods

2.1 Study Area

The study was carried out in Jalingo. Jalingo is the capital city of Taraba State North East, Nigeria. It is located on latitude 8° 54′ N – 8° 90′ and longitude 11° 22′ E – 11° 37′ E with an elevation of 349 meters above sea level. Like most parts of Northern Nigeria, Jalingo has wet and dry climate; the wet season lasts on the average from April to October with mean annual rainfall of 1000 mm – 1200 mm (NIMET, 2015). The dry season lasts from November to March. The driest months are December and January with relative humidity dropping to about 15 %. The mean annual temperature around Jalingo is about 28 °C with maximum temperatures varying between 30 °C - 39.4 °C. The minimum temperature ranges between 15 °C – 23 °C (NIMET, 2015).

Jalingo lies on the northern guinea savannah vegetation of Nigeria. The area is predominantly made up of secondary forest since most of the primary vegetation was cleared due to farming activities. The common plants found in this region include; Garden spurge (*Euphorbia hirta*), Asian sprangletop (*Leptochloa chinensis*), Foxtail millet (*Setaria viridis*), Spinny amaranth (*Amaranthus spinosus*), Amaranth (*Amaranthus viridis*), Morning glory (*Ipomoea carnea*), Pignut (*Hyptis suaveolens*), Bahama grass (*Cynodon dactylon*), Spiderwort (*Commelina benghalensis*), Wiregrass (*Eleusine indica*), Lemon verbena (*Lippia dubai*), sedge flower (*Cyperus difformis*), Castor plant (*Ricinus communis*), Gmelina (*Gmelina arborea*) and Neem (*Aserterata indica*).



Map of Jalingo L.G.A In Taraba State Showing Sample Area

2.2 Geology

The geology of the study area is made up of sandstone (Emeka and Abbas, 2011).

2.3 Field Work

Field reconnaissance was conducted to ascertain the physical attributes and terrain of the study area. A free survey was used in citing profile pit on each of three different sites of the study area. The profile pits were described and samples collected according to the guideline of FAO (2006). Core samples were collected for bulk density determination. Soil colour was determined with the Munsell colour chart (Munsell, 1994). A total of 10 samples were collected. The samples collected were air dried, sieved for routine laboratory analysis.

2.4 Laboratory Analyses

Particle size distribution was determined by the hydrometer method (Gee and Or, 2002). Bulk density was determined by the core method (Grossman and Reinsch, 2002). Particle density was determined by pycnometer method as outlined by Blake and Hartge (1986). Ksat was determined using a constant head method (Klute, 1986). Soil pH was determined using 1:2.5 soil-water ratio using a pH meter (Thomas, 1996). Organic carbon was determined by wet digestion method (Nelson and Sommers, 1996). Total nitrogen was determined by micro-Kjeldahl digestion technique (Bremner, 1996). Available phosphorus was determined using Bray I method (Olsen and Sommers, 1982). Exchangeable acidity was determined by the method described by McLean (1982). Exchangeable bases were determined by neutral ammonium acetate procedure buffered at pH 7.0 (Thomas, 1982). Cation Exchange Capacity was determined using neutral ammonium acetate leachate method (Summer and Miller, 1996). Porosity (Po) $=100 - (\ell p/\ell s) \times 100/1$ where; ℓp= bulk density, ℓs= particle density.

2.5 Statistical Analysis

The variability of soil properties of the horizons within the studied pedons was determined using the coefficient of variation (CV). The coefficient of variation was ranked according to the procedure of Wilding *et al.* (1994) where CV <15 % = low variation, CV ≥15 % ≤35 % = moderate variation, CV >35 % = high variation. The statistical analyses were done using GENSTAT statistical software version 8.1

2.6 Soil Classification

Field and laboratory data were used to classify the soils using USDA Soil Taxonomy (Soil Survey Staff, 2014) and World Reference Base (WRB) IUSS Working Group WRB (2015) classification systems.

3.0 Results and Discussion

3.1 Morphological Properties

The result (Table 1) showed that all the horizons observed have colours which varied from 2.5 YR 3/6 (Dark red), 10R 3/6 (Dark red), 2.5 YR 3/2 (Dusky red) in pedon 1, 2.5 YR 4/3 (Weak red), 10R 3/4 (Very dusky red), 2.5 YR 2.5/3 (Dark reddish brown), 7.5 YR 3/4 (Dark brown) in pedon 2, and 2.5 YR 3/6 (Dark red), 2.5 YR 2.5/2 (Very dark red), 2.5 YR 2.5/3 (Dark reddish brown) in pedon 3. The difference in coloration could be associated with drainage condition. Also, Osujieke *et al.* (2016), reported that parent materials and environmental factors (rainfall, humidity, and temperature) might have contributed to the soil colour variation of horizons. However, the dark colour tinge in surface horizon may be as a result of organic matter deposit. The textural class observed in most of the horizons of the pedons were loamy sand except for pedon 3 which has some indications of sandy loam at the Bt horizons. The structures of the pedons were crumb at the surface horizon and sub-angular blocky at the sub-surface horizons of pedons 1 and 2 while sub-angular blocky was recorded at all horizons in pedon 3. The consistencies (Table 1) were friable at the A horizon and firm at the Bt horizons of pedon 1, while at pedon 2, it was friable at the A and AB horizons, firm at BA and Bt horizons, but was firm in all horizons of pedon 3. The roots presence was few in A and Bt 1 horizons to no roots in the Bt 2 horizon of pedon 1 while A and AB horizon had many roots, few roots in BA horizon and very few roots in Bt horizon of pedon 2. A horizon had common roots, few roots at Bt 1 horizon and very few roots at Bt 2 horizon of pedon 3. This root variation is associated with the depth differences in the horizons, plant species and shallow rooting system of the plants found in the studied sites. The horizons of the studied pedons were well drained.

Table 1: Soil Morphological Properties of the Studied sites

Horizon	**Depth (cm)**	**Colour (moist)**	**TC**	**Structure**	**Consistence (moist)**	**Root**	**Drainage**
PEDON 1 (N 08^{o} 54.364$^{\prime}$, E 11^{o} 18.292$^{\prime}$, Elevation= 196.2 m)							
A	0 – 25	2.5YR 3/6 (Dark red)	LS	Crumb	Friable	Few	Well-drained
Bt1	25 – 50	10R 3/6 (Dark red)	LS	SBK	Firm	Few	Well-drained
Bt2	50 – 120	2.5YR 3/2 (Dusky red)	LS	SBK	Firm	Few	Well-drained
PEDON 2 (N 08^{o} 54.543$^{\prime}$, E 11^{o} 19.725$^{\prime}$, Elevation= 179.9 m)							
A	0 – 35	2.5YR 4/3 (Weak red)	LS	Crumb	Firm	Few	Well-drained
AB	35 – 59	10R 3/4 (Very dusky red)	LS	SBK	Firm	Few	Well-drained
BA	59 – 82	2.5YR 5/3 (Dark reddish brown)	LS	SBK	Firm	Few	Well-drained
Bt	82 – 150	7.5YR 3/4 (Dark brown)	LS	SBK	Firm	Few	Well-drained
PEDON 3 (N 08^{o} 55.358$^{\prime}$, E 11^{o} 23.813$^{\prime}$, Elevation= 199.6 m)							
A	0 – 22	2.5YR 3/6 (Dark red)	LS	SBK	Firm	Few	Well-drained
Bt1	22 – 45	2.5YR 5/2 (Very dark red)	SL	SBK	Firm	Few	Well-drained
Bt2	45 – 150	2.5YR 5/3 (Dark reddish brown)	SL	SBK	Firm	Few	Well-drained

TC= textural class, LS= loamy sand, SL= sandy loam, SBK= subangular blocky

3.2 Soil Physical properties

The sand fraction (Table 2) was predominant over other soil separates and recorded means of 82.68 %, 81.68 % and 76.68 % for pedons 1, 2 and 3, respectively. However, the pedons recorded low variation ≥2.42 % ≤5.22 % which is an indication of homogeneity of soils of the study area. The sandiness of the soil could be associated with the parent material known as sandstone from which the soil was formed. This agreed with the works Osujieke *et al.* (2017) and Obasi *et al.* (2016) that parent material influences soil texture. The clay fraction ranged from ≥10.65 % ≤13.99 % among the studied pedons but recorded low variation (10.83 %) at pedon 1 and moderate variation (≥16.51 % ≤17.70 %) at pedon 2 and 3. Clay increased with an increase in soil depth which forms an argillic horizon among the pedons. However, Nuga *et al.* (2008), stated that this higher clay content observed in the subsurface horizons in the pedons could be a result of illuviation and faunal activities taking place in the area. The variability recorded can be attributed to the rate of fine particle deposition as well as illuviation and erosion.

The silt content was low with a mean of 6.67 %, 7.5 % and 9.33 % for pedons 1, 2 and 3. The low silt content could be attributed to a high degree and intense weathering as opined by Madueke *et al.* (2012). However, high values of silt indicate the formation of young soil. Silt recorded moderate variability across the three pedons. This can be associated with weathering of silt into the finer particle. Silt/clay ratio is an important criterion used in the evaluation of clay migration, stage of weathering and age of parent material and soils (Nwaka, 1990; Yakubu and Ojanuga, 2013). Ayolagha, (2001), on the other hand reported that old parent materials usually have a silt/clay ratio below 0.15 while silt clay ratio above 0.15 is indicative of young parent materials. Results of this study show that all the soils have silt/clay ratio above 0.15 indicating that the soils are relatively young with a high degree of weathering potential. Silt/clay ratios are relatively higher in the surface horizons and decrease with increase in soil profile pit depth. The decrease in silt/clay ratio with profile pit depth is an indication that subsoil horizons are more weathered than surface horizons. Hence, soils with low silt clay ratio are more weathered as stated by Landon, (1991).

The bulk density range from 1.57 - 1.61 g/cm^3 (mean= 1.58 g/cm^3) in pedon 1, 1.54 – 1.61 g/cm^3 (mean= 1.58 g/cm^3) in pedon 2 and 1.51 – 1.57 g/cm^3 (mean= 1.53 g/cm^3) in pedon 3. Bulk density had low variability (≥1.45 % ≤2.15 %) in the pedons which could be attributed to the similarity in climatic condition and homogeneity of the pedons. There was an observed decrease in bulk density with profile depth among the three pedons. The mean bulk density values of the soil groups fall within the range that is expected of tropical soils (Landon, 1991). Hence, bulk density will not be impeding root penetration and tillage practices within the soil group, as lower bulk density promotes root penetration when compared to heavier bulk density values. However, (Brady and Weil, 2002; Odunze, 2006), opined that soils with heavier bulk density promote soil resistance to root penetration, poor aeration, slow movement of nutrients and water, and build up of toxic gases and root exudates. The particle density ranged from 2.44 g/cm^3 - 2.45 g/cm^3 across the three pedons. Particle density increased with soil depth among the pedons. This is in line with the findings of Brady (1987), who reported that particle density values increase with soil depth. Particle density had low variability (≥0.23 % ≤2.44 %) in the three pedons. Saturated hydraulic conductivity ranged from 1.25 – 3.35 cm/s among the pedons. The Ksat was moderately rapid – rapid according to the ratings (≥1.4 ≤3.0) cm/s of Landon, (1991). However, Ksat is dependent on soil properties such as texture, structure, bulk density and organic matter.

Table 2: Soil Physical Properties of the Studied sites

Horizon	Depth	Sand	Silt	Clay	SCR	BD	PD	Po	Ksat
	(cm)	⟶	%	⟵		⟶	gcm^{-3} ⟵	(%)	(cm/s)
		PEDON 1 (N 08° 54.364′, E 11° 18.292′, Elevation= 196.2 m)							
A	0 – 25	84.68	6.0	9.32	0.64	1.61	2.45	34.0	3.35
Bt1	25 – 50	82.68	6.0	11.32	0.53	1.57	2.44	36.0	2.36
Bt2	50 – 120	80.68	8.0	11.32	0.71	1.57	2.44	36.0	2.36
Mean		**82.68**	**6.67**	**10.65**	**0.62**	**1.58**	**2.44**	**35.33**	**2.69**
CV		**2.42**	**17.32**	**10.83**	**14.47**	**1.45**	**0.23**	**3.27**	**21.24**
Ranking		**LV**	**MV**	**LV**	**LV**	**LV**	**LV**	**LV**	**MV**
		PEDON 2 (N 08° 54.543′, E 11° 19.725′, Elevation= 179.9 m)							
A	0 – 35	84.68	6.0	9.32	0.64	1.61	2.45	34.0	2.35
AB	35 – 59	80.68	8.0	11.32	0.71	1.57	2.44	36.0	2.36
BA	59 – 82	84.68	6.0	9.32	0.64	1.61	2.45	34.0	3.35
Bt	82 – 150	76.68	10.0	13.32	0.75	1.54	2.44	37.0	1.68
Mean		**81.68**	**7.5**	**10.82**	**0.64**	**1.58**	**2.44**	**35.25**	**2.43**
CV		**4.69**	**25.53**	**17.70**	**14.03**	**2.15**	**0.23**	**4.26**	**28.25**
Ranking		**LV**	**MV**	**MV**	**LV**	**LV**	**LV**	**LV**	**MV**
		PEDON 3 (N 08° 55.358′, E 11° 23.813′, Elevation= 199.6 m)							
A	0 – 22	80.68	8.0	11.32	0.71	1.57	2.44	36.0	2.36
Bt1	22 – 45	76.68	8.0	15.32	0.52	1.52	2.44	38.0	1.25
Bt2	45 – 150	72.68	12.0	15.32	0.78	1.51	2.44	38.0	1.26
Mean		**76.68**	**9.33**	**13.99**	**0.67**	**1.53**	**2.44**	**37.33**	**1.62**
CV		**5.22**	**24.74**	**16.51**	**20.08**	**2.09**	**0.00**	**3.09**	**39.30**
Ranking		**LV**	**MV**	**MV**	**MV**	**LV**	**LV**	**LV**	**HV**

SCR= silt clay ratio, BD= bulk density, PD= particle density, Ksat= saturated hydraulic conductivity, CV= coefficient of variation, < 15= low variability (LV), ≥15≤35= moderate variability (MV), > 35= high variability (HV)

3.3 Soil Chemical properties

The result of the soil chemical properties was stated in Table 3. The pH(H_2O) of the pedons were moderately acidic according to the ratings of Chude *et al.* (2011), with means of 6.40, 6.43 and 6.41 in pedons 1, 2 and 3 respectively. Weil and Brady, (2016), stated that acidic pH can be attributed to the acidic nature of the parent material from which the soils were derived. Abua *et al.* (2010), also attributed soil pH of an area to the nature of the parent material, climate of the region, organic matter, and topographic situations. According to Halving *et al.* (2005), a pH range of 5.5 to 6.5 is the preferred range for most crops to thrive. Organic carbon ranged from 0.17 % - 0.60 % and was low among the three pedons according to the ratings of FDALR, (1985). Organic carbon had moderate variability (≥20.47 % ≤34.25 %) in pedons 1 and 3 while it had high variability (43.90 %) in pedon 2, this can be attributed to litterfall and increase in soil biodiversity as suggested by Miller and Grardiner (2001). Also, Gregorich *et al.* (1998), opined that cultural practices by the farmers and effect of erosion and deposition affect organic carbon distribution. Soil texture has a strong influence on soil's ability to store organic carbon (Gili *et al*., 2010) but its distribution reflects a combination of soil physical properties, biomass inputs as well as decomposition rates which are functions of climatic conditions (Angers and Eriksen – Hamel, 2008). There was an observed decrease in organic carbon content with increasing soil depth among the three pedons which is in agreement with the results of Tolessa, (2006) and Wakene, (2001). This is because the surface horizon is the site where all forms of biochemical processes take place. The surface horizon has more population of microfaunas and floras as a result of organic matter decomposition.

Total nitrogen was deficient among the three pedons according to the ratings of Chude *et al.* (2011) and FDALR, (1985) which indicates N deficiency. Total nitrogen had means of 0.010 % in pedon 1, 0.019 % in pedon 2 and 0.024 % in pedon 3. The low total nitrogen can be attributed to the crop harvests, bush and residue burning which hastens the volatilization of nitrogen during dry seasons as opined by Miller and Donahue (1992). The total nitrogen was observed to decrease with increase in soil depth in all the pedons. The amount of total nitrogen at the surface horizon is associated with the organic matter deposit and biogenetic activity within the horizon.

The amount of available phosphorus ranged from 7.0 – 24.5 mg/kg, 3.5 – 52.5 mg/kg and 14.0 – 28.0 mg/kg among pedons 1, 2 and 3, which indicated low – high amount at different horizons of the pedons according to the ratings of Landon, (1991) and FDALR, (1985). However, the concentration of available P closely followed organic matter distribution of the soils generally and was suggested by some forms of phosphates and organic sources (Brady and Weil, 2002). There was high variability (≥43.30 % ≤118.34 %) in available P across the three pedons. This can be attributed to the eroded particles in runoff water, biomass removed through harvests and fixation. Similarly, Paulos, (1996), found variations in available P contents in soils, which are related to the intensity of soil disturbance, the degree of P- fixation with Fe and cations. Also, Ano, (2004), reported that acid soils have a high capacity of fixing soil P due to the formation of the insoluble Al-P complex.
The total exchangeable bases showed that calcium (Ca) and magnesium (Mg) are the predominant basic cations in the soils. The Ca content ranged from 1.5 - 2.4 cmol/kg, Mg content ranged from 0.7 – 1.3 cmol/kg, K content ranged from 0.024 – 0.092 cmol/kg, and Na content ranged from 0.0043 – 0.0088 cmol/kg in the three pedons. However, Ca was low, and Mg was moderate, K and Na were very low according to the ratings of Landon, (1991). The availability of the total exchangeable bases could be attributed to parent material and anthropogenic activities such as tillage, use of acidic fertilizer. The result (Table 3) also indicated that total exchangeable bases have an irregular trend of increase with soil depth. This can be attributed to the material translocation that occurs from the surface horizons, which can be associated with the work of Miller and Donahue (1992) and Ambeager, (2006).

Cation exchange capacity (CEC) content of the soil was low among the three pedons when compared with the ratings of FDALR, (1985). The CEC ranged from 4.25 - 5.0 cmol/kg (mean= 4.58 cmol/kg) in pedon 1, 4.18 – 5.44 cmol/kg (mean= 4.73 cmol/kg) in pedon 2 and 4.71 – 5.50 cmol/kg (5.01 cmol/kg) in pedon 3. Cation exchange capacity had low variation (≥8.36 % ≤13.0 %) among the three pedons. The low CEC in the pedons can be associated with low chemical weathering activity of the soil, leaching, and acidity. This conformed with the works (Fashina *et al*., 2005; Okusami and Oyediran, 1985). Also, low CEC in soils could be attributed to the nature of clay minerals as suggested by Hassan *et al.* (2011). Soils with a larger amount of clay and organic matter have higher CEC than sandy soil low in organic matter (Havlin *et al., 2005).* The percentage base saturation was moderate according to the ratings of Landon (1991), among the pedons. However, the percentage base saturation had a mean of 66.60 % in pedon 1, 65.10 % in pedon 2 and 66 % in pedon 3 with an observed increase with increase in soil depth among the three pedons. Soil with percentage base saturation greater than 50 % are regarded as fertile soil and as such qualifies as eutric soils (Soil Survey Staff, 2013). This conformed to the findings of FAO, (1999) that soils with a base saturation of greater than 50 % are regarded as fertile soils while soils with less than 50 % were regarded as low fertile soils. Hence, the soils of the studied area are fertile.

3.4 Taxonomic Classification of Soils

The soils of the study sites were classified using USDA soil taxonomy and World Reference Base systems of soil classification. According to the USDA soil taxonomy, the study sites have an iso-hyperthermic temperature, ustic moisture regimes, argillic horizons and a base saturation above 35 % which qualified it as an Alfisol. Considering the soil moisture regime, they fall under the sub-order Ustalfs. The pedons have kandic horizon, high base saturation and low effective cation exchange capacity which qualified them as Kandiustalfs (Soil Survey Staff, 2014). Pedons 1 and 2 had a loamy sand particle size class throughout the upper 75 cm of the kandic horizon, red colour with hues around 2.5 and this classified the soils under the USDA soil taxonomy subgroup as Grossarenic Kandiustalfs (Arenic Lixisols). However, pedon 3 had loamy sand and sandy loam particle size class extending to the upper 50 cm of the argillic horizon and was classified under the USDA soil taxonomy sub-group as Arenic Kandiustalfs (Loamic Lixisols).

Table 3: Soil Chemical Properties of the Studied sites

Horizon	Depth	pH	OC	TN	Av.P	Ca	Mg	K	Na	TEA	CEC	BS
	(cm)	(H_2O)	%		(mg/kg)	cmol/kg						(%)
PEDON 1 (N 08° 54.364′, E 11° 18.292′, Elevation= 196.2 m)												
A	0 – 25	6.40	0.25	0.014	24.5	2.15	1.3	0.043	0.0056	1.52	5.00	70.0
Bt1	25 – 50	6.40	0.17	0.010	14.0	2.00	1.0	0.041	0.0061	1.44	4.49	67.9
Bt2	50 – 120	6.41	0.19	0.012	7.0	1.50	1.1	0.028	0.0052	1.60	4.25	62.0
Mean		**6.40**	**0.20**	**0.010**	**15.17**	**1.88**	**1.13**	**0.03**	**0.006**	**1.52**	**4.58**	**66.6**
CV		**0.09**	**20.47**	**16.67**	**58.08**	**18.07**	**13.4**	**21.81**	**8.01**	**5.26**	**8.36**	**6.23**
Ranking		**LV**	**MV**	**MV**	**HV**	**MV**	**LV**	**MV**	**LV**	**LV**	**LV**	**LV**
PEDON 2 (N 08° 54.543′, E 11° 19.725′, Elevation= 179.9 m)												
A	0 – 35	6.42	0.49	0.029	52.5	2.40	1.0	0.092	0.0043	1.48	4.25	82.3
AB	35 – 59	6.50	0.34	0.021	13.5	2.00	1.2	0.062	0.0070	1.60	4.18	78.2
BA	59 – 82	6.37	0.25	0.016	7.0	1.80	0.7	0.025	0.0048	1.78	5.06	50.0
Bt	82 – 150	6.46	0.17	0.010	3.5	1.70	1.0	0.024	0.0043	1.80	5.44	50.2
Mean		**6.43**	**0.31**	**0.019**	**19,12**	**1.97**	**0.97**	**0.05**	**0.005**	**1.66**	**4.73**	**65.1**
CV		**0.86**	**43.90**	**42.32**	**118.34**	**15.67**	**21.14**	**64.42**	**25.26**	**9.16**	**13.0**	**26.8**
Ranking		**LV**	**HV**	**HV**	**HV**	**MV**	**MV**	**HV**	**MV**	**LV**	**LV**	**MV**
PEDON 3 (N 08° 55.358′, E 11° 23.813′, Elevation= 199.6 m)												
A	0 – 22	6.27	0.60	0.032	28.0	2.30	1.3	0.084	0.0088	1.52	4.71	78.4
Bt1	22 – 45	6.51	0.35	0.021	14.0	2.15	1.0	0.046	0.0078	1.68	4.82	66.5
Bt2	45 – 150	6.45	0.34	0.020	14.0	2.10	0.85	0.031	0.0061	1.85	5.50	54.3
Mean		**6.41**	**0.43**	**0.024**	**18.67**	**2.18**	**1.05**	**0.05**	**0.008**	**1.68**	**5.01**	**66.0**
CV		**1.94**	**34.25**	**27.36**	**43.30**	**4.76**	**21.88**	**50.91**	**18.04**	**9.80**	**8.54**	**18.1**
Ranking		**LV**	**MV**	**MV**	**HV**	**LV**	**MV**	**HV**	**MV**	**LV**	**LV**	**MV**

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

4. Conclusion

The data generated showed that pedons had subangular blocky structure and firm consistency in their Bt horizons. There was an illuvial clay deposit in the Bt horizon which characterizes them as kandic horizon. Soils were generally acidic with low organic carbon, total nitrogen, and CEC contents. There were variations in physical and chemical properties among horizons of each the pedons. After the profile description and examination of the soil properties of the study area, the soils were classified as Grossarenic Kandiustalfs (Arenic Lixisols) in pedons 1 and 2 and Arenic Kandiustalfs (Loamic Lixisols) in pedon .

Acknowledgment

We appreciate Prof. T. A. Okusami for his advice on the course of this research work.

References

Abua, M.A., Offiong, R.A., Iwara, A. I. and Ibor, U.W. (2010). Impact of Newly Constructed Roads on Adjoining Soil Properties in Tinapa Resort, South-Eastern Nigeria**.** *Annals of Humanities and Development Studies,* 1(1):176-184.

Ambeager, A. (2006). Soil fertility and plant nutrition in the tropics and subtropics IFAV IPI. Pp. 96.

Angers, D.A. and Eriksen-Hamel, N.S. (2008). Full-inversion tillage and organic carbon distribution in soil profiles: a meta-analysis. *Soil Sci. Soc. of Am. Jour.* 72(5): 1370 - 1374.

Ano, O.A. (2004). *Soil Fertility Assessment*. Federal Fertilizer Department in collaboration with NSPFS. Abuja, Nigeria. Pp. 62.

Ayolagha, G.A. (2001). Survey and Classification of Yenagoa meander belt soils in the Niger- Delta. In: *Proceedings of the 27th Annual Conference of Soil Science Society of Nigeria* 5-9th Nov. 2001 Calabar, Nigeria.

Blacke, G.R., and Hartge, K.H. (1986). Particle Density. In: *Methods of Soil Analysis. Part 1. Physical and Mineralogical Methods,* Klute, A. (Ed.). 2nd Edn. American Society of Agronomy, Madison, WI, USA., pp: 363-382.

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

Brady, N.C. (1987). *The Nature and Properties of Soils*, 8th edition, Macmillan, New York.

Bremner, J.M. (1996). Nitrogen total. In: Sparks, D.L. (ed) *Methods of Soils Analysis, parts, Chemical method*. 2nd ed, SSSA Book Series No. 5, SSSA, Madison, W1 1085– 1125.

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. 62p.

Emeka, D.O. and Abbas, B. (2011). *The Geography of Taraba State, Nigeria.* Australia. LAP Lambert Academic Publishing Ltd .

FAO (Food and Agriculture Organization) (2006). *Guide lines for Soil profile Description,* 5th edition. AGLS, FAO, Rome.

FAO (Food and Agriculture Organization) (1999). World Reference Base for Soil Resources. World Soil Resources Rep. Vol. 84. Food and Agricultural Organisation of the UN, Rome, Italy, 61p.

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

FDALR [Federal Department of Agricultural Land Resources] (1985). The reconnaissance soil survey of Imo State (1: 250, 000). Owerri: Federal Department of Agricultural Land Resources. 133 pp.

Gee, G.W. and Or, G. (2002). Particle size, In: Dane, J.H, & Topp, G.C. (eds). *Methods of Soil Analysis. Part 4 Physical methods.* Soil Science Society of America Madison, WI, Book Series No. 5 ASA and SSA 255 – 293.

Gili, A.A., Trucco, R., Niveyro, S., Balzarini, M., Estelrich, D., Quiroga, A. and Noellmeyer, E. (2010). Soil texture and carbon dynamics in savannah vegetation patches of Central Argentina. *Soil Science Society of America Journal,* **7**4(2): 647-657.

Gregorich, E.G., Greer, K.J., Anderson, D.W. and Liang, B.C. (1998). Carbon distribution and losses: Erosion and deposition effects. *Soil Tillage Res*., 47: 291 – 302.

Grossman, R.B. and Reinsch, J.G. (2002). Bulk density and linear extensibility. In: *Methods of Soil Analysis part 4. Physical Methods*. Book Series. No. 5. ASA and SSA Madison, WI, pp. 201-228.

Hassan, A.M., Raji, B.A., Malgwi, W.B. and Agbenin, J.O. (2011). The Basaltic soils of Plateau State, Nigeria. Properties, classification and management practices. In: M.K.A., Adebayo, A.J. Odofin, A.O. Osunde, A. Bala and S.O. Ojeniyi (Eds). *Soil Resources Management, Global Climate Change, and Food Security. Proceedings of the 35th Annual Conferences of SSSN/*Minna, Nigeria March, seventh to11th, 2011.

Havlin, J.L., Beaton, J.D., Tisdale, S.L. and Nelson, W.L. (2005). *Soil Fertility and Fertilizers* (7th Ed) Upper Saddle River, New Jersey. 515pp

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.

Klute, A. (1986). *Methods of Soil Analysis*. No. 9, Part 1: *Physical and Mineralogical Properties.* Am. Soc. Agron., Madison, WI, USA.

Landon, J.R. (Ed) (1991). *Booker tropical soil manual: A Hand book 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., Asawalam, 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. Nov. 2003, 4th – 7th pp. 316-322

McLean, E.O. (1982). Aluminum. In: C.A. Black (Ed.). *Methods of Soil Analysis*. Agran. No. 9. Part II. Am. Soc. Agron, Madison, Wisconsin USA. Pp. 978 – 998.

Madueke, C.O., Asadu, C.L.A., Eshett, E.T., Akamigbo, F.O.R., Maduekeh, E.C.C., Onyeokoro, C., Maduka, E.I., Obi, P.C. and Okene, C. D. (2012). Characterization and Classification of soils on a toposequence formed from the coastal plain sands of South-eastern Nigeria. *Proceedings of the 36th Annual Conference of Soil Science Society of Nigeria*

Miller, R.W. and Grardiner, D. T. (2001). *Soils in our environment.* 9th ed. Englewood Cliffs, New Jersey: Prentice-Hall Inc.

Miller, R.W. and Donahue, R.L. (1992). *Soil: An introduction of Soils and Plant growth* 6th ed Prentice Hall of India, New Delhi.

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

Nelson, D. W, and Sommers, L. E. (1996). Total Carbon, Organic Carbon Organic Matter. In: O. L. Sparks (ed). *Methods of Soil Analysis Part 3, Chemical Methods.* Soil Science Society of America Book Series Number 5. American Society of Agronomy, Madison WIE, pp 960 – 1010.

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

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.

Nwaka, G.I.C. (1990). Studies on dune soils of Borno State. Morphology, classification, and physical properties. *Annals of Borno*, 6(7) 198-204.

Obasi, S. N., Osujieke, D. N., Imadojemu, P. E. and Ezendu, I.E. (2015). Characterization and Classification of Soils along Otamiri Watershed in Umuagwo, Southeastern Nigeria *FUTO Journal Series* Vol. 1(2): 62 – 68.

Odunze, A. C. (2006). Soil properties and management strategies for some sub-humid savanna zone Alfisols in Kaduna State, Nigeria. *Samaru Journal of Agricultural Research* 22: 3-14.

Ogunkunle, A.O. (1986). Spatial variability of some chemical properties in two mapping units in Southern Nigeria. *Soil Survey Land Evalu.* 6:26 – 32.

Okusami, T.A and Oyediran, G.O. (1985). Slope-soil relationship on aberrant toposequence in Ife area of southeastern Nigeria variabilities in soil properties. *Ife J. Agric*; 7:1-15.

Olsen, S.R. and Sommers, L.E. (1982). Phosphorus. In: *Methods of Soil Analysis* part 2. Page, A.L, Miller, R.H., Keeney, D.R. (eds). America Society of Agronomy Madison Wisconsin. Pp 15-72.

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.

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

Paulos, D. (1996). Availability of phosphorus in the coffee soil of Southwest Ethiopia. Pp. 119-1 29. *In* Tekalign, M., and Mitiku, H. (Eds.) Soil. The Resource Base for Survival. *Proc. of the Second Conference of the Ethiopian Society of Soil Science.* 23-24 September 1993, Addis Ababa, Ethiopia .

Schoenholtza, S.H., Miegroetb, H.V. and Burger J.A. (2000). A review of chemical and physical properties as indicators of forest soil quality: Challenges and opportunities. Department of Forestry, Mississippi State University, USA.

Soil Survey Staff (2014). Keys to Soil Taxonomy 12th Edition. USDA-NRCS, Washington DC

Soil Survey Staff, (2013). *Simplified Guide to Soil Taxonomy*. USDA-Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE.

Summer, M. E. and Miller, W. P. (1996). Cation Exchange Capacity. In: D.L. Sparks (eds) Methods of soil analysis. Part 2: Chemical Properties. (3rd ed) ASA, SSSA, CSSA, Madison, W.I. Pp

1201 – 1229.

Thomas, G. W. (1996). Soil pH and Soil Acidity. In: *Methods of Soil Analysis, part 3 Chemical Methods.* L. D. Sparks (eds) SSSA book series 159-165

Thomas, G. W. (1982). Exchangeable Cations. In: A. L. Page; R. H. Miller and D. R. Keeney (eds.). *Methods of Soil Analysis, Part 2, Chemical and Microbiological properties*. Madison, Wisconsin. Pp. 159 – 164.

Tolessa, D. (2006) Effect of tillage system, residue management and nitrogen fertilization on maize production in western Ethiopia. Dissertation for Award of Ph.D. degree at the University of the Free State, Bloemfontein, South Africa. 200 pp.

Ukut, A.N., Akpan, U.S. and Udoh, B.T. (2014). Characterization and classification of soils in steep-sided hills and sharp-crested ridges of Akwa Ibom State, Nigeria. *Net J. of Agric. Sci.* 2(2): 50 – 57.

Wakene, N. (2001). Assessment of important physicochemical properties of dystric udalf (dystric Nitosol) under different management system in Bako area, Western Ethiopia. Dissertation for Award of MSc degree at Alemaya University, Ethiopia, 115 pp.

Weil, R.R. and Brady, N.C. (2016). *The Nature and Properties of Soils.* (15th Ed) Pearson Education. ISBN: 978-0133254488.

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.

Yakubu, M. and Ojanuga, A.G. (2013). Pedogenesis, weathering status and mineralogy of the soils on Ironstone Plateaux (Laterites), Sokoto Nigeria. *Bayero Journal of Pure and Applied Science* 6(2): 93 – 100.