Profile Distribution of Physical and Chemical Soil Properties in Izombe, Rainforest Zone of Nigeria.

Donald Nweze Osujieke*, Pedro Ezemon Imadojemu*, Michael Akpan Okon, Obinna Marcellinus Okeke****

**Department of Soil Science and Land Resources Management, Federal University, P.O. Box, 1020, Wukari, Taraba State, Nigeria*
***Department of Soil Science and Technology, Federal University of Technology Owerri, P M B 1526 Owerri, Imo State*
Corresponding Author: Donald Osujieke, e-mail: bigdonax@yahoo.com

Abstract:

The assessment of the distribution of soil physico-chemical properties facilitates the use of proper soil management practices. Hence, the study was conducted in Izombe rainforest of Nigeria to ascertain the profile distribution of physical and chemical soil properties. Samples were collected from two profile pits base on horizon differentiation for laboratory analyses using standard procedures. Data generated were analyzed statistically using coefficient of variation and correlation. The result indicated that sand recorded 760 g kg^{-1} in pedon 1, 730.20 g kg^{-1} in pedon 2 and was predominant in the soil with higher amount at the surface horizon while clay and silt increased down the pedons. Bulk density ranges from 1.14 – 1.79 g cm^{-3}. The AB horizon was the least acidic of the pedons. Most soil chemical properties decreased down the profile. Sand and pH had low variation (≥4.80 % ≤12.60 %) while silt, organic carbon, total nitrogen had high variation (≥41.52 % ≤79.58 %) among the horizons. Fe, Mn and Zn had moderate to high variation among the horizons. Clay correlated negatively and highly significantly (r= -0.829, r= -0.883, p= 0.01) available phosphorus and Fe. Clay also had a positive significant correlation (r= 0.665, r= 0.641, p= 0.05) with bulk density and base saturation. pH had a significant negative relationship (r= -0.708, p= 0.05) with base saturation while cation exchange capacity had a highly significant positive correlation (r= 0.877, p= 0.01) with Pb. Fe had a negative and highly significant relationship (r= -0.838, p= 0.01) with Zn. The result indicated that most mineral element are domiciled in the A horizon and such demand proper management practices for soil nutrients sustainability.

Keywords: distribution, horizon, rainforest, profile pit, soil properties, variation.

Introduction

A vertical cross section through the pedosphere shows varying degree of changes taking place at both surface horizon and subsurface horizons. These changes influence the utilization of these soils for agronomic, engineering, environmental and aesthetic uses. Variation in soil horizons exists at many scales with different dominant controlling factors. Parent material, climate, and geological history are major factors affecting the distribution of soil properties at continental scale (Akamigbo and Asadu, 1983). Understanding the vertical distribution of soil properties along profile depths could help to predict the proneness of such soils to degradation. Knowledge of their variability is essential in applying location-specific land management interventions (Onweremadu *et al.*, 2015). Soil properties differ among soil profile horizons due to transport and storage of water and nutrient across and within the soil profile. Researchers (Oku *et al.*, 2010) reported that soil pH increased with depth and it is least variable, irrespective of depth. They also found variability of organic matter, total nitrogen, available phosphorus, and CEC to increase with depth and ranged between moderate and high.

Soil is likely to show great variability in their physical, chemical, biological and mineralogical properties because the soil is a heterogeneous unit. Knowledge of variability of soil properties is very indispensable as this determine the productivity and usage of the area. A study of the variability trends of soils is essential in order to highlight the soil potentials and enhance their management and productivity (Mahdi and Mark, 2006; Arnold, 1996). Ogunkunle (1993), working on the Alfisols of southwestern Nigeria, observed that soil pH was the least variable (low variability) property, irrespective of depth. Accordingly, horizons may differ in organic matter content, structure, texture, pH, base saturation, cation exchange capacity (CEC) and bulk density as well as many other soil physical and chemical properties. The rate of soil variation brings about rate of degradation from one location to another due to the composition of soils of the area. There is need to maintain the soil ecosystem through efficient land/soil management practices that will promote food security, soil nutrient balance and sustainable environment. Hence, the work is aimed to assess horizon variations in selected physical and chemical properties of Izombe soils.

LEGEND	
	Study Area
	Inter State Road
	Intra State Road

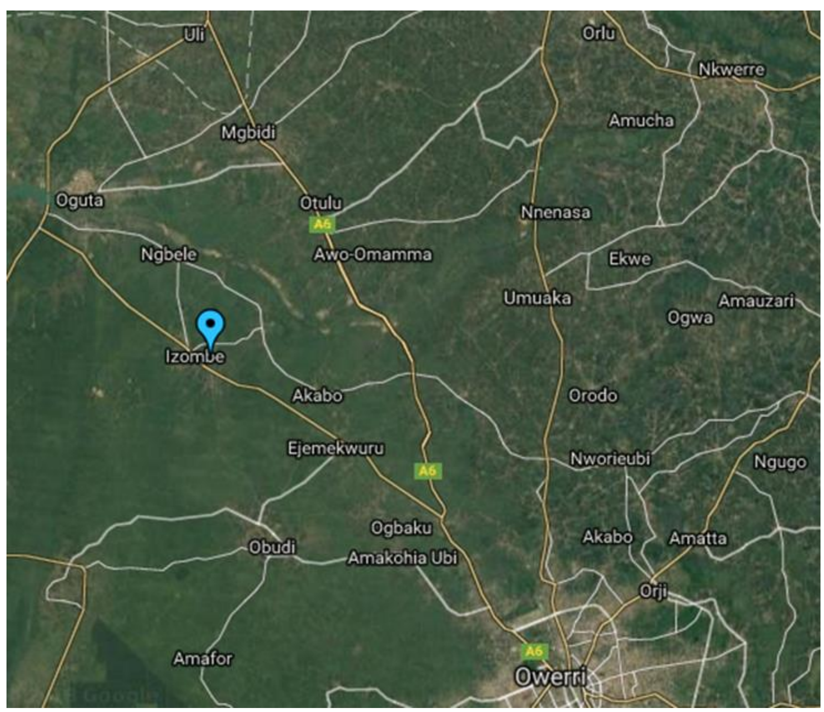

Fig. 1. *Location map of the study area (Google Imagery, 2018)*

Materials and Methods

Study area

The study area as shown in fig 1 is Izombe in Oguta Local Government Area in Imo state south-east, Nigeria. It lies between latitude $5^o\ 12'$ and $5^o\ 56'$ N and longitude $6^o\ 38'$ and $7^o\ 25'$ E. The annual rainfall ranges from 2500 mm to 3000 mm with mean temperature of 28 ^oC (NIMET, 2015).The original vegetation of the study area is the modified tropical rainforest which has been altered by human activities. The greater part of the area now is conserved with trees, shrubs, legumes. The geology of the area consists of alluvium which is marine deltaic deposits (Lekwa, 1985).

Field study and sample collection

A reconnaissance study was carried out on the study areas. Subsequently, free survey technique was used to sink two (2) soil profile pits in the study area. Samples were collected following the guideline of FAO, (2006). Also, core samples were collected for bulk density determination. The samples were prepared for laboratory analyses.

Laboratory analyses

Particle size distribution was determined by hydrometer method (Gee and Or, 2002). Bulk density was determined by core method (Grossman and Reinsch, 2002). Saturated hydraulic conductivity was determined using a constant head method (Klute, 1986). Soil pH was determined using 1:2.5 soil – liquid ratio using a pH meter (Thomas, 1996). Organic carbon was determined by wet digestion method (Nelson and Sommers, 1982). Total nitrogen was determined by micro-Kjeldah digestion technique (Bremner, 1996). Available phosphorous was determined using Bray II method (Olsen and Sommers, 1982). Exchangeable acidity was determined by the method described by MacLean (1982). Exchangeable bases were determined by neutral ammonium acetate procedure buffered at pH 7.0 (Thomas, 1982). Available micro nutrients (Fe, Pb, Mn and Zn) were extracted by DTPA as described by Sahlemedhin and Taye, (2000) and all these micro nutrients were measured by atomic absorption spectrophotometer.

Statistical analyses

Coefficient of variation as used by Wilding *et al.* (1994) was used to estimate the degree of variability existing among soil properties in the study sites where $CV < 15$ % = low variation, $CV \geq 15$ % ≤ 35 % = moderate variation, $CV > 35$ % = high variation. Correlation was also used to compare relationship between selected soil parameters.

Results and Discussion

The result (Table 1) indicated that sand fraction recorded (712 – 792) g kg^{-1} and (682 – 793) g kg^{-1} in pedon 1 and pedon 2, respectively. Sand fraction also recorded low variation (4.80 %, 9.20 %) in both pedons. The sand decreased down the profile with no specific trend in pedon 1 while in pedon 2 it decreased in a specific trend. It was observed that the highest sand fraction was indicated in the Ap and AB horizons of pedon 1 and Ap horizon of pedon 2. The predominance of sand over other soil fractions could be attributed to parent material, climate and land-uses. This is in concurrence with the findings of (Obasi *et al.*, 2015) on soils underlain by coastal plain sand in some agro-ecology in southeastern Nigeria. The low variation could be associated with homogeneity of the soil. Soil with high sand content are associated with nutrient leaching, high infiltration and infertility.

Table 1. *Soil physical properties of the studied site*

Horizon	Depth cm	Sand	Silt g kg^{-1}	Clay	TC	Ksat cm/m	BD g cm^{-3}	Po %
				Pedon 1				
Ap	0-30	792.0	40.0	168.0	SL	0.0334	1.14	54.81
AB	30-60	792.0	20.0	188.0	SL	0.0198	1.52	59.60
Bt_1	60-90	772.0	20.0	208.0	SCL	0.0114	1.64	48.25
Bt_2	90-120	712.0	60.0	228.0	SCL	0.0194	1.58	55.18
Bct	120-180	732.0	40.0	228.0	SCL	0.0430	1.79	58.46
Mean		**760.0**	**36.0**	**240.0**		**0.0300**	**1.53**	**55.26**
CV		**4.80**	**46.48**	**12.78**		**49.69**	**15.78**	**8.01**
				Pedon 2				
Ap	0-20	793.0	40.0	167.0	SL	0.0491	1.59	42.59
AB	20-50	782.0	30.0	188.0	SL	0.0480	1.59	42.40
Bt_1	50-75	752.0	20.0	228.0	SCL	0.0582	1.69	21.86
Bt_2	75-105	692.0	60.0	248.0	SCL	0.0590	1.70	21.86
Bct	105-180	632.0	10.0	268.0	SCL	0.0690	1.70	21.56
Mean		**730.2**	**32.0**	**219.8**		**0.0600**	**1.65**	**30.05**
CV		**9.20**	**60.11**	**19.01**		**15.09**	**3.54**	**37.79**

TC= textural class, SL= sandy loam, SCL= sandy clay loam, Ksat= saturated hydraulic conductivity, BD= bulk density, Po= porosity

Silt fraction recorded high variation in both pedons (46.48 %, 60.11 %) but also had no specific trend of decrease with soil depth. The high variation could be associated to intense rainfall that facilitated sorting of soil particles. The silt content is in conformity with the findings of Madueke *et al.* (2012) that soils of southeastern Nigeria are low in silt as a result of the high degree and extent of weathering and leaching they have undergone.

Clay fraction (Table 1) recorded (168 – 223) g kg^{-1} and (167 - 268) g kg^{-1} in pedon 1 and 2, respectively. However, clay increased down the profile while it recorded low variation in pedon 1 and moderate variation in pedon 2. The clay content of the soils increases with the increasing rainfall and annual temperature. The variation could be attributed to rate of clay migration, drainage pattern and soil structure. However, Obi and Akinbola (2009) reported that increase in clay with soil depth could be attributed to clay translocation and erosion in surface horizon. This is similar to the findings of (Osujieke *et al.*, 2017) in soils of southeastern Nigeria. It was observed that the Bt horizon had high clay content which is an indication of its argillic properties. Higher clay content in the subsurface than the surface horizons in the pedons with subsequent formation of argillic subsurface horizon may be attributed to sorting of soil materials by eluviations and illuviation processes of soil formation.

K_{sat} recorded mean of 0.03 cm m^{-1} and 0.06 cm m^{-1} for pedon 1 and 2 but was very slow according to the rating (<0.2 cm m^{-1}) of Landon, (1991). Ksat is influenced by soil texture and structure which in turn is influenced by total porosity and pore size distribution. Also, K_{sat} recorded high variation (49.69 %) in pedon 1 and moderate variation (15.09 %) in pedon 2. The rate of variation could be associated with soil texture, bulk density, available pore spaces and intense rainfall. The result showed that soils of Bct horizon conducts more water over other horizons in both pedons. The implication of slow hydraulic conductivity in soils is that the soil will have high runoff and more erosion.

Bulk density (Table 1) recorded (1.14 - 1.79) g cm^{-3} and (1.59 - 1.70) g cm^{-3} in pedon 1and 2, respectively. Also, bulk density increased down the profile but with an irregular trend in pedon 1. The bulk density values in this soil unit were lower than 1.85 g cm^{-3}, a value considered as very high by SSS, (2006) to impede root penetration. However, the value of bulk density is low when compared with findings of (Onweremadu *et al.*, 2011) in soils of southeastern Nigeria. However, the lower values at the surface soil were probably due to presence of organic matter content. The increase in bulk density with profile depth could be associated to decrease in organic matter content, less aggregation and compaction caused by the weight of the overlying soil layers, presence of parent material and low faunal and root activities. Low bulk density influences high porosity which is an indication that soils are not compacted.

Soil pH (Table 2) was slightly-strongly acidic in both pedons according to the ratings of Chude *et al.* (2011). The pH had an irregular pattern of distribution with soil depth. The AB and Bct horizon is the least and most acidic, respectively. Soil pH recorded low variation (12.60 %, 9.52 %) in both pedons which may have resulted from the parent material and intense rainfall which wash off most basic cations. Several researchers (Ndukwu *et al.*, 2012) have reported on low variation of soils of eastern Nigeria and it is the consequence of acidic nature of the parent rocks, coupled with the influence of the leached profile under high annual rainfall condition.

Organic carbon was low according to the ratings of (Akinrinde and Obigbesan, 2000) and recorded range of 0.14 % - 0.64 % and 0.18 % - 0.63 % in pedon 1 and 2. However, the level of organic carbon of the studied pedons was low compared with the findings (Amanze *et al.*, 2016) on soils of southeast Nigeria. Also, Ogeh and Ukodo, (2012) reported low OC in soils of rainforest zone of Nigeria. Organic carbon (Table 2) recorded high variation (56.42 %, 79.20 %) which could be attributed to higher organic matter deposit on soil surface, rate of decomposition and leaching due to intense rainfall. This is conformity with the findings of (Ukaegbu *et al.*, 2015) on soils of southeast Nigeria. However, OC decreased down the profile but with an irregular pattern in pedon 2. The Ap and B_{t1} horizon recorded the highest level of OC in pedon 1 and 2, respectively. The OC content on Ap horizon could be attributed to the organic material deposited on the surface horizon while that of the B_{t1} could be as a result of other carbon attributors in the soil.

Total nitrogen had range of 0.056 % - 0.07 % and 0.028 % - 0.098 % in pedon 1 and 2, respectively. The total nitrogen level was low according to the ratings of (Enwezor, 1990). The low content of total N in the soils could be attributed to low organic matter of these soils, since inorganic N is accounting for only a small portion of total N in soils (Almu and Audu 2001). The low amount of total N reflects the amount of organic carbon in the soils. Nitrogen can be introduced into the soils by natural processes such as lightening, decay of animal and plant tissues while the main cause of N deficiency in tropical soils is intense leaching and erosion due to the intense tropical rainfall.

Available phosphorus recorded mean of 21.74 mg kg^{-1} and 18.25 mg kg^{-1} in the studied pedons and were high according to the ratings (>15 mg kg^{-1}) of (Enwezor, 1990). Available P was high compare with the findings of (Osujieke *et al.*, 2016) in soils of southeast Nigeria. The available phosphorus recorded moderate variation (20.70 %, 23.09 %) in both pedons which could be attributed to organic material deposit, rate of fixation and leaching. The result is contrary to the findings of (Busari *et al.*, 2005; Uzoho and Oti, 2005) that have reported high P deficiency for tropical soils.

Exchangeable bases (Ca, Mg, Na, K) recorded mean of (2.25, 1.29, 0.095, 0.104) cmol kg^{-1} in pedon 1 and (2.64, 1.40, 0.08, 0.09) cmol kg^{-1} in pedon 2. Ca was low, Mg was moderate, Na and K were very low according to the rating of Landon (1991). The levels of exchangeable cations are dependent on the nature of parent materials and extent of weathering. The exchangeable bases were within the range reported by Amanze *et al.* (2016) in soils of southeast Nigeria. Exchangeable cations had no specific trend of distribution down the profile pits. The Ca and Mg had low variation in both pedons while Na and K had low variation in pedon 1 and high variation in pedon 2. The variation among the exchangeable cations is associated with leaching and runoff wash of the basic cations, pH level of the soil and fixation rate of the cations.

Cation exchange capacity had range of (2.20 – 4.40) cmol kg^{-1} in pedon 1 and (3.00 – 4.40) cmol kg^{-1} in pedon 2. CEC was low according to the ratings of (Esu, 1991) on tropical soil. The CEC result was low compared with the works of (Amanze *et al.*, 2016) on soils of southeast Nigeria. The low CEC could be due to the domination of low activity clay such as kaolinite in these soils which resulted from highly weathered parent rock. This is in concurrence with the finding of Akinrinde and Obigbesan, (2000) on soils of southern Nigeria. Also, Ukpong, (2000) stated that low level of cation exchange capacity in soils could be associated with tidal imports, runoff and seepage. However, CEC decreased down the profile in no specific trend. The Ap horizon recorded the highest level of CEC which suggested that organic matter could have been its major attribute. The CEC had moderate variation (29.06 %, 16.40 %) in pedon 1 and 2 which could be associated with organic matter level and runoff. Hence, (Enwezor, 1990; Esu, 1991) reported that organic matter is the major attribute of CEC in soils of southeastern Nigeria. Lombin *et al.* (1991) also reported that organic matter content was a major contributor to the CEC of the soil. Therefore, there is need to incorporate organic material into the soil to enhance the exchange site.

Available Fe was below the critical limit recommended by (Kparmwang *et al.,* 2000, Deb and Sakal, 2002). The Fe content was low compared with the findings of (Ahukaemere *et al.,* 2016; Ndukwu *et al.,* 2016) on soils of southeastern Nigeria but was high when compared with the findings of (Mulima *et al.,* 2015) in soils of Northeast Nigeria. The coefficient of variation showed that available Fe recorded high variation (37.82 %) in pedon 1 and moderate variation (32.77 %) in pedon 2. The variation could be associated with rate of mineralization and intense rainfall activities which is associated with study area. Fe content decreased down the profile but had no specific trend in pedon 1.

Lead (Pb) recorded (0.089 – 0.630) mg kg^{-1} in pedon 1 and (0.216 – 0.658) mg kg^{-1} in pedon 2. The Pb content was above the critical limit recommended by (Deb and Sakal, 2002; Esu, 1991). Pb recorded high variation (72.67 %, 46.57 %) in both pedons which be attributed to the fixation rate and the amount released by organic matter and mineral matter. The Pb decreased down the profile in an irregular trend. The Pb level was lower than the result reported by (Osakwe and Okolie, 2015; Das *et al.,* 2015) in soils of southern Nigeria. The lead level of the soil is not at toxicity level and thereby will not be harmful to the soil

Mn recorded mean of 2.56 mg kg^{-1} and 2.27 mg kg^{-1} for soils under pedon 1 and 2, respectively. Mn was below the critical limit recommended by (Sims and Johnson, 1991). Hence, the available Mn is suitable for crop production and environmentally friendly. It had an irregular pattern of decrease with soil depth and recorded the highest level in Bt1 horizon in Pedon 1 and Ap horizon in pedon 2. These values are within the range values reported by (Udoh *et al.,* 2008) in soils of southern Nigeria. However, Mn had moderate variation (27.53 %) in pedon 1 and low variation (10.86 %) in pedon 2. The variation could be attributed to soil textural class and rate of porosity. The AB horizon had the least Mn in both pedons while the B_{t1} horizon recorded the highest level of Mn in pedon 1 while the Ap horizon recorded the highest Mn level in pedon 2.

Zinc recorded range of (0.245 – 0.640) mg kg^{-1} in pedon 1 and (0.247 – 0.520) mg kg^{-1} in pedon 2 with no specific trend of increase down the profile. Zn level is below the critical limit according to the ratings of (Esu, 1991; Kparmwang *et al.,* 2000; Deb and Sakal, 2002) which is an indication of non toxicity in the soil and as such will pose no threat to the environment. The value of Zn are below the range reported by (Udoh *et al.,* 2008) in soil of southeastern Nigeria but above the range reported by Oyinlola and Chude, (2010) in soils of Northeastern Nigeria. The available Zn was more predominant at the B horizons which could be attributed to illuviation of materials.

Table 2. Soil chemical properties of the studied site

Horizon	Depth	pH(H_2O)	OC	TN	Av.P	Ca	Mg	Na	K	TEA	CEC	BS	Fe	Pb	Mn	Zn
	cm		→	% ←	mg kg^{-1} →				cmol kg^{-1} ←			(%)	→		mg kg^{-1} ←	
								Pedon 1								
Ap	0-30	5.11	0.64	0.056	24.30	2.80	1.26	0.078	0.102	1.06	4.40	79.81	3.68	0.630	2.691	0.320
AB	30-60	6.26	0.55	0.07	28.10	2.40	0.80	0.082	0.122	0.97	3.20	72.43	3.05	0.284	1.843	0.245
Bt_1	60-90	5.48	0.27	0.042	16.60	1.60	1.20	0.113	0.112	0.70	2.40	81.12	3.05	0.145	3.702	0.280
Bt_2	90-120	5.72	0.27	0.028	19.40	2.46	1.60	0.087	0.097	0.53	2.80	88.80	1.28	0.300	2.325	0.640
Bct	120-180	4.44	0.14	0.014	20.30	2.00	1.60	0.113	0.087	0.35	2.20	91.52	1.88	0.089	2.246	0.440
Mean		**5.40**	**0.37**	**0.03**	**21.74**	**2.25**	**1.29**	**0.095**	**0.104**	**0.72**	**3.00**	**82.74**	**2.59**	**0.29**	**2.56**	**0.39**
CV		**12.60**	**56.42**	**79.58**	**20.70**	**20.52**	**25.71**	**18.07**	**12.99**	**41.06**	**29.06**	**9.19**	**37.82**	**72.67**	**27.53**	**41.66**
								Pedon 2								
Ap	0-20	5.12	0.63	0.055	24.20	2.80	1.20	0.018	0.102	1.05	4.40	79.81	3.69	0.633	2.593	0.331
AB	20-50	6.20	0.54	0.069	20.96	2.40	0.80	0.080	0.122	0.94	3.20	72.43	3.17	0.285	1.942	0.247
Bt_1	50-75	5.28	1.60	0.098	16.80	2.80	1.20	0.122	0.123	0.70	3.00	85.78	2.16	0.375	2.255	0.520
Bt_2	75-105	5.66	0.46	0.056	15.00	2.40	1.80	0.096	0.071	0.80	3.80	84.65	1.87	0.216	2.415	0.490
Bct	105-180	4.88	0.18	0.028	14.30	2.80	2.00	0.104	0.041	0.88	4.20	84.89	1.85	0.658	2.165	0.410
Mean		**5.43**	**0.68**	**0.060**	**18.25**	**2.64**	**1.40**	**0.08**	**0.09**	**0.87**	**3.72**	**81.51**	**2.55**	**0.43**	**2.27**	**0.40**
CV		**9.52**	**79.20**	**41.52**	**23.09**	**8.30**	**34.99**	**47.47**	**38.52**	**15.26**	**16.40**	**6.85**	**32.77**	**46.57**	**10.86**	**28.19**

OC= organic carbon, TN= total nitrogen, Av.P= available phosphorus, TEA= total exchangeable acidity, CEC= cation exchange capacity, BS= base saturation

Table 3. *Correlation matrix of selected soil properties of the studied pedons*

	Sand	Silt	Clay	Ksat	BD	Po	pH	OC	TN	Av.P	CEC	BS	Fe	Pb	Mn	Zn
Sand	1															
Silt	-0.038	1														
Clay	-0.934**	-0.032	1													
Ksat	-0.517	-0.103	0.442	1												
BD	-0.502	-0.097	0.665*	0.350	1											
Po	0.564	0.181	-0.582	-0.804**	-0.403	1										
pH	0.333	0.042	-0.269	0.361	-0.178	0.103	1									
OC	0.340	-0.200	-0.191	0.267	-0.117	-0.385	0.126	1								
TN	0.239	-0.286	-0.041	0.211	0.316	-0.439	0.537	-0.713*	1							
Av.P	0.753*	0.028	-0.829**	-0.451	0.570	0.726*	0.286	0.053	-0.016	1						
CEC	-0.072	0.029	-0.210	0.473	-0.451	-0.357	-0.068	0.116	-0.090	0.147	1					
BS	-0.600	0.348	0.641*	0.206	0.438	-0.169	-0.708*	-0.132	-0.391	-0.567	-0.290	1				
Fe	-0.802	-0.267	-0.883**	-0.220	-0.606	0.294	0.179	0.183	0.084	0.627	0.393	-0.747**	1			
Pb	-0.068	-0.207	-0.208	0.395	-0.486	-0.268	-0.234	0.195	-0.139	0.151	0.877**	-0.169	0.351	1		
Mn	0.626	-0.006	-0.132	-0.420	-0.116	0.079	-0.230	-0.151	-0.270	-0.265	-0.133	0.146	0.260	-0.103	1	
Zn	-0.584	0.519	0.619	0.205	0.333	-0.282	-0.267	0.104	-0.082	-0.500	-0.176	0.822	-0.838**	-0.100	-0.127	1

BD= bulk density, OC= organic carbon, TN= total nitrogen, Av.P= available phosphorus, CEC= cation exchange capacity, BS= base saturation, **= Correlation is significant at the 0.01 level, *= Correlation is significant at the 0.05 level.

The sand fraction had positive and significant correlation (r= 0.753, p= 0.05) with the available phosphorus while it had negative and highly significant relationship (r= - 0.934, p= 0.01) with the clay fraction. The clay fraction had positive and significant relationship with the bulk density (r= 0.665, p= 0.05) and the base saturation (r=0.641, p= 0.05), while it had negative and highly significant relationship with available phosphorus (r= - 0,829, p= 0.01) and Fe (r= - 0.883, p= 0.01). Ksat had negative and highly significant relationship (r= -0.804, p= -0.01) with total porosity. This relationship may be associated to the textural composition of the soil.

However, Brady and Weil (2002) stated that the rate of hydraulic conductivity is dependent on soil pores. The pH had negative and significant relationship (r= -0.708, p= 0.05) with base saturation. This relationship could be associated to the leaching of most of the base forming cations thereby leaving the exchange complex dominated by acidic cations. However, the pH had negative relationship (r= -0.234, r= -0.230, r= -0.267) with Pb, Mn and Zn but related positively (r= 0.179) with Fe. Organic carbon correlated negatively and significantly (r= -0.713, p= 0.05) with total nitrogen. This may be due to the factor of age of the soil organic matter, the prevailing climatic condition, N-leaching and volatilization and microbial N-assimilation. The CEC correlated positively and highly significantly (r= 0.877, p= 0.01) with Pb. Bulk density correlated significantly positive (r= 0.665, p= 0.05) with clay but had negative correlation (r= -0.117) with OC. However, Fe had negative and highly significant relationship (r= -0.883, r= -0.747, r= -0.838, p= 0.01) with clay, base saturation and Zn. 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

Conclusion

This study has shown soil physicochemical properties and the variation among the horizons of the studied pedons. The organic carbon, total nitrogen, and exchangeable basic cation (Ca, Na, K) were predominantly low while available phosphorus was high. Also, Fe, Mn and Zn were below the critical limit required in the soil. Soil properties most be considered for sustainable agriculture and proper land management practices that will promote the environment. Application of organic matter will be essential for most of the nitrogen and basic cation to be utilized by crops for quality productivity.

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Reference

Ahukaemere, C.M., B.U. Uzoho, I.F. Irokwe, B.N. Ndukwu, D.N. Osujieke, 2016. Iron, zinc, copper and manganese Availability in four contrasting hydromorphic Soils of Egbema, South-Eastern Nigeria. Agrochemistry and Soil Science. No. 85. Kharkiv: NSC ISSAR, Pp. 27 – 34.

Akamigbo, F.O.R., C.L.A. Asadu, 1983. Influence of parent materials on soil southeastern Nigeria. East African Forestry Journal, 48: 8 – 11.

Akinrinde, E.A., G.O. Obigbeson. 2000. Evaluation of fertility status of selected soils for crop production in five ecological areas of Nigeria. Proc. 26th Annual Conf. Soil. Sci. Soc. Nig. Ibadan, Oyo State. Pp. 279 – 288.

Almu, H., M.D. Audu. 2001, Physico-chemical properties of soil of Awa irrigation project are of Kano State. Department of Soil Science, Kano University of Technology Wedi in: Proceedings of the 27th Annual Conference of Soil Science Society of Nigeria. Pp. 13 – 25.

Amanze, C.T., P.C. Oguike, G. Lekwa, 2016. Characterization and classification of soils at Mbara Ubowlla, Emekuku in Owerri North LGA, Imo State. Nig. J. Soil and Env. Res. Vol. 14: 245 – 255.

Arnold, R.W., 1996. Soil Survey Reliability: Minimizing the Consumer's risk in W. G. Nettleton, A. G. Hornsby, R. B. Broen, & T. L. Coleman (eds), Data Reliability and Risk Assessment in Soil Interpretations. SSSA Spec. Publ. 47, SSSA, Madison, WI. Pp 13 – 20.

Bremner, J.M., 1996. Nitrogen total. Sparks, D.L. (ed) methods of soils analysis, parts, chemical method. 2nd ed, SSSA Book Series No. 5, SSSA, Madison, W1 1085–1125.

Busari, M.A., F.K. Salako, R.A. Sobulo, M.A. Adetunji, N.J. Bello. 2005. Variation in Soil pH and Maize Yield as Affected by the application of Poultry Manure and Lime. In Managing Soil Resources for Food and Sustainable Environment. Proc. of 29th Annual Conf. Soil Sci. Soc. Nig. Pp 139 – 142.

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

Das, U., P. N. Vinayachandran, A. Behara, 2016. Formation of the southern Bay of Bengal cold pool, Springer Berlin Heidelberg Vol. 47(5): 2009 – 2023. https://doi.org/10.1007/s00382-015-2947-9.

Deb, D.L., R. Sakal, 2002. Micronutrients. In: Indian Society of Soil Science. Indian Research Institute, New Delhi. Pp. 391 – 403.

Enwezor, W.O., A.C. Ohiri, E.E. Opuwahribo, E.J. Udo. 1990. Literature review on soil fertility investigations in Nigeria. Niger Agric. J. 30: 59 – 75.

Esu, I.E., 1991. Detailed soil survey of NIHORT farm at Bunkure Kano state, Nigeria. Institute of Agricultural Research, Zaria. 72p.

FAO, 2006. Guidelines for soil profile description, 5th edition. AGLS, FAO, Rome.

Gee, G.W., G. Or., 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.

Grossman, R.B., J.G. Reinsch, 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.

Klute, A., 1986**.** Water retention: laboratory methods analysis. In: Methods of Soil Analysis (Ed. A. Klute). ASA Press, Madison, WI, USA.

Kparmwang, T., V.O. Chude, B.A. Raji, A.C. Odunze, 2000. Extractable micronutrients in some soils developed on sandstone and shale in the Benue valley Nigeria. Nigeria Journal of Soil Research. 1: 42 – 48.

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, G., 1985. Properties, Classification and site suitability evaluation of two soil mapping units in the guinea savanna, Nigeria. Soil Science Society of Nigeria. In: Babalola, O. (ed,), Nigeria journal of soil science. 91p.

Lombin, L.O.J., J. Adepetu, K.A. Ayotade, 1991. Complementary use of Organic Manures and in Organic Fertilizer in Arable Crop Production. Organic Fertilizer in the Nigerian Agriculture: Present and Future. Proceedings of a National organic Fertilizer Seminar, Kaduna Nigeria.

Madueke, C.O., C.L.A. Asadu, E.T. Eshett, F.O.R. Akamigbo, E.C.C. Maduekeh, C. Onyeokoro, E.I. Maduka, P.C. Obi, C.D. Okene, 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.

Mahdi, A., H. Mark, 2006. Integrated Crop Management; Field Soil Variability and Its Impact on Crop Stand Uniformity: Iowa State University, Iowa, U.S.A.

McLean, E.O., 1982. Aluminum. In: Pages, A.L., Miller, R.H and keeney, D.R. (Eds), Methods of soil analysis part 2 American society of Agro economy, Madison W.A. Pp: 978 – 998.

Mulima, I.M., M. Ismaila, K.M. Benisheikh, I. Saminu, 2015. Assessment of micronutrients status of soils under millet cultivation in Geidam Local Government, Yobe State, Nigeria. Asian Journal of Basic and Applied Sciences Vol. 2 (2) 32 – 41.

Ndukwu B.N., M.C. Chukwuma, C.M. Idigbor, S.N. Obasi, 2012. Forms and distribution of potassium in soils underlain by three lithologies in southeastern,Nigeria. International Journal of Agriculture and Rural Development 15 (2): 1104 – 1108.

Ndukwu B.N., D.N. Osujieke, C.M. Ahukaemere, M.O. Umeh, 2016. Micronutrients And Physicochemical Properties Of Soils Affected By Municipal Solid Wastes In Ekwulobia Southeastern Nigeria. Journal of Multidisciplinary Engineering Science Studies (JMESS) ISSN: 2458-925X Vol. 2 Issue 11, 1032 – 1040.

Nelson, D.W., L.E Sommers, 1982. Total carbon and organic matter. In: Methods of Soil Analysis Part II. Page, A.L. (Ed.). Chemical and Microbiological Properties. Am. Soc. Agron. Madison, WI., Pp: 359 – 580.

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

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

Obi, J.C., G.E. Akinbola, H.F. Anozie, 2009. Distribution of Dithionite and Oxalate – extractable Iron Oxides of a catena in the basement complex soils of Southwestern Nigeria. Nigerian Journal of Soil Science. 19(1):100 – 108.

Ogeh, J.S., E. Ukodo, 2012. Profile Distribution of Physical and Chemical Properties in Soils of a Toposequence in Benin, Rainforest of Nigeria. Nigerian Journal of Basic and Applied Science, 20(1): 68 – 72.

Ogunkunle, A.O., 1993. Variation of some soil properties along two top sequences on quartile schist and banded genesis in South Nigeria. *Geoderman* 30 (4), 397 – 402.

Oku, E., A. Essoka, E. Thomas, 2010. Variability of soil properties along an udalf toposequence in the humid forest zone of Nigeria. Kasetsart J. (Nat. Sci.) 44: 564 – 573.

Olsen, S.R., L.E. Sommers, 1982. Phosphorus In: methods of analysis part 2 (eds). Page, A.L, Miller, R.H., Keeney, D.R. America Society of Agronomy Madison, Wisconsin Pp. 15 – 72.

Onweremadu, E.U., C.M. Ahukaemere, O.A. Orji, 2015. Horizon Differences in Selected Physical Properties of Soils formed Over Dissimilar Lithologies in South-Eastern Nigeria. FUTO Journal Series (FUTOJNLS) VOL. 1(2) 55 – 61.

Onweremadu, E.U., J.A. Okuwa, J.D. Njoku, and U.O. Ufot, 2011. Soil nitrogen forms distribution in isohyperthermic Kandiudults of Central southeastern Nigeria. Nigeria J. Agric. Food and Environ. 7(2): 52 – 56.

Osakwe, S.A., L.P. Okolie, 2015. Physicochemical Characteristics and Heavy Metals Contents in Soils and Cassava Plants from Farmlands along A Major Highway in Delta State, Nigeria. Nigeria J. Appl. Sci. Environ. Manage. Vol. 19 (4) 695 – 704.

Osujieke, D.N., P.E. Imadojemu, J.N. Igbojionu, 2017. Characterization and variability of soils formed on a toposequential floodplain in Uratta, Southeastern Nigeria. FUW Trends in Science and Technology Journal. Vol. 2(1B): 628 – 632.

Osujieke, D.N., E.U. Onweremadu, C.M. Ahukaemere, B.N. Ndukwu, 2016. Classification of soils of a toposequence underlain by coastal plain sand in South-east Nigeria. Nig. J. Soil and Env. Res. Vol. 14: 256 – 263.

Oyinlola, E.Y., V.O. Chude, 2010. Status of available micronutrients of the basement complex rock – derived alfisols in northern Nigeria savanna. Tropical and Subtropical Agro ecosystems, 12: 229 – 237.

Sahlemedhin, S., B. Taye, 2000. Procedures for soil and plant anlysis. National Soil Research Centre, Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia. 110p.

Sims, J.T., G.V. Johnson, 1991. Micronutrient soil tests. In: J.J. Mortvedi. F.R. Cox, R.M. Welch. (Editors). Soil Sci. Soc. Am. Inc. Madison, Wisconsin, USA. Science 6(2): 93 – 100.

Soil Survey Staff, 2006. Soil quality information sheet; soil quality indicators aggregate stability. National Soil Survey Centre in collaboration with NRCS, USDA and the National Soil Tilth Laboratory. ARS, USDA.

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.

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.

Udoh, B.T., T.O. Ibia, B.U. Udo, S.O. Edem, 2008. Assessment of micronutrient status of inland depression and floodplain (wetland) soils in Akwa Ibom State Southeastern Nigeria. Journal of Tropical Agriculture, Food, Environment and Extension. Vol 7 (2): 156 – 161.

Ukaegbu, E.P., S.K., Osuaku, and C.C. Okolo, 2015. Suitability assessment of soils supporting oilpalm plantations in the coastal plains sand, Imo state, Nigeria. NJSS Vol. 25: 125 – 134.

Ukpong, I.E., 2000. Ecological classification of Nigeria mangroves using soil nutrient gradient analysis. Wetlands Ecol. Manage., 8: 263 – 272.

Uzoho, B.U., N.N. Oti, 2005. Phosphorus adsorption characteristics of selected Southeastern Nigerian soils. Agro-Sci. J. Agric. Food, Environ. Ext. 4(1):50 – 55.

Wilding, L.P., J. Bouma, D.W. Boss, 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.