Available online at www.worldnewsnaturalsciences.com

World News of Natural Sciences

An International Scientific Journal

WNOFNS 47 (2023) 84-103 EISSN 2543-5426

Characterization and classification of soils along a toposequence in Eziama Ikeduru, Imo State, South-Eastern Nigeria

Okechukwu Uzoma Iheme[1,a], Ejike Joel Ejiako[2,b], Uzochukwu Godfrey Nwakanma[3,c]

[1]Department of Soil Science and Technology, Federal University of Technology, PMB 1526, Owerri, Imo State, Nigeria

[2]Department of Pure and Applied Chemistry, University of Calabar, PMB 1115, Calabar, Cross River State, Nigeria

[3]Department of Chemistry, Federal University of Petroleum Resources Effurum, PMB 121, Effurum, Delta State Nigeria

[a-c]E-mail address: ihemeokey@gmail.com , joelsej37@gmail.com , nwakanmagodfrey@gmail.com

ABSTRACT

Inherent physical, chemical and morphological properties of soils in a place greatly determine the agronomic activities carried out in the place. Soils with high ECEC, high base saturation, low bulk density, high organic matter content, high silt clay ratio, etc. show high soil fertility. The toposequence in Eziama, Ikeduru which was formed from coastal plain sand was delineated into three physiographic units, summit middle slope and valley bottom. One profile pit was studied in each of the units. The profile pits were described with the procedure as recommended by Food and Agricultural Organization and soil samples from identifiable horizons were subjected to laboratory analyses. Coefficient of variation was used to measure the variation amongst selected properties. Selected soil properties were also correlated to measure the relationship existing between these properties. The data obtained showed that the color varied from dusky red (2.5 YR 3/2) to red (2.5 YR 5/8) and generally became brighter down the profiles. The texture ranged from sandy clay loam at the B horizons to sandy loam at the A horizons. The silt clay ratio ranged from 0.039 to 0.549, showing that more advanced weathering has taken place in the soils of the studied area. Organic carbon ranged from 1.2 to 13.6 g/kg and generally decreased down the pits. Total nitrogen was generally low and ranged from 0.34 to 1.1 g/kg. The ECEC of the area was also low, indicative of effects of leaching which is predominant in soils formed on coastal

(Received 18 January 2023; Accepted 09 February 2023; Date of Publication 10 February 2023)

plain sands. The percentage base saturation ranged from 23.3 to 66.98%. The pH ranged from 5.37 to 4.82 (strongly acidic to very strongly acidic). The C:N ratio ranged from 3.4 to 16.59. The fertility status of the soils was generally low due to the low Ca:Mg ratio, low K:Mg ratio, high C:N ratio, low pH., the soils belong to the soil order Ultisols. The soil at the summit was classified as Inceptic hapludult, that of the middle slope as Typic hapludult and that of the valley bottom as Arenic paleudult.

***Keywords*:** Characterization, Classification, Toposequence, ECEC

1. INTRODUCTION

Appropriate use of an area of land depends on the inherent characteristics of such a land. Soils, depending on their topographic position, parent material, organic matter content, environmental factors (like erosion, vegetation, etc.), climate, human activities, vary in their physical, chemical, mineralogical and morphological characteristics. Characterization of a soil involves determination of the physical, chemical, mineralogical and morphological properties of the soil. These properties are of great importance in effective soil management for improved crop production anywhere in the world.

Soils of South-eastern Nigeria are characterized by low cation exchange capacity, low organic matter content, low base saturation, low pH (high acidity). These characteristics can be attributed to acidic nature of parent rocks in the area[4][11], the high rainfall prevalent in the area which causes leaching of soil nutrients and to over cropping as a result of over population, resulting in the continuous reduction in soil fertility[19]. The major differences in soils that vary with topography are as a result of some combinations of climatic, pedogenic and geological processes. In a given geographical location, the landform, indirectly controls most of the processes in pedogenesis. Erosion processes are more intensive on the steeper slopes and convex landform; accumulation processes are concentrated on the flatter areas and concave landforms[14]. The most obvious relationship of soil properties to landform/topography probably occurs in humid regions where soils on nearly level areas reflect to have thicker solum than on sloppy land[22]**.** Slope orientation can also greatly affect soil organic carbon distribution with depth, the presence or absence of an E horizon, pH and presence of exchangeable bases.

In South-eastern Nigeria, many soils occur in defined sequences along the landscape which also influence the land use. Such a sequence of soils is known as a toposequence. A toposequence is a sequence of related soils that share the same parent material and have similar conditions with regards to climate, vegetation and time but differ from one another, primarily because of topography[23]. Topography is the major factor affecting most processes taking place on the earth surface, especially in soil formation. Different geochemical conditions are experienced on different landscape positions (summit, middle slope and valley bottom), depending upon the influence of topography on the drainage and hydrology of the soil cover[7]**.**The soils on the uplands (summit) commonly are well drained and are characterized by shallow soil depth and poor nutrient composition as a result of erosion which washes down these soil particles and nutrient to the lower slope positions. However, in the lowest landscape positions (valley), where the soils are rich in clay and organic matter, with signs of various degrees of gleying, water may saturate the regolith to such a degree that drainage and aeration are restricted. Here, the weathering of some minerals and the decomposition of organic matter are retarded, while the loss of iron and manganese is accelerated. In such low-lying topography, special profile features characteristic of wetland soils may develop[9]. The main aim of this study was to determine selected morphological, physical and chemical properties of the soils along the toposequence in Eziama, Ikeduru Imo state of south eastern Nigeria, critically analyze these properties for the fertility evaluation of these soils and classification of these soils along this toposequence using USDA soil taxonomy and World Reference Base and make possible recommendation for the suitable agricultural practices for the area.

2. MATERIALS AND METHOD

2. 1. Study Area

The study was carried out along a toposequence in Amambaa, Eziama, Ikeduru, Imo State, southeastern Nigeria lying between latitude 5°33’32’’ and 5°33’24’’ and longitude 7°8’51’’ and 7°8’37’’. The general surface elevation ranges from 90.3m to 138.2m above sea level. The area has a sloppy landscape, with slope percent of 8% at the summit, 5% at the middle slope and 2% at the valley bottom. The soils were derived from coastal plain sand. The vegetation is a secondary forest and farming is the major socio economic activity in the area, which involves the production of *Manihot esculentus*, *Zea mays, Elaeis guineensis, Telferia occidentalis*, *Gmelina arborea*, *Dioscorea* spp, *Mangifera indica, Treculia Africana, Pentaclethra macrophylla*, *Anacardium occidentale*. It is within the humid tropics, characterized by two major seasons, the wet and dry seasons. The wet season starts around April and ends around October, with the highest precipitation experienced between June and July, while dry season lasts from November through March. However, the duration of these seasons has been affected by change in recent global climate change. Rainfall is high in the area, with an annual rainfall varying from 1500 mm to 2200 mm (60 to 80 inches), annual relative humidity is about 77% while mean annual temperature is about 26-30 °C[18]**.**

2. 2. Field Study

A reconnaissance visit was made to the study area to locate the area and to fraternize with the owners of the portions of land that were used before the study was carried out. The toposequence was delineated into three (3) topographic units (summit, middle slope and valley bottom), one profile pit was sunk in each unit and each profile pit was delineated into horizons based on morphological properties of the soils which were analyzed *in situ*. Each of the profile pits was geo-referenced using a hand held global positioning system (GPS).

Samples were collected from each horizon for bulk density determination by core sampler method and each soil profile was described in line with the procedure as recommended by FAO(21). Soil samples were also collected based on horizon differentiation in each of the profile pits. The soil sample collected were bagged, properly labeled and transported to the laboratory. The soil samples collected were air-dried, gently crushed using a mortar and pestle, and passed through a 2mm-sieve to obtain fine earth separates.

2. 3. Laboratory Analyses

The processed soil samples were analyzed for some physical and chemical properties following the procedure outlined by the International Soil Reference and Information Centre and Food and Agricultural Organization as briefly highlighted herein.

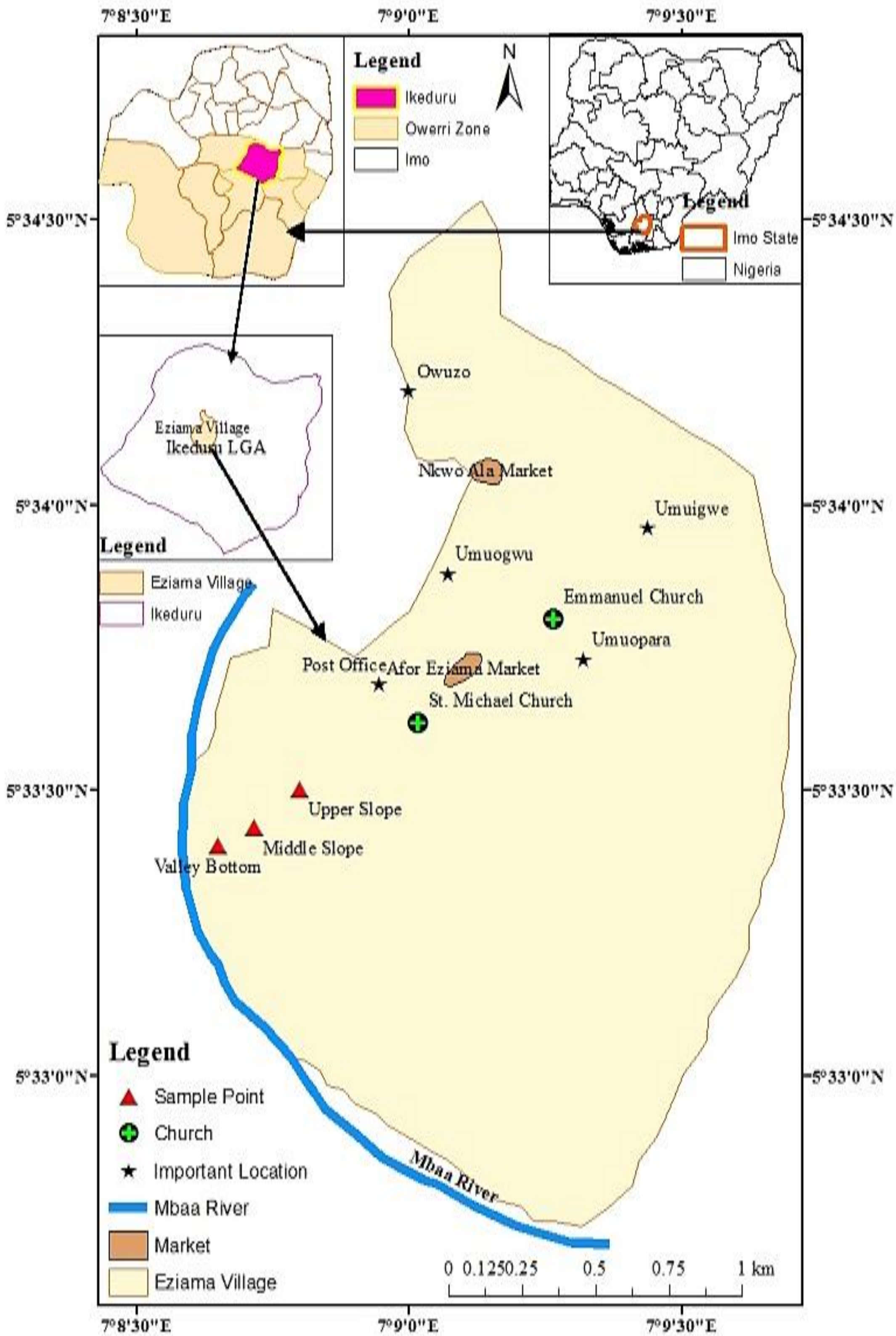

Figure 1. Map of Nigeria, showing Eziama Ikeduru L. G. A, Imo State.

2. 4. Particle size distribution

Particle size analysis was carried out using the Bouyoucous hydrometer method. The textural class was determined with the aid of a textural triangle.

2. 5. Soil Bulk density

This was determined by core method. The mass of undisturbed oven dry soil in a core was measured, also the volume of core was determined, and the bulk density was calculated using the formula

$$\text{Bulk density (g/cm}^3\text{)} = \frac{\text{mass of oven dry soil}}{\text{volume of core}}$$

2. 6. Moisture content

This was determined using gravimetric method and the percentage moisture content was calculated using the formula

$$\text{Moisture content} = \frac{\text{mass of moisture}}{\text{mass of oven dry soil}} \times 100\%$$

2. 7. Total porosity

This was calculated using a mathematical relationship between bulk density and particle density.

$$\text{Total porosity} = [1- \frac{\text{bulk density}}{\text{particle density}}] \times 100\%$$

2. 8. Soil pH

This was determined electrometrically using 1:2.5 soil/water ratio in both water and KCl[18].

2. 9. Total exchangeable bases (TEB)

Total exchangeable bases were extracted using 40 ml of ammonium acetate as the extractant. Calcium and magnesium in the extract were determined by EDTA titration. The titre values gotten were used to calculate the respective quantities of calcium and magnesium and the values gotten were converted to cmol/kg. Sodium and potassium in the extract were determined using a flame photometer. The readings gotten were extrapolated from standard graph plotting of instrument reading against concentration of sodium and potassium, respectively. Total exchangeable bases were calculated as the summation of Ca, Mg, Na and K.

2. 10. Total exchangeable acidity

This was determined by titration method[10]. Here the acidic cations (H and Al) were extracted using 40ml of 1N KCl as extractant. The resulting extract was titrated with 0.05N NaOH after adding some reagents to test for exchangeable acidity (H+Al).

2. 11. Effective cation exchange capacity (ECEC)

This was determined by the summation of total exchangeable bases and exchangeable acidity.

2. 12. Percentage base saturation (%BS)

This was calculated by dividing total exchangeable bases (TEB) by the corresponding effective cation exchange capacity (ECEC) value, then multiplied by 100. Thus,

$$BS = \frac{TEB}{ECEC} \times 100\%$$

Aluminum saturation was calculated using the formula below

$$Al\ sat. = \frac{meq\ AL}{ECEC} \times 100\%$$

2. 13. Organic carbon content

Organic matter content was determined using Walkey and Black digestion method[17]. Organic matter was then calculated by multiplying organic carbon by 1.724 (Van Bermelins correction factor).

2. 14. Total nitrogen

Total nitrogenwas determined by the micro-Kjeidhal wet method.

2. 15. C:N ratio

This was calculated by dividing organic with total nitrogen.

2. 16. Available phosphorus

Available phosphorus was determined by Bray II method. Here, 1g of air dried soil sample was put into a 5 ml centrifuge tube and 7 ml of the P extracting solution was also added, it was shaken for 1 minute centrifuged for 2 ppm for 15 minutes. 2 ml of the clear supernatant was pipette into 20 ml test tube, followed by 5 ml of distilled water and 2 ml of ammonium molybdate. It was mixed properly, after which 1 ml of $SnCl_2 \cdot H_20$ (stannous chloride) dilute solution was added and mixed again, the absorbance was read in a UV spectrophotometer at 660 nanometer. A standard curve was prepared using the absorbance of salt of known concentrations (potassium dihydrogen phosphate). The actual P value of the soil samples was extrapolated using the curve.

2. 17. Statistical analyses

Data gotten from various laboratory analyses were presented using tables. Data were also subjected to coefficient of variation (CV) and ranked using the procedure of [24]. Correlation and regression were also used to estimate the degree of relationship existing among soil properties for the purpose of prediction.

3. RESULTS AND DISCUSSION

The results of some selected morphological, physical and chemical properties of the studied site were represented in Tables 1, 2, 3 and 4 respectively, while Tables 5 and 6 show variability and relationship amongst some selected physico-chemical properties along the toposequence.

Table 1. Selected Morphological Properties of Soils of Eziama, Ikeduru

Horizon	Depth (cm)	Color	Mott-ling	Structure	Consist-ency	Pores	Roots	Faunal ativity	Boun-dary
SUMMIT									
A1	0-26	2.5YR 3/4	Nil	Weak Granular	Non-sticty	Many, coarse	Many, coarse	Nil	Clear
A2	26-54	2.5YR 4/4	Nil	Granular	Non-sticty	Many, coarse	Many, coarse	Nil	Diffuse
Bt1	54-83	2.5YR 3/6	Nil	Sub-angular	Non-sticty	Few, fine	Few, coarse	Nil	Clear
Bt2	83-180	2.5YR 4/8	Nil	Sub-angular	Nons-sticty	Few, fine	Few, coarse	Nil	
MIDDLE SLOPE									
Ap	0-26	2.5YR 3/4	Few, fine	Weak Granular	Non-sticty	Few, coarse	Many, fine	Nil	Clear
A1	26-49	2.5YR 4/4	Nil	Granular	Non-sticty	Few, fine	Many, fine	Nil	Diffuse
Bt1	49-73	2.5YR 4/8	Nil	Sub-angular	Non-sticty	Few, fine	Many, fine	Nil	Diffuse
Bt2	73-180	2.5YR 4/8	Nil	Sub-angular	Non-sticty	Few, fine	Nil	Nil	
VALLEY BOTTOM									
Ap	0-10	2.5YR 3/6	Few, coarse	Granular	Non-sticty	Few, coarse	Many, coarse	Nil	Diffuse
A1	10-26	2.5YR 3/4	Nil	Granular	Non-sticty	Few, fine	Many, fine	Nil	Clear
AB	26-57	2.5YR 3/2	Few, fine	Granular	Non-sticty	Few, fine	Many, fine	Nil	Clear
Bt1	57-73	2.5YR 4/8	Nil	Sub-angular	Non-sticty	Few, fine	Few, fine	Nil	Clear
Bt2	73-180	2.5YR 5/8	Nil	Sub-angular	Non-sticky	Nil	Few, fine	Nil	

Table 2. Selected soil physical properties of soils of Eziama, Ikeduru.

HORIZON	Depth (cm)	Sand (g/kg)	Silt (g/kg)	Clay (g/kg)	TC	BD (g/cm^3)	TP (%)	MC (g/kg)	SCR
SUMMIT									
A1	0-26	742.4	60	197.6	SL	0.74	72.1	115.	0.304
A2	26-54	782.4	50	167.6	SL	1.11	58.81	60	0.298
Bt1	54-83	792.4	50	157.6	SCL	1.12	57.74	39	0.317
Bt2	83-180	732.4	10	257.6	SCL	1.13	57.35	59	0.039
	Mean	762.4	42.5	195.1		1.025	61.5	68.29	0.239
	S.D	29.44	22.17	45		0.19	7.094	32.63	0.134
	C.V	3.861	52.17	23.065		18.554	11.53	47.81	56.026
MIDDLE SLOPE									
Ap	0-26	762.4	40	197.6	SL	1.5	43.4	93	0.202
A1	26-49	782.4	20	197.6	SL	1.53	42.3	104	0.101
Bt1	49-73	752.4	30	217.6	SCL	1.54	41.9	90	0.138
Bt2	73-180	742.4	20	237.6	SCL	1.56	41.1	89	0.084
	Mean	759.98	27.5	212.6		1.533	42.175	94	0.131
	S.D	17.08	9.59	19.15		0.025	0.957	6.88	0.052
	C.V	2.25	34.87	9.006		1.631	2.269	7.319	39.9
VALLEY BOTTOM									
Ap	0-10	802.4	70	127.6	SL	1.24	53.2	107	0.549
A1	10-26	782.4	60	157.6	SL	1.4	47.2	94	0.38
AB	26-57	762.4	80	157.6	SL	1.51	43	74	0.507
Bt1	57-73	722.4	40	237.6	SCL	1.53	42.3	120	0.168
Bt2	73-180	682.4	60	257.6	SCL	1.58	40.4	120	0.233
	Mean	750.4	62	187.6		1.452	45.22	10.3	0.367
	S.D	48.1	24.69	56.57		0.136	5.101	1.9477	0.166
	C.V	6.42	39.835	30.15		9.33	11.28	18.9	45.277

TC = Textural class, BD = Bulk density, TP = Total porosity, MC = Moisture content, SCR = Silt/Clay ratio, C.V = Coefficient of variation, S.D = Standard deviation

Table 3. Some Selected Chemical Properties of Soils of Eziama, Ikeduru.

Horizon	Depth (cm)	pH ($H_2$0)	Ph (KCl)	T.N (g/kg)	Ca	Mg	Na	K	H (Cmol/ kg)	Al
					SUM					
A1	0-26	5.2	4.21	1.1	0.24	1.06	0.006	0.019	1.56	0.4
A2	26-54	5.34	4.28	0.87	0.16	1.33	0.005	0.017	1.6	0.0
Bt1	54-83	5.37	4.35	0.5	2.8	0.267	0.004	0.013	1.52	0.0
Bt2	83-180	5.18	4.38	0.37	0.23	0.133	0.004	0.023	1.28	0.0
	Mean	5.272	4.31	0.71	0.88	0.698	0.005	0.018	1.49	0.1
	SD	0.097	0.076	0.335	1.282	0.587	0.001	0.005	0.144	0.2
	CV(%)	1	1.7	47.22	145	84.16	20	23.1	9.65	200
					MID					
Ap	0-26	5.08	4.24	0.50	0.64	0.4	0.004	0.018	1.36	0.52
A1	26-49	4.99	4.33	0.50	0.72	0.4	0.004	0.015	1.56	0.0
Bt1	49-73	5.4	4.24	0.43	1.44	0.667	0.003	0.02	1.36	0.0
Bt2	73-180	4.88	4.28	0.39	0.08	0.27	0.004	0.023	1.24	0.0
	Mean	5.087	4.27	0.62	0.72	0.434	0.004	0.002	1.38	0.13
	SD	0.224	0.043	0.307	0.558	0.167	0.0005	0.004	0.133	0.26
	CV(%)	4.405	0.96	49.52	77.51	38.44	12.5	21	9.6	200
					VAL					
Ap	0-10	5.18	4.72	0.69	0.32	1.2	0.005	0.032	1.72	0.48
A1	10-26	4.91	4.8	0.47	0.72	0.4	0.004	0.032	1.72	0.56
AB	26-57	5.13	4.75	0.43	0.72	0.8	0.006	0.023	0.92	1
Bt1	57-73	4.82	4.97	0.35	0.96	0.267	0.011	0.02	1.8	0.0
Bt2	73-180	5.11	4.25	0.34	0.16	0.27	0.038	0.032	0.92	0.6
	Mean	5.03	4.69	0.456	0.567	0.587	0.013	0.028	1.416	0.528
	SD	0.156	0.269	0.141	0.327	0.346	0.013	0.454	0.006	0.357
	CV(%)	3.1	5.727	30.92	56.77	58.936	100	21	32.06	67.6

T:N = Total Nitrogen, Ca = Calcium, Mg = Magnesium, Na = Sodium, K = Potassium,
H = Hydrogen, Al = Aluminum SUM = Summit, MID = Middle slope, VAL = Valley bottom

Table 4. Some Selected Chemical Properties of Soils of Eziama, Ikeduru**.**

Horizon	Depth (cm)	O.C (g/kg)	O.M (g/kg)	Av.P (ppm)	TEB	TEA	Al ECEC	BS (%)	C:N Ratio	% AL
SUM										
A1	0-26	13.6	23.3	8.82	1.325	1.96	3.285	40.3	12.36	12.2
A2	26-54	9.9	17.2	7.77	1.512	1.6	3.112	48.6	11.37	0.0
Bt1	54-83	5.4	9.3	7.56	3.084	1.52	4.604	66.98	10.8	0.0
Bt2	83-180	2.4	4.1	6.93	0.479	1.28	1.759	27.2	6.4	0.0
	Mean	7.825	13.475	7.77	1.6	1.59	3.19	45.77	10.23	3.05
	SD	4.931	8.48	0.785	1.0866	0.282	1.163	16.659	2.635	6.1
	CV(%)	63.02	62.93	10.11	67	17.7	36.47	36.39	25.75	20.0
MID										
Ap	0-26	5.3	9.137	9.73	1.062	1.88	2.942	36.1	10.6	17.7
A1	26-49	5.2	8.964	9.73	1.139	1.56	2.699	42.2	10.4	0.0
Bt1	49-73	4.2	7.2	9.25	2.13	1.36	3.49	61.031	9.76	0.0
Bt2	73-180	2.39	4.12	6.65	0.377	1.24	1.617	23.3	6.12	0.0
	Mean	4.272	7.355	8.84	1.177	1.51	2.687	40.657	9.22	4.425
	SD	1.349	2.327	1.477	0.724	0.279	0.786	15.7	2.097	8.85
	CV(%)	31.594	31.646	16.7	61.58	18.5	29.25	38.6	22.75	200
VAL										
Ap	0-10	9.4	16.2	12.6	1.557	2.2	3.757	41.4	13.62	12.78
A1	10-26	7.8	13.4	12.5	1.156	2.28	3.436	33.6	16.59	16.3
AB	26-57	7.6	3.1	9.46	1.603	1.92	3.523	45.5	17.67	28.38
Bt1	57-73	1.2	2.1	8.6	1.258	1.8	3.058	41.18	3.4	0.0
Bt2	73-180	1.2	2.1	8.4	0.5	1.52	2.02	24.8	3.5	29.7
	Mean	5.44	9.38	9.6	1.215	1.944	3.156	37.29	10.96	17.432
	SD	3.932	6.755	2.442	0.443	0.308	0.685	8.201	7.01	12.21
	CV(%)	72.29	72.01	25.43	36.314	15.8	21.67	21.99	63.98	70.09

OC = Organic carbon, O.M = Organic matter, AV.P = Available Phosphorus, TEB = Total Exchangeable Bases, BS = Base Saturation, C/N = Carbon Nitrogen ratio, SUM = Summit, MID = Middle slope, VAL = Valley bottom

Table 5. Coefficient of variation of selected physico-chemical properties of the studied area.

	BD	TP	SCR	pH (H_2O)	OC	TN	TEB	TEA	ECEC	BS	C:N Ratio
Mean	1.35	49.3	0.255	5.122	5.81	0.0533	1.322	1.701	3.023	40.9	10.2
S.D	0.26	9.75	0.158	0.186	3.73	0.0225	0.727	0.335	0.839	12.9	4.45
C.V	19.09	19.77	61.69	3.62	64.1	42.09	54.99	19.65	27.75	31.5	43.6
Rank	Mod.	Mod.	High	Low	High	High	High	Mod.	Mod.	Mod.	High

BD = Bulk density, TP = Total porosity, OC = Organic carbon, TN = Total nitrogen, TEB = Total exchangeable bases, TEA = total exchangeable acidity, ECEC = Effective cation exchange capacity, BS = Base saturation, C:N rat = Carbon/Nitrogen ratio, Alsat = Aluminum saturation, S.D = Standard deviation, C.V = Coefficient of variation, Mod. = mederate.

3. 1. Morphological properties

The summary of the morphological properties of the studied area was presented in Table 1. The various pedons had different color matrix from dusky red (2.5 YR 3/2) to red (2.5 YR 5/8), moist. The color at the surface soils (epipedon) in the three pits were dark reddish brown (2.5 YR 3/4) for the summit and middle slope, and dark red (2.5 YR 3/6) for the valley bottom. In all the pits, the color became brighter with increase in depth. The variation in the color of the soils may be due to varied levels of organic matter content, water content and presence and oxidation states of iron and manganese oxides[13]. Soil organic matter may be responsible for the dark brown to black colour in the surface soil. A bright colour experienced down the pedon can be related to the eluviation of sesquioxides, carbonates and/or clay minerals out of the eluvial (upper) horizons to the iluvial (lower) horizons. The structure was granular at the A horizons and subangular blocky at the B horizons. Few mottles were also encountered at the middle slope and valley bottom. Textually, the soils ranged from sandy clay loam at the endopedon to sandy loam at the epipedon showing higher amount of finer particles at the lower horizons as a result of iluviation of clay down the pedon. Generally, the soils were non-sticky, non-plastic (moist) when rubbed between the fore finger and thumb. Pores were encountered and faunal activity was reduced to minimal in the three profile pits.

3. 2. Selected Soil Physical Properties

The result of selected physical properties was shown in Table 2. The percentage sand in the studied site ranged from 792.4 g/kg – 732.3g/kg at the summit, 782.4 g/kg – 742.4 g/kg at the middle slope and 802.4 g/kg – 682.4 g/kg at the valley bottom with mean values of 762.4 g/kg, 759.9 g/kg and 750.4 g/kg, respectively. The percentage silt ranged from 60 g/kg - 10 g/kg at the summit, 40 g/kg - 20 g/kg at the middle slope and 80 g/kg – 40 g/kg at the valley bottom with mean values of 42.5 g/kg, 27.5 g/kg and 62 g/kg, respectively. The percentage clay ranged from 257.6 g/kg – 157.6 g/kg at the summit, 237.6 g/kg – 197.6 g/kg at the middle slope and 257.6 g/kg – 127.6 g/kg at the valley bottom with mean values of 195.1 g/kg, 212.6 g/kg and 187.6 g/kg, respectively. Silt clay ratio ranged from 0.039 – 0.594 with mean values of 0.134 at the summit, 0.131 at the middle slope and 0.367 at the valley bottom. The result shows mean values of bulk density in the three topographic as 1.025 g/cm^3 at the summit, 1.533 g/cm^3 at the middle slope and 1.452 g/cm^3 at the valley bottom. The mean values of total porosity of the studied site ranged from 61.5% at the summit, 42.175% at the middle slope to 40.4% at the valley bottom. Also, the mean values of percentage moisture content ranged from 68.3 g/kg at the summit, 94 g/kg at the middle slope to 103 g/kg at the valley bottom. The results obtained showed that the soils are generally sandy clay loam to sandy loam, well drained in all the pedons.

Sand separates dominated in the three topographic units and this could be attributed to the parent material (coastal plain sand) from which the soils of the studied area were formed, tropical climate and land use[18]. These factors influence pedogenesis and properties of soils[6]. Sand fraction showed no regular trend at the summit but decreased with depth at the middle slope and valley bottom.

At the epipedon, the trend of distribution of sand was in the following order, lower slope > middle slope > upper slope, probably due to the effect of slope which accelerated movement of sand particles by run-off water, wind and gravity.

The clay content of the soils of the studied site showed no regular trend topographically. Clay content also showed no regular trend with depth at the summit, but increased with depth at the middle slope and valley bottom.

The observed increase may be linked to argillation-iluviation processes [12] At the epipedon, clay decreased with slope, summit> middle slope > lower slope due to reasons earlier stated by [12] that topography has influence on pattern of soil distribution over landscape. This was in line with the findings of [15]**.** On the average, the soils were characterized by greater percentage of clay at the endopedon than at the epipedon. This could be attributed to the eluviation of clay from upper to lower horizons of the soil[12]. Silt content was very low in all the profiles, ranging from 1% to 8%. In most cases, the values did not follow a definite trend, showing little fluctuations within depths of all the pedons. This was in agreement with the research made by [20] in the same agro ecological zone. The silt clay ratio ranged from 0.039 – 0.549, showing that more advanced weathering has taken place in the soils of the studied site [18].

The bulk density increased with depth in the three physiographic units and this could be due to the overburden effect on the deeper horizons as well as declining organic matter content with depth [19]. Although bulk density is meant to decrease with increase in clay (fine separate) and decrease with decrease in sand (coarse separate) in the soil[18], the bulk density of the studied area increased with decrease in sand and increased with increase in clay, this shows that macro porosities of these soils are greater than those of the micro porosities. The bulk density values did not show any regular trend topographically. However, it was highest at the middle slope soils and this could be due to the compacting effects of heavy raindrops on the area, due to the bareness of the site. It could also be attributed to excessive cropping which is characteristic of the area, resulting in depletion and decline in organic matter content, consequently causing increase in bulk density as a result of close packing (compaction) of different soil separates. The lowest bulk density was obtained at the summit where the soil was covered with economic trees and the forest has stayed uncultivated for about 25 years.

This may be the effect of decomposed organic matter resulting from the presence a secondary forest at the summit [18]. Porosity decreased with depth irrespective of the physiographic position. It was high at the studied area, this shows greater availability of soil air, soil water, soil aerobes and root abundance and these have beneficial effects on the agronomic suitability of the soils of the studied area[18].

3. 3. Selected Soil Chemical Properties

The result of selected chemical properties was presented using tables 3 and 4. The mean values of pH in water ranged from 5.27 at the summit, 5.08 at the middle slope and 5.03 at the valley bottom. The pH in KCl had mean values of 4.31 at the summit, 4.27 at the middle slope and 4.69 at the valley bottom. Organic carbon and organic matter, respectively had mean values of 7.825 g/kg and 13.475 g/kg at the summit, 4.272 g/kg and 7.33 g/kg at the middle slope and 5.44 g/kg and 9.38 g/kg at the valley bottom. Total nitrogen had mean values of 0.071 at the summit, 0.045 at the middle slope and 0.046 at the valley bottom. The mean values of available phosphorus were 7.77ppm at the summit, 8.84 ppm at the middle slope and 9.60 ppm at the valley bottom. The mean values of total exchangeable bases and total exchangeable acidity respectively were 1.6 cmol/kg and 1.59 cmol/kg at the summit, 1.177 cmol/kg and 1.51cmol/kg at the middle slope and 1.215 cmol/kg and 1.944 cmol/kg at the valley bottom. The effective cation exchange capacity had mean values of 3.19 cmol/kg at the summit, 2.687 cmol/kg at the middle slope and 3.155 cmol/kg at the valley bottom. The base saturation means were 45.77% at the summit, 40.659% at the middle slope and 37.209% at the valley bottom.

The pH of the studied area ranged from very strongly acidic to strongly acidic. This acidic pH could be as a result of the parent material that formed the soil [8]. It could also be as a result of anthropogenic and natural activities, including leaching of basic cations out of the soil solum, acid rains, application of fertilizer and other activities like excessive cropping on a particular soil. pH showed no regular trend down the pit in the three physiographic units. However, it slightly decreased down the slope and this could be as a result of greater rate of leaching occurring at the middle slope and valley bottom as a result of cropping and vegetation.

The highest pH recorded in the summit could be as a result of the vegetative cover, which more or less reduces the rate of leaching and run off, it could also be as a result of the fallow period of the site. The pH in KCl ranged from extremely acidic to very acidic and showed least variation in all the physiographic positions.

The ECEC of the studied area showed no regular trend with increase in depth and topographically. Apart from the valley bottom that had its highest ECEC value at the epipedon, showing that cations at the epipedon were washed down the slope [18][15]. The summit and the middle slope had their highest ECEC value at their B horizon, this shows that part of the cations at the epipedon have both been washed down the pit by leaching and also down the slope by surface runoff, it can also be as result of attraction of these cations by the negatively charged clay particles which are in higher proportion at the B horizons. Although ECEC increases with increase in organic carbon, this high ECEC in the B horizons with low organic matter could be attributed to clay fractions than to organic matter due to the decline of organic matter with profile depth [15].

Since it has been established by [15][18] that ECEC increases down the slope as a result of washing down and translocation of cations from upper to lower slope positions, the ECEC of the studied site which showed no regular trend topographically (highest at the summit and valley bottom with mean values of 3.19 cmol/kg and 3.15 cmol/kg, respectively) could be as a result of vegetation, climate and anthropogenic activities such as cropping. Whereas the high value at the valley bottom may be attributed to washing down and translocation of cations from upper to lower slope positions, the high value at the summit could be attributed to the presence of a secondary forest that gives vegetative cover to the area, thereby reducing runoff and leaching, and supply of litter material by the trees which decompose and liberate cations to the soil. Also, the Ca:Mg ratio of the study site could be rated low and this may result in phosphorus and calcium deficiency [18].

The Ca and Mg levels of the soil according to [3] were lower than the critical levels of 2.00 and 1.20 cmol/kg, respectively; this implies that the soils need good fertility management strategies for optimum crop production. However, the ECEC of the studied area was within the range of the critical values of ECEC for coastal plain sand soils [18]**.** The percentage base saturation was highest at the B horizons in the three topographic units, and this might be as a result of iluviation of basic cations down the soil profile after intensive leaching from the surface horizon [18]**.** At the epipedon, the highest base saturation was recorded at the valley bottom, showing the effect of washing down of basic cations down the slope. But generally, the highest base saturation was recorded at the summit, followed by that of the middle slope. This greater base saturation at the summit and middle than that of the valley bottom may be as a result of the fact that the endopedons of the summit and middle slope have trace aluminum values, the acidity of those topographic units were just due to hydrogen ions. Percentage base increased with increase in pH and showed a strong correlation which implies that increase in basic cations led to an increase in the pH. The total exchangeable acidity decreased with depth and showed no regular trend topographically, but was highest at the valley bottom.

Organic carbon decreased with depth in the three physiographic positions and showed no regular trend with topography. This was in line with the findings of [1][15][18]. However, the highest organic carbon value was recorded at the summit where there was a secondary forest of about 25 years of fallow and this consequently increased the organic matter content due to the litter materials dropped by the trees covering the area. The lowest organic matter content at the middle slope may be as a result of tillage and continuous cropping that has been taking place at the area which has depleted the organic carbon pool, it could also be as a result of vegetation and climate. Due to the bareness of the site, the soil receives little litter material also high temperature and moisture which help in the decomposition of the available organic matter, and as reported by [1], soil organic carbon depends on the rates of renewal (source) and loss (removal) of carbon from the soil. Also, it is noteworthy that the trend of distribution of organic carbon down the slope was the reverse of the of bulk density. The area with the highest bulk density value had the least organic matter content and vice versa. It inversely correlated with bulk density, and this could also be attributed to the reason stated while explaining the variation in bulk density.

Total nitrogen decreased with depth in the three topographic units and the pattern of its distribution closely follows that of organic carbon. This was in line with the findings of [18]. The highest (0.0710%) content of total nitrogen corresponded to the profile having highest value of organic carbon (7.825) content. The lowest amount of total nitrogen (0.045%) was recorded in the pedon which also had the lowest organic matter content (4.272%). Total nitrogen (N) was low for all slope positions, with middle slope having the lowest value of 0.045%. This agreed with[15] and could be attributed to leaching as a result of heavy rainfall in the area and plant uptake. Carbon-nitrogen ratio ranged from 3.4 – 17.69, with higher C:N ratios recorded in upper horizons of soils of the valley bottom. The mean values of C:N ratio ranged from 9.22 at the middle slope, 10.23 at the summit and 10.956 at the valley bottom. This shows that the soils of the studied area will be fertile to support plant growth and crop production if appropriate management strategies are adopted.

Available phosphorus decreased with depth irrespective of the physiographic position and increased downslope and as follows: 7.77 ppm (summit), 8.84 ppm (middle slope) and 9.60 ppm (valley bottom). For similar reason stated for low total N, organic matter was identified as the principal source of soil phosphorous for many soils [8]

3. 4. Variability Among Selected Physico-Chemical Properties Along The Toposequence

Variability among some physical and chemical properties in the different geomorphic positions was presented using Table 5. The coefficient of variation of some properties showed little to high variation along the toposequence and this may be accounted for by some natural factors, anthropogenic factors also as a result of topography.

Whereas the variation in texture at the respective topographic position as shown in Table 2 could be attributed to some processes like argilation, leaching down of some finer particles taking place at that particular site, the variation along the toposequence may be accounted for by wind and water erosion which is accelerated by topography, thus causing the transportation of these particles down the slope. According to [12] topography has influence on pattern of soil distribution over landscape. The variation in bulk density along the toposequence may be accounted for by anthropogenic activities like cropping, by organic matter levels in the soils and by the standing vegetation at the different physiographic positions and this variation in the bulk density affected the porosity of the area.

Organic carbon and nitrogen showed high variation along the toposequence and this variation may be as a result the factors mentioned above that affected bulk density. Whereas cultivation affected carbon and nitrogen by reducing their abundance in the cultivated soils, standing vegetation affected them by the rate of replenishment, and as such the area with dense vegetation had the highest organic carbon and total nitrogen.

The ECEC and base saturation, showed moderate variation along the toposequence, and this may be attributed to the processes mentioned above which are accelerated by topography. It can also be as a result of agronomic activities and vegetation which affects the movement of these cations by water.

3. 5. Relationship between selected physico-chemical properties of the studied area

The correlation coefficient, coefficient of determination and regression was presented using Table 6. Whereas some properties that showed modest correlation were not statistically significant, some were significant when related to the product moment correlation values at the 0.05 and 0.01 levels of significance. From the table, correlating properties like pH and total porosity, pH and organic carbon, etc. showed modest positive correlation but were not statistically significant. Correlating properties like organic carbon and total porosity, organic carbon and total nitrogen and some others showed positive correlation that was statistically significant. Also the ones that were statistically significant had a coefficient of determination that is greater than 30%. Correlating bulk density and organic carbon gave a correlation coefficient of -0.696 (≤ 0.01) and a coefficient of determination of 48.5% which shows that bulk density greatly reduced with increase in organic carbon and vice versa. This might be as a result of the fact that the soils at the lower horizons had greater proportion of clay than upper ones due to illuviation of fine clay particles which later compacted together and these horizons were characterized by low organic matter content due to their depth. Organic matter reduces soil compaction, thereby reducing bulk density. This can also be as a result of continuous cultivation which increases the bulk density and reduces the organic content [18].

Table 6. Correlation coefficient, coefficient of determination and regression equation of selected properties

X	Y	R	r^2	Regression equation	
pH	OC	0.353	0.125	y = - 30.5 + 7.09x	OC = - 30.5 + 7.09 pH
pH	Av. P	-0.159	0.025	y = 17.1 - 1.57x	Av. P = 17.1 - 1.57 pH
pH	ECEC	0.447	0.200	y = - 7.33 + 2.02x	ECEC = - 7.33 + 2.02 pH
pH	BS	0.658*	0.433	y = - 193 + 45.8x	BS = - 193 + 45.8 Ph
pH	BD	-0.473	0.224	y = 4.70 - 0.655x	BD = 4.70 - 0.655 pH
pH	TP	0.473	0.223	y = - 77.2 + 24.7x	TP = - 77.2 + 24.7 Ph
pH	TN	0.382	0.146	y = - 0.183 + 0.0462x	TN= - 0.183 + 0.0462 Ph
OC	Av. P	0.406	0.165	y = 7.91 + 0.200x	Av. P = 7.91 + 0.200 OC
OC	ECEC	0.511	0.261	y = 2.35 + 0.115x	ECEC = 2.35 + 0.115 OC
OC	BS	0.278	0.077	y = 35.3 + 0.96x	BS = 35.3 + 0.96 OC
OC	BD	-0.696**	0.485	y = 1.62 - 0.0480x	BD = 1.62 - 0.0480 OC
OC	TP	0.696**	0.485	y = 38.7 + 1.81x	TP = 38.7 + 1.81 OC
OC	TN	0.900**	0.810	y = 0.0218 + 0.00543x	TN=0.0218+ 0.00543 OC
Av. P	ECEC	0.445	0.198	y = 1.18 + 0.203x	ECEC=1.18+0.203 Av. P
Av. P	BS	0.046	0.002	y = 38.0 + 0.33x	BS = 38.0 + 0.33 Av. P
Av. P	BD	0.112	0.013	y = 1.20 + 0.0157x	BD= 1.20 + 0.0157 Av. P
Av. P	TP	-0.111	0.012	y = 54.6 - 0.59x	TP = 54.6 - 0.59 Av. P
Av. P	TN	0.124	0.014	y = 0.0396 + 0.00152x	TN=0.0396+0.00152 Av. P
ECEC	BS	0.838**	0.703	y = 1.92 + 12.9x	BS = 1.92 + 12.9 ECEC
ECEC	BD	-0.289	0.084	y = 1.61 - 0.0886x	BD= 1.61 - 0.0886 ECEC
ECEC	TP	0.290	0.084	v = 39.1 + 3.35x	TP = 39.1 + 3.35 ECEC
ECEC	TN	0.320	0.102	y = 0.0275 + 0.00857x	TN=0.0275+0.00857 ECEC
BS	BD	-0.205	0.042	y = 1.51 - 0.00408x	BD = 1.51 - 0.00408 BS
BS	TP	0.205	0.042	y = 42.9 + 0.154x	TP = 42.9 + 0.154 BS

BS	TN	0.210	0.044	y = 0.0384+0.000365x	TN=0.0384+0.000365 BS
BD	TP	-1	1	y = 100 - 37.7x	TP = 100 - 37.7 BD
BD	TN	-0.806**	0.65	y = 0.148 - 0.0705 x	TN = 0.148 - 0.0705 BD
TP	TN	0.806**	0.65	y =-0.0386 + 0.00187x	TN=-0.0386+0.00187 TP

When correlated with organic carbon, total porosity gave a correlation coefficient of 0.696 (≤ 0.01) and a coefficient of determination of 48.5%. This shows that the porosity of the soil increased with increase in organic carbon, also, 48.5% of the total porosity is due to organic carbon and the remaining 51.5% of the total porosity may be due to some other soil factors like root penetration, cracks in soil, faunal activities, etc. This was in line with the findings of [16].

When correlated with organic carbon, ECEC gave a correlation coefficient of 0.511 and a coefficient of determination of 26.1%. This also shows that organic carbon also contributed to the ECEC of these soils and this contribution is about 26.1% of the ECEC. Also, base saturation and pH had a correlation coefficient of 0.658 (≤ 0.05) and a coefficient of determination of 43.3% and this implies that increase in base saturation also increased the Ph. This was in line with the findings of [18].

The correlation coefficient of total nitrogen with organic carbon was 0.9 (≤ 0.01) and they had a coefficient of determination of 81%. This relationship between organic carbon and total nitrogen explains that organic matter is the principle source of nitrogen to many soils. Also, total nitrogen showed a significant positive correlation with available phosphorus.

3. 6. Fertility Evaluation of the studied site

According to [2] that used some important soil characteristics namely; organic carbon, total Nitrogen, exchangeable K, Ca, Mg, Na, and available P to rate the suitability of soils for crop production, the soils along the toposequence can be rated as low in fertility. Based on the data on tables 2, 3 and 4, these soils are generally acidic (5.03 – 5.272) and coarse in texture. All the soils are very low in total Nitrogen (0.045 -0.071%), OC (4.272-7.825 g/kg) and exchangeable K (0.018 – 0.0278 cmol/kg). Only available P (7.77 – 9.6ppm) is moderately high in availability in the soils. The soils are low in fertility and cannot sustain arable crop production efficiently without fertility enhancement measures.

Also when comparing other fertility parameters like C:N ration, Ca:Mg ratio, K:Mg ratio, the soils can also be rated low in fertility. [19)] opined that a decrease in Ca:Mg ratio to a level below 3 results in the unavailability of Calcium and phosphorus and based on this, the studied site may experience unavailability of calcium and phosphorus. However, the soils could be managed by liming, planting acid tolerant tree and use of appropriate cultural practices [5].

3. 7. Soil classification

The soil of the studied area was classified into the order Ultisols due to low base saturation, well developed clay bulge (argillic horizon), low pH. At sub order level, the soil was classified as udults due to its moisture regime which is sufficiently high year round in most years to meet plant needs. At great group level, the soils at the summit and middle slope were classified as hapludult due to minimum horizonation and no observable distinctive characteristic for classification and that of the valley bottom as Paleudult due to the fact that they are redder/higher chroma value. At sub-group, the soil of the summit was classified as Inceptic hapludult, that of the middle slope as Typic hapludult and that of the valley bottom as Arenic paleudult.

Summit

Order: Ultisols
Sub-order: udults
Great group: hapludults
Sub-group: Inceptic hapludult

Middle slope

Order: Ultisols
Sub-order: udults
Great group: hapludults
Sub-group: Typic hapludult

Valley bottom

Order: Ultisols
Sub-order: udults
Great group: paleudults
Sub-group: Arenic paleudult.

4. CONCLUSIONS

Soils can be acidic, neutral or basic. Increase in pH increases the ECEC of a soil and this indicates the soil is highly fertile. Also the organic matter content of a soil affects its pH and buffering capacity, and when decomposed, organic matter releases nitrogen, phosphorus and basic cations to the soil which consequently increases the soil pH, resulting in rich nutrient reserve.

From the result obtained, the soils were seen to have greater percentage of sand than silt and clay. The soils also showed high volume of pore spaces.

Textually, the soils were sandy loam at the A horizon and sandy clay loam at the B horizons. The silt clay ratio also showed considerable weathering has taken place in the area. Also, the soils were acidic, low in ECEC, base saturation, total nitrogen, organic matter, Ca:Mg ratio, K:Mg ratio and moderately high in C:N ratio and these low values of these chemical properties may be attributed to the parent material from which the soils are formed. It could also be due to climatic factors like high rainfall, temperature, etc and anthropogenic factors like cultivation and soil management practices.

This consequently reduced the fertility status of these soils, thereby reducing their agronomic potentials. However, the soils had poor nutrient reserve which can be improved upon by adopting good management practices. This will markedly enhance the agronomic potentials of these soils. Also, due to the sandiness of the area and influence of topography on the movement of soil and soil nutrients, the soils are easily prone to erosion hazards.

References

[1] Abayneh Esayas, (2001). Some physicochemical characteristics of the Raya valley soils, Ethiopia. *Ethiopian Journal of Natural Resource*, 3(2): 155-171

[2] Ahukaemere, C. M. (2018). Suitability evaluation of some soils of South-Eastern Nigeria for oil palm (Elaeis guineensis) and cocoa (Theobroma cacao) cultivation. *International Journal of Agriculture and Rural Development*, 21, 3355-3361

[3] Ahukaemere, C. M., Eshett, E. T., & Ahiwe, C. (2014). Characterization and fertility status of wetland soils in Abia State agro-ecological zone of southeastern Nigeria. *Nigerian Journal of Soil Science* 24(1), 147-157

[4] Ahukaemere, C. M., & Akpan, E. L. (2012). Fertility Status and Characterization of Paddy Soils of Amasiri In Ebonyi State, Southeastern Nigeria. *PAT*, 8(2), 159-168

[5] Akpan-Idiok, A. U. (2012). Physicochemical properties, degradation rate and vulnerability potential of soils formed on coastal plain sands in southeast, Nigeria. *International Journal of Agricultural Research* 7(7), 358-366

[6] Akamigbo F.O.R.(1999) Influence of land use on soil properties of the humid tropical agroecology of southeastern Nigeria. *Agric J.* 30: 59-76

[7] Audu, S. D., & Lekwa, G. (2014). Characterization and Classification of Soils Along a Toposequence in Ajata-Ibeku Abia State South Eastern Nigeria. *The International Journal of Science and Technoledge*, 2(5), 379

[8] Bekele, T. (1994). Phytosociology and ecology of a humid Afromontane forest on the central plateau of Ethiopia. *Journal of Vegetation Science* 5(1), 87-98

[9] Belay, T. (1998). Pedogenesis and soil-geomorphic relationships on the piedmont slopes of Wurgo Valley, Southern Welo, Ethiopia. *SINET: Ethiop. J. Sci.* 21(1): 91-111

[10] DeFrees, D. J., Loew, G. H., & McLean, A. D. (1982). The rotational spectra of HCNH/+/and COH/+/from quantum mechanical calculations. *The Astrophysical Journal*, 257, 376-382

[11] Eshett, E. T., Omueti, J. A., & Juo, A. S. (1990). Physico-chemical, morphological, and clay mineralogica properties of soils overlying basement complex rocks in Ogoja, northern cross river state of Nigeria. *Soil Science and Plant Nutrition* 36(2), 203-214

[12] Esu, I.E,. Akpan-Idiok, A.U. and Eyong, M.O. (2008). Characterization and classification of soils along a typical Hillslope in Afikpo Area of Ebonyi State, Nigeria. *Nigeria Journal of Soil and Environment* 8: 1-6

[13] Fageria, N. K. (2012). Role of soil organic matter in maintaining sustainability of cropping systems. *Communications in Soil Science and Plant Analysis* 43(16), 2063-2113

[14] Hughes, M. W., Almond, P. C., Roering, J. J., & Tonkin, P. J. (2010). Late Quaternary loess landscape evolution on an active tectonic margin, Charwell Basin, South Island, New Zealand. *Geomorphology*, 122(3-4), 294-308

[15] Lawal, B.A., Tsado, P.A., Eze, P.C., Idefoh, K.K., Zaki, A.A., Kolawole, S., (2014). Effect of Slope Positions on some Properties of Soils under a *Tectona grandis* Plantation in Minna, Southern Guinea Savanna of Nigeria. *International Journal of Research in Agriculture and Forestry* Volume 1, Issue 2, 37-43

[16] Mohammed Assen. P.A.L., Leroux, C.H., Barker, and Heluf Gebrekidan, (2005). Soils of Jelo micro catchment in the Chercher highlands of eastern Ethiopia: I. Morphological and Physiochemical Properties. *Ethiopian Journal of Natural Resources*, 7(1): 55-81

[17] Nelson, D. W and Sommers, L. E (1996). Total carbon, organic carbon and organic matter. In: Methods of Soil Analysis. Part 3. Chemical Methods. Soil Science Society of American Book series. Nsukka. pp 103.

[18] Onweremadu, E.U. Eshett, E.T. Osuji, G.E. Unamba-Oparah, I. Obiefuna J.C. and Onwuliri, C,O.E. (2007). Anisotropy of Edaphic Properties in slope soils of a University Farm in Owerri, Southeastern Nigeria. *Journal of American Science*, 3(4), 52-61

[19] Onweremadu, E. U., Onyia, V. N., & Anikwe, M. A. N. (2007). Carbon and nitrogen distribution in water-stable aggregates under two tillage techniques in Fluvisols of Owerri area, southeastern Nigeria. *Soil and Tillage Research*, 97(2), 195-206

[20] Orji, U. E. N. and Obasi S. N. (2012) Properties and classification of erosion prone soils of ukpor, Nnewi South L.G.A. Anambra State Nigeria. *International Journal of agric. and Rural Dev.* Vol. 15(2): 1079-1084

[21] Popova, Z., Kercheva, M., & Pereira, L. S. (2006). Validation of the FAO methodology for computing ETo with limited data. Application to South Bulgaria. *Irrigation and Drainage: The Journal of the International Commission on Irrigation and Drainage*, 55(2), 201-215

[22] Richardson, C. J., Flanagan, N. E., Ho, M., & Pahl, J. W. (2011). Integrated stream and wetland restoration: A watershed approach to improved water quality on the landscape. *Ecological Engineering*, 37(1), 25-39

[23] Rogobete, G., & Grozav, A. (2013). Soil genesis and problematic soils. *Research Journal of Agricultural Science*, 45(2)

[24] Wilding, L. P. (1985). Spatial variability: its documentation, accomodation and implication to soil surveys. In Soil spatial variability, Las Vegas NV, 30 November-1 December 1984 (pp. 166-194)