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Characterization and Classification of Soils Along a Toposequence in Ikwuano Local Government Area of Abia State Nigeria

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Abstract: Five soil profiles were studied along a toposequence located on a coastal plain sand parent material in Ikwuano local government area of Abia State in South eastern Nigeria. The profile pits were sited at the crest (A) upper slope (B), middle slope (C) lower slope (D) and valley bottom (E) positions. The profile pits were described and soil samples from identifiable horizons were taken for laboratory analysis. The data obtained showed that the colour for most of the soils vary from black (10YR 2/1) to brownish black (10YR 3/1) at the surface horizon while in the subsurface horizon the soil vary from dark brown (7.5YR 4/4) to reddish brown (5YR 4/6) except pedon E were the colour matrix vary fron brown (7.5YR 4/4) to orange (7.5 YR 6/6). The texture ranges between loamy sand and sandy loam at the surface of the soil to sandy clay loam at the sub-surface. The percentage organic carbon (0.16 to 1.81) and total nitrogen (0.014-0.126) contents of the area are generally low. Phosphorus and potassium are very low to moderate (0.68-11.78 mg kg^{-1} and 0.013 to 0.449 Cmol (+) Kg^{-1}, respectively). The pH level of the soil ranges from 4.4-6.1 indicating that the soil is very acidic to moderately acidic. The ECEC is very low with base saturation ranging from 28.4 to 96.4%. According to USDA Soil Taxonomy the soils in pedon A, B, C and D belong to the soil order of Alfisol while pedon E belong to soil order of Ultisol . Pedons A,B,C,and D belong to sub-group of typic Kandiudalf while pedon E belong to the sub group of typic Kandiaquults in the USDA soil classification systems.

Key words: Soils, toposequence, Ikwuano

INTRODUCTION

Soil frequently occurs in a well defined and fairly regular sequence by Smyth and Montgomery,[1]. These sequences have been referred to as toposequence by Moormam[2] and Okusami *et al.*,[3] thus, soil properties (morphological, physical and chemical) and the potentials for crop production often vary from crest to the valley bottom due to difference in soil types. Odenerho[4] observed that the distribution of individual soil series on a toposequence as well as the spatial distribution of the toposequence itself has considerable influence on the land use pattern of an area.

Farmers often cultivate the entire toposequence. Some however, restrict their cultivation to only a section of it. Eshett[5] observed in South-eastern Nigeria, Yam (*Dioscorea* Sp.) based cropping systems in the upper, middle and lower slopes of the toposequence, while the valleys are continuously used for rice (Oryza sativa) cultivation.

Stoop[6] observed a high degree of variability in crops stands and low average productivity on the West African landscape and noted that crop field tends to decrease from fertile valley bottom soil to generally infertile up lands. In spite of these reported variability in soil properties and crops yield along the toposequence, recommendation for agronomic practices are often made to farmers without due consideration for specific topographic locations that might influence the management options such as fertilizer rate and types, tillage operations and herbicides application by Oluwatosin *et al.*,[7]. This brings about sharp variations in crop yield.

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Moorman *et al*.,[2] noted that an understanding of the basic soil properties is essential for developing soil management practices that will maintain the productive potential of a soil.

Appropriate and proper use of an area of land depends upon the characteristic of such a land. There is therefore need to characterize soils and classify them in a manner that will ease communication and transfer of knowledge about such soils to farmers and other stakeholders.

The objectives of the study are therefore to describe the physical and chemical soil properties of a toposequence and to classify the soil in a toposequence using USDA, Soil classification system by Soil taxonomy[8].

MATERIALS AND METHODS

The study was conducted at Amaoba-Ime in Ikwuano local government area of Abia State, Nigeria. Amaoba-Ime falls within latitude 05°27'N and longitude 07°32'E. The toposequence is 582 m long with elevation ranging from 109 to 152 m above mean sea level in Table 1 and Fig. 2. The climate of the area is characterized by bimodal rainfall regime with precipitation of over 2000 mm per annum, high temperature and relative humidity. The vegetation of the area is tropical rain forest consisting mainly of trees, shrubs and grasses. The soils are of coastal plain sand parent materials. The toposequence was delineated into five topographic units (crest, upper slope, middle slope, lower slope and valley bottom). Soil samples were collected from identifiable horizons of the profile pit in each of the topographic units. Each of the profile pits position was georeferenced with a Global Positioning System (GPS); the GPS also gave the altitude of each point and the distance from one another (Fig. 1).

Analytical procedure: The samples collected were air-dried, sieved through 2 m sieve and used for the study. The samples for Fe and Al determination were further passed through 1mm sieve. Particle size was done by the hydrometer method of Bouyoucos[9] and organic matter by the dichromate oxidation methods by Walkey and Black[10]. Soil pH was determined in 1:2.5 soil: water suspension using a glass electrode pH meter by Mclean[11]. Total nitrogen was determined by the method of Bremner[12] while the effective cation exchange capacity was by the summation method. Available phosphorus was by the Bray and Kurtz no 1[13] method.

Table 1: Location data of the pedons taken with a GPS

Pedon	Elevation(m.a.s.l.)	Bearing	Coordinates
A	152	65°	5° 27' 42.0''N
			7° 32' 21.6''E
B	136	64°	5° 27' 40.5''N
			7° 32' 19.3''E
C	127	62°	5° 27' 36.5''N
			7° 32' 14.7''E
D	117	61°	5° 27' 32.5''N
			7° 32' 09.6''E
E	109	61°	5° 27' 30.4''N
			7° 32' 07.3''E

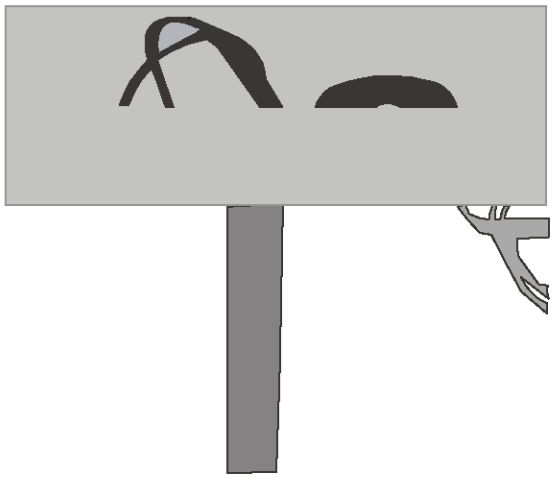

Fig. 1: The Global Positioning System (GPS) used in the study

RESULTS AND DISCUSSION

Morphological and Physical properties: The location of each of the pedon is given in Table 1.The morphological properties of the soil are given in Table 2. The soils are formed on coastal plain sand and have relatively high percentage of sand. The various pedon have different colour matrix ranges from dark brown to reddish brown (7.5YR $^{3}/_{3}$) to reddish brown (5YR $^{4}/_{6}$ down the profile. In Pedon A, (crest), the colour ranged from black to dark brown (10YR $^{2}/_{1}$) to dark brown (7.5YR $^{4}/_{4}$) and finally to reddish brown (5YR $^{4}/_{6}$) colour matrix.

In Pedon B (upper slope), the colour ranges from brownish black (10YR 3/1) to dull reddish brown (5YR $^{4}/_{4}$) and then to bright reddish brown (5YR $^{5}/_{8}$) colour. The Pedon C (middle slope) has colour matrix ranging from brownish black (7.5YR $^{3}/_{2}$) on the surface horizon to reddish brown (5YR $^{4}/_{6}$) down the profile. Pedon D (lower slope) has the colour matrix grading from brownish black (5YR $^{3}/_{1}$) to reddish brown (5YR $^{4}/_{6}$) down the profile. Finally, in Pedon E (valley bottom), the colour graded from

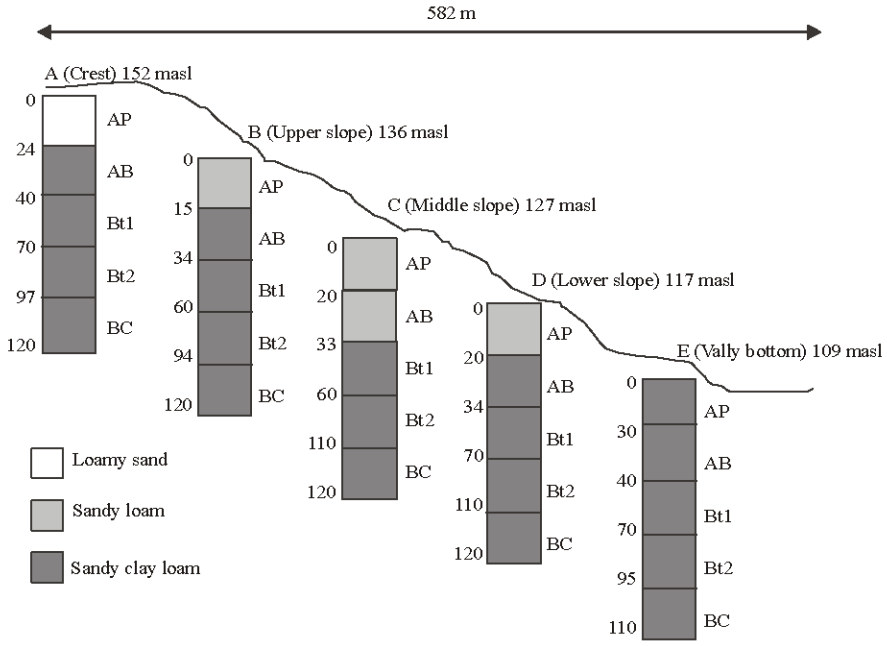

Fig. 2: Schematic representation of the toposequence

Table 2: Morphological Characteristics of the Pedons in Amaoba Soils of Ikwuano L.g.a Abia State, Nigeria

Horizon	Depth Cm	Matric colour	Texture	Structure moist	Consistence moist	Boundary	Roots	Drainage	Stonnies
Pedona									
AP	0-25	10YR $^{2}/_{1}$	L	Weak medium	Loose	Wavey gradual	Medium and common	Well drained	-
AB	25-40	7.5YR$^{3}/_{3}$	SCL	Strong	Firm	Wavey gradual	Medium and common	Well drained	-
Bt_1	40-70	7.5YR $^{4}/_{4}$	SCL	Strong	Firm	Smooth and diffuse	Medium and few	Well drained	-
Bt_2	70-97	7.5YR $^{4}/_{4}$	SCL	Moderate Sbk	Firm	Smooth and diffuse	Coarse Very few	Well drained	-
Bc	97-120	5YR $^{4}/_{6}$	SCL	Strong Sbk	Firm	Smooth and diffuse	Coarse Very few	Well drained	-
Pedon B									
AP	0-15	10YR $^{3}/_{1}$	L	Weak medium	Loose	Smooth and clear	Medium and many	Well drained	-
AB	15-34	5YR $^{4}/_{4}$	SCL	Bk	Friable	Wavey gradual	Medium and common	Well drained	-
Bt_1	34-60	5YR $^{4}/_{6}$	SCL	Sbk	Firm	Smooth and diffuse	Medium and common	Well drained	-
Bt_2	60-94	7.5YR $^{5}/_{6}$	SCL	Sbk	Firm	Smooth and diffuse	Fine and few	Well drained	-
Bc	94-120	5YR $^{5}/_{6}$	SCL	Sbk	Very firm	Smooth and diffuse	Medium and few	Well drained	-
Pedon C									
AP	0-20	7.5YR $^{3}/_{2}$	SL	Weak medium	Loose	Smooth and clear	Very fine and many	Well drained	-
AB	20-33	7.5YR $^{3}/_{3}$	SL	Abk	Firable	Wavey and gradual	Coarse and few	Well drained	-
Bt_1	33-64	7.5YR $^{4}/_{4}$	SCL	Sbk	Firm	Smooth and diffuse	Mediun and few	Well drained	-
Bt_2	64-110	5.YR $^{4}/_{6}$	SCL	Ssbk	Very firm	Smooth and diffuse	Medium very few	Well drained	-
Bc	110-120	5YR $^{4}/_{6}$	SCL	Ssbk	Very firm	Smooth and diffuse	Very fine and very few	well drained	-
Pedon D									
AP	0-20	5YR $^{3}/_{1}$	L	Weak medium	Loose	Smooth and slear	Very Fine and Many	Well drained	-
AB	20-34	7.5YR $^{3}/_{3}$	SCL	Abk	Friable	Wavey and gradual	Coarse and common	Well drained	-
Bt_1	34-70	5YR $^{4}/_{6}$	SCL	Sbk	Firm	Smooth and diffuse	Coarse and common	Well drained	-
Bt_2	70-110	5YR $^{4}/_{6}$	SCL	Sbk	Very firm	Wavy and diffuse	Few and common	Well drained	-
Bc	110-120	2.5YR $^{4}/_{8}$	SCL	Sbk	Very firm	Smooth and clear	Fine and very few	Well drained	-
Pedon E									
AP	0-30	7.5YR 3/2	SL	Weak medium	Friable	Smooth and clear	Very Fine and common	Well drained	-
AB	30-40	10YR 2/2	SL	Weak medium	Firm	Smooth and clear	Very Fine and common	Well drained	-
Bt_1	40-70	10YR 4/4	SL	Weak medium	Firm	Smooth and clear	Coarse and common	Well drained	-
Bt_2	70-95	7.5YR 4/4	SL	Weak medium	Firm	Smooth and clear	Coarse and common	Well drained	Very
Bc	95-110	7.5YR 6/6	SL	Coarse Sg	Firm	Smooth and clear	Medium and many	Well drained	Stoney Very Stoney

Key Structure: Sbk = Sub angular blocky Abk = Angular blocy, Sg = Single grain, L = loam Sl = Sandy loam Scl = sandy clay loam

brownish black (7.5YR $^{3}/_{2}$) to brown colouration (10 YR $^{4}/_{4}$) and finally to orange colour (7.5YR $^{6}/_{6}$) down the profile. Pedon A, C and E have very brownish black colour than Pedon B and D whose colour graded between very dull reddish brown to reddish brown. (7.5Yr $^{3}/_{3}$) (2.5YR $^{4}/_{8}$).A variation in colour matrix was observed among the soils of the topo units. The drainage condition and physiographic position may have major influence on the soil colour.

The particle size distribution of the pedons are shown in Table 2, all the profile have high percentage of sand and low percentage of clay content in their sub-surface horizons. Sand accounts for over 70% by weight of the particle size of the soil at the surface horizon for all the pedons while clay ranges from 11.8 to 22.60% by weight of the particle size of the soil at the surface horizon for all the pedons. Generally there was a decrease in sand with depth with clay accumulating in the subsoils. The silt/clay ratio was < 1 in all the profiles. The low silt/clay ratio, indicated feralitic pedogenesis.

In pedon B, C and D the surface horizons are sandy loam, while pedon A has only loamy sand. Pedon E has sand clay loam texture. There was no presence of gravel in pedon A, B, C and D. But pedon E has gravel at its Bc horizon. The sub-surface horizons are mostly sandy clay loam. The higher clay content observed in the sub-surface horizon in the pedons can be as a result of illuviation and faunal activities taking place in the area.

In all the pedons, the soil depth is more than 120 cm except in pedon E which is 110cm due to the presence of underlying rock which prevented further movement down the profile. The soil depth according to observation might have been affected by the nature of the parent material present in the area.

Chemical characteristics: All the profiles were acidic with pH < 6.1 and a mean of 4.96. This is a reflection of the acid sands of south-eastern Nigeria Udo,[4]). Generally the organic matter content is low and it also decreases with increase in depth. It was observed that bush burning is a major method of bush clearing in the study area and this most likely would have contributed to the lowering of the organic matter content. The same trend was observed for total nitrogen. Available phosphorus was low to medium (0.69 to 11.73 $\mu g g^{-1}$). The effective cation exchange capacity for all the soils was low. This could be due to the nature of the soil parent material. The coastal plain sand are dominated by 1:1 clay lattice mineral and are Kaolinitic in nature with low ECEC (Udo[4]; Unamba Opara, [14]). Therefore the range of ECEC of 2.8-5.1 Cmol kg^{-1} is a reflection of these soils. The available phosphorus content of these soils is in the range of 0.68-11.78 mg kg^{-1} Table 3. The distribution of phosphorus down the profile shows no regular pattern of decrease. Generally the phosphorus level in the study range from very low to moderate. This phenomenon may be due to the phosphorus fixing capacity and their subsequent

Table 3: The chemical properties and particle size distribution of soils of the study area

			Ph		Exchangeable acidity			Exchangeable bases Cmol Kg^{-1}			
Horizon		Depth (Cm)	H_{20}	INKCL	AL+	H+	Ca	Mg	K	Na	TEB
A	Ap	0-25	6.1	5.8	0.10	0.5	1.60	0.80	.499	.191	3.09
	AB	25-40	6.0	5.5	0.40	0.2	1.60	0.40	.404	.179	2.583
	Bt_1	40-70	5.6	5.0	0.90	0.1	2.00	1.20	.111	.189	3.500
	Bt_2	70-97	5.5	4.8	0.10	0.1	2.00	0.80	0.99	.204	3.103
	Bc	97-120	5.2	4.6	0.06	0.1	1.20	0.80	.130	.194	2.207
B	Ap	0-25	4.4	4.1	2.40	0.4	1.20	0.40	.114	.180	1.894
	AB	25-40	4.5	4.1	2.00	0.4	1.80	0.20	.090	.185	2.275
	Bt_1	40-70	4.7	4.1	2.00	2.0	0.40	-	.081	.315	0.796
	Bt_2	70-97	5.1	4.4	2.00	0.8	0.40	0.40	.068	.184	1.052
	Bc	97-120	4.9	4.5	2.00	0.4	0.80	0.40	.055	.175	1.430
C	Ap	0-20	4.6	4.5	2.40	0.0	0.80	0.40	.130	.172	1.502
	AB	20-33	4.9	4.6	2.00	0.4	1.20	-	.066	.197	1.463
	Bt_1	33-64	4.8	4.7	1.60	0.4	1.20	0.80	.059	.167	2.226
	Bt_2	64-110	5.0	4.6	1.60	0.8	1.60	0.40	.107	.182	2.289
	Bc	110-120	5.0	4.5	2.00	0.4	0.80	0.40	.041	.166	1.407
D	Ap	0-20	5.0	4.5	2.00	0.4	1.20	0.40	.146	.175	3.902
	AB	20-34	4.7	4.1	2.60	0.6	0.80	0.40	.092	.194	1.486
	Bt_1	34-70	4.7	4.1	2.40	0.2	1.60	0.80	.067	.188	2.655
	Bt_2	70-110	4.6	4.2	2.40	0.4	1.20	-	.051	.187	1.438
	Bc	110-120	4.8	4.2	2.20	0.6	0.80	0.40	.047	.059	1.406
E	Ap	0-30	4.7	4.1	2.60	0.0	0.80	0.40	.089	.182	1.471
	AB	30-40	4.7	4.2	2.80	0.4	1.60	0.40	.060	.161	2.221
	Bt_1	40-70	4.9	4.3	2.00	0.8	0.80	0.40	.052	.176	1.428
	Bt_2	70-95	4.9	4.3	1.80	0.0	0.80	0.40	.052	.162	1.412
	Bc	95-110	4.7	4.3	1.60	0.0	1.20	-	.091	.175	1.466

Table 3:Continue

		Ecec cmolKg^{-1}	Bs %	OrgC %	OM %	N_2 %	C/N Ratio	AVAIL p mg kg^{-1}	SAND %	Silt %	CLAY %	Text-ural class
A	Ap	3.190	96.9	1.34	2.31	.112	11.96	6.458	84.2	4.0	11.8	LS
	AB	2.983	86.5	.63	1.09	.042	15.0	4.480	70.2	4.0	25.8	Scl
	Bt_1	4.400	79.5	.55	.95	.042	13.09	3.446	76.2	2.0	21.8	Scl
	Bt_2	4.203	73.8	.51	.88	.042	12.14	5.514	68.2	4.0	27.8	Scl
	Bc	3.807	57.9	.48	.48	.028	10.0	3.791	4.2	2.0	23.8	Scl
B	Ap	4.294	44.1	1.34	2.31	.070	19.4	2.068	80.3	3.6	16.1	SL
	AB	4.275	53.2	.79	1.36	.042	1.80	4.285	76.3	3.6	20.1	SL
	Bt_1	2.796	28.4	.43	.75	.042	10.23	4.825	74.2	4.0	21.8	Scl
	Bt_2	3.052	34.4	.35	.61	.014	25.00	1.379	72.2	4.0	23.8	Scl
	Bc	3.430	41.6	.16	2.7	.098	1.60	2.757	68.2	6.0	25.8	Scl
C	Ap	3.902	38.5	1.42	2.45	.042	33.80	1.723	80.3	3.6	16.1	SL
	AB	3.463	42.3	.83	1.43	.042	19.76	.689	78.2	4.0	17.8	SL
	Bt_1	3.826	58.2	.43	.75	.028	15.35	1.723	74.2	4.0	21.8	Scl
	Bt_2	3.889	58.8	.29	.41	.084	3.45	4.480	72.2	4.0	23.8	Scl
	Bc	3.497	41.2	.20	.34	.084	2.38	2.068	74.3	3.6	22.1	Scl
D	Ap	3.951	48.9	2.05	3.53	.070	28.28	3.102	78.3	5.6	16.1	SL
	AB	4.086	36.2	.99	1.70	.056	17.67	1.723	70.3	5.6	24.1	Scl
	Bt_1	5.055	52.5	.47	.82	.056	8.39	1.034	70.3	3.6	26.1	Scl
	Bt_2	3.838	37.4	0.39	0.68	.42	9.28	1.034	66.2	4.0	29.8	Scl
	Bc	3.606	38.9	.20	.34	.126	1.58	2.068	66.3	3.6	30.1	Scl
E	Ap	4.071	36.1	1.81	3.13	.098	18.46	6.204	66.0	11.4	22.6	Scl
	AB	5.021	44.2	1.42	2.45	.056	25.35	11.718	66.0	5.4	22.6	Scl
	Bt_1	3.428	41.6	.83	1.43	.42	19.76	4.480	72.0	5.4	22.6	Scl
	Bt_2	3.212	43.9	.47	.82	.042	11.19	3.446	70.0	3.4	26.6	Scl
	Bc	3.066	47.8	.32	.54	.028	11.42	6.204	72.0	3.4	24.6	Scl

slow-release by soils containing relatively high level of iron and aluminium oxides denoted by Coleman et al.,[15]. Osodeke *et al.*[16] showed that the soils are relatively high in the sesquioxides and their toxicity could be a hindrance to crop production.

Taxonomic classification of the soils: Pedon A is on an elevation of 152m above sea level. The colour matrix varies from Black (10YR $^{2}/_{1}$), very dark brown (7.5 YR $^{3}/_{3}$), brown, (7.5YR $^{4}/_{4}$) to reddish brown (5YR $^{4}/_{6}$).The range of the texture down the horizon of the profile includes, loamy sand, to sandy clay loam. This is indicated in Table 2 and 3. The ECEC varies irregularly throughout the profile. With the E C E C ranges from 2.98 to 4.40 Cmol Kg^{-1} of soil. The base saturation is medium to high ranges from 57.9 to 96.9%. The clay increases down the profile as organic carbon decreases and the soil is deep.Pedon B is situated at an elevation of 136m above sea level. The colour varies from brownish black (10YR $^{3}/_{1}$) dull reddish brown (5YR $^{4}/_{4}$), reddish brown (5YR $^{4}/_{6}$), bright brown (7.5YR $^{5}/_{6}$) to bright reddish brown (5YR$^{5}/_{6}$).The textural range down the horizon of the profile includes sandy loam to sandy clay loam. The ECEC varies irregular throughout the profile with its ranges from 2.796-4.294 Cmol Kg^{-1} of soil. The base saturation is low ranges from 28.4% to 44.1%, organic matter decreases from the top to the sub-surface horizon with the ranges from 0.27-2.31.

Pedon C lies within an elevation of 127 m above sea level. The colour matrix varies from brownish black (7.5YR $^{3}/_{2}$), to reddish brown (5YR $^{4}/_{6}$) down the profile. The range of the texture down the horizon of the profile include; sandy loamy to sand clay loam Table 2 and 3 indicated it. The ECEC varies irregularly throughout the profile, with the ranges from 3.407 to 3.902 Cmol Kg^{-1} soils. The base saturation is moderate, ranges from 28.5 to 55.8%. The clay increases down the profile as organic matter decreases from the top to the surface to the sub-surface horizon.

Pedon D is situated within an elevation of 117 m above sea level, which has a very gently slope. The colour varies from brownish black (5YR $^{3}/_{1}$), reddish brown (5YR $^{4}/_{6}$), to down the profile. The ranges of texture down the horizon of the profile include sandy loam to sandy clay loam. The ECEC varies with ranges from 3.606 to 5.055 Cmol-Kg^{-1} soils.

The base saturation range from 36.2 to 52.5%, it has high clay content than those of A, B and C especially at the sub surface horizon, within the profile it ranges from 16.1 to 30.1% down the profile, organic carbon decreases.

The area where Pedon E is located falls within an elevation of 109 m above sea level and enters its mouth to the Qua Ibo River, it has a concave slope. The soil colour varies from brownish black (7.5YR$^{3}/_{2}$), brown (10YR $^{4}/_{4}$) to orange (7.5YR $^{6}/_{6}$) The texture ranges down the profile this include, sandy loam in all the horizon except the Bc horizon which have sandy clay loam. It is moist throughout the year because, it is nearer to the stream. The ECEC varies irregularly throughout the profile, with the range of 3.066 to 5.021 Cmol Kg^{-1} soil. The base

saturation range from 36.1 - 47.8%. The clay content is low, as a result of coastal shales deposits; it contains the highest organic carbon at the surface than the soil of other topounits. And the presences of rock out crops are seen within the Bc horizon of Pedon E.

The soils of the study area were classified using the USDA soil Taxonomy (1994) system. The soils of pedon A, B, C and D has an argillic horizon and because of its base saturation which is greater than 35% (by some of cations) it belongs to soil order of Alfisol. The soil has an Udic moisture regime an Iso-hyperthermic temperature regime, hence it belongs to the sub order udalf, it also belongs to the great group of the soil kandiudalf. They do not have any lithic, paralithic or petroferric contact within 150cm of the mineral soil surface; they have CEC of less than 16 Cmol/Kg (by sum of bases extracted with 1N NH_4Oac at pH_7) and do not have their clay content decreasing with 20% clay than maximum clay content. They have clay increase of 3% or more in the fine earth fraction and so belong to sub group of typic kandiudalfs.

Pedon E has a cambic sub surface horizon that is illuvial horizon in which there has not been enough clay movement to qualify as argillic. The colour values are more than 4 and organic carbon decreases with depth it therefore belongs to the soil order ultisol. Due to its aquic moisture regime it belongs to the sub-order Aquults. It has lithic contact within 110 cm of the mineral soil surface. It also has Iso-hyperthermic temperature regime, it therefore belongs to the soil great group of kandiaquult with sub-group of typic kandiaquults.

CONCLUSION

The study has shown that there is a variation in soil properties along a toposequence hence the need to exercise caution in treating them as a uniform plot, especially in terms of fertilizer application and tillage practices. The classification of the soils will also enhance the transfer of information about the soils within and between communities of soil users.

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