CHARACTERIZATION AND CLASSIFICATION OF SOME SOILS OF A TOPOSEQUENCE IN EZELU, IMO STATE NIGERIA, ARABLE CROP PRODUCTION.

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ABSTRACT
Inadequate information on soil especially as influenced of landscape position is a major factor limiting agricultural production in Nigeria. In order to characterize and classify soils on a toposequence at Ezelu Area of Imo State, Nigeria, three profile pits were dug in each of the topounits (Summit, midslope and footslope). A total of fifteen (15) samples were collected based on horizon differentiation. Soil samples were subjected to routine laboratory analyses. Sand particle dominated over the soil separate with the mean value of 706g/kg, 634g/kg and 530g/kg for each topounut. Distribution of clay increased with depth for pedons. The soils were moderately to strongly acidic (pH 5.6 – pH 4.3). The highest concentration of organic carbon content occurred at the footslope and decreased with depth for the pedons (22.9 – 5.0g/kg). Effective cation exchange capacity (ECEC) was highest (7.75 cmol/kg) in footslope. The soils dominantly had argillic B-horizon (Bt) which manifest increase in clay contents with depth indicating advanced stage of weathering. The findings also revealed that each topounit in the study had udic moisture regime. The soils in the study area were grouped under Alfisol soil order. Soils of summit and midslope were classified as Psammentic Hapludalfs (Eutric luvisols) while those at footslope were classified as Typic Hapludalf (Dystric luvisols).

Keyboards: Toposequence, topounits, taxonomy, pedon.

INTRODUCTION

Soils exhibit great spatial variability in their physical and chemical properties along slopes. Onweremadu *et al.* (2012) reported that soils vary in space due to differences in lithologic materials, slope, climate and land use over time. Topography plays a major role as one of the factors that influence pedogenesis and the process that dictates the dictates the distribution and use of soil on the land space. According to Chukwu *et al*. (2013) increase in population has led to increasing demand on land resources all over the world leading to the clearing of landscape on slope for agriculture without proper soil management practices, being put in place. This has serious implication because the more intensively upland is cultivated, the more the soil deteriorates rapidly due to erosion and loss of fertility. Udoh (2012) state that natural resources including soils cannot be properly managed without proper understanding of their characteristics, characterization and classification of soils of any given location help in generating soil and location data which are useful in sustained use of the soil resources (Onweremadu *et al;* 2007). The need to provide this information is more demanding at present than before because of the problems arising from misuse of land resulting inland degradation. In Ezelu area, most of the lands are found along a toposequence and this has a great influence on the land use of the area.

An outstanding effect of topography on the landscape in Ezelu is its influence on surface drainage as soils are susceptible to erosion. Esu (2010) noted that 85% of land degradation worldwide is due to erosion. Most landscapes in the area are dissected to runoff water which adversely influence pedogenesis (Onweremadu and Uhuegbu, 2007) hence the rate at which soil resource form for human use.

There is paucity of information on soils of Ezelu in Okigwe area especially on sloping landscape, it becomes necessary to investigate the characteristics for the purpose of classification of soils of Ezelu. The objective of the present study was to characterize and classify the soils in the study area.

MATERIALS AND METHODS

The Study Area

The study was carried out at Ezelu Onuimo local government area of Imo State Nigeria. Onuimo is in the southeast Area of Imo State Nigeria. It is located between latitude $5^0 35'$ and $6^0 30'$N. and longitudes 7^0 34' and $8^0 57'$E. The major geological material in the area is Imo clay shale and coastal plain sand. The soil is typically an ultisol and mainly acidic in nature (Chikere-Njoku and Nwosu, 2004). The climate is essentially humid tropical, characterized by annual mean precipitation of 2000mm with mean temperature range of 27^0C – 32^0C (Njoku, 2006). The vegetation is a humid rainforest characterized by multiple plant species.

Field Study

A reconnaissance visit was made to the project site in order to get the relevant information that was useful for the study. Transect technique guided the field sampling in which a transverse was cut to link the summit of the toposequence to its valley footslope. A soil profile was sunk in each topounit. The geographical land units summit, midslope and footslope. Global positioning system (GPS) receiver was also used to georeference all soil profiles. Soil samples were collected based on genetic horizons. Soil colours were determined at sampling points using munsel colour chart along side with the texture, consistency and structure using moist soil sample.

Table 1: The Locations of the Pedons Using the G.P.S Software

Topounits	Elevation (m)	Coordinates
A. Summit	17.4 m	Lat $5^0$55'.033''N Long $7^0$9'.332''E
B. Midslope	176 m	Lat $5^0$55'.100'N Long $7^0$9'.359'E
C. Footslope	145 m	Lat $7^0$9'.361''E Long $7^0$9'.322'E

Laboratory Studies

The soil samples were air-dried, sieved with a 2mm sieve for the analysis. Particle size distribution was determined by hydrometer method (Gee and Or, 2002). Soil pH was determined using glass electrode direct meter reading while bulk density was determined by Core method (Grossman and Reinsch, 2002). Soil organic carbon was determined using Walkley and Black Method (Nelson and Sommers, 1996) and organic matter estimated by multiplying with a factor of 1.724. Total Nitrogen was determined by kjeldahl digestion procedure (Bremner, 1996). Available phosphorus was by Bray II method and exchangeable acidity by KCl extraction method (Mclean, 1965). Exchangeable Bases (Ca, Mg, Na and K) were extracted by leaching with 1N NH_4O_{AC} (pH 7.0). Exchangeable Ca and Mg were determined by atomic absorption spectrophotometer Na and K by flame emission spectrophotometer. Cation exchange capacity (CEC) was determined by ammonium saturation method (Jackson, 1968). Percent base saturation, effective cation exchange capacity (ECEC) and CEC/unit clay were calculated. The data obtained were subjected to statistical analysis using T-test and correlation of the soil properties using simple linear correlation. Means were separated using the least significant difference at 5% probability level.

RESULTS AND DISCUSSION

Morphological Characteristics

The summit had a moist surface colour of dark reddish brown (5YR 3/2 moist) and subsurface colour of dark red (2.5YR 4/8 moist) to yellowish red (5YR 4/6 moist). The red soil colour may be due to the presence of sesquioxides as the colour is the function of chemical and mineralogical composition as well as textural make up of soil and conditioned by topographic position and moisture regime. The summit soils also had weak, fine to moderate crumb surface structures over moderate crumb subsurface structures (Table 2). The consistence of the summit pedon was firm surface with firm sub-surface soils (moist).

The midslope pedon, under moist conditions was characterized by soils with dark brown (10YR 3/3) surface colour over reddish (2.5YR 4/6) sub-surface colour (Table 2) it also had weak moderate crumb surface structure over moderate granular sub-surface soil structure. The consistence of this pedon was firm to firm surface over firm to firm subsurface soil (moist). The firm moist consistence of these soils suggests a rapid permeable property that is significant in root penetration.

The soils at the footslope were characterized under moist conditions by dark (5YR ¾) surface over reddish brown (2.5YR 4/6) to weak red (10YR 4/4) sub-surface soils. The sub-surface reddish brown to brown may be due to the reduction of hematite into goethite which is brownish in colour. The footslope pedon also had weak to moderate granular surface structures over weak fine crumbs (Table 2). The horizon boundaries were clear or gradual smooth topography.

Table 2: Morphological Properties of the study area

Horizon	Depth (Cm)	Colour moist	Texture	Structure	Consistence (Moist)	Boundary
			Summit			
A	0- 9	Darkish Brown (10YR 3/2)	LS	Weak fine SBK	Firm	Gradual smooth
AB	9.27	Yellowish red (5YRS 4/6)	LS	Weak fine SBK	Firm	Gradual wavy
Bt1	27 – 42	Dark brown (7.5 YR3/3)	SCL	Moderate SBK	Firm	Clear smooth
Bt2	42 – 93	Red (2.5YR 4/8)	SCL	Moderate SBK	Firm	Gradual wavy
Bt3	93 – 150	Dark (10YR 3/6)	SC	Single Grained	Firm	
			Midslope			
A	0-11	Dark brown (10YR 3/3)	LS	Weak fine SBK	Firm	Gradual smooth
AB	11- 39	Yellow red (5YRS 4/6)	SCL	Moderate SBK	Firm	Clear smooth
Bt1	39 – 80	Dark red (2.5YR 3/6)	SCL	Moderate SBK	Firm	Gradual smooth
Bt2	80 – 120	Red (2.5YR 4/6)	SCL	Moderate SBK	Firm	Gradual smooth
Bt3	120 – 185	Red (10YR 5/8)	SC	Single Grained	Firm	
			Footlsope			
A	0-20	Dark reddish brown (5YR ¾)	SCL	Moderate SBK	Firm	Clear smooth
AB	20 – 41	Red (2.5YR 4/6)	SL	Weak fine SBK	Firm	Gradual smooth
Bt1	41-77	Red (10YR 4/6)	SC	Single grained	Firm	Gradual smooth
Bt2	71-110	Red (10YR 5/6)	SC	Single grained	Loose	Clear smooth
Bt3	110 – 195	Weak red (10YR 4/4)	SC	Single grained	Firm	-

LS = Loamy sand, SL = Sandy loam, S = Sandy, SCL = Sandy clay loam

Physical Properties

The particle size distribution of the pedons are shown in table (table 3). At the summit, sand particles dominated with 83.80 g/kg at the surface to 57.80 g/kg down the profile. At the midslope sand particles dominated with 81.80 g/kg at the surface soil and 53.80 gkg^{-1} down the profile while at the toeslope, sand fractions was in the range of 63.80 g/kg at the surface and 57.80 g/kg at the last horizon of the profile. The predominant sand fraction of the slope showed that the soil is formed on a coastal plain sand. Clay particles increases down the profile with mean values of 22.20, 29.80, 38.20 g/kg at summit, midslope and footslope respectively. The texture of the summit and midslope varied from sandy loam to sand clay loam while valley bottom varied from sandy clay to sandy clay loam.

Decreasing silt/clay ratio with depth observed in valley bottom (Table 3) suggest increased weathering of silt to clay with depth. This phenomenon in addition to illuviation explained the increase in clay with depth observed in the pedons. However, Esu (2010) attributed this increase in clay content with depth to the climate of the humid tropics occasioned by pronounced weathering. However the picture is a little different at the summit and midslope, silt/clay ratio fluctuates (Table 3). The silt/clay ratio was <1 in all the pedons indicating that the soil is ferraletic pedogenesis (Chukwu *et al*., 2013).

The bulk density of all the pedons ranged from 1.18 to 1.48 mgm^{-3} with mean ranged from 4.92, 4.96, 5.00 mgm^{-3} at the summit, midslope and footslope respectively. Bulk density values observed varied from summit to footslope. Tandele *et al*. (2013). Attributed this variation in bulk densities of soils of different topographic position to probably close to accumulation of fine sand particles.

Table 3: Physical Properties of the Toposequence

Horizon	Depth (Cm)	Sand SCR g/kg →	Silt	Clay g kg^{-1}	TC silt/clay ←		BD(mgm^{-3})	TP(%)
				Summit				
A	0- 9	838	60	102	LS	0.58	1.19	54.0
AB	9.27	798	80	122	LS	0.65	1.25	53.0
Bt1	27 – 42	678	80	242	SCL	0.33	1.37	48.0
Bt2	42 – 93	638	80	282	SCL	0.28	1.43	46.0
Bt3	93 – 150	578	120	362	SC	0.33	1.46	45.0
	Mean (x)	**706**	**84**	**222**	SC	**1.90**	**49.20**	**0.43**
	CV	**21.61**	**26.07**		**SC**	**8.20**	**8.29**	**46.51**
				Midslope				
A	0-11	818	40	142	LS	0.28	1.20	54.0
AB	11- 39	658	60	282	SCL	0.21	1.28	52.0
Bt1	39 – 80	578	60	362	SCL	0.16	1.33	50.0
Bt2	80 – 120	578	80	342	SCL	0.23	1.40	47.0
Bt3	120 – 185	538	100	362	SC	0.27	1.47	45.0
	Mean (x)	**634**	**63**	**298**	SC	**1.33**	**49.60**	**0.23**
	CV	**17.62**	**33.53**	**31.27**	**SC**	**7.51**	**7.33**	**17.39**
				Footslope				
A	0-20	638	100	262	SCL	0.38	1.18	55.0
AB	20 – 41	458	100	262	SL	0.22	1.26	54.0
Bt1	41-77	498	120	442	SC	0.31	1.30	50.0
Bt2	71-110	478	100	422	SC	0.23	1.38	47.0
Bt3	110 – 195	578	80	402	SC	0.19	1.48	44.0
	Mean (x)	**530**	**100**	**382**	SC	**1.32**	**50.00**	**0.26**
	CV	**14.27**	**14.14**	**18.51**	**SC**	**8.33**	**9.26**	**50.00**

LS = Loamy sand, SL = Sandy loam, SC = Sandy clay, SCL = Sandy Clay Loam, TC = Textural class, SCR = Silt: Clay ratio, BD = Bulk Density, TP = Total Porosity.

Soil Chemical Properties

The chemical properties of the profiles are shown in table 4. The results showed the soils from the summit to footslope were acidic, with pH (H_20) ranged 4.3 to 5.6 in the subsoil (Table 4). The summit and midslope had a mean value of 8.70 gkg^{-1} and 12.20 gkg^{-1} respectively. The higher organic carbon content was at footslope with the range of 22.9 gkg^{-1} at the surface and 5.0 gkg^{-1} at depth with a mean value 10.4 gkg^{-1}, the higher values in the organic carbon at footslope were attributed to the higher amount of litter on the surface and reduced organic matter mineralization in the soil. The total Nitrogen value ranged from 2.0 to 0.2 g/kg with a mean value of 0.74 g/kg 1.08g/kg and 0.4 g/kg at summit, midslope and footslope respectively. The total nitrogen value varied indicating low level of N in summit and footslope while midslope has a considerable high content at the top soil decreasing progressively with depth. This may be due to rapid mineralization (Esu, 2010). Organic carbon and total nitrogen decreases with depth due to concentration of plant and animal residues on the soil surface (Onweremadu *et al.*, 2011). The carbon/nitrogen ratio (C/N) of top unit ranged from 3.6 to 54.99 with a mean ranged of 17.62, 11.50 and 13.73 for summit, midslope and footslope respectively. The highest mean value of 17.62 ratio was recorded at the summit while the lowest recorded at the midslope.

The available phosphorus values ranged from 0.58 to 2.7 mgkg^{-1} with mean values of 1.32, 1.40 and 1.80 mgkg^{-1} at summit, midslope and footslope respectively. There is no definite distribution pattern of all the topographic positions. However, it was high at horizon AB of midslope. The exchangeable cations are very low to low (0.13 to 2.20 cmolkg^{-1}) for Ca (1.63-2.64 cmolkg^{-1}). Effective cation exchange (ECEC) varied widely in the soils with low to moderate value (3.48 to 7.75 cmolkg^{-1}). The percentage basic saturation (%BS) ranged from moderate to high at summit and midslope except footslope which had moderate base saturation (58.52 to 70.94%) Table 4. It reflects the dominance of basic cations in the exchange complex. This also may be attributed to high distribution of total exchangeable acidity of the soil. According to Ufot *et al*., (2016). Basic saturation is directly related to the fertility status of the soil hence, soils with high %BS tends to be more fertile than soils with low %BS. A soil with 80% Base Saturation means that soils of the soil is satisfied with basic cations (K^+, Ca^{2+}, Mg^{2+}, Na^+) while others acidic cation (H^+, Al^{3+}).

Table 4: Chemical Properties of the Soil of the Toposequence Pedon

Horizon	Depth (Cm)	pH (H_20)	OC (g/kg)	TN (%)	C:N	Av.P (mg/kg)	Ca	Mg	Na	K	ECEC	Ca:Mg	BS (%)
							Cmol/kg						
						Summit							
A	0- 9	5.62	20.1	1.7	11.82	1.00	2.01	1.85	0.11	0.15	5.52	1.09	74.64
AB	9.27	5.02	10.8	0.2	54.00	1.00	1.60	1.52	0.15	0.14	4.81	1.05	70.89
Bt1	27 – 42	4.52	6.0	0.9	6.67	1.66	1.89	1.76	0.16	0.13	4.24	1.07	92.92
Bt2	42 – 93	4.32	4.8	0.4	12.00	1.85	1.63	1.15	0.13	0.17	3.48	1.42	88.51
Bt3	93 – 150	4.52	1.8	0.5	3.60	1.10	2.11	1.24	0.13	0.15	3.93	1.70	92.37
	Mean (x)	**4.80**	**8.70**	**0.74**	**17.62**	**1.32**	**1.85**	**1.50**	**0.14**	**0.15**	**4.40**	**1.27**	**83.87**
	CV	**11.04**	**82.18**	**79.73**	**117.20**	**30.30**	**12.43**	**20.67**	**14.29**	**13.33**	**18.18**	**22.83**	**12.35**
						Midslope							
A	0-11	4.72	19.4	1.7	11.41	1.95	2.31	2.20	0.18	0.17	6.38	1.05	76.49
AB	11- 39	4.52	14.8	1.3	11.38	2.70	2.06	2.01	0.16	0.19	5.52	1.02	80.07
Bt1	39 – 80	4.41	12.4	0.8	15.50	0.85	2.11	1.90	0.17	0.21	6.49	1.11	67.64
Bt2	80 – 120	4.42	8.8	1.1	8.00	0.98	1.87	1.80	0.21	0.24	6.62	1.04	62.34
Bt3	120 – 185	4.42	5.6	0.5	11.20	0.80	2.40	2.00	0.23	0.20	6.03	1.20	80.10
	Mean (x)	**4.54**	**12.20**	**1.08**	**11.50**	**1.40**	**2.15**	**2.00**	**0.19**	**0.20**	**6.21**	**1.17**	**73.33**
	CV	**2.86**	**43.69**	**42.59**	**23.13**	**64.29**	**9.77**	**7.50**	**15.79**	**15.00**	**7.09**	**17.09**	**10.91**
						Footslope							
A	0-9	4.62	22.9	2.0	11.45	1.15	2.36	2.15	0.17	0.19	7.57	1.10	70.94
AB	9 – 27	4.42	11.0	0.4	27.5	1.70	2.00	2.11	0.15	0.17	7.43	0.94	58.52
Bt1	27 – 42	4.52	8.0	0.7	11.43	0.92	2.63	1.70	0.16	0.20	7.50	1.55	62.67
Bt2	42 –93	4.41	5.2	0.9	5.78	1.00	2.36	2.08	0.20	0.19	7.73	1.13	62.48
Bt3	93 – 150	4.52	5.0	0.4	12.50	1.80	2.64	1.96	0.17	0.18	7.75	1.35	63.87
	Mean (x)	**4.50**	**10.42**	**0.88**	**13.73**	**1.31**	**2.40**	**2.00**	**0.17**	**0.19**	**7.63**	**1.21**	**63.70**
	CV	**2.00**	**70.92**	**75.00**	**59.29**	**31.30**	**10.83**	**9.00**	**11.76**	**5.26**	**2.10**	**19.83**	**7.10**

OC = Organic Carbon, TN = Total Nitrogen, ECEC = Effective Cation Exchange Capacity, C/N = Carbon Nitrogen ratio, Ca:Mg = Calcium-Magnesium ratio, Av.P = Available Phosphorus, BS = Base Saturation. CV = Coefficient of Variation

Soil Classification According to USDA Taxonomy

The soils of summit and midslope has translocated clay in B horizon (Bt), this signified the presence of argillic or kandic horizon. They have moderate to high supply cation, and more than 35% base saturation by the sum of cations. The soils are therefore classified as Alfisols (USDA) soil order and subgroup as Psammentic Hapludult and Eutric Luvisol (WRB). The soils of the valley bottom was classified as Alfisols of USDA soil order and luvisol (WRB) and subgroup of Typic Hapludult (USDA) and Dystric Luvisol (WRB) based on argillation which manifest increase in clay content with depth down the profile indicating advanced stage of weathering and leaching which characterize kaolinite clay mineral of low clay activity. Organic carbon content decrease with depth, low exchange capacity, high leaching etc. These soils meet the requirement; coarse-textured surface horizons over vertically (morphologically) continuous subsurface horizons, ECEC within subsurface B horizons that are less than 12 cmol (+) kg^{-1} clay; a regular decrease in organic carbon content with increasing depth; and all these in addition to the requirement of clay content increase with depth.

An udic moisture regime was inferred for all pedon observed based on poor drainage condition which they were formed. This soil moisture regime is common to the soils of humid climates that have a well distributed rainfall.

Table 5: Summary of the Soil Classification

Pedon/Mapping Unit	USDA	WRB
1	Psammentic Hapludult	Eutric Luvisol
2	Psammentic Hapludult	Eutric Luvisol
3	Typic Hapludult	Dystric Luvisol

CONCLUSION

The result of this study revealed that topography affects the overall soils properties of a given landscape. The soils have very low exchangeable carbon, and low ca:mg ratio, low values of available phosphorus. The soils of the area are best classified at subgroup level as Psammentic Hapludult (USDA) or Eutric Luvisol (WRB) at the summit and midslope while the footslope can be classified as Typic Hapludult (USDA) or Dystric Luvisol (WRB). (USDA, System of Soils Taxonomy, 2003).

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