CHARACTERIZATION AND CLASSIFICATION OF SOILS OF A TOPOSEQUENCE IN ORU AREA, IMO STATE SOUTHEASTERN NIGERIA.

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ABSTRACT
Characterization of soils is helpful in the appraisal of soil productivity and land use planning. A pedological characterization and classification of soils of a toposequence in Oru Area of Southeastern Nigeria was carried out. A transect was used to align soil pedons dug on three physiographic positions; Summit, midslope and footslope. Soil samples were collected from horizons based on soil profile differentiation. Soil samples were analyzed using standard methods. Data collected were subjected to statistical analysis using descriptive statistics such as mean and coefficient of variation. Results revealed that the texture of the three (3) pedons ranged from sandy loam to loamy sand and sandy clay loam. Sand content had mean values of 69.76% (summit), 68.88% (midslope) and 72.40% (footslope). High CVs of 44.6% summit, 50.6% midslope and 48.1% footslope, 53.1% summit, 58.2% midslope and 49.5% footslope. 71.7% summit, 57.0 midslope and 56.7% footslope were recorded in both organic matter, total nitrogen and available phosphorus in the three (3) physiographic units respectively. The soil reactions were moderately acidic (pH 5.5 - 5.7). The exchangeable bases (Ca, mg, K, Na) were low to moderate with the highest values at the footslope. The percentage base saturation were high with mean values of 74.38% (summit), 75.84% (midslope), and 78.40% (footslope). The soils were classified as Typic Hapludults. Soil management practices which include: application of mulching, organic and inorganic fertilizers, mixed cropping and fallowing should be adopted to improve the fertility of the area.
Keywords: Characterization, Classification, Soil properties, Topography.

INTRODUCTION
Soils vary in space due to differences in lithologic materials, slope, climate and land use over time (Onweremadu, 2012). Topography plays a major role as one of the factors that influence pedogenesis and the process that dictates the distribution and use of soil on the land space (Mebit, 2006). 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 and Lekwa, (2012) stated 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 soil related data which are useful in sustained use of the soil resources (Onweremadu, and Uhuegbu, 2010). The need to provide this information is more demanding at present than before because of the problems arising from misuse of land resulting in land degradation. In Oru area, most of the soils are found along slopes and this has a great influence on the land use of the area. The most important effect of topography on the landscape in Oru is its influence on water flow pattern, thus, the soil is susceptible to erosion. Esu *et al.*, (2008) noted that 85% of land degradation worldwide is due to erosion. Soil degradation by erosion in the tropics especially in the Southeastern Nigeria is enormous and wornsome (Onweremadu, 2005). Most landscapes in the area are dissected by runoff water which adversely influence pedogenesis (Onweremadu and Uhuegbu, 2007).
There is little or no detailed information on soils of Oru area of Imo State, a zone that is characterized by slopes. It becomes necessary to investigate the properties of these soils on slopes in other to improve agricultural production of the area. Such detailed information would guide agricultural use and management of soils of the area to benefit the farmers. Variability of soil frequently occur in a well-defined sequence across a landscape was related to differences in a particular soil forming factors such as topography. When soils are arranged according to changes in relief or topography, it is referred to as toposequence (Brady and Weil, 2008). Thus, the objective of this study was to characterize and classify soils of a toposequence in Oru area, Southeastern, Nigeria.

MATERIALS AND METHODS
Study Area
The study area is located at Oru, Imo State, Nigeria. Oru lies on latitude 5^0 35' and 5^0 55' N; and longitude 6^0 57' and 7^0 43' E. The toposequence has three identifiable units namely; summit, midslope and footslope. The study area has a typical tropical rainforest with annual rainfall ranging from 2,000 to 2,250 mm temperature ranged from 27^0 C to 28^0 C and relative humidity range from 60 – 80%. The soils are derived from coastal plain sand (Benin formation) (Ofomata, 1975). The vegetation of the study area is

that of forest with secondary forest in some areas. Some of the plants conspicuously growing wild include oil palm (*Elaeis guineensis*), raffia palm (*Raphia hookeri*), mango (*Mangifera indica*), and various species of shrubs, herbs and grasses. The major food crops grown in Oru include yam (*Dioscorea spp*), cassava (*Manihot esculenta*) and maize (*Zea mays*).

Field Sampling

A reconnaissance study was carried out on the study areas. Transect survey technique was used and three (3) soil profile pits were sunk along the toposequence with respect to physiographic positions namely: summit, midslope and footslope. Soil samples were collected based on horizon differentiation. Soil colour chart was determined at sampling point using munsel colour chart alongside with the texture, consistency and structure. Soil samples collected were air-dried, crushed and sieved using 2mm sieve, preparatory to laboratory analysis.

Table 1: Location Data of the Physiographic Positions taken with A GPS Receiver

Topounit	Elevation(m,a,s,l,m)	Coordinates
Summit	194	$5^0$55˙ .033N,7^0 9˙.332
Mid-slope	176	5^0 55˙.100, 7^0 9˙ .359
Foot-slope	145	5^0 55˙.156, 7^0 9˙ .361

Laboratory Analysis

Particle size distribution was determined by hydrometer method (Gee and Or, 2002). Bulk density was measured by core method (Grossman and Reinsch, 2002). Organic carbon was measured by wet digestion (Nelson and Sommers, 1996). Organic matter was derived from carbon. Soil pH was determined in 1:2.5 soil liquid ratios in water and 0.1 N KC (Thomas, 1996). Exchangeable base were extracted with ammonium acetate (NH_40A_C). Exchangeable calcium and magnesium were determined by ethylene diamineatra acetic acid titration method while exchangeable potassium and sodium were estimated by flame photometer (Jackson, 1962). Total nitrogen was determined by Micro Kjedal method (Bremner, 1996) while available phosphorus was determined by Bray II method (Olsen and Sommers, 1982).

Soil Classification

Field and laboratory data were used to classify the soils using USDA Soil Taxonomy (Soil Survey Staff, 2010) and World Reference Base (WRS) (FAO, 2006) Classification systems.

Data Analysis

Generated data were subjected to descriptive statistical tools of mean, standard deviation and coefficient of variation.

RESULTS AND DISCUSSION

The result of the morphological and physical properties of the pedon at each slope position were presented in Table 2. All the soils units were gently to undulating plain with slope 3 – 7%. They have dark reddish brown (5YR 3/4) moist to dark brown (10YR3/3) moist sandy clay loam to loamy sand surface over red (2.5YR 4/8) moist to yellow red (5YR4/6) moist sandy clay loam subsurface. The red soil colour may be due to the presence of sesquioxides as the colour is the function of chemical and composition as well as textural makeup of soil and conditional by topographical position and moisture regime. The parent materials and environmental factors (rainfall, humidity and temperature) may have contributed to the soil colour variation of each horizon. The amount of eluviations and or illuviations that have occurred within these toposequence may have equally contributed to the soil colour matrix in each topographic unit.

The physical properties as shown in Table 3 and showed that sand fraction ranged from 65.2% - 77.2%, summit, 65.2 –81.6%, midslope and 63.6% – 87.6%, footslope with the mean values of 69.76, 68.88 and 72.40% summit, midslope and footslope respectively. The sand content decreases as depth increases at the summit and midslope, but did not have a regular decrease or increase at the footslope. Sand fraction dominated having highest value at the footslope compared to those of summit and midslope. The highest proportion of sand observed at the footslope could be as a result of deposition by erosion and runoff. Clay fraction ranged from 16.8 % - 32.8 % at the summit, 10.4 – 36.8 %, summit, 10.4 – 36.8 %, mid-slope, 6.4 % - 32.4 %, foot-slope with the mean values of 25.84%, 26.22% and 20.80% respectively. The clay fraction of the soils increased with depth in all the soils. The increased in clay content of soil with depth may be the consequence of eluviations-illuviation process as well as contributions of the underlying geology through weathering (Esu *et al;* 2008). Bulk density values were 1-79 mgm^{-3} – 1.74 mgm^{-3}, summit, 1.56 mgm^{-3} – 1.84 mgm^{-3}, mid-slope and 1.18 mgm^{-3} – 1.48 mgm^{-3}, footslope. Bulk density values observed, varied appreciably from summit to footslope. The variation could be as a result of nature of the parent materials, erosion effect and soil management practices. However, values of bulk densities were lower than critical limits for root restriction (1.75 – 1.80) mgm^{-3} (Soil Survey Staff, 2006).

Table 2: Morphological Properties of Soils

Horizon	Depth	Colour	Texture	Structure	Consistence	Boundary
			SUMMIT			
A	0-9	Darkish Brown (10YR 3/2)	LS	Weak Fine SBK	Firm	Gradual smooth
AB	9`-27	Yellowish red (5YR 4/6)	LS	Weak Fine SBK	Firm	Gradual wavy
Bt1	27-42	Dark Brown (7.5YR 3/3)	SCL	Moderate SBK	Firm	Clear smooth
Bt2	42-93	Red (2.5YR 4/8)	SCL	Moderate SBK	Firm	Gradual wavy
Bt3	93-150	Dark (10R 3/6)	SC	Single Grained	Firm	Gradual smooth
			MIDSLOPE			
A	0-11	Dark Brown (10YR 3/3)	LS	Weak Fine SBK	Firm	Gradual smooth
AB	11`-39	Yellowish red (5YR 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	Gradual smooth
			FOOTSLOPE			
A	0-20	Dark reddish Brown (5YR 3/4)	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 (10R 4/6)	SC	Single Grained	Firm	Gradual smooth
Bt2	77-110	Red (10R 5/6)	SC	Single Grained	Loose	Clear smooth
Bt3	110-195	Weak Red (10YR 4/4)	SC	Single Grained	Firm	Clear smooth

KEY: LS = Loamy Sand, SL = Sandy Loam, S = Sandy, SCL = Sandy Clay Loam

Table 3: Physical Properties of the Studied Sites

Horizon	Depth Cm	Sand %	Silt %	Clay %	B.D	T C
			Summit Slope			
A	0-15	77.20	6.00	16.80	1.70	SL
AB	15-30	69.20	6.00	24.80	1.74	SCL
Bt1	35-60	69.60	4.00	26.40	1.66	SCL
Bt2	60-90	67.60	4.00	28.40	1.55	SCL
Bt3	90-150	65.20	2.00	32.80	1.51	SCL
	MEAN	**69.76**	**4.40**	**25.84**	**1.63**	
	C.V (%)	**6.50**	**38.00**	**22.70**	**6.00**	
			Mid Slope			
A	0-13	81.60	8.00	10.40	1.98	LS
AB	13-24	71.20	6.00	22.80	1.84	SCL
Bt1	24-48	67.20	2.00	30.80	1.82	SCL
Bt2	48-75	65.20	4.00	30.30	1.56	SCL
Bt3	75-150	59.20	4.00	36.80	1.48	SCL
	MEAN	**68.88**	**4.80**	**26.22**	**1.74**	
	C.V (%)	**12.1**	**47.50**	**38.7**	**12**	
			Foot Slope			
A	0-15	87.60	6.00	6.40	2.09	LS
AB	15-35	79.60	10.00	10.40	1.96	SCL
Bt1	35-60	65.60	8.00	26.40	1.98	SCL
Bt2	60-85	65.60	6.00	28.40	1.84	SCL
Bt3	85-150	63.60	4.00	32.40	1.7	SCL
	MEAN	**72.40**	**6.80**	**20.80**	**1.91**	
	C.V (%)	**14.70**	**33.50**	**55.80**	**7.80**	

KEY: TC = Textural Class, B.D = Bulk Density, STD = Standard Deviation, CV = Coefficient of Variation, SL = Sandy Loam, SCL = Sandy Clay Loam, LS = Loam Sand.

Table 4 shows the result of the chemical properties of the studied soils. The result showed that soils for the toposequence were moderately acidic when compared to the rating of Singer and Munns (1999). The soils had a soil pH values ranging from 5.54 – 6.21 summit, 5.21 – 5.88 mid-slope and 5.31 – 6.12 foot-slope. The soil pH (H_20) result could be as a result of leaching and erosion promoted by the high rainfall in the areas. Organic matter content ranges from 0.96 – 2.82 % at the summit, 0.79-2.85 % at the midslope and 1.03 - 3.23 %, footslope with mean values of 1.76%, 1.87% and 2.15 %, respectively. However, it was observed that the surface horizons recorded the highest percent organic matter at each physiographic unit (Table 4). This may be as a result of deposition of organic materials on the soil surface. The soil at the foot-slope recorded the highest amount of organic matter compared to summit and midslope. This could be attributed to more litter materials, velocity of runoff, intensity of rainfall, slope, vegetation type, soil texture and hydro-morphology, Igwe (2001). The available phosphorus values ranged from 0.9mg/kg – 4.56mg/kg, summit, 1.2mg/kg – 4.84mg/kg, mid-slope and 1.8 – 6.63mg/kg, foot-slope. With mean values 2.34 mg/kg, 3.14 mg/kg, 3.53 mg/kg summit, midslope and footslope respectively. There is no definite distribution pattern of all the topographic positions. The exchangeable bases (Ca, Mg, K, Na) were low to moderate in the study site and increased down the slope from upperslope to footslope. The exchangeable (Ca, Mg, K, Na) bases mean values ranged from 1.76 – 2.20 cmolkg^{-1} for Ca, 1.12 – 1.36 cmolkg^{-1} for Mg, 0.20 – 0.24 cmolkg^{-1} for K, 0.10 – 0.15 for Na from summit to footslope. The exchangeable (Ca, Mg, K, Na) bases were found highest at the footslope. This is attributed to the slopy nature of the land which led to the loses of these nutrients from upland and then deposited at the footslope (Onweremadu *et al*., 2007). Base saturation of the study area were high ranging from 65.5 – 89.0% according to (FMANR,2012) rating standard.

Table 4.3: Chemical Properties of the Studied Sites

Horizon	Depth Cm	pH(H20)	O.C.%	O.M.%	TEA	A3	H+	T.N%	Ca	Mg	K	Na	ECEC	%BS	Avail. P
mgkg^{-1}						Cmolkg^{-1} ←		→			Cmolkg^{-1} ←				
							SUMMIT								
A	0-15	6.21	1.63	2.82	0.6	0.4	0.2	0.14	2.8	1.6	0.34	0.13	5.47	89.0	4.56
AB	15-30	5.72	1.33	2.3	1.2	0.9	0.3	0.15	1.6	1.2	0.27	0.09	4.36	72.4	3.69
Bt1	35-60	5.54	0.93	1.61	1.0	0.8	0.2	0.08	1.6	0.8	0.21	0.07	3.68	72.8	1.60
Bt2	60-90	5.67	0.65	1.13	1.2	0.1	0.2	0.056	1.6	1.2	0.22	0.11	4.33	72.2	0.90
Bt3	90-150	5.72	0.55	0.96	1.2	0.7	0.5	0.04	1.2	0.8	0.18	0.1	3.48	65.5	0.96
	MEAN	**5.77**	**1.02**	**1.76**	**1.04**	**0.76**	0.28	**0.09**	**1.76**	**1.12**	**0.24**	**0.1**	**4.26**	**74.38**	**2.34**
	C.V (%)	**4.4**	**44.9**	**44.6**	**25.1**	**30.3**	**46.6**	**53.1**	**34.5**	**29.9**	**25.7**	**22.4**	**18.3**	**11.7**	**71.7**
							MID SLOPE								
A	0-13	5.64	1.65	2.85	0.7	0.05	0.2	0.142	2.0	1.2	0.25	0.11	4.26	83.5	4.36
AB	13-24	5.88	1.55	2.68	1.1	0.8	0.3	0.134	2.8	1.2	0.23	0.10	6.23	82.3	4.84
Bt1	24-48	5.42	1.19	2.06	1.3	0.9	0.4	0.103	1.6	0.8	0.24	0.09	4.03	67.7	4.09
Bt2	48-75	5.35	0.57	0.99	1.26	0.8	0.4	0.04	2.0	1.6	0.29	0.14	5.23	77.0	1.200
Bt3	75-150	5.21	0.45	0.79	1.25	0.9	0.35	0.03	1.66	0.8	0.23	0.12	4.00	68.7	1.20
	MEAN	**5.5**	**1.08**	**1.87**	**1.12**	**0.69**	**0.33**	**0.09**	**2.01**	**1.28**	**0.25**	**0.11**	**4.75**	**75.84**	**3.14**
	C.V (%)	**4.8**	**50.9**	**50.6**	**22.1**	**52.4**	**25.4**	**58.2**	**23.8**	**40.7**	**10**	**17.2**	**20.4**	**9.8**	**57**
							FOOT SLOPE								
A	0-15	6.12	1.87	3.23	0.9	0.6	0.3	0.16	2.2	1.2	0.23	0.12	4.64	80.6	6.63
AB	15-35	6.03	1.63	2.82	1.0	0.7	0.3	0.14	2.4	1.2	0.19	0.21	5.00	80.0	4.12
Bt1	35-60	5.8	1.51	2.61	1.4	1.0	0.4	0.13	2.4	1.6	0.20	0.12	5.72	75.5	3.30
Bt2	60-85	5.69	0.61	1.06	1.2	0.8	0.4	0.05	2.0	1.2	0.14	0.12	4.66	74.2	1.80
Bt3	85-150	5.31	0.52	1.03	0.9	0.8	0.1	0.05	2.0	1.6	0.25	0.17	4.92	81.7	1.80
	MEAN	**5.79**	**1.23**	**2.15**	**1.08**	**0.78**	**0.3**	**0.11**	**2.2**	**1.36**	**0.24**	**0.15**	**4.99**	**78.4**	**3.53**
	C.V (%)	**5.5**	**50.5**	**48.1**	**20.1**	**19**	**40.8**	**49.5**	**9.1**	**16.1**	**20.8**	**27.6**	**8.8**	**4.2**	**56.7**

KEY: O.C = Organic Carbon, O.M = Organic Matter, TEA = Total Exchangeable Acidity, T.N = Total Nitrogen
ECEC = Effective Cation Exchange Capacity, %BS = Percentage Base Saturation.

Results on the variability of each of the soil properties tested are recorded in Table 5. The results of the coefficient of variation indicates that bulk density recorded a low variation across all the physiographic positions of the toposequence investigated Table 5. Several authors have reported the significant influence of cultivation and organic matter on bulk density (Akamigbo *et al*, 2009; Onweremadu *et al.*, 2010). Low variation recorded at the foot-slope contradicts the work of Baeven *et al*, (1993) who reported that most footslope are highly variable in same agro-ecological soil. Bulk density variation may be attributed to changes in organic matter distribution. However, percentage clay of soils of the study area had moderate variation (22.70)% at the summit, high variation (38.7%) at the mid-slope and high variation (55.8%) at foot-slope. The degree of variability recorded could be as a result of the elluviation and alluvial deposition of soil particles. Soil pH (H_20) recorded a low variation across all the physiographic positions. The pH values showed an increasing with physiographic position with values of 4.4% for summit, 4.8% for mid-slope and 5.5% for foot-slope. The low variation of soil pH agreed with work of Mulla and McBratny,(2001). These results reflect the integrated effect of geology, length, gradient and sequence. Available phosphorus recorded high variation 71.7% for summit, 57.0% mid-slope and 56.7% for foot-slope. Percent base saturation had low variation across the physiographic units with values 11.7% for summit, 9.8% for mid-slope and 4.2% for foot-slope. Organic matter recorded a high variation across the physiographic position of the toposequence investigated with values 44.6%, 50.6%, 48.1% for the summit, mid-slope and foot-slope, respectively. This could be attributed to vegetation cover across the toposequence and landscape position.

Table 5: Variability of Selected Soil Properties

Soil Properties	CV%	Ranking(Aweto,1980)
	SUMMIT	
Sand	6.50	Little Variation
Clay	22.70	Moderate Variation
pH	4.40	Little Variation
OM	44.60	High Variation
TN	53.10	High Variation
Avail P.	71.70	High Variation
TEA	25.10	Moderate Variation
TEB	11.70	Little Variation
	MIDSLOPE	
Sand	12.1	Little Variation
Clay	38.7	High Variation
pH	4.8	Little Variation
OM	50.6	High Variation
TN	58.2	High Variation
Avail P.	57	High Variation
TEA	22.1	Moderate Variation
TEB	9.8	Little Variation
	FOOTSLOPE	
Sand	14.7	Little Variation
Clay	55.8	High Variation
pH	5.5	Little Variation
OM	48.1	High Variation
TN	49.5	High Variation
Avail P.	56.7	High Variation
TEA	20.1	Moderate Variation
TEB	4.2	Little Variation

CV = Coefficient of Variation, OM = Organic Matter, TN = Total Nitrogen, Avail. P = Available Phosphorus, TEA = Total Exchangeable Acidity .

SOIL CLASSIFICATION

The soils of the study area were classified using USDA Soil Taxonomy (Soil Survey Staff, 2012) and World Reference Base (FAO, 2006) soil classification systems. The study location fall under udic moisture regime and isohyperthermic temperature. The pedons have base saturation value greater than 35% which qualifies it as an Alfisol. Considering the soil moisture regime of all the pedons were classified as udalf at suborder level. Thus, according to the diagnostic criteria for classification as adopted by USDA Soil Taxonomy (Soil Survey Staff, 2010), both soils of the summit, mid-slope and foot-slope studied are classified as Typic Hapludalfs.

CONCLUSION

The study showed that the soils of the studied area are highly weathered belonging to alfisols. However, the studied area is suscepitible to the forces of degradation, therefore, soil management practices which include; application of mulching, organic and inorganic fertilizers, mixed cropping and fallowing should be adopted to improve the fertility of the area.

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