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Characterization and Classification of Soils along Otamiri Watershed in Umuagwo, Southeastern Nigeria

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Abstract
The study was carried out near the research farm of Imo State Polytechnic Umuagwo Imo State Nigeria to investigate the variability as well as classify soils along Otamiri watershed. Three pedons were dug at about 100 m apart in the study area. Samples collected were subjected to laboratory analyses while coefficient of variation (CV) was used to assess the variability of soils within the pedons. Clay content had no particular trend in pedons 1 and 2 (1.76 – 4.48, 8.76 – 10.48 % respectively) and increased consistently in pedon 3 (11.76 – 17.76 %) although it decreased sharply in Bt2 horizon due to argillation that occurred at Bt1. The Suit Clay Ratio were low as all values recorded were less than 1. This suggests that soils investigated have attained advanced stage of weathering, and highly leached which characterized most soils in the southeastern Nigeria. The texture of the three pedons investigated ranged from sandy to loamy sand and sandy loam. Soil pH was moderately acidic (5.85, 5.74 and 5.87 in pedons 1, 2 and 3 respectively), organic matter was also low having the following means: 0.52, 0.73 and 0.46 % in the respective pedons. Exchangeable cations were low indicating means of 0.51, 0.73 and 0.68 g/kg for Ca, 0.15, 0.36 and 0.50 g/kg for Mg, while K and Na were < 0.02 g/kg all in pedons 1, 2 and 3 respectively. Soil pH, bulk density, porosity, CN ratio and sand exhibited low variability (CV < 15 %). Total nitrogen, total exchangeable bases, organic matter, Na, H and Ca varied moderately (CV > 15 ≤35 %) while Al, Al saturation, Available P, ECEC, K, Mg, TEA, clay, silt/clay ratio and silt had high variability (CV > 35 %). Pedons 1 and 2 were therefore classified as Arenic Hapludults and pedon 3 classified as Typic Kandiudults.

Keywords: Soil variability, Watershed, Pedology, Humid environment, Fluviation

1.0 Introduction

The characterization of soils provides the basic information necessary to create functional soil classification schemes, and assess soil fertility in order to unravel some unique soil problems in an ecosystem (Lekwa *et al.,* 2004). The coupling of soil characterization, soil classification and soil mapping provides a powerful resource for the benefit of mankind especially in the area of food security and environmental sustainability. Soil characterization provides the information for our understanding of the physical, chemical, mineralogical and microbiological properties of the soils we depend on to grow crops, sustain forests and grasslands as well as support homes and society structures (Ogunkunle, 2005). Soil classification, on the other hand, helps to organize our knowledge, facilitates the transfer of experience and technology from one place to another and helps to compare soil properties. According to Eswaran (1977), some different uses of soil characterization data include to aid in the correct classification of the soil and enable other scientists place the soils in their taxonomies or classification systems and to serve as a basis for more detailed evaluation of the soil as well as gather preliminary information on nutrient, physical or other limitations needed to produce a capability class. A soil characterization study, therefore, is a major building block for understanding the soil, classifying it and getting the best understanding of the environment (Esu, 2005). Akamigbo (2001) noted that soil classification usually means criteria based on soil morphology in addition to characteristics developed during soil formation. Criteria are designed to guide choices in land use and soil management. As indicated, this is a hierarchical system that is a hybrid of both *natural* and objective criteria.The USDA soil taxonomy provides the core criteria for differentiating soil map units. Soil taxonomy based soil map units are additionally sorted into classes based on technical classification systems. Land Capability Classes, hydric soil, and prime farmland are some examples.

Although a lot of farming activities take place in

Umuagwo as the region has been recognized over the years for its farming activities, little or no work has been done to investigate the soil properties of the region. The objective of this research work was to characterize and characterize the soils along Otamiri watershed, research farm Imo State Polytechnic Umuagwo, Imo State Nigeria

2.0 Materials and Method

2.1 Study Location

The study area was identified in the research farm of Imo State Polytechnic Umuagwo near Otamiri river which lies between latitudes $05^{o}17^{1}$ and $05^{o}49^{1}$ N and longitudes $07^{o}54^{1}$ and $06^{o}56^{1}$ E. The region consists of the tropical rainforest of the southeastern Nigeria with average annual rainfall distribution of 2,250 to 2,800 mm. It has annual temperature range of 27 – 32 ^{o}C and annual relative humidity range of 85 - 90 % (Ofomata, 1975). The study area serves as basins and watersheds for Otamiri river as most of the rainfall it receives drain to Otamiri. A transect was cut across the watershed and three profile pits were dug. The profile pit length and breadth was 1.2 m x 1.0 m and the depth varying from 1.3 m to 1.43 m. After careful horizon differentiation, the profile pits was described using the procedure outlined by the FAO (1983).

After description, soil samples were taken from each of the constituent horizons, placed in polythene bags appropriately labeled. The samples were air dried for three days under shade, crushed and sieved using 2mm sieve and the sieved samples preserved for laboratory analysis.

2.2 Laboratory Soil Analysis

Particle size distribution was determined by hydrometer method according to the procedure of (Gee & Or, 2002), Bulk Density was measured by core method (Grossman & Reinsch, 2002). Porosity was computed from bulk density and particle density. Soil pH was determined in 1:2.5 soil liquid ratios in water and 0.1 N KCl (Thomas, 1996). Organic Carbon was determined using method described by (Nelson & Sommers, 1982), Organic matter was derived from organic carbon. Total Nitrogen was determined using modified micro Kjeldahl method (Bremner & Mulvaney,1982).Total available phosphorus was determined using Bray II method (Olsen & Sommers, 1982). Cation exchange capacity (CEC) was measured by repeated saturation using 1 M NH_4OAC followed by washing, distilling and titrating (Soil Survey Staff, 1996).

2.3 Statistical Analysis

Coeficient of Variation (C.V) as used by Wilding (1985) (Table 1) was used in this study to estimate the degree of variability existing among soil properties in the study site. Comparisons were drawn from the results from the laboratory analysis of the pedons. Percentage coefficient of variation was determined using the equation

$$\%CV = \frac{S.D}{X} \times \frac{100}{1} \qquad 1$$

where S.D = standard deviation

X = mean

Table 1
Co-efficient of variation will be ranked according to Wilding as follow (1985)

Level (%)	Ranking
C.V < 15	Little variation
C.V > 15=35	Moderate variation
C.V > 35	High variation

3.0 Result and Discussion

The morphological properties of soils were as shown in Table 2. All colours were measured under wet condition. Pedon 1 had colour ranging from 7.5 YR 4/1 (dark gray) to 7.5 YR 8/2 (reddish brown). Pedon 2 ranged from 7.5 YR4/1 (dark gray) to 7.5 YR 5/4 (brown) while pedon 3 ranged from 7.5 YR 5/3 (light brown) to 7.5 YR5/4 (brown). Pedons 1 and 2 peds were structureless in all horizons and were granular in form with very fine sizes. Bt2 indicated a weak structured grade, crumby form with fine sizes. However, at pedon 3, soil structure indicated a very strong grade in all horizons although Bt2 was crumby in form, while all other horizons ranged from angular blocky to blocky in form. Structure size ranged from coarse to massive at pedon 3. Soil consistence indicated non sticky (so) when wet, friable (fr) when moist and loose (l) when dry in pedons 1 and 2. Pedon 3 had consistence ranged slightly sticky to sticky when wet, friable when moist and soft when dry.

Table 2: Morphological properties of soil

Location	Depth (cm)	Colour	Structure	Consistence		
Pedon 1		(Wet)		Wet	Moist	Dry
A	0 – 21	7.5YR 4/1	0, gr, vf	so	fr	l
AB	21 – 35	7.5YR 5/1	0, gr, vf	so	fr	l
Bt 1	35 – 84	7.5YR 7/2	0, gr, vf	so	fr	l
Bt 2	84 – 145	7.5YR 8/2	1, cr, f	so	fr	l
Pedon 2						
A	0 – 16	7.5YR 4/1	0, gr, vf	so	vfr	l
AB	16 – 45	7.5YR 6/3	0, gr, vf	so	fr	l
Bt 1	45 – 17	7.5YR 6/3	0, gr, vf	so	fr	l
Bt 2	71 – 153	7.5YR 7/2	0, gr, vf	so	fr	l
Pedon 3						
A	0 – 19	7.5YR 5/3	3, abk, c	ss	fi	s
AB	19 – 49	7.5YR 6/3	3, bk, c	ss	fi	s
Bt 1	49 – 87	7.5YR 6/4	2, cr, f	ss	fi	s
Bt 2	87 – 165	7.4YR 5/4	3, bk, m	so	fi	s

Key: gr = granular, vf = very fine, cr = crumby, bk = blocky, abk = angular blocky, c = coarse, l = loose, so = non sticky, s = sticky, ss = slightly sticky,

Table 3 Physical Properties of Investigated Soils

Location	Depth (cm)	Sand ←	Silt (%)	Clay →	SCR	TC	B.D. g/cm^3	Porosity (%)
Pedon1								
A	0-21	96.96	1.28	1.76	0.73	S	1.32	50.18
AB	21-35	86.96	1.28	11.76	0.10	LS	1.40	47.17
Bt1	35-84	90.96	0.28	8.76	0.03	S	1.43	46.03
Bt2	84-145	94.96	0.56	4.48	0.13	S	1.52	42.64
mean		92.46	0.85	6.69	0.13	---	1.41	46.50
CV(%)		4.80	59.90	66.40	131.10	---	5.80	6.70
Pedon2								
A	0.16	88.96	2.28	8.76	0.26	S	1.38	47.92
AB	16-45	96.96	1.28	1.76	0.72	S	1.45	45.28
Bt1	45-71	93.94	0.56	5.48	0.14	S	1.53	42.26
Bt2	71-153	86.96	2.56	10.48	0.24	LS	1.60	39.62
Mean		91.70	1.67	6.62	0.25	----	1.49	43.77
CV(%)		5.00	55.20	58.10	76.10	----	6.40	8.20
Pedon3								
A	0-19	84.96	3.28	11.76	0.27	LS	1.40	47.17
AB	19-49	81.96	2.28	15.76	0.14	LS	1.42	46.15
Bt1	49-87	78.96	3.28	17.76	0.18	SL	1.42	46.15
Bt3	87-165	82.96	0.56	16.48	0.03	SL	1.53	42.26
Mean		82.21	2.35	15.44	0.15	----	1.44	45.43
CV(%)		3.00	54.60	16.80	64.20	----	4.10	4.80

BD = Bulk density, SCR = silt/clay ratio, TC = textural class, S = sand, LS = loamy sand, SL = sandy loam, LV = low variability, MV = moderate variability, HV = high variability

The results of the physical properties of the investigated soils along Otamiri watershed in Imo State Polytechnic Umuagwo were shown in Table 3. The Table shows that all the pedons were generally sandy with highest sand occurring in pedon 1 followed by pedon 2 and the lowest occurred at pedon 3. Mean sand were 92.46, 91.70 and 82.21 %, respectively. Also silt distributions were low and means followed as of; 0.85, 1.67 and 2.35 % for pedons 1, 2 and 3, respectively. Clay content had no particular trend in pedons 1 and 2 and increased consistently in pedon 3 although it decreased sharply in Bt2 horizon due to agillation that occurred at Bt1. Mean clay content were 6.69, 6.62 and 15.44 % in pedons 1, 2 and 3, respectively. The SCR were low as all values recorded were less than 1. This suggests that soils investigated have attained advanced stage of weathering, highly weathered and highly leached which characterized most soils in the southeastern Nigeria. The mean silt/clay ratios were 0.13, 0.25 and 0.15 in pedons 1, 2 and 3, respectively. The texture of the three pedons investigated ranged from sandy to loamy sand and sandy loam. Bulk density increased down the horizons in all pedons investigated while porosity decreased down the profile. Mean bulk density were 1.41, 1.49 and 1.44 g/cm^3 and mean porosity were 46.50, 43.77 and 45.43% all in pedons 1, 2 and 3, respectively.

The textural class of the investigated soils exhibited sandy, loamy sand and sandy loam. This texture is as a result of the parent material of soils of Imo State Polytechnic Umuagwo which is coastal plain sand. The low silt/clay ratio suggests advanced stage of weathering as silt/clay ration were < 1.0. The consistent clay increase down the profile in pedon 3 was due to clay movement down the profile suggesting illuviation and formation of argillic horizon in Bt1. The increase in bulk density down the horizon may be due to decrease in organic matter content, compaction emanating from the weight of over burdened surface soils and impact of roots on the subsurface soils as well as human influence on soils (Eshett, 1996). Also the farmers plough with local (desi), plough which disturb the soil up to 20 cm only and lower layers remain undisturbed for years together which sometimes result in pan formation (agric horizon). These results are in conformity with the findings of Meelu *et al.* (1979).

The chemical properties of investigated soils along Otamiri watershed near the research farm of Imo State Polytechnic Umuagwo were shown in Table 4. The pH distributions were irregular and ranged from moderately to slightly acidic in all pedons. The mean pH were 5.85, 5.74 and 5.87 in pedons 1, 2 and 3, respectively. Organic matter and total nitrogen all decreased down the horizons in all investigated pedons. Means organic matter were 0.522, 0.723 and 0.462 % while mean total nitrogen were 0.025, 0.036 and 0.023 % all in pedons 1, 2 and 3, respectively. Also the mean CN ratios were 12.09, 11.77 and 11.82 in pedons 1, 2 and 3 respectively. Available P increased down the profile in pedons 1 and 2 and decreased in pedon 3, mean available P were 51.99, 31.84 and 16.82 mg/kg in pedons 1, 2 and 3 respectively. Total Exchangeable bases values were low and decreased down the profile in all investigated soils. Mean TEB were 0.682, 1.093 and 1.207 g/kg in pedons 1, 2 and 3 respectively. Total exchangeable acidity values were low and more so the exchangeable Al were in trace amount especially in pedons 1 and 2. Mean TEA were 0.27, 0.35 and 1.15 g/kg in pedons 1, 2 and 3 respectively. Base saturation was highest in pedon 2 where it recorded mean of 75.51 % compared to 71.17 and 50.75 % recorded in pedons 1 and 3 respectively. Al saturation were very low in pedons 1 and 2 (0.05 %) indicating that Al content of the soils were in trace level whereas in pedon 3 mean Al saturation rose to 45.84 %.

The result of the chemical properties indicated that pH was moderately acidic being in the range of 5.3 – 6.0. Organic carbon, organic matter and total nitrogen were all very low. Organic matter was less than 1.0 %, total N was less than 0.05 % and are considered low according to Tabi *et al.,* (2012). Available P were high in all pedons especially in pedons 1 and 2 where it recorded 51.99 and 31.84 mg/kg respectively compared to pedon 3 where it recorded 16.82 mg/kg all being above 15 mg/kg according to Tabi *et al.,* 2012. The high available P content may be due to the optimum pH mediums which were slightly and moderately acidic compared to very low pH or very high pH which may lead to P fixation in arable soils. The low exchangeable bases as observed in all pedons may be due to increased leaching which characterizes most tropical soils (Onweremadu, 2006). The total exchangeable bases were low indicating that Al toxicity may not be a problem to these soils. Generally the ECEC of the soils were low being less than 4.0 g/kg in all investigated soils this may be as a result of the coastal plain sand parent material which has encouraged intense leaching of exchangeable cations in these soils.

Table 4: Chemical Properties of Investigated Soils

Location	Depth (cm)	pH (H_2O)	OC	OM	TN	C-N Ratio	Avai. P (mg/kg)	Ca	Mg	K	Na	TEB	Al	H	TEA	ECEC	B Sat. (%)	Al Sat. (%)
			←	%	→			←				g/kg			→			
Pedon1																		
A	0-21	5.73	0.359	0.619	0.030	12.44	3.59	0.631	0.043	0.011	0.010	0.695	0.01	0.36	0.37	1.063	65.26	0.05
AB	21-35	6.17	0.322	0.555	0.027	12.83	35.00	0.591	0.143	0.011	0.010	0.757	0.01	0.36	0.37	1.127	67.17	0.05
Bt1	35-84	5.78	0.321	0.553	0.027	11.89	82.60	0.714	0.321	0.007	0.012	1.054	0.01	0.24	0.25	1.304	80.82	0.05
Bt2	84-145	5.72	0.211	0.364	0.018	11.23	86.80	0.123	0.081	0.010	0.011	0.225	0.01	0.08	0.09	0.315	71.43	0.05
Meam		5.85	0.303	0.522	0.025	12.09	51.99	0.514	0.147	0.010	0.010	0.682	0.01	0.26	0.27	0.952	71.17	0.05
CV		4.1	6.5	6.5	6.2	3.8	98.5	9.7	83.3	23.9	10.8	23.0	0.0	21.7	21.0	10.7	11.9	0.0
Pedon2																		
A	0.16	5.65	0.539	0.929	0.046	11.77	16.18	0.734	0.430	0.012	0.011	1.187	0.01	0.28	0.29	1.477	80.37	0.05
AB	16-45	5.61	0.501	0.864	0.043	11.89	23.60	0.476	0.328	0.010	0.010	0.734	0.01	0.28	0.29	1.024	71.68	0.05
Bt1	45-71	6.01	0.426	0.734	0.037	12.23	30.18	0.809	0.432	0.018	0.013	1.272	0.01	0.44	0.45	1.722	73.87	0.05
Bt2	71-153	5.72	0.234	0.403	0.020	11.19	57.40	0.921	0.236	0.012	0.012	1.181	0.01	0.36	0.37	1.551	76.14	0.05
Mean		5.74	0.425	0.732	0.036	11.77	31.84	0.735	0.356	0.013	0.011	1.093	0.01	0.34	0.35	1.443	75.51	0.05
CV		3.8	11.8	11.8	10.9	2.1	30.0	26.0	15.0	31.2	13.5	27.2	0.0	27.7	26.9	25.2	6.0	0.0
Pedon3																		
A	0-19	5.99	0.339	0.584	0.029	12.02	35.70	0.984	0.543	0.011	0.010	1.548	0.84	0.36	1.20	2.748	56.33	30.56
AB	19-49	5.55	0.318	0.548	0.027	11.43	10.50	0.654	0.345	0.012	0.010	1.021	1.00	0.12	1.12	2.141	47.47	52.06
Bt1	49-87	5.87	0.215	0.370	0.019	12.23	16.13	0.754	0.532	0.032	0.011	1.329	0.52	0.40	0.92	2.249	59.09	40.90
Bt3	87-165	6.08	0.201	0.346	0.017	11.60	4.980	0.324	0.587	0.011	0.010	0.932	1.04	0.35	1.39	2.322	40.14	59.86
Mean		5.87	0.268	0.462	0.023	11.82	16.82	0.679	0.501	0.016	0.010	1.207	0.85	0.30	1.15	2.365	50.75	45.84
CV		3.9	22.8	22.8	21.2	3.5	63.7	21.2	23.5	64.6	5.6	20.4	31.1	51.6	13.4	13.6	11.2	26.1

OM = organic matter, TN = total nitrogen, Av.P = available phosphorus, TEB = total exchangeable bases, TEA = total exchangeable acidity, ECEC = effective cation exchange capacity, B. Sat = base saturation, Al Sat. = aluminum saturation,

3.1 Soil Classification

The diagnostic criteria for classification of Pedons 1, 2 and 3 according to the USDA Soil Taxonomy (Soil Survey Staff, 1999) include an udic soil moisture regime and an hyperthermic soil temperature regime characteristic of semi arid to subhumid subtropical climate. The low silt/clay ratio (<1.0) suggests advanced stage of weathering and highly leached soils which is a characteristic of Ultisols and Alfisols. The high preponderance of sand indicated a dominance of low activity clay such as kaolinite. There was consistent clay increase in pedon 3 leading to formation of argillic horizon in Bt1 horizon. There was high sandy distribution and irregular clay movement down the horizon in pedons 1 and 2. Pedons 1 and 2 were therefore classified as Arenic Hapludults and pedon 3 classified as Typic Kandiudults.

4.0 Conclusion

The result obtained from laboratory analyses indicated that the investigated soils were dominated with sandy soil fractions. Silt/clay ratios were very low indicating that soils were highly leached and highly weathered which were Alfisols or Ultisols. Bulk density were within the acceptable limit of < 1.85 for ease of root penetration. Soil pH were moderately or slightly acidic. Organic carbon, organic matter and total nitrogen were low. ECEC of the soils were low being less than 4.0 g/kg in all investigated soils this may be as a result of the coastal plain sand parent material which has encouraged intense leaching of exchangeable cations in these soils. Soil pH is the only chemical property that recorded low variability while most chemical properties were moderately and highly variable. Also most physical properties varied lowly (LV) except clay and silt which exhibited high variability. Pedons 1 and 2 were therefore classified as Arenic Hapludults and pedon 3 classified as Typic Kandiudults.

Recommendations

Soils were very low in basic cations, therefore farmers should be encouraged to use organic manure to improve soil fertility.

Use of heavy equipment on the soil should be discouraged as it compacts the soils and may lead to erosion which further causes nutrient loss from the soils.

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