Pedological Properties and Classification of Soils Underlain by Asu River Group Parent Materials in Ohaozara, Southeastern Nigeria

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Abstract

The study was carried out in Ohaozara Southern Ebonyi State in Southeastern Nigeria and aimed at studying the pedological properties as well as classifying the soils underlain by Asu River group parent material. Study area was identified in a rice soil of about 120 hectares used by FGN/IFAD Value Chain Development program (VCDP). Three profile pits were dug on a transect line of about 100 – 200m apart. Samples were collected and analyzed using standard procedures. Soil colours ranged from yellow (5YR7/3) at the A horizon to reddish yellow (5YR7/8) at the Bt2 horizon of pedon in location 1 when measured under dry condition. Also at the location 1 when soils were measured under moist condition, the colours ranged from very pale brown (10YR7/3) at the topmost horizon to reddish yellow (7.5YR7/8) at the Bt2 horizon. At location 2, soil colour ranged from white (5YR8/1) at the topmost horizon to reddish yellow (10YR7/6) at the Bt2 horizon when dry. However, when moist it ranged from light grey (7.5YR7/1) to strong brown (7.5YR5/6) from top to bottom of the profile. Location 3 had colours ranging from light grey (5YR7/1) at the top to yellow (10YR8/4) at the bottom when dry and from very pale brown (10YR7/3) to yellow (5YR7/6) from horizon A to horizon Bt2 when moist. Silt-clay ratios decreased down the profile in all investigated locations and scored means of 0.95, 1.02 and 1.10 in locations 1, 2 and 3 respectively. Bulk density and porosity had an opposite trend as bulk density increased down the profile, porosity decreased down the profile. The means of bulk density were 1.34, 1.44 and 1.32 g/cm^3 while the means of the porosity were 49.34, 45.66 and 50.17 % in locations 1, 2 and 3 respectively. Therefore, pedon 1 is classified as Typic Eutrudept (USDA) and Eutric Cambisols (WRB) while pedons 2 and 3 were classified as Aquic Eutrudepts (USDA) and Gleyic Leptosols (WRB).

Keywords: Pedological properties, soil classification, Asu river group, southeastern Nigeria

Introduction

Soil pedology focuses on understanding and characterizing soil formation, evolution, and the theoretical frameworks through which we understand a soil body(s), often in the context of the natural environment. Among the key components of pedological properties of the soil are the morphological, physical and chemical characteristics of the soil. Morphological, physical and chemical properties of the soils are of great importance in understanding how the soils could be properly utilized. Soil morphology is studied from the *in situ* evaluation of the soil profile while the physical and chemical properties are measured by laboratory techniques. For agricultural purpose, physical properties of the soils are not easily modified in the plantation (Ugwa et al., 2017). It is even harder to alter them than the chemical properties (Brady, 2002; Malgwi, et al., 2000). Different workers (Orimoloye, et al., 2010; Kamalu, et al, 2014), have associated yield decline to poor physical properties and these may include low soil depth, changes in water holding capacity and relatively light texture soils. Enwezor, et al., (1981) had reported that most soils of southern Nigeria are inherently low in soil fertility, very susceptible to erosion and acidic with poor physical properties.

A long continuation of wetland soil cultivation often causes characteristic changes in soil morphology and properties, including surface gray coloring and the development of iron and manganese accumulation horizons. The major morphological features such as grey or low chroma (<3) colour, mottles are characteristics of this soils, and is an indication of soil wetness brought about by oxidation – reduction cycle due to ground water fluctuation inter-relationship between these features. The reduced Fe present in these soils impact grayish colour on the soil matrix (Malgwi et al., 2000).

Soil characterization and classification provide a powerful resource for the benefit of mankind, especially in the area of food security and environmental sustainability (Esu, 2004). According to Ajiboye and Ogunwale (2010), studies conducted on the soils of some regions of Nigeria and subsequent classifications were based majorly on the soil parent materials at the higher category classes. Soil classification study is however a major building block in terms of understanding the soil, classifying it as well as getting the best understanding of the environment. Esu and Akpan-Idiok (2010), characterized the morphological and physico-chemical properties of alluvial soils and classified them according to the USDA Soil Taxonomy System (Soil Survey Staff, 1999) and the World Reference Base for Soil Resources (WRB) Classification System (FAO, 2001). Therefore USDA Soil Taxonomy (Soil Survey Staff, 1999) and the WRB for soil resources (FAO, 2001) are the two most used classification systems in Nigeria (Esu, 1999).

This study aimed at determining the morphological and physical properties of the soils derived from Asu River parent material as well as classify them for better management and agricultural sustainability.

The Study Area

Location

The study area is located near Umunaga – Uburu in Ohaozara Local Government Area of Ebonyi State Southeastern Nigeria, with the Latitude of 6^{o} 01′ N and Longitude of 7^{o} 78′ E. The study area is located within the partially modified low rain forest and wooded/ grassland derived savannah southeastern Nigeria and experiences rainfall between March - November with highest intensities occurring between June-September while about three months of dry season occur from December – February (Ogbodo, 2013). The area lies within the humid tropics with Ustic moisture regime (Obasi and Obasi 2020). This concept is one of moisture that is limited but is present at a time when conditions are suitable for plant growth. The soil in moisture control section in ustic moisture regime is dry in some or all parts for 90 or more cumulative days in normal year (Soil Survey Staff, 2003; Ahukaemere et al., 2018; Ahukaemere and Obasi, 2018). This location receives a mean annual rainfall of between 2250 mm in the South and 1500 mm in the northern part of the zone, average annual temperature of about 27^{o}C with relative humidity of 85% (Nwakpu, 2003).

Geology and Geomorphology

The study area falls within the Asu-River Geologic Group (Lower Cretaceous), Eze-Aku shale formation and Nkporo Formations. The Asu River Group is a major stratigraphic unit in the study area, consisting of dark micaceous shale, fine grained and calcareous sandstone bodies (Ogbodo 2013). The sediments later became folded given rise to two major structural features, the Abakalili anticlinorium and related Afikpo synclinorium (Esu, 2004; Ukaegbu and Akpabio 2009). It is made up mainly of hydromorphic soils which consist of reddish brown gravely and pale coloured clayey soil, shallow in depth, and of shale parent material (Obasi, 2010; Ogbodo, 2013).

Field Work

Reconnaissance study was carried out and the study area identified near Umunaga in Ogbuoma autonomous Community Uburu in Ohaozara Local Government Area of Ebonyi State. The study area was in a FGN/IFAD/ Value Chain Development Programme (VCDP) site having about 120 hectares of land. The study area has been subjected to rice farming over the years due its prevalent lowland nature. Three profile pits were dug at an appreciable interval of 100 – 200 m apart within the study area.

Laboratory Analysis

Soil samples were air dried, pulverized, and sieved through a 2 mm sieve mesh. The properties analyzed include particle size distribution determined by hydrometer method (Gee and Bauder, 1986). Soil pH was determined in a 1:1 soil/water ratio using digital pH meter and conductivity meter respectively. Exchangeable acidity was determined by the 1N KCl method. Exchangeable bases; Calcium (Ca), Magnesium (Mg), Potassium (K), and Sodium (Na) were determined using NH4OAc saturation method (IITA, 1979). Ca and Mg in solution were determined using Atomic Absorption Spectrophotometer, while K and Na were determined using Flame Emission Photometer. Organic carbon was determined by Walkley and Black dichromate wet oxidation method (Nelson and Sommers,1982). Total nitrogen was determined by micro-kjeldahl technique (Bremner and Mulvaney, 1982). The Effective Cation Exchange Capacity (ECEC) was determined summation method, while the available phosphorus was extracted by Bray II method (Olsen and Sommers 1982). Base saturation was calculated as the sum of all base forming cations, divided by cation exchange capacity and multiplied by 100.

Results and Discussion

The morphological properties of soils were as shown in table 1. The parent material is Shale/Alluvium derived from Asu River group (Ukaegbu and Akpabio 2009). The profiles were deep enough for rice cultivation and drainage indicated well drained for Ap and AB horizons and poorly drained for Bt1and Bt2 horizons. Soil colours ranged from yellow (5YR7/3) at the A horizon to reddish yellow (5YR7/8) at the Bt2 horizon of pedon in location 1 when measured under dry condition. Also at the location 1 when soils were measured under moist condition, the colours ranged from very pale brown (10YR7/3) at the topmost horizon to reddish yellow (7.5YR7/8) at the Bt2 horizon. At location 2, soil colour ranged from white (5YR8/1) at the topmost horizon to reddish yellow (10YR7/6) at the Bt2 horizon when dry. However, when moist it ranged from light grey (7.5YR7/1) to strong brown (7.5YR5/6) from top to bottom of the profile. Location 3 had colours ranging from light grey (5YR7/1) at the top to yellow (10YR8/4) at the bottom when dry and from very pale brown (10YR7/3) to yellow (5YR7/6) from horizon A to horizon Bt2 when moist. The coating of iron oxides often gives rise to yellow, brown or red colouration in the soil matrix and these may provide information on some soil properties. The low chroma observed in most of the epipedons may have resulted due to wetness situation of the studied soils, as FAO, (2006) noted that morphological feature such as low chroma is an indicative of soil wetness.

Table 1: Morphological Properties of Soils

Location 1	Colour (dry)	Colour (moist)	Structure	Consistence			Mottles	Root Abundance	Horizon Boundaries
				Wet	Moist	Dry			
A	5 YR 7/3, y	10 YR 7/3, vpb	2,bk,c	s	fi	vh	-	C,m	clear
AB	5 YR 7/4, y	5 YR 6/1, pg	2,m,vc	vs	Vfi	eh	f	Mf,f	clear
Bt1	5 YR 7/8,r y	5 YR 7/6, ry	2,abk,c	vs	vfir	eh	m	Vf,f	Gradual
Bt2	5 YR 7/8,r y	7.5 YR 7/8, ry	2,abk,vc	vs	Vfi	eh	m	Vf,f	-
Location 2									
A	5 YR 8/1,w	7.5 YR 7/1, lg	2,m,vc	s	Fi	vh	-	C,m	Clear
AB	5 YR 8/2,pw	7.5 YR 7/1, lg	2,abk,vc	vs	Vfi	vh	f	Vf,f	Abrupt
Bt1	10 YR 7/6, ry	2.5 YR 7/6, lr	2,sbk,c	vs	Efi	eh	m	Vf,vf	Clear
Bt2	10 YR 7/6, ry	7.5 YR 5/6, sb	2,m,vc	vs	Efi	eh	m	Vf,vf	-
Location 3									
A	5 YR 7/1, lg	10 YR 7/3, vpb	2,m,vc	ss	Fi	vh	-	C,m	gradual
AB	10 YR 7/6, ry	10 YR 8/6, y	2,m,vc	vs	Vfi	vh	f	Vf,vf	Clear
Bt1	10 YR 7/8, ry	5 YR 7/8, ry	2,m,vc	vs	Vfi	vh	f	Vf,vf	Abrupt
Bt2	10 YR 8/4, y	5 YR 7/6, y	2,m,vc	Ps	Efi	eh	m	Vf,vf	-

Colour: y = yellow, ry = reddish yellow, w = white, pw = pinkish white, lg = light grey, Lr = light red, sb = strong brown, vpb = very pale brown, pg = pinkish grey. **Mottles:** f = few, m = many; **Structure:** 2 = moderate, Bk = block, M = massive, abk = angular blocky, sbk = subangular blocky, c = coarse, vc = very coarse. **Consistence: S**= sticky. Vs = very sticky, ss = slightly sticky, Ps = slightly plastic, fi = firm, vfi = very firm, efi = extremely firm, vh = very hard, eh = extremely hard, h = hard. **Roots:** C= common, vf = very fine, vf = very few, mf= moderately few, f=fine.

Mottles were absent at the epipedons in all investigated soils, few in the middle or AB horizons and many at the Bt1 and Bt2 horizons in all investigated soils although the Bt1 horizon at location 3 had few mottles. All the pedons had abundant redoximorphic features in form of strong brown mottles due to the reducing/waterlogged soil conditions. Researchers observed similar mottles respectively in subsoils of floodplains in southern Nigeria (Akpan-

Idiok, and Ogbaji, 2013; Obasi et al., 2015a), surface-water grey soils in Bangladesh (Khan *et al.,* 2012) and pedological properties of typical alluvial soils in Tanzania (Asheri et al., 2017).

Soil structure determination indicated that all the investigated soils had moderate structures; structure that is well formed and distinct peds, moderately durable and evident, although not distinct in undisturbed soil. In location 1, structure was blocky and coarse at the epipedon while at the Bt2 horizon it was sub-angular blocky in form and very coarse in its size. At location 2, the structure was massive in form and very coarse in its size at the A and Bt2 horizons. The same trend was observed at the location 3 where all horizons had massive and very coarse structure. This massive structure shows little or no tendency to break apart under light pressure into smaller units. This structure was due to relative presence of clay structure from the shale/alluvium parent material of the study area. This tends to bind the particles together with some sort of strong and cohesive forces which when dry forms coarse to very coarse or massive structure. This results corroborates the reports of Obasi et al., (2015b) who worked on the soil of Otamiri Watershed in Umuagwo-Ohaji in the same agro-ecology.

Soil consistence when wet ranged from sticky in locations 1 and 2 to slightly sticky in location 3 at their surface horizon and from very sticky in locations 1 and 2 to slightly plastic in location 3 at their Bt2 horizons. Consistence when moist ranged from firm to very firm from top to bottom of profile in location 1, firm to extremely firm from top to bottom of the profile in locations 2 and 3. When dry, consistence of the studied soils ranged from very hard to extremely hard from top to bottom in all locations. The stickiness of the consistence when wet reveals the fact that the investigated soils are of shale parent materials under Asu river group. The firmness when moist and hard to extremely hard when dry were as a result of clay properties which exhibited binding properties on the soil particles.

Root abundance indicated that the top (Ap) horizons had common and many roots while AB horizons had moderately few and fine roots at location 1, very few and very fine in locations 2 and 3. All other horizons in all locations ranged from very few and fine to very few and very fine in locations 1, 2 and 3. The roots were more on or near the epipedons of the studied soils. Most of the roots encountered were from the rice plant which decreased down the horizons in all investigated soils.

Horizon boundary attributes varied among and within pedons, whereby distinctness ranged from abrupt to gradual in all investigated soils, but topography was dominantly smooth.

The differentiation of horizons within the pedons was made on soil colour and textural variations similar to that of Orimoloye et al., (2010)**,** implying that the soils are young. The overall, morphology of the studied soils were typical of shale/alluvial soil formation of the Asu river group. This is in line with the study of Asheri et al., (2017) who stated that the morphology and genesis of Tanzanian lowland soils were of alluvia soil formation.

The physical properties of the studied soils are shown in table 2. Soils textural properties indicated that sand and silt had similar trends as they decreased down the profile in all studied locations. While clay took an opposite trend as it increased down the horizons in all locations. Sand had means of 46.24, 41.74 and 46.76%; Silt had means of 25, 28 and 22% while clay had means of 27.54, 27.76 and 26.76% all in locations 1, 2 and 3 respectively. The textural class of the studied soils ranged from sandy loam at the epipedons to clay loam at the endopedons of locations 1 and 2 while location 3 recorded sandy loam in all its horizons.

Table 2: Soil Physical Properties

Location	Depth (cm)	Sand ←	Silt %	Clay →	Silt/Clay Ratio	TC	BD g/cm^3	Porosity (%)
Pedon 1								
Ap	0 – 15	51.24	28.0	20.76	1.35	SL	1.28	51.69
AB	15 – 37	48.24	27.0	24.76	1.09	SL	1.31	50.56
Bt1	37 – 75	45.24	24.0	28.76	0.83	SL	1.36	48.67
Bt2	75 – 110	40.24	21.0	38.76	0.54	CL	1.42	46.42
Mean		46.24	25.0	27.54	0.95		1.34	49.34
CV		4.1	28.3	7.2	3.93		4.6	Nd
Rank		LV	MV	LV	LV		LV	Nd
Pedon 2								
Ap	0–75	44.24	31.0	24.76	1.25	SL	1.32	50.19
AB	17–43	42.24	30.0	27.76	1.08	SL	1.43	46.04
Bt1	41–83	40.24	27.0	32.76	0.82	CL	1.48	44.15
Bt2	83–124	40.24	24.0	25.76	0.93	CL	1.53	42.26
Mean		41.74	28.0	27.76	1.02		1.44	45.66
CV		4.4	57.7	13.3	4.33		6.2	Nd
Rank		LV	HV	LV	LV		LV	Nd
Pedon 3								
Ap	0–16	50.24	33.0	17.76	1.86	SL	1.20	54.72
AB	16–38	47.24	27.0	25.76	1.05	SL	1.28	51.69
Bt1	38–76	45.24	25.0	29.76	0.84	SL	1.34	49.34
Bt2	76–126	44.24	22.0	33.76	0.65	SL	1.46	44.91
Mean		46.74	26.75	26.76	1.10		1.32	50.17
CV		2.5	55.4	14.1	3.92		8.3	Nd
Rank		LV	HV	LV	LV		LV	Nd

Clay content increased with depth in all pedons providing some indication of clay eluviation-illuviation. Asheri et al.,(2017) observed consistent clay increase with depth as an indication of clay migration in an alluvial soils. Also, the relatively higher clay concentrations at locations 1 and 2 are indications that these areas would retain more moisture compared to location 3 since Kebeny et al., (2015) reported that a pedon with high clay content have higher moisture retention capacity with a gradual moisture decrease as suction potential increased, compared to ones dominated by sand with a rapid decrease in moisture content as the suction potential increased.

Silt-clay ratios decreased down the profile in all investigated locations and scored means of 0.95, 1.02 and 1.10 in locations 1, 2 and 3 respectively. Silt-clay ratio (SCR) is an important criterion used in the evaluation of clay migration, stage of weathering and age of parent material and soil (Yakubu and Ojanuga, 2013). The more highly weathered a soil is, the lower the silt fraction. FAO, (1990) reported that silt-clay ratio less than 0.20 indicates a low degree of weathering. Ayolagha, (2001) on the other hand reported that old parent materials usually have a SCR below 0.15 while SCR above 0.15 is indicative of young parent materials. However, results of this study showed that all the soils had silt-clay ratios above 0.2 indicating a high degree of weathering potentials in all the soils. Higher SCR (0.95, 1.02 and 1.10) recorded in locations 1, 2 and 3 of soils underlain by the Asu river group indicated young parent material.

Bulk density and porosity had an opposite trend as bulk density increased down the profile, porosity decreased down the profile. The means of bulk density were 1.34, 1.44 and 1.32 g/cm^3 while the means of the porosity were 49.34, 45.66 and 50.17 % in locations 1, 2 and 3 respectively. This trend has been observed by Obasi et al., (2015) who worked on the rice soils of the region.

However, Esheri et al., (2017) noted that the decreasing state of bulk density was due to the fact that subsurface layers are more compacted and have less organic matter, aggregation, and root penetration compared to surface layers, leading to less pore spaces. Bulk density therefore affects several processes in the soils including; infiltration, rooting depth, available water capacity, soil porosity, plant nutrient availability, and soil microbial activity, which in turn influence key soil pedogenic processes as well as productivity. USDA-NRCS (2016) suggested that bulk density values greater than 1.65 g/cm3 are unfavorable to root growth in sandy clay loams and clay loams. Thus, the observed bulk density values in Pedons of the studied soils are favorable in that regard.

The results of soil chemical properties of the study site are as shown in the table 3 below. The results indicated that soil pH had no particular trend in some part of the study area. This is because while the trend decreased in locations 1 and 2, it however increased in location 3. Mean pH were 5.25, 5.16 and 5.15 in locations 1, 2 and 3 respectively. Soil pH is one of the most essential chemical properties of the soil and has been rated as follow by Landon (1991); pH (H_2O) of 4.6 - 4.9 as very low, < 5.5 as low and 5.5 to 7.0 as medium. The pH of the studied locations were however low and may be attributed to low amounts of bases caused by leaching during fluctuations of water table and percolation of water during flooding periods, removal of bases through crop harvests and farming practices. The increase of pH down the profile in location 3 is in agreement with Khan et al., 2012 who observed similar trend of pH increasing with depth in annually flooded soils of Bangladesh.

Organic carbon, organic matter and total nitrogen all decreased down the profile recording means of 0.715, 0.571, 0.468%; 1.108, 0.991, 0.568%; 0.068, 0.055, 0.044% for OC, OM and TN in locations 1, 2 and 3 respectively. The decreasing situation of OC, OM and TN down the profile were related and caused by reduction of litter deposits and organic substances down the profile. Available phosphorus increased in the first 3 horizons and decreased in the Bt2 horizon of location 1 while it decreased in the other locations. Available P scored means of 27.68, 24.18 and 20.3 mg/kg in locations 1, 2 and 3 respectively. The phosphorus content of the representative pedons is generally high (>15 mg/kg) based on the rating Tabi et al., (2012) who worked on the Chari flood plain of Cameroun. Researchers such as Enwezor et al., (1990); Adepetu, (2000) corroborated this by stating that available P <15 mg/kg was low for Nigerian soils. Uzoho et al., (2004) believed high acidity (pH < 5.0) usually leads to low soil available P as P gets fixed in high acidic soils. However, the studied soils had pH > 5.0 < 5.5 which though not optimum pH (5.5 – 7.0) for good crop growth and sustenance leading to a medium to high P content of the studied soils.

Table 3: Chemical Properties of Studied Soils

Location	Depth (cm)	pH	OC	OM %	TN	C/N Ratio	Avail.P mg/kg	Ca	Mg	K	Na^+	H^+	Al^{3+} Cmol/kg	TEA	TEB	ECEC	B. Sat %	Al Sat %
Pedons 1																		
A	0–15	5.55	1.084	1.876	0.103	10.52	28.3	1.86	0.93	0.079	0.056	0.53	trace	0.53	2.925	3.455	84.66	5.00
AB	1 –37	5.28	0.963	1.660	0.091	10.58	30.6	1.72	1.08	0.194	0.062	0.46	0.50	0.96	3.056	4.016	76.10	12.45
B ti	37–75	5.12	0.506	0.872	0.048	10.54	32.3	1.63	0.93	0.173	0.053	0.56	0.44	1	2.786	3.786	73.59	11.62
Bt2	75–110	5.08	0.308	0.531	0.029	10.62	19.5	1.96	0.71	0.162	0.051	0.71	trace	0.71	2.883	3.593	80.24	5.00
Mean		5.25	0.715	1.108	0.068	10.57	27.68	1.79	0.91	0.152	0.055	0.57	0.24	0.8	2.913	3.713	78.65	8.52
Cv		4.1	51.5	45.1	51.7	Nd	20.6	8.2	16.7	33.2	133.1	18.6	115.	27.6	3.8	6.6	6.2	Nd
Rank		LV	HV	HV	HV	Nd	MV	LV	MV	MV	HV	MV		MV	LV	LV	LV	Nd
Pedon 2																		
A	0–75	5.19	0.835	1.440	0.079	10.56	29.8	1.03	0.57	0.098	0.033	1.02	trace	1.02	1.731	2.751	62.92	5.00
AB	17–43	5.22	0.621	1.071	0.059	10.52	26.9	1.22	1.26	0.083	0.046	0.51	0.96	1.47	2.609	4.079	64.00	23.53
Bti	41–83	5.09	0.510	0.879	0.048	10.62	21.8	1.36	0.78	0.073	0.051	0.32	0.33	0.65	2.354	3.004	78.40	10.98
Bt2	83–124	5.12	0.352	0.607	0.033	10.66	18.2	0.95	1.01	0.062	0.056	0.65	0.69	1.34	2.078	3.418	60.80	20.19
Mean		5.16	0.571	0.991	0.055	10.59	24.18	1.14	0.82	0.079	0.046	0.63	0.41	1.12	2.193	3.313	66.50	14.93
Cv		1.2	35.0	35.0	35.4	Nd	21.4	16.3	16.7	19.4	21.3	47.4	84.5	32.7	17.2	17.5	12.1	Nd
Rank		LV	MV	MV	HV	Nd	MV	MV	MV	MV	MV	HV	HV	MV	MV	MV	LV	Nd
Pedon 3																		
A	0–16	5.06	0.615	1.060	0.058	10.60	22.5	0.91	6.63	0.086	0.063	0.44	0.71	1.15	1.759	2.909	60.50	24.41
AB	16–38	5.20	0.482	0.833	0.046	10.47	17.5	1.27	0.78	0.071	0.052	0.63	0.56	1.19	2.173	3.363	64.60	16.65
Bt1	38–76	5.22	0.409	0.705	0.038	10.76	19.8	1.32	0.88	0.097	0.043	0.69	0.43	1.12	2.34	3.46	67.60	12.43
Bt2	76–126	5.10	0.365	0.629	0.035	10.42	21.3	1.49	1.0	0.053	0.037	0.48	0.38	0.86	2.58	3.44	75.00	11.05
Mean		5.15	0.468	0.568	0.044	10.56	20.3	1.25	2.32	0.077	0.049	0.56	0.52	1.08	2.213	3.293	66.90	10.40
Cv		1.5	23.4	23.4	23.2	Nd	10.6	16.8	31.0	24.9	23.2	21.3	28.4	13.8	15.6	7.9	9.1	Nd
Rank		LV	MV	MV	MV	Nd	LV	MV	MV	MV	MV	MV	MV	LV	MV	LV	LV	Nd

OC = organic carbon, 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, CV= Coefficient of Variation, LV= Low variability, MV= Moderate variability, HV= High Variability.

Calcium had no particular trend in locations 1 as it tends to be highest in Bt2 horizon. It however increased progressively in location 2 although it dropped to the lowest at Bt2 horizon whereas it increased all through down the profile across all horizons in location 3. Ca had means of 1.79, 1.14 and 1.25 cmol/kg in locations 1, 2 and 3 progressively. The Ca content of the soils were very low (<2 Cmol/kg) according to Tabi et al., 2012) in all investigated pedons.

Magnesium had no particular in all locations and recorded high accumulation at the surface horizon of location 3. The means Mg were 0.91, 0.82 and 2.32 in locations 1, 2 and 3 respectively. Mg contents of locations 1 and 2 were low (0.5 – 1.5 cmol+/kg) while location 3 was medium (1.5 – 3.0 cmol+/kg). Potassium and Sodium did not have definite trend in location 1 while K also had no definite trend in location 3. However, K and Na decreased consistently in pedon 2 and Na in pedon 3. Means of K and Na were 0.152, 0.079, 0.077; 0.055, 0.046, 0.049 cmol/kg in locations 1, 2, and 3 respectively. Location 1 was low (0.1 – 0.3 cmol+/kg) in K scoring 0.152 cmol+/kg. All other locations were very low in K (<0.1 cmol+/kg). All investigated locations were very low in Na being <0.1 cmol+/kg according to Tabi et al., (2012).

Total exchangeable acidity (TEA) was low compared to their total exchangeable bases (TEB) counterparts in all the investigated soils. Their means were 0.8, 1.12, 1.08; 2.91, 2.19, 2.21 cmol/kg for TEA and TEB at locations 1, 2 and 3 respectively. As a result the base saturation was moderate to optimum in the investigated soils compared to the Al saturation which was quite low. Mean base saturation and Al saturation were; 78.65, 66.50, 66.90%; 8.52, 14.93, 10.40% in locations 1, 2 and 3 respectively. This situation therefore suggests that Al toxicity may not be a challenge to the dominant crops grown on the investigated soils. Msanya et al., (2001) suggested that soils with BS > 50% are fertile soils and vice versa although the following classes were recognized: BS < 20% as low, 20-60 as medium, and above 60% as high.

Taxonomic Classification

The diagnostic criteria for classification of soils of Ohaozara according to the USDA Soil Taxonomy (Soil Survey Staff, 2010) include an udic soil moisture regime and a hyperthermic soil temperature regime characteristic of semi-arid to sub-humid subtropical climate. The investigated soils have their silt/clay ratios as <1.0 in location 1, and > 1.0 in locations 2 and 3, suggesting that the investigated soils were mostly young soils such as Inceptisol or Entisol. There was consistent clay increase in all studied soils leading to formation of argillic horizon in Bt1 horizon of location 2 and kandic horizons in locations 1 and 3. Organic matter contents and stratification qualified pedons in locations 1, 2 and 3 as Fluvents, since there was an irregular decrease in organic-carbon content (Holocene age) between a depth of 25 cm and either a depth of 125 cm below the mineral soil surface. Isohyperthermic soil temperature regime placed the investigated soils on the suborder Tropepts, The temperature regime and percentage base saturation were considered at the subgroup level in the soil taxonomy. A base saturation (by NH4OAc) of more than 60 percent or more at a depth between 25 and 75 cm from the mineral soil surface. There was presence of lithic contact in location 1, at a depth of 110 cm while water was encountered in locations 2 and 3 at a depth of 124 and 126 cm respectively.

Therefore, pedon 1 is classified as **Typic Eutrudept (USDA) and Eutric Cambisols (WRB)** while pedons 2 and 3 were classified as **Aquic Eutrudepts (USDA) and Gleyic Leptosols (WRB)**.

Conclusion

The parent material is Shale/Alluvium derived from Asu River group. The profiles were deep enough for rice cultivation and drainage indicated well drained for Ap and AB horizons and poorly drained for Bt1and Bt2 horizons. Soils textural properties indicated that sand and silt had similar trends as they decreased down the profile in all studied locations. While clay took an opposite trend as it increased down the horizons in all locations. Therefore, pedon 1 is classified as Typic Eutrudept (USDA) and Eutric Cambisols (WRB) while pedons 2 and 3 were classified as Aquic Eutrudepts (USDA) and Gleyic Leptosols (WRB).

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