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CLASSIFICATION OF SOILS ALONG OGOCHIE RIVER FLOODPLAIN IN NGOR-OKPALA, IMO STATE, SOUTHEASTERN NIGERIA

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Abstract*:* *The study classified soils of three topographic units of Ogochie River floodplain in Ngor-Okpala Local Government Area of Imo State. A transect was used to connect the topo units, namely; summit, mid slope and foot slope. Nine (9) profile pits, 3 in each topo unit were dug and described using FAO guidelines. These profile pits were geo-referenced using hand held Global Positioning System (GPS) Receiver. Soil samples were collected from horizons, air-dried and sieved for standard routine analysis.The results showed that the soils were shallow in depth, colours ranged from hue of 7.5YR and 5YR with chroma greater than 3. The texture ranged from sand, sandy loam and loamy sand in the surface and sandy clay loam in the subsurface horizons. The structure ranged from weak, fine to strong massive angular blocky as depth increases. The soil pH varied from strongly to moderately acid (4.9-5.36). The Electrical Conductivity was low with mean values less than 1dsm^{-1}. The contents of Organic Matter (0.4-1.68 %), Total Nitrogen (0.02-0.08%), available Phosphorus (1-2.92 ppm) and ECEC (3.97-5.25 cmol/kg). Soils were classified using Soil Taxonomy (USDA 2010) as Aeric kandic plinthiaquults (footslope), Aeric typic hydraaquent (Midslope), and Aeric aquandic fluvents (summit) and correlated with World Reference Base (2006) as Haplic plinthosol (footslope), Haplic fluvisol ((Midslope) and Haplic fluvisol (footslope).*

Keywords: Wetlands, Soil, Classification, Toposequence, Tropical Nigeria

Introduction

Wetlands (fadama) are permanently or seasonally flooded low lying lands occurring along water courses, or on valley bottoms and which usually have high water table (Adeniran *et al*., 2010; Tiner, 1999). A combination of hydric soil, hydrophitic vegetation and hydrology properties define wetlands as described in the National food security act manual and corps of engineers wetland delineation manual (Brinson, 1993). Wetlands are among the most important ecosystems on Earth and are unique because of their hydrologic conditions and role as transitional ecosystems (Mitsch and Gosselink, 2000) stated that the total wetland area in Africa amounts to about 5.6 million Km^2, which is about 16 percent of the total area of the continent (Ojekunle, 2011). In Nigeria, wetland comprises inland swamp, mangrove and fresh water swamp and shallow to deep water fadama (Ayotade *et al*., 1980). The important wetlands available in Nigeria are Hydejia and Kirikasama, Lake Chad, Komduge, Yobe, Kanji Lake, Baturiya, Adiami- Nguru flood plains, Matgadru- Kabok flood plains, the Niger-Delta flood plains and the coaster lagoons near Lagos and delta of Cross river. In many parts of the world, wetlands have historically been reviled as disease ridden wastelands and actively drained. Drained wetlands are among the most productive agricultural and forest soils, the relatively level topographic position of wetlands is desirable for construction practices. Currently, wetlands cover less than seven percent of the Earth's land area (Mitsch and Gosselink, 2000). There is significant pressure to develop critical wetland ecosystems in the tropics because these areas are highly sought after for agricultural and construction practices (Stanturf *et al*., 2000). USDA (2002) defined wetland soils as soils that formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part. Under natural conditions, these soils are either saturated or inundated long enough during the growing season to support the growth and reproduction of hydrophilic vegetation. Wetland soils also known as hydric soils have a number of agricultural and non-agricultural applications. In order to determine whether a specific soil is a hydric soil or non-hydric soil, more specific information about the depth and duration of water table is needed (Soil Survey Staff, 2010). Hanselman and Noll (2003) reported that little work has been published on natural variability of wetland soils. In Nigeria, there is scarcity of data on the properties of fadama soils and their critical moisture contents for tillage. The major objective of this study was to classify and characterize the wetland soils of Ogochie River in Ngor Okpala Local Government Area of Imo state.

Materials and Methods

Ogochie River is located at Ngor- Okpala Local Government Area of Imo State which lies between latitudes $5^0 20^1$N and longitude $7^0 8^1$E with an elevation of 52m above sea level. The hydrology of Ogochie River is governed by Imo River and affected by tides, although seasonal influences which are related to the climatic regime are evident. The area lies within the humid tropics with a mean temperature range of 26-29^{0}C. The climate of the area is characterized by distinct wet and dry seasons. The wet season begins in April and lasts till November, while the dry season begins in November till March. A short period of draught is usually experienced in July and August, while a period of harmattan characterized by cold dry winds and lower temperatures normally occurs between December and February (Moses, 1979; Enemugwem, 2009).

Table 1: Co-ordinates of Pedons

Pedon Number	Co-ordinates	Elevation	Physiographic Unit
Pedon 1	Lat.$5^0 20^1 10.7^{11}$N, Long. $7^0 8^1 48.1^{11}$E	45m	Footslope
Pedon 2	Lat.$5^0 20^1 12.2^{11}$N, Long. $7^0 8^1 48.1^{11}$E	43m	Footslope
Pedon 3	Lat.$5^0 20^1 14.9^{11}$N, Long. $7^0 8^1 48.1^{11}$E	47m	Footslope
Pedon 4	Lat.$5^0 20^1 16.4^{11}$N, Long. $7^0 8^1 48.1^{11}$E	47m	Midslope
Pedon 5	Lat.$5^0 20^1 17.8^{11}$N, Long. $7^0 8^1 47.2^{11}$E	46m	Midslope
Pedon 6	Lat.$5^0 20^1 19.3^{11}$N, Long. $7^0 8^1 47.2^{11}$E	46m	Midslope
Pedon 7	Lat.$5^0 20^1 21.6^{11}$N, Long. $7^0 8^1 47.2^{11}$E	44m	Summit
Pedon 8	Lat.$5^0 20^1 22.7^{11}$N, Long. $7^0 8^1 47.2^{11}$E	45m	Summit
Pedon 9	Lat.$5^0 20^1 24.9^{11}$N, Long. $7^0 8^1 47.2^{11}$E	46m	Summit

The relative humidity is high throughout the year especially in rainy season averaging 85 percent. The mean annual rainfall ranges from 2500-3000mm (Ofomata, 1975).The major parent material in the study area is the coastal plain sands and flood plains (Benin formation and Deltaic deposits) and marine deposits. The area has generally a lowland geomorphology, less than 80m above sea level. They belong to the group of soils termed the acid sands in southern Nigeria (Obihara, 1961). The natural vegetation of the study area is tropical rainforest. The plant species are arranged in tiers with the forest floor harbouring a great category of sun heating species. The rain forest is highly depleted of plant species due to human activities. The dominant plant species is the Oil palm (*Elaeis guineensis*), others include; Oil bean tree (*Pentaclethra macrophyla*), Gmelina (*Gmelina arborea*), Butterfly pea (*Centrosema pubescens*), Raffia palm (*Raphia vinifera*), Wine palm (*Butia capitata*), Water fern (*Histiopteris incisa*), Cassava (*Manihot esculenta.*), WaterYam (*Dioscorea alata.*). Cereals and grasses include; Elephant grass (*Pennisetum purpureum,*), Giant star grass (*Cynodon plectostachyus*), Siam weed (*Chromolaena odorata*), Goat weed (*Ageratum conyzoides*) and clusters of bamboo and shrubs.

Field Studies

A reconnaissance visit was carried out with the aid of a location map of the study area to identify the areas to be studied and the locations were georeferenced using a global positioning system (GPS) receiver. A combination of transect and random sampling techniques were used as a traverse was cut along the river bank in sampling. Three topounits were identified namely footslope, midslope and summit, a total of nine (9) profile pits were dug, three on each topounit and described using FAO (2006), USDA Soil Taxonomy (2010) and World reference base (2006) procedures. Core samples were collected from each horizon. Samples were collected from the bottom to the top according to horizon differentiation in each profile pit and the maximum depth of soil examination differed for each pit. In total, 34 soil samples were collected. Surface humidity was dry at the time of sample collection, which was in the dry season between in January, 2013. Soil samples were air-dried, gently crushed, sieved using 2-mm sieve and analysed in the laboratory.

Laboratory Analysis

Particle size distribution was determined by hydrometer method according to the procedure of (Gee and Or, 2002). Bulk Density was measured using core method as Grossman and Reinsch (2002) recommended. Soil pH was determined in 1:2.5 soil liquid ratios in water and 0.1N KCl using pH meter (Hendershot *et al*., 1993).Organic carbon was determined using wet oxidation method described by (Walkley and Black, 1934; Nelson and Sommers, 1982). Available phosphorus was determined using Bray II solution method (Olsen and Sommers, 1982). Electrical conductivity was measured in 1:2 saturation extract (Udo *et al*., 2009). Exchangeable bases (magnesium, calcium, sodium and potassium). Exchangeable Na and K were extracted using 1*N* NH_4OAc using flame photometer (Jackson, 1964), while Ca and Mg were determined using ethelene diamine tetracetic acid (EDTA) (Thomas, 1988). Total nitrogen was determined by Kjehdahl digestion method (Jackson, 1964; Bremner and Yeomans, 1988). Exchangeable acidity was determined titrimetrically (Mclean, 1982). Effective cation exchange capacity (ECEC) was calculated from the summation of all exchangeable bases and exchangeable acidity (Soil Survey Laboratory Staff, 1992).Percentage base saturation (percent BS) was determined by computation.

Soil Classification

Based on the results obtained from the laboratory analysis and field morphological properties, the soils were classified according to soil taxonomy (Soil Survey Staff, 2010), and correlated with world reference base (2006). Data collected from the study site were subjected to summary statistics such as Mean. Also, Coefficient of variation (CV) was used to estimate the degree of variability existing among soil properties in the study site. Coefficient of variation is ranked as follows; low variation ≤ 15 percent, moderate variation 15 percent≤ 35 percent and high variability 35 percent (Wilding *et al*., 1994). Pearson correlation analysis was implemented to determine the relationship between the soil properties.

Table 2: Mean values of soil physical properties

Profile number	Sand	Silt g/kg	Clay	Texture	MC g/kg	BD g/cm^3	T.porosity percent
Peodn 1	857	7	136	SL	456	1.68	36.6
Pedon 2	854	10	136	SL	679	1.5	43.7
Pedon 3	813	34	153	SL	400	0.83	68.4
Pedon 4	809	40	151	LS	458	1.24	53.5
Pedon 5	784	30	186	SL	646	1.42	46.7
Pedon 6	820	36	144	SL	273	0.82	69.2
Pedon 7	811	47	142	LS	689	0.95	64.4
Pedon 8	817	34	149	SL	401	1.29	51.4
Pedon 9	824	20	156	SL	297	0.99	62.6

Texture: **SL**=Sandy loam, **LS**= Loamy Sand

Results and Discussion

Physical and Morphological Properties

The soils were characterised with strong brown, reddish brown, reddish yellow to yellowish red colour matrix of hues of 7.5 to 5 years and chroma values of 4-8 in all horizons. These colours indicate a relatively high amount of iron oxide, which may be due to the parent material (Nkheloane *et al*., 2012). The alternate wetting and drying conditions in these soils resulted in the reduction and subsequent release of iron oxides which are accumulated in the form of strong brown, brown and red mottles in the subsurface of the profiles, also in very shallow pedons, melanization may occur. The structural development of the soils in the study site ranged from fine-weak to massive-strong sub-angular blocky peds. In moist state, the soils were friable and firm, soils were observed in dry consistence to be hard to extremely hard as depth increases. The main factor influencing the structure of floodplain soils is the hydrology/water table. Base presence of roots decreased with depth in all pedons due to high water table. The inadequate root room in wetland soils for the study area can be represented by the critical limits of effective root depth caused by anaerobic condition of the soil and hardpan. The particle size distribution pattern shows that the sand contents were high in all pedons between 784-857 g/kg. The general sandy nature of the study site could be due to the climate and parent material of the area as well as the depositional activities of the Ogochie River. The bulk density of the study site ranged between 0.83-1.68 g/cm^3, this is due to high water absorption capacity. The bulk density increased down the profile, increased bulk density in the subsurface horizon is an indication of low soil porosity and soil compaction. It may cause restrictions to root growth and poor movement of air and water through the soil. The moisture content of the soils sampled in the study site ranged between 273-689 g/kg. The epipedon of all profiles were partly saturated to unsaturated having lower moisture content compared with the subsurface horizon with moisture content at field capacity. Moisture content increased as depth increased. The study area could be said to be endosaturated due to the unsaturation to partly saturation of the soil surface and total saturation of the subsurface horizons. Moisture content range between 10 percent -15 percent (dry basis) is workable and trafficable for cultivation practice. Beyond the critical moisture content, cultivation becomes tedious, leading to high slippage, sinkage of machinery and lose of trafficability (Adeniran *et al*., 2010).

Table 3: Mean Values of Soil Chemical Properties

Profile number	pH H_2O	pH KCl	O.M percent	Al^{3+}	H^+ cmol/kg	TEA	T.N percent	Ca^{++}	Mg^{++}	K^+	Na^+ cmol/kg	TEB	ECEC	BS percent	Av.P (ppm)	Al percent	EC (dSm^1)
Pedon1	5.37	4.05	0.4	0.4	0.3	0.7	0.02	1.5	0.9	0.19	0.10	2.68	3.38	80.1	1.04	12.88	0.10
Pedon2	5.36	4.08	1.27	0.8	0.5	1.3	0.06	2.0	1.3	0.21	0.08	3.59	4.84	71.5	0.68	16.18	0.11
Pedon3	5.25	4.15	0.95	0.7	0.3	0.1	0.04	2.0	1.2	0.19	0.13	3.06	4.48	77.5	1.44	16.69	0.10
Pedon4	5.60	4.04	1.01	0.5	0.5	1.1	0.05	1.7	0.9	0.24	0.15	3.0	3.97	75.7	2.51	11.92	0.13
Pedon5	4.90	4.39	0.83	0.6	0.2	0.8	0.04	2.6	1.6	0.12	0.13	4.45	5.25	84.4	0.67	11.72	0.11
Pedon6	5.33	3.96	1.04	0.6	0.3	0.9	0.05	1.8	1.0	0.22	0.08	3.18	4.08	77.6	2.04	15.69	0.11
Pedon7	5.19	4.02	1.48	0.5	0.5	1.0	0.07	2.7	1.0	0.27	0.09	4.35	5.35	78.6	2.92	11.85	0.10
Pedon8	5.16	4.12	0.86	0.3	0.2	0.8	0.04	2.1	1.3	0.23	0.09	3.78	4.58	81.8	1.0	14.58	0.07
Pedon9	5.28	3.91	1.68	0.7	0.2	0.9	0.08	1.9	0.1	0.21	0.10	3.11	4.11	76.6	1.03	18.2	0.11

OM = Organic matter, **Al**= Aluminum, **Ca**=Calcium, **Mg**= Magnesium, **P**=Phosphorus, **K**=Potassium, **Na**= Sodium, **TEA**=Total exchangeable acidity,**T.N**=Total nitrogen, **TEB**= Total exchangeable bases, **ECEC**= Effective cation exchange capacity, **BS**= Base saturation, **Avail. P**= Available phosphorus, **EC**= Electrical conductivity.

Chemical Properties

Soil reaction of the study site were strongly to slightly acidic ranging between 4.90-5.60 and 3.91-4.39 in water suspension and 1N KCl respectively. Ideally floodplain soils experience changes in soil reaction due to fluctuating high water table. Low values (<5) could be due to the dominance of Al^{++} and H^{+} ions in the soil exchange complex (Soil Survey Staff, 2003). The soils have low amount of organic matter content which ranged between 0.4-1.68 percent, the low availability of O_2 is the most important factor limiting rates of decomposition in wetland soils, others include temperature, nutrient availability, the molecular composition of organic matter, and acidity. The average total nitrogen content of the study site was low, ranging from 0.02 percent-0.08 percent, corresponding with organic carbon content compared with the critical value of 0.2 percent recommended (FPDD,1989). The low N level may be associated with intermittent flooding and drying which is known to favour nitrogen loss through nitrification-denitrification process (Wong et al., 1991). Also low N may be partially attributed to the predominantly sand texture of the soils. Available P content of the soils were low ranging from 0.67-2.92ppm, low level of available P indicates that P may be chemically bound as phosphates of Fe and Al owing to the observed high acidity of the soil of the study area (Effiong *et al*., 2006) or due to absolute low value of soil P or that P is removed by sedimentation (Ogban, 1999; Patrick, 1990). Total exchangeable bases ranged between 2.68-4.45 cmol/kg and were dominated by calcium ($Ca2^{+}$) and magnesium ($Mg2^{+}$) ions. The low contents of basic cations may be due to low pH, intense leaching weathering and ferrolysis, hence low inherent fertility status with regards to the major nutrients. Exchangeable acidity values were moderate to high with mean values of 0.1-1.3cmol/kg, slightly below the critical value of 2.0cmol/kg, depicting the strongly and slightly acidic nature of the soils, although the exchangeable acidity may affect sensitive crops. The percentage aluminium saturation of the study area slightly high to high, with mean values ranging from 11.72 percent -18.2 percent, Soil clay minerals contain aluminium but it has no impact on plant productivity unless pH_w fall below 5.4. The mean base saturation percentage values ranged between 71.5 percent- 84.4 percent, though above 50 percent, the separating index between fertile and less fertile soil (Landon, 1984). However, Astera (2008) noted that the strongest, healthiest and nutritious crops are grown in soils where percentage base saturation is above 90 percent, this does not only provide luxury levels of nutrients to crop and soil life, but are strongly affected by soil texture and pH. Electrical conductivity of the saturation extract of the study site ranged between 0.07-0.13 dSm^{-1}, which is seen as low being <1 dSm^{-1}, indicating non saline nature of the soils and the fresh water status of the hydrology of the study site. The ECEC values in the soils of the study site were low and ranged between 3.38-5.35 cmol/kg, High annual precipitation, small amount of basic cations in the parent materials, the low buffering capacity to retain them against leaching and removal by erosion probably explain the low ECEC in the floodplain.

Soil Classification

The soils of the study area were classified according to soil taxonomy (Soil Survey Staff, 2010) and correlated with world reference base (2006). The mean annual soil temperature of the soil and study area was above 25^0 C , thereby isohyperthermic, located in an aquic moisture regime which had ochric epipedon and kandic sub surface horizon in the soil profile.

Table 4: Taxonomic classification of the soils

Pedon Number	Physiographic Unit	Classification	
		Soil Taxonomy	World Reference Base
1	Footslope	Aeric Kandic Plinthiaquults	Haplic Plinthosols
2	Footslope	Aeric Kandic Plinthiaquults	Haplic Plinthosols
3	Footslope	Aeric Typic Hydraaquents	Haplic Fluvisol
4	Midslope	Aeric Typic Hydraaquents	Haplic Fluvisol
5	Midslope	Aeric Typic Hydraaquents	Haplic Fluvisol
6	Midslope	Aeric Aquandic Fluvents	Haplic Fluvisol
7	Summit	Aeric Aquandic Fluvents	Haplic Fluvisol
8	Summit	Aeric Aquandic Fluvents	Haplic Fluvisol
9	Summit	Aeric Aquandic Fluvents	Haplic Fluvisol

Temperature regime is isohyperthermic in all pedons

The footslope was characterised with high chroma of 4 or more, having an iron- rich, humus-poor mixture of clay with quartz. It soils changed irreversibly to an iron stone hard pan on exposure to air, however it was soft in moist state. The soils had CEC less than 24cmol/kg , thus classified as Aeric kandic plinthiaquults (Soil Taxonomy); Haplic Plinthosols, (World Reference Base). The midslope was characterised with loamy sand and had chroma of 4 or more. The soils more than 8 percent or more clay in the fine earth fraction and classified as Aeric typic hydra aquent (Soil Taxonomy); Haplic Fluvisol (World Reference Base),while the summit was characterised with chroma of 4 or more, the organic carbon content decreased irregularly within the soil profile. The soils were sandy with a bulk density of 1.0g/cm^3 or less. They were classified as Aeric aquandic fluvents (Soil Taxonomy); Haplic Fluvisol (World Reference Base).

Conclusion

The soils of the study area were shallow in depth with strong evidence of reduction of Fe^{3+} to Fe^{2+} and development of reddish, yellowish and brown colours. The textures were sandy loams to loamy sands at the surface horizons and sandy clay loam in the sub soil horizons. Weak, to sub-angular blocky structures, hard consistence as depth increases, concretions of Fe and Al in the lower horizons, and the presence of gradual boundary between the horizons were some of the physical and morphological evidences of the youthfulness and subtle horizonations within the soils. The soils varied in chemical characteristics with strongly to moderate acid conditions, low in organic matter, total nitrogen; available phosphorus, cation exchange capacity, sodium percentage and electrical conductivity. These were indications of low nutrient reserves of the soils.Based on measured physical, chemical and morphological parameters, results showed that the soils have limited suitability for conversion to productive uses unless amended.

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