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CHARACTERIZATION OF SOME HYDRIC SOILS IN THE NIGER-DELTA REGION OF NIGERIA FOR LAND EVALUATION PURPOSES

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ABSTRACT
A study was conducted in the Niger Delta region of Nigeria to characterize and evaluate some hydric soils for their agricultural purposes. Two locations namely Yenogoa in Bayelsa State and Patani in Delta State were selected for the study, and three representative profile pits duged in each of the locations and characterized for their morphological, physical and chemical properties. The soils were classified using the USDA soil Taxonomy and correlated with the FAO / UNESCO soil legend. The results showed that the soils were shallow in depth, gleyed and mottled with characteristic features of (10 YR 4/4; 5 Y 4/1, and 2. 5Y 4/2, and 5Y 5/1). The textures ranged from sandy loam, sandy clay loam and sandy clay at the surface and sub surface horizons. The structure ranged from weak, to sub angular blocky, and the consistence were non-sticky to slightly sticky and plastic. Few fine roots and dominance of Fe and Mn concretions with clear smooth and gradual boundaries were prominent morphological properties. The soil pH varied from strongly to moderately acid (5.5 – 6.5). The electrical conductivity (EC) were high with mean values of 9.24 dsm^{-1} and 10.26 dsm^{-1}. The contents of organic matter (8.85 -9.85 gkg^{-1}); total nitrogen (0.72 gkg^{-1}); available phosphorus (5.18 -5.94 $mgkg^{-1}$) and ECEC (5.01 -5.03 $Cmolkg^{-1}$) were low, thereby depicting the low fertility status of the soils. The soils were classified as Typic halaquents (USDA) and Thionic fluvisols FAO / UNESCO soil legend.

KEYWORDS: Characterization, Hydric soil and land evaluation purposes.

INTRODUCTION

The hydric soils are soils that are saturated at or near the soil surface with water that virtually lacks free oxygen for significant periods during the growing season. They are also soils that are flooded frequently for long periods during the growing season. (USDA, 1985). They belonged to the gleyic group of soils and thus, could either be hydraquents, sulphaquents or halaquepts. They have also been described as soils characterized by low strength, irreversible hardening, extremely low in pH when dried and high in sodium salt contents (Guthrie, 1986). The distribution of these soils have two aspects; namely the geographical pattern of occurrence which is related closely to physiography and climate, and the total area which has to do with places where the land's drainage capacity falls short of evacuating the water surplus which may originate from rainfall, surface runoff and ground water flow (Van Diepen, 1986, Eswaran and Cook, 1986, and Egbuchua and Ojeifo, 2007). The field identification of these soils also has to do with the morphological characteristics which is often observed as gray colours with features of Fe and Mn concretions near the surface and strict wetness of the soils. Thus, the ecosystem in which most hydric soils developed include marshes, swamps, bogs, inland valleys, coastal plains, tidal flats, mudflats, estuaries as well as in alluvial or marine deposits (Kyuma, 1986, Eswaran and Cook, 1986, and Akamigbo 2001).

Wilding and Rehage (1986), reported that the major pedogenetic processes of these soils include the mobilization and immobilization of iron and manganese concretions and mottling (FAO/UNESCO, 1999). Characterizing hydric soils for land evaluation purposes will among other things, establish relationship between soil properties and landscape parameters; as well as gather preliminary information on the soil nutrients, and other limitations needed in a soil data bank. It will also judge the behaviour or response of the soils to specific uses. (Esu, 2004). Information on hydric soils for land evaluation purposes is scanty in the Niger-Delta. This is because most studies in the Niger – Delta region are concentrated in oil and gas deposits. The inaccessible terrain in which these soils are located in most cases make research studies on the soils very difficult. With the increasing fertility depletion of most upland soils and the need to explore other soil types for agricultural purposes, it was therefore the objective of this study to characterize these soils regarded as fragile for their agricultural purposes.

MATERIALS AND METHODS

Study Areas

Two distinct locations in the Niger-Delta region were selected for the study. These were Yenogoa in Bayelsa State which lies essentially between latitude 4^0 50^1 to 5^0 00^1 N and longitude 6^0 11^1 to 6^0 25^1 E and Patani in Delta State which also lies between latitude 4^0 45^1 to 5^0 45^1 and longitude 6^0 25^1 to 6^0 35^1 E. The two areas are characterized by heavy rainfall with average mean of 2,550 – 2,755 mm per annum. The mean minimum annual temperature ranged from 23 – 31^0C with a high relative humidity of about 78–82%. The soils are of young geologic formation of the Quaternary and Recent alluvium underlain by cretaceous sediments and are extensively low-lying. They are usually poorly drained in most parts of the year and, could either be classified as hydraquents, sulfaquents or Halaquepts (Soil Survey Staff, 1998).The land uses in the areas are principally fishing activities while petroleum and gas drilling are major economic activities.

Field Work

Air-photo map at a scale of 1:50,000 was used to delineate the soil boundaries while the terrain features such as relief, drainage, rivers, creeks and land use features were the main interpretative criteria. From each of the mapping units, three profile pits were randomly dug to a standard of 2 x 1m to varied depths, examined and described for morphological properties based on the guidelines for profile description (Soil Survey Staff, 1999). The morphological data described include the colour, texture, structure, consistence, inclusions, rootlets and boundary. Soil samples were also collected from the individual horizons of the profiles using hand trowel for the analyses of the physical and chemical properties of the soil.

Sample Preparation / Analytical Procedures.

The samples collected were air-dried at a room temperature of 25-27^{0}C for 4 days, crushed, sieved to pass through a 2mm sieve mesh and properly labeled in envelopes for analyses.

Analytical Methods

The soils were analyzed following the laboratory procedures of IITA, (1979) and Canadian Society of Soil Science, (Carter,1993). The particle size distribution analysis was done with 50g of the soil samples using sodium hexameta phosphate (Calgon) as the dispersing agent. Hydrometer readings were taken at 40 seconds and 2 hours respectively. The bulk density was determined by the core-method using a metal sampler. Particle density was determined by the pycnometer method while the total porosity was calculated from the particle and bulk densities using the relationship as established by vomocil (1963). Soil permeability was determined using the Munsel colour chart. The soil pH was determined using a glass electrode pH meter. Organic Carbon was determined by oxidizing soil samples with dichromate solution and titrated with ferrous sulphate solution. The total nitrogen was determined using micro- Kjeldahl method and available phosphorus, extracted by the Bray N0 1 method, while the phosphorus in solution was determined colorimetrically by the molybdenum blue method. The exchangeable cations were extracted by leaching 5 g of the soil with 50 ml of ammonium acetate at pH 7. The potassium and sodium in the leachate were determined with a frame photometer (Column Model 21), while the calcium and magnesium were determined with Atomic Absorption spectrophometer (Perkin Elmer Model 306). The exchangeable acidity was determined by adding barium chloride buffer solution to the soil samples and titrated against 0.1 N HCl. The electrical conductivity was determined in a 1:2.5 soil / water ratio using the conductivity meter.

Classification

The soils were classified according to the USDA soil Taxonomy (Soil Survey Staff, 1999) and correlated with the FAO / UNESCO soil legend. These classification systems were based on the results of the morphological, physical and chemical characteristics evaluated.

RESULTS AND DISCUSSION

Morphological Characteristics

The results of the morphological characteristics are shown in tables 1^a and 1^b respectively for Yenogoa and Patani sample locations. The results showed that the soils in the two locations were shallow in depth due to constant fluviatile deposition and sedimentation processes with no distinct diagnostic horizons. The soils were gleyed up to the soil surface in most parts of the year. The same observations have been reported by Luzio, (1986), Ayolagha, (2001) and Egbuchua and Ojeifo, (2007) in their studies on wetland soils. The textures ranged from sandy loams to loamy sands at the surface, and sandy clay loams to sandy clay in the sub soil horizons. Weak, structureless and sub-angular blocky were prominent structural features. The consistence varied from slightly sticky, plastic, and friable;. Many fine tubular pores, few roots, clear smooth and gradual boundaries were major morphological evidence of the soils in the two locations.

Table 1^a: Morphological Properties of some hydric soils in the Niger-Delta region, of Yenogoa in Bayelsa State, Nigeria.

Hori.	Depth cm)	Colour	Mottle	Text	Struct.	Consist.	Concretions	Rootlets	Boundary
				(Mapping unit A)					
Ap	0 –15	10YR 4/4	2.5 Y 4/2	Sl	0, sbk	nst, fr	-	ffr	CS
Bw	15-45	10R 4/2	2.5 Y 4/2	Scl	0,sbk	fr, nst	Fe, Mn	ffr	CS
2Bw$_1$	45 –55	5YR 4/1	2.5Y4/2	Sc	1, sbk	spl.	Fe,Mn	n	g
				(Mapping unit B)					
Ap	0 –25	2.5 Y4/2	5Y5/1	Sl	0,sbk	nst	-	ffr	CS
Bg	25 –38	2.5Y4/2	2.5Y4/2	Scl	0,sbk	nst	Fe, Mn	ffr	CS
2Bgw	38 –57	5YR 4/1	2.5YR4/2	Sc	1,sbk	sst,sp	Fe, Mn	n	g
				Mapping unit C					
As	0 –12	10YR4/4	2.5YR4/2	Sl	0,sbk	n st	-	ffr,	CS
Bg	12 –37	5YR 4/1	2.5Y 4/2	Scl	0,sbk	nst	Fe, Mn	ffr	CS
2Bgw	37 –61	5YR 4/1	2.54/2	Sc	1, sbk	sst,p	Fe, Mn	n	g

Abbreviations:

1. Colour: 10YR 4/4 = dark yellowish brown; 5 Y 4/1 = dark grey, 10 R 4/2 = dark greish brown, 5Y 4/1= dark gray.
2. Mottle: 2.5Y4/2 = mottled, 5Y 5/1 = mottled.
3. Texture: Sl = sandy loam; Scl= sandy clay loam, Sc = sandy clay.
4. Structure: 0 = structureless, 1 = weak, sbk = subangular blocky.
5. Consistence: nst = nonsticky, fr = friable; Spl = slightly plastic; Sst = slightly sticky, p = plastic.

6. Rootlets: ffr = fine few roots; n = none.
7. Concretion: Fe = iron; Mn = Manganese.
8. Boundary: cs = clear smooth; g = gradual.

Table 1^b. Morphological Properties of Some hydric Soils in the Niger-Delta region of Patani in Delta State, Nigeria.

Hori.	Depth (cm)	Colour	Mottle	Text	Struct.	Consist.	Concretions	Rootlets	Boundary
				(Mapping unit A)					
Ap	0 –10	5YR 5/1	m	Sl	0, sbk	Sst	-	ffr	CS
Bw	10-35	5Y 5/1	m	Scl	1,sbk	Sst	Fe, Mn	ffr	CS
2Bgw	35 –60	5Y 4/1	m	Sc	1, sbk	Spl.p	Fe,Mn	-	g
				(Mapping unit B)					
Ap	0 –15	5 Y4/1	m	Sl	0,sbk	sst	-	ffr	CS
Bg	15 –45	5Y4/1	m	Scl	1,sbk	sst	Fe, Mn	ffr	CS
2Bgw	45 –65	2.5YR 4/2	m	Sc	1,sbk	Spl,pl	Fe, Mn	-	g
				(Mapping unit C)					
As	0 –18	5YR5/4	m	Sl	0,sbk	sst	-	ffr,	CS
Bg	18 –35	5YR 5/1	m	Scl	1,sbk	sst	Fe, Mn	ffr	CS
2Bgw1	35 –65	2.5Y 4/2	m	Sc	1, sbk	Spl.pl	Fe, Mn	-	g

Abbreviations:
1. Colour:10YR 4/4 = dark yellowish brown; 5 Y 4/1 = dark grey, 10 R 4/2 = dark greish brown, 5Y 4/1= dark gray.
2. Mottle: 2.5Y4/2 = mottled, 5Y 5/1 = mottled.
3. Texture: Sl = sandy loam; Scl= sandy clay loam, Sc = sandy clay.
4. Structure: 0 = structureless, 1 = weak, sbk = subangular blocky.
5. Consistence: nst = nonsticky, fr = friable; Spl = slightly plastic; Sst = slightly sticky, p = plastic.
6. Rootlets: ffr = fine few roots; n = none.
7. Concretion: Fe = iron; Mn = Manganese.
8. Boundary: cs = clear smooth; g = gradual.

TABLE 2. Physical Properties of Some hydric Soils in the Nigeri-Delta region, Nigeria**.**

Hori.	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Silt/Clay ratio	Bulk density (gcm^{-3})	Particle density (gcm^{-3})	Porosity (%)	Textural class
				Yenogoa bayelsa state					
				Mapping unit A					
Ap	0 –15	75.5	16.0	7.5	2.13	1.33	2.12	37.3	Sl
Bw	15-45	68.0	20.0	22	0.91	1.33	2.17	38.2	SCL
$2Bw_1$	45 –55	40.0	15.0	37	0.41	1.35	2.19	38.4	SC
Ap				Mapping unit B					
	0 –25	74.3	14.8	10.9	1.36	1.34	2.15	37.7	SL
Bg	25 –38	67.6	12.4	20.0	0.62	1.37	2.18	37.2	SCL
2Bgw	38 –57	52.4	13.5	34.1	0.40	1.37	2.19	37.2	SC
As				Mapping unit C					
	0 –12	77.5	15.2	7.3	2.08	1.33	2.10	36.7	SL
Bg	12 –37	78.3	8.7	13.0	0.67	1.35	2.12	36.4	SLC
2Bgw	37 –61	76.8	5.2	27.0	0.19	1.37	2.16	36.6	SC
	$\bar{X}$	67.66	13.42	18.98	0.97	1.35	2.15	37.30	
				Patani delta state					
				Mapping unit A					
As	0-10	69.3	17.2	13.5	1.27	1.33	2.12	37.3	SL
Bg	10-35	75.4	8.9	15.7	0.57	1.37	2.17	36.9	SCL
2Bgw	35-60	61.3	10.1	28.6	0.35	1.42	2.24	36.7	SC
				Mapping unit B					
As	0-15	73.2	15.7	11.1	1.14	1.33	2.13	37.6	SL
Bg	15-45	61.7	16.7	21.6	0.77	1.34	2.15	37.7	SCL
2bgw	45-60	68-8	7.3	23.9	0.31	1.35	2.16	37.5	SC
				Mapping unit C					
Ap	0-18	69.7	12.1	18.2	0.66	1.33	2.12	37.3	SL
Bw	18-35	75.8	9.7	14.5	0.67	1.32	2.15	36.7	SCL
$2Bw_1$	35-65	42.3	18.6	39.1	0.48	1.31	2.13	36.5	SC
	$\bar{X}$	66.39	12.92	20.69	0.72	1.34	2.15	37.03	

TABLE 3. Chemical Properties of some hydric soils in the Niger- Delta region, Nigeria

Hori.	Depth (cm)	pH H_2O	E.A Sec/hr	Org.C. (gkg^{-1})	Total N(gkg^{-})	Avail. P. ($mgkg^{-1}$)	Ca.	Mg	K	Na.	CEC.	ECEC	EC
				YENOGOA bayelsa state			→		$Cmolkg^{-1}$	←		(dsm^{-1})	
				Mapping unit A									
Ap	0 –15	5.4	2.56	12.35	0.98	5.35	3.41	0.78	0.15	0.96	4.31	5.30	8.51
Bw	15-45	6.1	3.41	8.47	0.75	3.24	2.25	0.51	0.18	0.93	5.10	4.87	8.16
$2Bw_1$	45 –55	6.3	3.54	5.38	0.12	3.38	3.45	0.75	0.17	1.25	6.35	4.57	9.38
				Mapping unit B									
As	0 –25	5.7	2.41	13.41	0.93	6.21	3.38	0.83	0.15	0.75	5.34	5.11	10.14
Bg	25 –38	6.4	3.35	9.24	0.84	5.10	3.15	0.43	0.15	0.84	4.78	4.59	9.34
2Bgw	38 –57	6.5	3.21	4.31	0.53	5.45	3.41	0.67	0.18	1.31	5.85	5.75	10.71
				Mapping unit C									
As	0 –12	5.5	2.71	12.38	0.85	6.10	3.25	0.67	0.13	1.25	4.28	6.33	9.38
Bg	12 –37	6.2	3.55	9.11	0.81	5.71	3.18	0.56	0.11	1.77	5.10	5.02	10.41
2Bgw	37 –61	6.3	3.58	5.01	0.38	6.10	3.27	0.81	0.15	1.35	5.75	5.58	10.73
	$\bar{X}$	6.04	3.15	3.85	0.69	5.38	3.31	0.67	0.15	1.09	5.17	5.01	9.24
				PATANI, Delta State			→		$Cmolkg^{-1}$	←		(dsm^{-1})	
				Mapping unit A									
As	0 –10	5.8	2.51	14.25	0.91	5.84	3.75	0.58	0.15	0.95	5.32	5.43	10.34
Bg	10-35	6.3	3.47	10.15	0.78	6.10	3.41	0.53	0.16	0.91	5.35	5.01	10.11
2Bgw	35 –60	6.5	3.51	6.10	0.58	5.38	3.85	0.61	0.18	1.45	6.10	6.39	12.31
				Mapping unit B									
As	0 –15	5.7	2.41	14.11	0.93	6.31	2.17	0.43	0.17	0.31	5.25	3.62	9.76
Bg	15–45	6.3	3.31	7.85	0.74	5.42	3.43	0.51	0.18	0.43	4.38	4.55	9.85
2Bgw	45 –60	6.4	3.63	4.21	0.58	6.51	3.75	0.65	0.16	1.05	5.38	5.61	0.14
				Mapping unit C									
As	0 –18	5.6	2.61	13.75	0.85	6.45	3.10	0.75	0.13	1.10	5.10	5.08	10.13
Bg	18 –35	6.3	3.71	10.11	0.75	5.38	2.15	0.63	0.12	1.09	5.35	3.99	9.38
2Bgw	35 –65	6.4	3.72	8.11	0.38	6.11	3.45	0.65	0.15	1.35	5.75	5.60	10.31
	$\bar{X}$	6.14	2.21	9.85	0.72	5.94	3.40	0.59	0.16	0.96	5.33	5.03	10.26

Physical Characteristics

The data of the physical characteristics are depicted in Table 2. The texture ranged from sandy loams to loamy sands at the surface horizons and sandy clay loam to sandy clay in the sub soil horizons. Sand fractions were the dominant soil separates and irregularly distributed within the profiles, with mean values of 67.77% for Yenogoa and 66.39% for Patani mapping units. The silt contents were moderately distributed with mean values of 13.42% and 12.92% respectively. The moderate values of silt could be attributed to constant fluviatile deposits and sedimentation processes. The clay contents were low in the surface horizons but increased gradually in the subsoil horizons with no definite pattern of distribution. The low clay contents could be attributed to some extent the processes of selective destruction of clay in the surface soil layers and ferrolysis (Brinkman, 1970). The irregular distribution and stratification of sand and clay in the profile horizons suggested different periods of deposition of sediments rather than, the deep weathered nature of the parent materials in-situ. Silt fractions were also irregularly distributed thereby, confirming the findings of Ojanuga (1991) that the soils were weakly developed. The silt / clay ratios ranged from 0.31 – 2.13 with mean values of 0.97 and 0.72 for the two locations. According to Van Wambeke (1962), Asomao, (1973) and Sombrek and Zonneveld (1971), silt / clay ratios of any given soil that is below 0.15 is an indication that the soil is of old parent materials, while those above 0.15 were indicative of young parent materials with low degree of weathering. The values of bulk and particle densities ranged from 1.31 – 1.4.2 gcm^{-3}, and 2.12-2.14 gcm^{-3} respectively. Lower values of bulk density were found in the surface horizons and increased gradually with depth of profiles. This could be as a result of decreased organic matter contents of the soils, less aggregation and compaction caused by the weight of overlying soil layers. The same observation have been reported by Ayolagha, (2001) and Egbuchua and Ojeifo, (2007) in their studies on wetland soils of Nigeria. The data for the particle density showed that quartz, feldspars, micas and other silicate clay minerals were major constituents of the mineral portions of the soils. The total porosity ranged from 36.5–37.7%. This values were considered low. According to Kachinkii (1965), best soils should have porosities of over 50%; good soils between 45-50%; satisfactory soils 40-45%; unsatisfactory soils under 40% and poor soils, below 30%. With mean porosity values of 37.30% and 37.03% calculated for the two soil units, hydric soils could best be described as unsatisfactory soils.

Chemical Characteristics

Table 3 shows the data of chemical analyses of the study. The soils pH varied from strongly to moderate acid (5.4-6.5) with mean values of 6.04 and 6.14 for Yenogoa and Patani soil units. The acidic nature of the soils could be attributed to the redox products of ferrolysis that is common in wetland soils. The exchange acidity of the soils were low to moderate with mean values of 3.15 and 2.21 $cmolkg^{-1}$ depicting the slightly acidic nature of the soils. The organic matter contents were generally low across the soil units with mean values of 8.85 gkg^{-1} and 9.85 gkg^{-1} respectively. Organic matter contents were found to concentrate more in the surface soil horizons and decreased with depth of profile pits. The low organic matter contents associated with the soils could be ascribed to climatic and local relief of the areas and frequent flushing by sea water intrusions. Total nitrogen contents were also low and followed the same trend with organic matter by decreasing with increased profile pits. The mean values for the two soil units were 0.69 gkg^{-1} and 0.72 gkg^{-1} which were far below 1.5 -2.0 gkg^{-1} established by FMANR, (1990) as suitable for most Nigeria soils. The low total nitrogen contents of the soils could be as a result of NH^{+}_{3} volatilization and denitrification which is common in wetland soils (Kyuma, 1986). The available phosphorus was low across the soil units with mean values of 5.18 $mgkg^{-1}$ and 5.94 $mgkg^{-1}$. These low values could be associated with high contents of siliceous parent materials, high phosphorus absorption capacity and the acidic nature of the soils respectively. The same low phosphorus contents of most soils with aquic moisture regimes have been reported by Kyuma, (1986), Udo, (2001) and Egbuchua and Ojeifo (2007) in their wetland investigation studies of Nigeria. The basic cations of Ca, Mg and K were low with mean values of 3.31 and 3.40 $cmolkg^{-1}$, 0.67 and 0.59 $cmolkg^{-1}$, 0.15 and 0.16 $cmolkg^{-1}$ respectively. Exchangeable sodium was high with mean values of 1.09 and 0.96 $cmolkg^{-1}$. The high exchangeable Na content might be as a result of soluable salts in sea water that flood the study areas at high tides. The cation exchange capacity and effective cation exchange capacity were low depicting the low contents of organic matter and clay which are the essential colloidal materials for cation exchange absorption in soils. It could also be to that fact that most wetland soils are derived from relatively unweathered basic volcanic ejecta (Kyuma, 1986).

Classification

Based on the USDA soil Taxonomy and with approximate correlation of FAO / UNESCO soil legend, the near absence of a diagnostic horizon qualified the soils for classification in the Entisols Order of soil Taxonomy. The aquic moisture regime of the profiles coupled with low chroma of less than 2, and gleyzation processes qualified the soils to be fitted into the Suborder Aquents. Because of long period of wetness due to tidal influences and high sodium salt spray, the soils fitted into the great group Halaquents or Hydraquents and as Typic Halaquents (USDA). The FAO / UNESCO equivalent of it, is Thionic fluvisols.

CONCLUSION

Hydric soils are soils that are saturated at or near the soil surface with water, and virtually lack oxygen for significant periods of a given year. The occurrence of such soils are usually conditioned by both climate and physiography thus, they are most prevalent in humid climate and low-lying land. Characteristically the soils were shallow in depth with strong evidence of reduction of Fe^{3+} to Fe^{2+} and development of gray colours. The textures were sandy loams to loamy sands at the surface horizons and sandy clay loam to sandy clay in the sub soil horizons. Weak, to sub-angular blocky structures, slightly plastic consistence, concretions of Fe and Mn 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 and high in sodium and electrical conductivity. These were indications of low nutrient reserves and high salinity of the soils. The land evaluation of the soils based on measured chemical parameters showed that hydric soils have limited suitability for conversion to productive uses.

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