CHARACTERIZATION, CLASSIFICATION AND FERTILITY EVALUATION OF SOME WETLAND SOILS OF OGUTA, IMO STATE, SOUTHEASTERN NIGERIA.

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ABSTRACT
The farmers and land users in Oguta local government area of Imo State, Southeastern, Nigeria have little or no scientific knowledge of Oguta wetland soils.This research was carried out to establish baseline information that will assist farmers and other land users to guide their decision making. Four profile pits were dug on the study sites in Osse moto Oguta. Free survey was used. With the aid of Global Positioning System (GPS), and soil sampling tools. Soil samples were collected based on the FAO guidelines for profile description.The results revealed that Loamy Sand is the dominant texture of the soils of the area. Soil reaction (pH in water) varied from strongly acid to slightly acid (5.18 to 6.74), organic carbon varied from low to moderately low (0.02 to 1.12 %) in the study area. Total nitrogen varied from very low to low (0.003 to 0.050 %), available P varied from very low to low (0.70 to 11.20 mg/kg), exchangeable bases (Ca, Mg, k and Na) were generally low (Ca: 0.10 to 2.30 cmol/kg; Mg: 0.13 to 1.65 cmol/kg; K: 0.117 to 0.142 Cmol/kg; and Na: 0.174 to 0.255 Cmol/kg). ECEC varied from very low to low (2.000 to 7.424 cmol/kg). Base saturation varied from very low to moderately low (13 to 68%). Soils were classified as Inceptisols (USDA) or Cambisols (FAO/WRB). The result revealed that the soil is suitable for agriculture, but cannot efficiently sustain arable crop for optimum performance.
Keywords: Wetland, wetland soils, pedons, alluvium, floodplain, inceptisols.

1. INTRODUCTION
Wetland is land that has the water table near or above the land's surface or which is saturated for a long enough period to promote wetland or aquatic processes as indicated by hydric soils, hydrophytic vegetation, and various kinds of biological activity that are adapted to the wet environment.(National Wetlands working group, 1988).Wetland is typically flooded for part of the year, and
forming a transition zone between aquatic and terrestrial systems (Brady and Weil, 2002). Wetlands are among the most productive and economically valuable ecosystems in the world. They provide critical ecosystem goods and services, including carbon storage, biodiversity conservation, fish production, fuel production, water purification, flood and shoreline protection, erosion control, and recreation (Moreno *et al.*, 2012). Wetlands are considered to be marshes,
peatlands, floodplains, mangroves, depressional wetlands and lacustrine wetlands-submerged permanently or periodically under flowing or still fresh, salty or brackish water.

An environment without wetland is incomplete. Wetlands are vital to the health of our environment. They perform the same function for our ecosystem as kidneys do for human bodies, in that they filter and remove pollutants (Saltwater Recreational Fishing in Florida, 1993). They are natural systems worthy of careful evaluation for their biological, hydrological and socio-cultural values. Wetlands are complex environment because they provide critical ecosystem goods and services such as carbon sequestration, biodiversity, conservation, fish production, water purification, flood and shoreline surge protection, erosion control and recreation (Moreno *et al*., 2012). According to Eshett (1993), wetland distribution in Nigeria cuts across vegetational, geological, topographical, soil, and political boundaries. Wetland ecosystems are fundamentally linked to hydrology, which creates the physico-chemical conditions that makes them different from well drained terrestrial or fully aquatic deepwater systems (Mitsch and Gosselink, 2000).
Soil characterization, classification and fertility evaluation contribute to the alleviation of adverse effect of soil diversity, and aid precision agriculture. They are the main sources of information for precision agriculture, land use planning and management (Ogunkunle, 1986). This is because; characterization and classification provide information for the understanding of the micro-morphological, physical, chemical, mineralogical and microbiological properties of the soil (Ogunkunle, 1986).
This study was to characterize, classify, and evaluate some wetland soils of Oguta local government area of Imo State, Southeastern Nigeria. Specifically, the study aim to;
i. determine the physical and chemical properties of the studied soils.
ii. evaluate the suitability of these soils for arable crop production.
iii. estimate how the soil properties relate with each other.

2. MATERIALS AND METHODS
The Study Site
The study was carried out at Osse moto village, Oguta Local Government Area of Imo State Southeastern Nigeria. Osse Moto lies between latitudes 5^0 $39^'$ North and 5^0 $44^'$ North and between Longitudes 6^0 $45^'$ East and 6^0 53' East. Oguta is a

town on the east bank of Oguta Lake in Imo state southeastern Nigeria. The headquarters of Oguta local Government area is at Oguta1.

Geology and Geomorphology

The major geological formation of the area is Alluvium (Pettera *et al*., 1989). It lies within the lowland areas of southeastern Nigeria (Orajaka, 1975). Oguta wetland generally includes marshes, hydric soil, seepage slope, wet prairies, aquant and riverine swamps.

Topography

The topography of the study area ranges from lowlands to sloping grounds. The western part is low-lying and generally featureless, while the eastern and northern portion has a highly undulating topography interspersed with flat plains. This part is marked by spectacular gullies, with the main river, Njaba laden with sediment.

Climate

The climate according to the Koppen's classification is Af with a short dry season extending from November to February and a long rainy season during the remainder of the year. Mean annual rainfall is about 2,120 mm per year, with a unimodal distribution at the peak in September. The period between July and August is characterized by overcast skies and milder temperature (August break). The mean temperature ranges from 25^0C to 28^0C. The dry season is dominated by dusty harmattan winds. The moisture regime is udic (that is, moisture regime in which the soil moisture control section is not dry in any part for as long as 90 cumulative days in normal years. It is common to the soils of humid climate that have well distributed rainfall), (Akamigbo, 2010).

Vegetation

The archetype vegetation of the area is the Rain-forest, but this has been reduced to a mosaic of small plots of field crops (cassava, yams, cocoyams, vegetables), and agroforestry (Oil palms, *Irvingia sp., Cola sp., Musa sp*., etc). Whereas oil palm is grown in groves or plantations, the others are grown around homesteads. Except in the main urban communities, settlements are dispersed and field plots and agro forestry surrounds the homesteads. The area is characterized by abundance of many plant species. The vegetation is in layers or canopies with sun-loving ones appearing as emergent. There are also hardy trees in large mass.

Hydrology and Drainage

Oguta houses one of the largest natural lakes in southeastern Nigeria, located in a natural depression within the extended east bank flood plain of the River Niger downstream of Onitsha. The lake is source of municipal and domestic water for Oguta community. It is also the receptacle of urban sewage from Oguta and the environs, and a trap for sediment. The alluvium underlying the area is a good aquifer that is annually recharged by rainfall and flood waters.

Field Work

Free survey was used for the field studies. Profile pits were dug to a depth of about 200 cm. The materials used in carrying out the field work include; spade, hand trowel, cutlass, camera, global positioning system and munsell soil colour chart. The site and profile descriptions were based on the FAO guidelines for profile description (FAO, 1998). Properties such as soil colour, soil structure, soil texture, root consistency, horizon boundary and faunal activity were assessed.

Delineation of horizon boundaries was accomplished before actual sample collection for laboratory analysis. Soil samples were taken from each constituent horizon, starting from the bottom horizon. The samples were placed in appropriately labeled polythene bags and transported to the laboratory. All the soil samples were air-dried under shade for three days, crushed with pistle and mortal and passed through a 2-mm sieve prior to routine laboratory analysis.

Laboratory Analysis

The samples were analyzed in accordance with standard laboratory procedures for the following parameters:

Particle Size Distribution

Particle size distribution was determined using the modified hydrometer method as described by Gee and Bauder (1986).

Bulk Density

Bulk density was determined by the procedure outlined by Arshad *et al.,* (1996). It was calculated thus;

$$Bulk\ Density = \frac{Mass\ of\ oven\ dried\ soil\ samples\ (g)}{Volume\ of\ core\ sampl (cm3)} \ldots\ldots.(1)$$

That is, $B.D = \frac{W3-W1}{r2h}$

Where;

B.D is bulk density

W3 is the mass of oven dry soil

W1 is the mass of core sampler

Total Porosity

This was computed from bulk density value thus;

% $Porosity = 1 - [\ Db\ X\ 100 Dp1]$……………(2).

Where;

Db is bulk density g/cm3

Dp is particle density g/cm3

Moisture Content
This was determined by the gravimetric method (Obi, 1990). And was calculated using the formula
$\%MC = Ws - DsDs\ X$ 1001……………….. (3)
Where: % MC means percentage Moisture Content
Ws means weight of wet sample
Ds means weigh of dried sample

Soil pH Determination
This was measured electrometrically using glass electrode pH meter both in distilled water and in 0.1N KCl suspension using soil-liquid ratio of 1:2.5 (Hendershot *et al*., 1993)

Organic Carbon
Soil organic carbon was analyzed using the Walkley and Black wet digestion method as contained in Nelson and Sommers, (1982).

Organic Matter
This was computed by multiplying the value of Organic Carbon with Van Bermnerlens factor of 1.724.

Total Nitrogen
Total nitrogen was determined by the micro-kjeldahl digestion and distillation method as described by (Bremner and Mulvaney, 1982)

Available Phosphorous

Available Phosphorous was determined by the Bray-1 method as described by Kuo (1996).

Exchangeable Bases
The exchangeable bases (Ca, Mg, Na and K) were extracted with neutral normal ammonium acetate (NH_4O_{AC}) buffered at pH 7.0 (Thomas, 1982). Exchangeable Calcium and Magnesium were determined in the extract by ETDA titration, while Potassium and Sodium were determined by the use of Flame Photometer (Udo *et al*., 2009).

Total Exchangeable Bases (TEB)
This was gotten by summing up all the exchangeable bases (Ca, Mg, K, Na).

Exchangeable Acidity
Exchangeable acidity (Al^{3+} + H^+) and exchangeable Aluminum (Al^{3+}) were determined by titration as described by Thomas (1996). The exchangeable Hydrogen was obtained by subtracting exchangeable Aluminum (Al^{3+}) from exchangeable acidity (Al^{3+} + H^+).

Total Exchangeable Acidity (TEA)
This was calculated by summing up exchangeable Aluminum (Al^{+3}) and exchangeable Hydrogen (H^+)

Effective Cation Exchange Capacity (ECEC)
This was obtained by the summation of all the exchangeable cations (Ca, Mg, K, Na) and exchangeable acidity (Al^{3+}, H^+).

Base Saturation (BS)
This was obtained by dividing the total exchangeable bases (TEB) by the corresponding effective cation exchange capacity (ECEC) value and multiplied by 100. Thus;
$\% BS = \frac{TEB}{ECEC}$ X $\frac{100}{1}$…………………… (4)

Aluminum Saturation
Percentage Aluminum saturation was computed thus;
$\% Al^{3+}Saturation = \%Al^{3+}ECECX$ 1001…….(5)

Statistical Analysis
The measured variables in the data set were analyzed statistically using Genstat- software according to the procedure of Wilding *et al*., (1994) who grouped coefficient of variability as: CV ≤ 15 % low; CV > 15 ≤ 35 % medium; CV > 35 % high. The relationship existing among the soil properties was assessed using correlation analysis at 5% level of significance.

3. RESULTS AND DISCUSSION

Morphological Characteristics
Data on the morphological properties of the soils of the study site are presented in Table 1. The soils are imperfectly drained, which is a characteristic of wetland soils. Matrix colour (moist) was generally darker at the surface horizons, than at the sub-surface horizons. The matrix colour ranged from dark reddish brown (2.5YR ¾) for the surface horizons to brownish yellow (10YR 6/6) for the sub-surface horizons in the studied pedons. Except for horizon Bt1 of pedon 1 and horizon A1 of pedon 3, were light green (10 YR 7/2) and Pinkish grey (7.5 YR 7/2) were recorded respectively (Table 1). The light matrix colour recorded here could be attributed to low organic matter content of the soils, due probably to anaerobic reactions resulting from poor drainage created by high water table. The darker matrix colour at the surface horizon could have resulted from melanization of the soils due to accumulation of materials from the alluvial deposits by rivers in the study area.
The consistence of the soils is examined by the trend of the particle size distribution down the profile. The texture of the soils ranged from sand to Loamy Sand. The structure and coarse nature of the soils explained why the soils were generally drained and prone to leaching, even erosion. All the soils were mottled, these morphological features observed is an indication of soil wetness brought about by oxidation-reduction cycles due to ground water

fluctuation. Ahn (1970) and Smyth and Montogomery (1972) reported inter-relationship between these features.

Physical Properties

Table1 shows some selected physical properties of the studied soils. Values of sand content ranged from 79 to 91%, Silt (0 to 10%) and clay (7 to 17%). Wetland soils generally differ in clay mineralogy because of alluvium and neo-formation (Ogban *et al*., 2011). The high silt clay ratio (SCR) (CV= 66, 49.4, 39.4 and 52.9) respectively (Table1) is an indication of high weathering intensity. This is consistent with the report of Igwe and Stahr (2004) while silt-sized particles were lower in content (Igwe *et al*., 1995). The results in (Table 3) indicate that there is a weak inverse relationship between percent Sand and percent Silt (r=-0.540, p=0.01, n=18), this is an indication that as sand is increasing; silt is decreasing and vice versa. Ahn (1979) reported highest acidity in sand- sized fractions of tropical soils. This could be why soils of the area are popularly referred to as "acid sands."High sand content coupled with heavy rainfall may have resulted in the exchangeable cations being leached out of the profiles.

Particle size distribution followed no specific pattern (Table1). The predominant sandy nature of the soils, suggests low bulk density and high porosity. Loamy Sand texture dominates the horizons of the studied soils, with the exception of a few Sandy horizons (Bt2 of pedon 1; Bt2 of pedon 2 and Ap of pedon 4), (Table 1). The results show that pedon 4 had the highest mean bulk density of (1.61g/cm3), followed by pedon 1 (1.28g/cm3) and the lowest at pedon 3 (0.92g/cm3). Vertically down the profile, bulk density increased with depth in pedon 1. However, the bulk density followed no specific pattern in pedon 2, 3 and 4 (Table 1). Clay accumulation and low organic matter content could have caused the recorded high bulk densities down the profile.

The mean percentage moisture content was highest at pedon 1 (11.40%) and lowest at pedon 3 (9.75%). This probably may have occurred due to high water table observed at the site. The results show that moisture content did not follow a regular pattern. This could be attributed to differential exposure of the various pedogenic horizons to drying effect of the sun and atmospheric air.

Chemical Properties

The results of the laboratory analyses for the chemical properties are shown in Table 2. The soils were strongly acid to slightly acid, except for few horizons (Bt of pedon 1; Ap of pedon 3 and Btg of pedon 4) with values that fall within the range of 6.5 to 7.3 which according to Fitzpatrick (1990) rating, is neutral. The pH (H_2O) values ranged from 5.18 to 6.74, while pH (Kcl) ranged from 4.46 to 5.9. The pH in kcl is lower than the pH in water, indicating that the kcl brought more of the acidity to the soil solution, leading to the exchange complex being dominated by Al^{3+} and H^+ ions. The acidic pH values agree with the assertion of (Udo 1980; and Eshett *et al*., 1988) that such reaction is characteristic of soils in Nigeria's South-eastern region and is the result of acidic nature of parent rocks, coupled with the influence of leached profiles under higher annual rainfall conditions. Most tropical soils, particularly soils of Southeastern Nigeria are acidic. This is more or less as a result of poor management practices coupled with leaching resulting from heavy rainfall experienced in the area which washes away basic cations, leaving behind acidic ions in the soil. Organic carbon content was generally low, in line with the report of Igwe and Stahr (2004). The organic carbon decreases with depth. This is an indication of continuous decomposition of organic materials; a fluvic property (Soil Survey Staff, 1996). Organic matter have been reported to have positive influence on the ECEC (r=0.245), base saturation (r=0.260), structure, buffering capacity and water holding capacity of soils. The organic matter content in the surface horizon of all the pedons can sustain arable crop production. The mean percentage organic matter was 0.54%, 0.20%, 0.32% and 0.43% in pedons 1 to 4, respectively.

Percentage total nitrogen was very low. The mean values for pedons 1, 2, 3 and 4 were 0.017%, 0.011%, 0.018% and 0.024% respectively. This low level of total nitrogen status could be

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Percentage total nitrogen was very low. The mean values for pedons 1, 2, 3 and 4 were 0.017%, 0.011%, 0.018% and 0.024% respectively. This low level of total nitrogen status could be attributed to indiscriminate bush burning in the area which according to Lal (1974), hastens volatilization of available nitrogen. Aside bush burning, leaching, coupled with intermittent flooding and drying which is known to favour nitrogen loss through nitrification – denitrification process (Wong *et al*.,1991), may have contributed to the nitrogen level. The relationship between organic carbon and total nitrogen has been established (Adeyanju, 2005); (r=0.558,p=0.05, n-18). Available Phosphorous in the studied soils is low. The low level of available P is due to the low level of organic matter, because organic matter is a major source of phosphorous. The level of potassium is low and this promotes phosphorous fixation. The organic carbon content observed in these pedons may have resulted in low phosphorous status in the soils. Ogban *et al*., (2011) reported that available Phosphorous is generally low for all the wetland soils, with average values less than 15mg/kg. Calcium and Magnesium are the predominant exchangeable bases. The cation distribution is in the order: Ca >Mg >Na >K in all the soils, except for pedon 4 which exhibits a different pattern (Table 2). The exchangeable bases are low. This may be due to the nature of the parent material in the location, intense leaching, weathering etc and hence, low inherent fertility status with regards to the major and micro nutrients. This was in agreement with the findings of Olaleye (1998);Fasina and Adeyanju (2007).

Effective Cation Exchange Capacity (ECEC) was low for all the pedons ranging from 3.672 to 7.424 cmol/kg . These are in line with the values reported for most Nigerian soils (Ogunwale and Ashaye, 1975). The ECEC value is low but not too low compared to other soils of the humid tropics. The reason could be attributed to high leaching and low organic matter content of the soils. Percentage base saturation varied from 21 to 68% in all the horizons of the studied soils. According to FAO (2004), the percentage base saturation of the studied soils ranged from low to high (Table 2). Considering the mean values of the percentage base saturation (51%, 34.5%, 43.5% and 39.5% respectively for pedon 1–4) as shown in Table 2. The soil is therefore classified as Inceptisols (Soil Survey Staff, 1999). The highest mean value of base saturation recorded at pedon1 (51%) is in connection with the higher distribution of TEB over TEA, compared to the other 3 pedons were their TEA are higher than their TEB, which could be as a result of anthropogenic activities going on in those pedons.

Exchangeable aluminum, a non-essential element whose presence in large amounts in the soil solution is detrimental to proper root functioning and good crop yield, was low in the soils. The mean values are 1.90, 2.93, 2.07 and 1.55 cmol/kg for the four profiles respectively. It followed therefore, that the chances of this cation attaining toxic levels of saturation in soil solution is very low. This will augur well for food crop cultivation on these soils (Eshett *et al*., 1988).

Table 1: Some Selected Physical Properties of the Studied Wetland Soils.

Horizon	Depth (cm)	BD(g/cm3)	TP(%)	MC(%)	% Sand	%Silt	% Clay	SCR	TC
				Pedon1					
A_P	0-20	1.02	62	10	81	2	17	0.12	Loamy Sand
AB	20-35	1.13	57	13	79	4	17	0.24	Loamy Sand
Bt1	35-85	1.22	54	11	85	0	15	0.10	Loamy Sand
BT2	85-99	1.27	52	10	91	4	5	0.27	Sand
Bt3	99-200	1.75	34	13	87	2	11	0.18	Loamy Sand
	Mean	**1.28**	**52**	**11**	**84.6**	**2.4**	**15**	**0.16**	
	%CV	**21.9**	**20.5**	**13.3**	**5.6**	**69.7**	**16.3**	**66.0**	
	Ranking	**Medium**	**Medium**	**Low**	**Low**	**High**	**Medium**	**High**	
				Pedon 2					
A_P	0-20	1.28	52	11	81	8	11	0.72	Loamy Sand
AB	20-35	1.29	51	10	85	4	11	0.36	Loamy Sand
Bt1	35-85	1.29	51	10	83	4	13	0.31	Loamy Sand
Bt2	85-150	1.18	55	9	83	8	9	0.89	Sand
	Mean	**1.26**	**52.25**	**10**	**83**	**6**	**11**	**0.57**	
	%CV	**4.2**	**3.6**	**8.2**	**2.0**	**38.5**	**14.8**	**49.4**	
	Ranking	**Low**	**Low**	**Low**	**Low**	**High**	**Low**	**High**	
				Pedon3					
Ap	0-25	1.26	52	11	83	4	13	0.13	Loamy Sand
AB	25-55	0.81	69	9	84	5	11	0.36	Loamy Sand
Bt1	55-90	0.93	65	10	83	6	11	0.55	Loamy Sand
Bt2	90-200	0.92	65	10	81	8	11	0.72	Loamy Sand
	Mean	**0.92**	**65.25**	**9.75**	**82.75**	**5.50**	**11.50**	**1.94**	
	%CV	**27.9**	**14.9**	**9.8**	**1.5**	**34.8**	**8.7**	**39.4**	
	Ranking	**Medium**	**Low**	**Low**	**Low**	**Medium**	**Low**	**High**	
				Pedon 4					
Ap	0-20	1.24	53	9	91	2	7	0.29	Sand
AB	20-55	1.31	51	11	79	6	15	0.40	Loamy Sand
Bt1	55-90	1.27	52	12	81	6	13	0.46	Loamy Sand
Bt2	90-180	1.20	54	10	79	10	11	0.91	Loamy Sand
	Mean	**1.61**	**52.50**	**10.50**	**82.5**	**6.00**	**11.50**	**0.52**	
	%CV	**3.7**	**3.7**	**12.2**	**7.0**	**54.4**	**29.7**	**52.9**	
	Ranking	**Low**	**Low**	**Low**	**Low**	**High**	**Medium**	**High**	

Where: SCR=Silt Clay Ratio, TC=Textural Class, BD= Bulk Density, TP=Total Porosity, MC= Moisture Content.

Table 2: Some Selected Chemical Properties of the Studied Wetland Soils.

Horizon	Depth (cm)	P^H (H_2O)	P^H KCL	TN	OC (%)	OM	Avail. P (mg/kg)	Ca	Mg	K	Na	Al^{3+} (cmolkg-[1])	H^+	TEA	TEB	ECEC	%Al^{3+}	%BS
								Pedon1										
A_P	0-20	5.53	4.84	0.016	1.12	1.93	7.7	1.5	1.39	0.131	0.189	2.52	1.28	3.8	3.208	7.008	36	46
AB	20-35	6.06	5.37	0.042	0.36	0.63	11.2	1.0	0.25	0.135	0.191	2.68	0.72	3.4	1.576	4.976	54	32
Bt	35-85	6.74	6.10	0.01	0.04	0.07	5.6	2.3	1.01	0.138	0.21	1.40	1.60	3.0	3.658	6.658	21	55
Btg	85-99	5.35	4.46	0.008	0.02	0.03	3.5	2.0	1.27	0.139	0.209	1.48	0.72	2.20	3.618	5.818	25	62
Btn	99-200	6.46	5.57	0.007	0.02	0.03	2.1	1.1	0.76	0.129	0.203	1.40	0.08	1.48	2.192	3.672	38	60
	Mean	**6.03**	**5.27**	**0.017**	**0.31**	**0.54**	**6.02**	**1.58**	**0.94**	**0.134**	**0.200**	**1.90**	**0.88**	**2.78**	**2.850**	**5.626**	**34.8**	**51**
	%CV	**9.8**	**12.1**	**88.1**	**95.6**	**95.2**	**59.6**	**35.6**	**48.5**	**3.2**	**4.9**	**34.1**	**66.5**	**33.7**	**32.5**	**23.9**	**37.1**	**24.1**
	Rank	**Low**	**Low**	**High**	**High**	**High**	**High**	**High**	**High**	**Low**	**Low**	**Low**	**High**	**Low**	**Medium**	**Medium**	**High**	**Medium**
								Pedon2										
A_p	0-25	5.18	4.29	0.027	0.32	0.55	9.1	1.3	1.01	0.142	0.206	3.00	0.6	3.6	2.658	6.258	48	42
AB	25-52	6.02	5.12	0.010	0.08	0.14	4.9	1.5	0.38	0.137	0.211	3.08	1.12	4.2	2.228	6.428	48	35
Bt	52-85	6.04	5.14	0.004	0.04	0.07	6.3	0.1	0.13	0.142	0.22	3.84	0.16	4.0	0.592	4.592	84	13
Btg	85-150	6.39	5.49	0.003	0.02	0.03	7.0	2.1	0.89	0.136	0.221	1.8	1.8	3.6	3.347	6.947	26	48
	Mean	**5.91**	**5.01**	**0.011**	**0.12**	**0.20**	**6.83**	**1.25**	**0.60**	**0.139**	**0.215**	**2.93**	**0.92**	**3.85**	**2.206**	**6.056**	**51.5**	**34.5**
	%CV	**8.7**	**10.2**	**91.0**	**92.8**	**25.6**	**67.1**	**69.2**	**2.3**	**3.4**	**28.3**	**76.7**	**7.8**	**53.8**	**53.1**	**16.8**	**46.6**	**44.3**
	Rank	**Low**	**Low**	**High**	**High**	**Medium**	**High**	**High**	**Low**	**Low**	**Medium**	**High**	**Low**	**High**	**High**	**Medium**	**High**	**High**
								Pedon3										
A_p	0-25	6.67	5.95	0.035	0.40	0.69	7.7	2.0	1.52	0.117	0.227	1.8	1.76	3.56	3.864	7.424	24	52
AB	25-55	6.05	5.10	0.010	0.10	0.17	4.9	0.8	0.76	0.121	0.242	1.4	2.4	3.8	1.923	5.723	24	34
Bt	55-90	6.20	5.25	0.021	0.22	0.38	5.8	0.3	0.25	0.122	0.245	3.48	0.08	3.56	0.917	4.477	78	20
Btg	90-200	6.49	5.51	0.004	0.02	0.03	0.7	1.7	1.52	0.122	0.255	1.6	0.12	1.72	3.597	5.317	30	68
	Mean	**6.35**	**5.45**	**0.018**	**0.19**	**0.32**	**4.8**	**1.2**	**1.01**	**0.121**	**0.242**	**2.07**	**1.09**	**3.16**	**2.575**	**5.735**	**39**	**43.5**
	%CV	**4.4**	**6.8**	**77.9**	**89.3**	**90.4**	**61.9**	**65.6**	**61.4**	**2.0**	**4.8**	**46.1**	**97.6**	**30.6**	**54.4**	**21.6**	**67.1**	**48.1**
	Rank	**Low**	**Low**	**High**	**High**	**High**	**High**	**High**	**High**	**Low**	**Low**	**High**	**High**	**Medium**	**High**	**Medium**	**High**	**High**
								Pedon4										
A_p	0-20	6.15	5.2	0.05	0.56	0.97	4.90	0.50	1.65	0.126	0.174	1.0	0.8	1.8	2.450	4.250	24	58
AB	20-55	6.34	5.74	0.031	0.30	0.52	4.90	1.50	1.01	0.129	0.185	2.4	1.4	3.8	2.824	6.624	36	43
Bt	55-90	5.78	5.08	0.003	0.02	0.03	4.20	0.50	1.27	0.134	0.175	1.4	2.3	3.7	2.079	5.799	24	36
Btg	90-180	6.61	5.91	0.013	0.12	0.21	10.50	0.30	0.19	0.136	0.186	1.4	1.6	3.0	0.812	3.812	38	21

Mean	**6.22**	**5.48**	**0.024**	**0.25**	**0.43**	**6.13**	**0.70**	**1.03**	**0.131**	**0.18**	**1.55**	**1.53**	**3.08**	**2.041**	**5.121**	**30.5**	**39.5**
%CV	**5.6**	**7.2**	**85.4**	**80.4**	**95.2**	**47.9**	**77.4**	**32.4**	**3.6**	**3.5**	**36.3**	**80.4**	**20.4**	**42.8**	**33.6**	**60.3**	**50.2**
Rank	**Low**	**Low**	**High**	**High**	**High**	**High**	**High**	**Medium**	**Low**	**Low**	**High**	**High**	**Medium**	**High**	**Medium**	**High**	**High**

Where: TN=Total Nitrogen; OC= Organic Carbon; OM= Organic Matter; Avail. P.=Available Phosphorous; Ca= Calcium; Mg= Magnesium; K= Potassium; Na= Sodium; Al^{3+} =Aluminium Ion; H^+= Hydrogen ion; TEA= Total Exchangeable Acidity; TEB= Total Exchangeable Base; ECEC= Effective Cation Exchange Capacity; $\%Al^{3+}$ Sat.= Percentage Aluminium Saturation; %BS= Percentage Base Saturation.

RELATIONSHIP BETWEEN SOIL PROPERTIES

A correlation matrix of soil properties of the studied wetland soil is presented in Table 3. Soil reaction (pH) showed strong negative correlation with Organic matter(r = -0.620, p = 0.01, n = 18) indicating that an increase in organic matter, will lead to a decrease in soil pH.

There was a strong positive correlation between bulk density and moisture content (r = 0.595, p = 0.01, n =18) which means that an increase in moisture content, will lead to an increase in bulk density. Bulk density and total porosity showed a very strong negative correlation (r = -0.999, p = 0.05, n = 18) indicating that when the bulk density is increasing, total porosity will be decreasing. The results also showed that total porosity had a strong negative correlation with moisture content (r = -0.589, p=0.01,n =18). This implies that as moisture content is increasing, total porosity is decreasing. There was a weak negative correlation between potassium and total porosity (r = -0.495, p = 0.01, n = 18), indicating that as porosity is increasing, potassium one of the major nutrients decreases.

Available P correlated positively strong with %sand (r = 0.525, p= 0.01, n =18) and negatively strong with base saturation (r = -0.532, p = 0.01, n = 18) indicating that as available P is increasing, percent sand is as well increasing, whereas, as available P is increasing, percent base saturation is decreasing, and is in line with the findings of Ogban*et al*., (2011). Calcium showed varied positive correlation coefficient with soil properties as follows: Magnesium (r = 0.480, p = 0.01, n =18), Effective Cation Exchange Capacity (r = 0.740, p = 0.05, n = 18), and base saturation (r=0.696, p = 0.01, n = 18). Very strong positive correlation was observed between Magnesium and base saturation (r = 0.804, p = 0.05, n = 18) indicating that an increase in Magnesium leads to increase in base saturation which agrees with the existing realities that magnesium is one of the major factors that contributes to base saturation. While the results showed a weak positive correlation between Magnesium and the following soil properties; sand (r = 0.421, p = 0.01, n =18) and ECEC (r = 0.428, p = 0.01, n = 18).

Sodium shows weak negative correlation with potassium (r=-0.404, p=0.01, n=18), which implies that as sodium is increasing, potassium will be decreasing. A strong positive correlation was recorded between ECEC and TEA (r = 0.506, p = 0.01, n = 18). This implies that a decrease in Total Exchangeable Acidity (TEA), will lead to decrease in Effective Cation Exchange Capacity (ECEC). This is one of the reasons that made the studied soils unable to efficiently sustain arable crop production.

Base saturation correlated positively strong with sand (r=0.590. p=0.01, n=18) and negatively strong with TEA (r = -0.688, p = 0.01, n = 18). TEA had a strong negative correlation with percent sand (r = -0.599, p = 0.01, n = 18). Also, there is a strong negative correlation between sand and silt at 5 % probability level (r = -0.540, n = 18), indicating that as percent sand is increasing, percent silt is decreasing and vice versa.

Soil Classification

Based on the physical, chemical and morphological characteristics of the studied soils, the soils were classified using USDA Soil Taxonomy (2010) and WRB (2007). The soils of Osse Moto village, Oguta Local Government Area of Imo State Southeastern Nigeria are referred to as alluvial soils. The soils were formed from floodplains, with aquant characteristics (that is, characteristics associated with wetness). The soils have Ochric epipedon (light coloured, low organic carbon content etc), and Cambic subsurface horizon for all the pedons (that is, horizon that has been changed or altered by physical movement or by chemical reactions, generally non illuvial (Soil Survey Staff, 1999). The soils are developed in humid region, with weak to moderate horizon development, retarded because of cold climate, waterlogged soils, textures finer than loamy, that is, very fine sand. The soils therefore belong to the soil order Inceptisols (FAO, 2006).

The soils had Udic moisture regime (that is, moisture regime in which the soil moisture control section is not dry in any part for as long as 90 cumulative days in normal years), and Iso-hyperthermic temperature regime that is, they have a mean annual rainy season, June, July and August, and dry season, December, January and

February, with temperature difference less than 5^0C. (Soil Survey Staff, 1999). The soils therefore, belong to the sub order Aquepts; great group fluvaquepts; sub group Endoaquepts; family Fluvaquentic Endoaquepts (pedon 1); Aeric eppiquents (pedon 2); Aquandic Endoaquepts (pedon 3) and Fluvaquentic Endoaquepts (pedon 4); the soils belong to the lake series (because Oguta houses one of the natural lakes in South-east Nigeria located in a natural depression within the extended east bank floodplain of the River Niger downstream of Onitsha. In the World Reference Base system, the soils are classified as Cambiso

Table 4.3 Correlation Matrix of the Studied Soil Properties

Property	PH	BS	OM	AV.P	Ca	Mg	ECEC	Al.Sat.	BD	TP	%SAND	%SILT	%CLAY
PH	1												
BS	0.07InS	1											
OM	-0.289ns	0.047ns	1										
AV.P	-0.098ns	-0.533*	0.0382ns	1									
Ca	0.097ns	0.696*	0.003ns	-0.157ns	1								
Mg	-0.109ns	0.804*	0.330ns	-0.398ns	0.480*	1							
ECEC	-0.14Ins	0.260ns	-0.0245ns	0.098ns	0.739**	0.428*	1						
Al.Sat	-0.150ns	-0.716**	-0.16ns	0.245ns	-0.557*	-0.728**	-0.391ns	1					
BD	-0.158ns	0.073NS	-0.330ns	-0.244ns	-0.143ns	-0.201ns	-0.360ns	-0.59ns	1				
TP	0.147ns	-0.054NS	0.348ns	0.234ns	0.159ns	0.224ns	0.378ns	0.051ns	-0.999**	1			
%SAND	-0.075ns	0.590*	-0.135ns	-0.525*	0.232ns	0.421*	-0.117ns	-0.340ns	0.253ns	-0.25ns	1		
%SILT	-0.96ns	-0.527*	-0.240ns	0.368ns	-0339ns	-0.389ns	-0.110ns	0.229ns	-0.149ns	0.134ns	-0.540*	1	
%CLAY	-0.205ns	-0.061ns	0.295ns	0.249ns	0.27Ins	-0.049ns	0.350ns	0.067ns	-0.113ns	0130ns	-0.33ns	-0.310ns	1

Where: *=significant at 0.01 probability level; **=Significant at 0.05 probability level; ns=Significant, BS=Base saturation; OM= Organic Matter; Av.P.=Available Phosphorus ; Mg=Magnesium; ECEC=Effective Cation Exchange Capacity; Al. Sat.= Aluminium Saturation; BD=Bulk Density; TP= Total Porosity.

Fertility Evaluation of the wetland soils for arable crop production

Based on the fact that the studied soils were generally acidic, moist, and coarse in texture, with textural class of loamy sand and sand. In line with FAO (2004), the soils are low in fertility and cannot efficiently sustain arable crop production as shown in the interpretation guide for evaluating analytical data. The soils therefore, are grouped in S2 category as moderately suitable for arable crop production.

4. CONCLUSION AND RECOMMENDATION

The study found that the soils of Oguta local Government Area of Imo State was moderately suitable for agriculture, but cannot efficiently maintain optimum yield of most arable crop. Therefore, intensive crop production on the wetlands requires the application of optimum rates of N and P fertilizers on the soils derived from recent alluvium. Constant inputs of organic and mineral fertilizers will be required to enhance soil fertility and improve crop yield. Liming is recommended on the studied soils. Crops that requires very low amount of P are recommended for planting on the area, and phosphorous carrier fertilizers are required in higher amount in the field. Conservation tillage should be practiced in the area, not only to improve the soil fertility but also to conserve both the physical and chemical fertility of the soils, and to sustain crop production in the area. It is recommend that the soils be fallowed during the rainy season, and farmed in a diverse way during the dry season, when they may be the only place with enough water to support crops. I also recommend that further studies be carried out on the effect of climate on wetland soils, to ascertain their suitability not only for arable crop production, but also as a foundation and construction materials.

REFERENCES

Akamigbo F.O.R (2010). Fundamental methods of soil resource survey, classification, interpretation and application. Published and printed by University of Nigeria Press Ltd. Bookshop / Bank Building Complex, UNN.P.84.

Ahn, P.M, (1970). West African Soils. Oxford University Press Britain, Pp.332.

Adeyanju J.A.,(2005).Geneties of harvest and leaf-yield indices in cowpea. Journal of crop improvement 23 (3) PP. 266-274.

Arshad, M.A.B; Lowery and B. Grossman (1996): Physical text for monitoring soil quality.

In: J.W. Doran and A.J. Jones (eds). Methods for Assessing Soil quality. Soil Sci. Soc. Am. Spec. Publ. 49. SSSA, Madison, W.I. Pp. 123 -143.

Brandy, N. and Weil, R. (2002). The Nature and Properties of Soils. 13th (ed.). Prentice Hall Upper Saddle River N.J. Pp. 254-261

Bremner, J.M and Mulvaney, G. S. (1982).Nitrogen Total. In: Page, A.L; Miller R. H. and Keeney, D. R. (eds.). Methods of Soil Analysis .Parts 2.American Society of Agronomy, No, 9, Madison , WIS Pp:595-624.

Eshett, E.T, Omueti, J.A.I, and Juo, A.S.R, (1988). Characterization of Wetland Soils supporting Rice Production in Southeastern Nigeria. Thailand Journal of Agricultural Science Vol.2, Pp:35-50.

Eshett.E.T, (1993). The wetlands soils of Nigeria properties, classification and traditional land use practices. Wetlands and Ecotones Studies on land water interactions, 227-224Pp.

Fasina A. S, Omueti J. A. I, Ayodele O. J (2007).Characterization, Classification and Crop Production Potentials of Soils of Asu River Basin, Anambra State. In Proc. of the 33 rd Annual Conference of Soil Science Society of Nigeria held at University of Ado – Ekiti, Nigeria. Pp49-59.

F.A.O (1998), F.A.O / UNESCO.Soil / Map of the world, Revised Legend. World Soil Resources report No. 60. F.A.O. Rome. John Wiley and Sons Inc. New York. 234Pp.

FAO (2002) Gateway to land and water information: Nigeria national report. Rome: Food and Agriculture Organization of the United Nations [Available from: http://www.fao.org/landandwater/swlwpnr/reports/rc_codes.htm] Last updated: 12 December 2002 [Accessed: 1 April 2008].

FAO, (2006).Guideline for Soil description (4thed.). Rome. Food and Agricultural Organization of the United Nations.Pp 97.

Fitzpatrick, (1990). An Introduction to soils, their formation, classification and distribution, 2nd edition Longman, London.P.87

Gee, G. W; Bauder J.W. (1986). Particle size analysis. In: Methods of Soil Analysis. Port I.A. Klute (ed) Madison, W.I. American Society Agronomy. 9:91-100.

Hendershot, W.H., Lalande, H., and Duquette, M. (1993). Soil Reaction and Exchangeable Acidity, Pp.141-142. In M.R. Carter, (ed). Soil Sampling and Methods of Analysis. Canadian Society of Soil Science, Lewis Publishers, Boca Ratio, Florida.

Igwe, C. A., and Stahr, K. (2004).Waterstable aggregates of flooded inceptisols from Southeastern Nigeria in relation to mineralogy and chemical properties.

Australian Journal of Soil Research 42:171-179.

Kuo S. (1996). Phosphorus. In D. L. Spark (eds.). Methods of Soil Analysis Part 3.Chemical Methods. SSSA Book Series 5, Madison, Wisconsin, USA Pp:869-920.

Lal, (1974). Soil Temperature, Soil Moisture and Maize yield from mulched and unmulched tropical soils. Journal of Plant and Soil 40(1), Pp.129-143.

Mitsch W. J., and J. G. Gosselink (2000). Wetlands. John Wiley and Sons, New York.P.206.

Moreno et al., (2012).Structural and Functional Loss in Restored Wetland Ecosystems. Plos Biol. Journal 10: 1001247.

National Wetlands Working group, (1988). Ecological Land Classification Series No.24 Polyscience publications, Montreal Pp.452.

Nelson, D.W. and Sommers, L.E. (1982).Total Carbon, Organic Carbon and Organic Matter. In: Page, A.L., Miller, R.H. and Keeney , D.R.(eds.) Methods of Soil Analysis . Part 2.America Society of Agronomy. Madison WIS. Pp. 539-599.

Obi, C.A. (1990). Relationship between work experience and teaching practice grades of vocational education students. University of Nigeria, Nsukka . Business Education Journal, 2(2), 131-135.

Ogban, P.I., Effiong, G.S., Obi, J.C. and Ibia, T.O., (2011). Characteristics Potentials, and Constraints of Wetland Soils for Agricultural Development in AkwaIbom State, Southeastern Nigeria. Nigeria Journal of Agriculture, Food and Environment.Vol.7 No.2, Pp.80-87.

Ogunkunle A.O. (1986). Spatial variability of some chemical properties in two mapping units in Southeastern Nigeria. Soil Survey Land Eval.6:2632.

Ogunwale, J.A. and Ashaye, T.I, (1975). Sandstone derived Soils of Catena at Iperu,

Nigeria. J. Soil Sci., 26: 22-31.

Olaleye A. O (1998). Characterization,Evaluation, Nutrient dynamics and Rice Yields of selected Wetland soils in Nigeria. PhD. Thesis in the Department of Agronomy, University of Ibadan, pp 202.

Ojanuga, A.G.,Okusami, T. A and Lekwa, G. (1996).Wetland soils of Nigeria, status of Knowledge and potentials, Soil Science Society of Nigeria Monograph No Pp 2.

Orajaka, S.O. (1975) Geology. In: G.E.K. Ofomata (ed) Nigeria in maps: Eastern states. Benin City: Ethiope Publishing House. Pp. 5-7.

Petters et al., 1989. Effects of Land use on infiltration characteristics of soils in Northern Akwa-Ibom State, South-Eastern Nigeria. Journal of Tropical Agriculture, Food, Environment and Extension. 16(3), Pp.29-36.

Saltwater Recreational Fishing in Florida, (1993).The Economics of Resident and Tourist Participation.Florida Sea Great.SGEB. P.136

Smyth, A. and Montgomery, R.F.(1962). Soil and Land use in Central Western Nigeria. Government Printer, Ibadan, Nigeria.P.265.

Soil Survey Staff, (1993).Soil Survey Manual.Soil Conservation Service U. S. Department of Agriculture Handbook 18, U. S Govt. Printing Office, Washington, D. C. 871.

Soil Survey Staff, (1996). Keys to Soil Taxonomy. Seventh Edition, USDA National Resource Conservation Service, Washington DC, 644.

Soil Survey Staff, (1999). Soil Taxonomy: A basic system of Soil Classification for making and Interpreting Soil
Surveys. Agric. Handbook 436, USDA, Washington D.C. Pp. 869.

Thomas, G.W, (1982). Exchangeable cations.In A. L page.Methodof Soil Analysis, part 2, 2nd (ed). Agron.Monogr. 9; American Society Agronomy and SSSA, Madison, W.I, Pp 159-165.

Udo E. J, Ibia T.O, Ogunwale J.A, Ano A.A, Esu I.E,(2009). Manual of Soil Plant and Water Analysis.Sibon Book Limited Lagos Pp. 82-92.

USDA Soil Taxonomy, (2010). Key to Soil Taxonomy . Soil Survey Staff .11thEdition , USA.

WRB, (2007). World Reference Base for World Soil Resources world Soil Resources reports 103, Rome.

Wilding et al., 1994. Enteric Coated Limed release systems for colonic targeting. International Journal of Pharmaceutics 111(1), Pp. 99-102

Wong MTF, Wild A, Juo ASR (1991). Retarded leaching of nitrate measured in monolith Iysimeters in South -east Nigeria. J. Soil Sci. 38:51 - 518.

WRB, (2007). World Reference Base for World Soil Resource Report 103, Rome.