DOI: http://dx.doi.org/10.4314/gjass.v16i1.3

GLOBAL JOURNAL OF AGRICULTURAL SCIENCES VOL. 16, 2017: 17-30
 ISSN 1596-2903
www.globaljournalseries.com, Email: info@globaljournalseries.com

COMPARATIVE ASSESSMENT OF WETLAND AND COASTAL PLAIN SOILS IN CALABAR, CROSS RIVER STATE

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(Received 17 March 2017; Revision Accepted 15 June 2017)

ABSTRACT

The comparative assessment of wetland and coastal plain soils for agricultural productivity were studied. The investigation was carried out in two areas: Atimbo and Obufa Esuk in Calabar, Cross River State. The dominant particle size in both coastal and wetland soil was sandy texture. The mean bulk density values of 1.35 g/cm^3 and 1.30 g/cm^3 were obtained for Atimbo and Obufa Esuk coastal plain soil while 1.33 g/cm^3 and 1.30 g/cm^3 were obtained for Atimbo and Obufa Esuk wetland soil respectively. Total porosity in wetland soils was lower than coastal plain soil whereas moisture content in wetland soil was higher than coastal plain soil. Except Ap horizon in Atimbo coastal plain soil, the pH observed for the studied soils were all below pH of 5.0 unit which signifies high acidic condition. The mean organic carbon content in coastal plain soil was lower than wetland soil. Available phosphorus in the studied soils were high with Atimbo and Obufa Esuk coastal plain soil having a mean value of 32.10 and 32.42 mg/kg respectively, whereas those in Atimbo and Obufa Esuk wetland soils were 32.73 and 33.88 mg/kg respectively. The exchangeable calcium content obtained for both coastal and wetland soils were all below the critical limit of 5.0 cmolkg^{-1}. Although exchangeable magnesium content was low in both soils but wetland soils was only slightly below the critical value of 1.5cmol/kg when compared to coastal plain soil. Both wetland and coastal plain soils were below (>0.2 cmolkg^{-1}) critical level of K in soils of the zone. Also, exchangeable Na in both soil were low and below 0.3 cmol/kg limit and are adequate for cultivation of arable and tree crops. ECEC in both soils were low whereas percent base saturation was high. The mean C:N ratio in Atimbo and Obufa Esuk coastal plain soil were 11.45 and 15.48 respectively. Comparatively, the C:N ratio in Atimbo and Obufa Esuk wetland soils was slightly higher having a mean value of 16.39 and 18.14 respectively. This also reflect low rate of decomposition because of anaerobic condition of the soil. The Mg:K ratio were low in both soils. The Ca:Mg ratio values were high in wetland soil when compared with a normal range of 3:1-5:1 for productive soils and was low for coastal plain soil. Per cent silt content, moisture content, and exchangeable sodium of soil sample analyzed from wetland and coastal plain soil in Atimbo were significantly different ($p<0.05$). The result of the studied soils indicated that coastal plain soil is already losing its fertility status as typified by low values of organic carbon, total nitrogen, Exchangeable cations and high acidity couple with low moisture content; hence there is need to harnessed wetland soil for crop productivity. Wetland soils could be exploited for the cultivation of rice, oil palm, coconut, plantain, pineapple and sugar cane with judicious application of lime, and N and K fertilizers since these crops can perform well under acidic condition.

KEYWORDS: Wetland soil, coastal plain soil, soil fertility, soil properties

INTRODUCTION

The soils of the humid tropics have received overwhelming acceptance for agriculture and other uses. These soils have the potential that can be exploited for crop production, unfortunately they are either highly weathered and leached soils formed on coastal plain sands under excessive rainfall regime as found in the southern part of Nigeria or wetted for long duration of growing season (Egbuchua and Ojobor, 2011; Akpan-idiok, 2012).

Coastal plain soils are extensive in Nigeria and are mostly located mainly in the southern part of the country. These soils are characterized by high hydrogen ion (H^+) concentration which affects the availability and uptake of several essential nutrients such as calcium (Ca), magnesium (Mg), potassium (K), phosphorus (P) and molybdenum (Mo) for plant growth, thus resulting to low crop yield (Ogban and Ibia, 1998). They are also characterized by the presence of aluminium (Al), iron (Fe) and manganese (Mn) at high level which are capable of suppressing the availability of these essential nutrients. Conversely, wetland soil is regarded as important ecosystems which are transitional between open water and terrestrial ecosystems. They exhibit wetness characteristics such as mottling or gleying in their profiles

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(gleyic and histic horizons), of which the depth at low tide does not exceed six meters (Ramsar Convention Secretariat, 2011). Wetlands soils are grossly underutilized in Nigeria. Rice and sugar cane are grown on them in the raining season.

In recent time, agricultural use of wetland soils has increased significantly in many developing countries particularly in Africa including Nigeria (McCartney *et al.,* 2010). This increase is driven partly by increasing population, deterioration of upland soils, economic and financial motivation (Schuyt, 2005) and increasing issues of food insecurity in developing countries (Taiwo, 2013). Wetland soils being the nature's free gift could mitigate the problem of water unavailability, and if properly harnessed could sustain long growing season crops (Juo and Hossner, 1992) compared to coastal plain soils. However, wetlands soils in Calabar and its evirons are hardly utilized at the moment for beneficial agricultural production of crops by the small scale farmers. Most wetland soils in Calabar and its environs receive industrial and domestic wastes and effluent from local industries and inhabitants of these areas. This can lead to environmental pollution if not properly manage by the government.

Objectives of Study

i. To assess the physico-chemical properties of the wetland and coastal plain soils within the study areas.
ii. To estimate the relationship between soil properties within wetland and coastal plain soils.

MATERIALS AND METHODS

Description of Study Area

The study was conducted in Atimbo (latitudes N04^{0} 46.247^{I} and longitudes E006^{0} 59.822^{I}) and Obufa Esuk (latitudes N05^{0} 04^{I} 023^{II} and longitudes E005^{0} 13^{I} 335^{II}) in Calabar, Cross River State. The study area is located 39 m above sea level within humid tropical climate, having a mean annual rainfall exceeding 2000 mm. The mean annual temperature range between 27–28^{0}C and relative humidity varies with seasons from 80–90% in the rainy season while 60- 80% relative humidity is recorded during the dry season. The soils of the area are derived from coastal plain parent materials overlying the tertiary coastal plain sand geological formation usually referred to as 'acid sand' and the soil type is classified as Kandiudults according to USDA soil Taxonomy (Akpan-Idiok *et al.,* 2012).

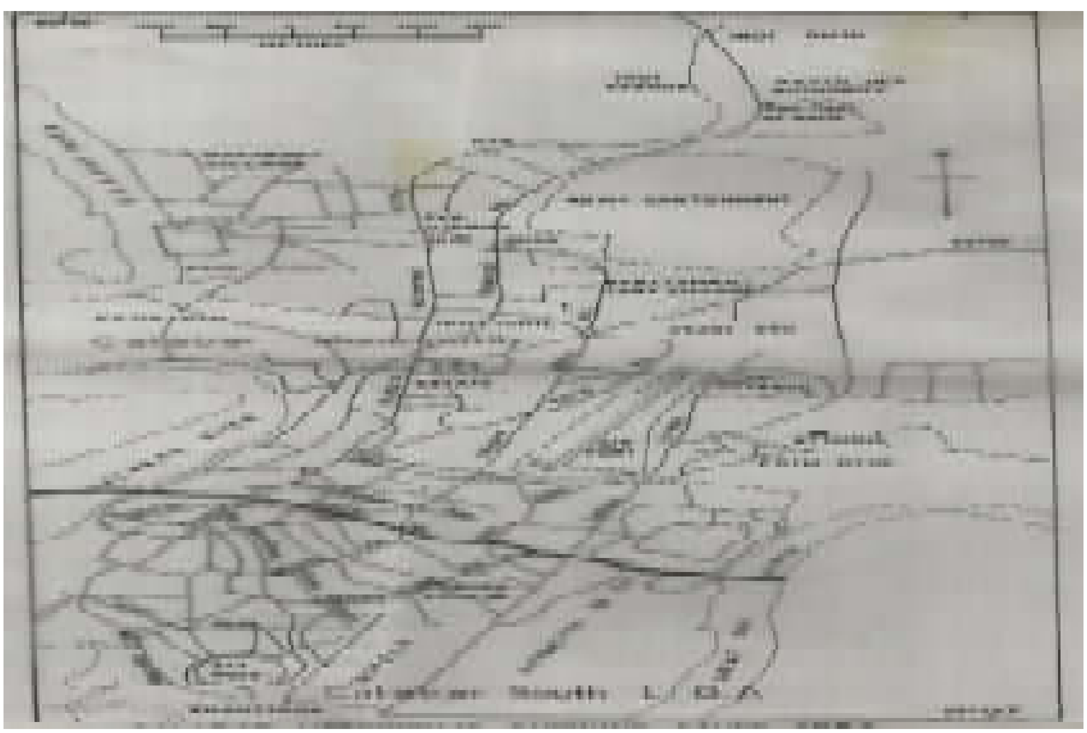

Figure 1: map of Calabar Metropolis showing study areas

Field studies

Two representative soil profile pits each were sited at Atimbo and Obufa Esuk in Calabar, Cross River state. Soil profile horizons were demarcated, described and sampled according to the procedure outline by (FAO, 1990). Soil colours were described using Munsell Colour Chart. Soil samples were taken from all horizons distinguished in the profile pit and bagged in properly labelled polyethylene bags for laboratory analysis (morphological, physical and chemical properties)

Laboratory preparation and analysis of soil samples

Soil samples collected from the study area were air dried, crushed and passed through a 2mm sized sieve and stored in labeled polythene bag for physico-chemical analysis.

Physical properties

Particle size distribution was determined by hydrometer method using sodium hexametaphosphate (calgon) as dispersant (Udo *et al.,* 2009). Bulk density (ρ_b) was determined using the core method as described by Blake and Harge (1986). Particle density was calculated by the pycnometer method following the procedure outline by Blake (1965). The gravimetric method of determining moisture content as described by Gardner (1986) was used. The total porosity was calculated from the particle and bulk densities using the relationship established by Vomocil, 1965.

CHEMICAL PROPERTIES

Soil pH: Soil pH was determined using soil water ratio 1:2:5 using a glass electrode pH meter as described by Udo *et al.,* (2009). .

Total nitrogen: This was determined by Kjedahl digestion method (Jackson 1969)**.**

Organic carbon: This method was determined by the wet oxidation methods of Walkley and Black as outlined by (Nelson and Somers 1982).

Available phosphorus: Available phosphorus was determined by Bray No 1 method (Bray and Kurtz, 1945) and the P in the solution was determined calorimetrically by the ascorbic acid method (IITA, 1979).

Exchangeable cations: Soil exchangeable calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K) were extracted with neutral ammonium acetate. The Ca and Mg in the extracted leachate were determined by ethylenediaminetetraacetic acid (EDTA) titration method (Lanyon and Heald, 1984) while Na and K were determined by flame photometric method (Kundsen *et al.,* 1982).

Exchangeable acidity: Al^{3+} and H^+ were determined by leaching the soil with IN potassium chloride (KCl) solution and the extract titrated with standard NaOH solution (IITA, 1979).

Effective cation exchange capacity (ECEC): Was determined by summation of Exchangeable cations and exchangeable acidity.

Percentage base saturation: This was obtained by expressing the sum of exchangeable cation as a percentage of the effective cation exchange capacity (IITA, 1979)

$$BS= \frac{\text{Exchangeable cations}}{\text{ECEC x100}}$$

Statistical Analysis

The data collected were analysed using descriptive statistics (the mean, range, standard deviation) and inferential statistic (t-test) with the help of SPSS software version 22.

RESULTS AND DISCUSSIONS

Morphological Characteristics of the Soils

The results of the morphological characteristics are shown in Tables 1 for coastal plain soils and wetland soils in Calabar. The results showed that the soils in the coastal plain soil were deep, having a depth of 0-11cm for the Ap horizon, 11-69 cm for the Bt1 horizon, 69-120 cm in the Bt2 horizon and 120-196 cm for the C horizon (bedrock) in Obufa Esuk while that of Atimbo had a depth of 0-11cm for the Ap horizon, 11-46 cm for the A horizon, 46-88 cm for the Bt1 horizon and 88-120 cm for the Bt2 horizon. The textures ranged from sandy loam to sandy clay in the coastal plain soils of Obufa Esuk and sandy clay loam in Atimbo coastal plain soil. Weak, medium, granular and moderate, medium, sub-angular blocky structure was observed for surface and sub-surface soil respectively. The consistence of the soil was non-sticky, non-plastics to slightly sticky, slightly plastic when wet. It was also, friable, very sticky and plastics when moist for surface and sub-surface soil respectively. Many, fine, medium pores and few, fine, medium roots were observed. The horizons boundaries were clear, smooth, clear, wavy and gradual smooth in the two locations.

Comparatively, morphological characteristics of wetland soils in Calabar in Tables 1 showed that the soils were shallow in depth due to constant fluviatile deposition and sedimentation processes. The depth varies from 0-11cm for the Ap horizon, 15-45cm for the A horizon and 45-65cm for the BA horizon for the Atimbo wetland soils whereas in Obufa Esuk soils its varied from 0-10cm for the Ap horizon, 10-30cm for the AB horizon and 30-71cm for the B horizon. The textures ranged from clay loam to sandy loam in Obufa Esuk and sandy clay loams in Atimbo wetland soils. Structureless, Weak, fine granular were prominent structural features for Atimbo wetland soil while that of Obufa Esuk wetland were weak, fine granular for the Ap horizon, moderate, sub angular blocky structure for both AB and B horizons. The consistence for Atimbo wetland were slightly sticky, friable while that of Obufa Esuk were non sticky, friable for the Ap horizon and slightly sticky, friable for both AB and B horizon. Many fine roots and few fine roots were found on the Ap and A horizons of the Atimbo wetland soil. No roots were observed on the BA horizon. Many fine roots were seen on both Ap and AB horizons of Obufa Esuk wetland soil but no roots was found in the B horizon. Clear smooth boundaries were the major morphological evidence on the Atimbo wetland soil while diffuse smooth and clear smooth boundaries were major morphological evidence of the soils in Obufa Esuk location.

Table 1: Morphological properties of coastal and wetland soils in Calabar

Horizon	Depth (cm)	Colour (wet)	Texture	Structure	Consistence	Inclusion (Rootlets)	Boundary
		Obufa Esuk Coastal Plain soil					
Ap	0 -11	10YR 4/2	Sl	1,m, g	np, fr	m	cw
Bt1	11 – 69	7.5YR 3/2	Sl	2, m, sbk	slst, fr	m	cs
Bt2	69 – 120	10YR 4/6	Scl	2, m, sbk	slp, fr	f	cs
C	120 – 196	10YR 5/8	Sc	2, m, sbk	vst, fi	f	
		Atimbo coastal Plain soil					
Ap	0 – 11	10YR 4/2	Scl	1, f,m,g	nst, fr	m	cs
A	11 – 46	10YR 4/3	Sc	2,m,sbk	slp, fr	f	cs
Bt1	46 – 88	10YR 5/4	Scl	2,m, sbk	slst, fr	f	gs
Bt2	88 – 120	10YR 5/4	Scl	2,m,sbk	slst, fr	f	
		Atimbo Wetland					
Ap	0 -15	10YR 2/2	Cl	1, fg	slp, fr	m	cs
A	15 -45	10YR 2/2	Sl	1, fg	slp, fr	f	cs
BA	45 -65	10YR 2/1	Sl	0, fg	slst, l	f	cw
		Obufa Esuk wetland					
Ap	0 – 10	10YR 3/2	Scl	1, fg	slp, fr	m	cs
AB	10 -30	2.5YR4/1	Sc	2,sbk	slp, fr	m	ds
B	30 -71	2.5YR5/2	Scl	2, sbk	st, l	f	ds

Symbols are as interpreted in Esu (2010) soil profile description

Colour: 10YR 4/2 = dark greyish brown; 7.5YR 3/2 = dark brown; 10YR 4/6 = dark yellowish brown; 10YR 5/8 = yellowish brown; 10YR 4/3= brown; 10YR 5/4 = yellowish brown.

Texture: scl = Sandy clay loam; sc = sandy Clay; sl = sandy loam.

Structure: I, = weak, 2 = moderate, 3 = strong; f = fine; m= medium, g = granular; sbk = sub angular blocky structure

Consistence: fi = firm, fr = friable, nst = none sticky; vst = very sticky; slst = slighty sticky; slp= slightly plastics

Rootlets: m = many, f = few;

Boundary: c = clear; w = wavy; g = gradual; s = smooth

Physical properties of the Soils

The soil physical characteristics are depicted in Table 2. The textural class of the coastal plain soil showed loamy sand, sandy loam, sandy clay and loam in Atimbo coastal plain soils while sand, loamy sand, and sandy loam were encountered in Obufa Esuk coastal plain soil. The sand fraction was the dominant particle size and ranged from 66.3–82.3 per cent with a mean value of 74.05 per cent, silt fraction ranged from 7-11 per cent with a mean of 9.75 per cent and clay fraction ranged from 7.7–22.7 per cent with a mean of 16.2 per cent in Atimbo coastal plain soils. Similarly, in Obufa Esuk the sand fraction was the dominant particle size and ranged from 72– 87 percent with a mean of 82 per cent, silt fraction ranged from 9-18 per cent with a mean of 12.5 per cent and clay fraction ranged from 3–10 per cent with a mean of 5 per cent. The clay fraction was observed to increase with the depth of the profile while sand decrease with profile depth. Comparatively, the result of particle size distribution of the wetland soils revealed that soil texture varies from sandy clay loam to sandy loam and loamy sand to clay loam in Atimbo and Obufa Esuk soils respectively. The percent sand was also the dominant particle size fraction and ranged from 62.0–70.0 per cent with a mean of 66.0 percent, silt fraction ranged from 15-22 per cent with a mean of 19.67 per cent and clay fraction ranged from 8.0 –23.0 per cent with a mean of 14.33 per cent in Atimbo coastal plain soils . Similarly, in Obufa Esuk the sand fraction was the dominant particle size and ranged from 45.0 – 85.0 percent with a mean of 71.0 percent, silt fraction ranged from 13.0 – 23.0 per cent with a mean of 16.67 per cent and clay fraction ranged from 2.0 – 32.0 per cent with a mean of 12.33 per cent .The clay fraction was observed to increase with the depth of the profile while sand decrease with profile depth.

The silt / clay ratios ranged from 0.48 – 1.29 and 1.80 - 3.33 for Atimbo and Obufa Esuk coastal plain soils respectively. This indicates that the soils are of young parent materials judging from the standard stipulated by Van Wambeke (1962) and Sombroek and Zonneveld (1971). The silt / clay ratios ranged from 0.65 – 2.75 with mean values of 1.74 in Atimbo wetland soils whereas in Obufa Esuk soils it ranged from 0.72 – 7.0 with a mean value of 4.02. Based on the standard set by Van Wambeke (1962) and Sombroek 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. This implies that the wetland soils both in Atimbo and Obufa Esuk under investigation are of young parent materials and the degree of weathering are low. The value for bulk density ranged from 1.30–1.40 g/cm^3 with a mean value of 1.35 and 1.20–1.40 g/cm^3 with a mean value of 1.30 for Atimbo and Obufa Esuk coastal plain soil 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. Comparatively, the value for bulk density ranged from 1.30–1.38 g/cm^3 with a mean value of 1.33 g/cm^3 for Atimbo and 1.20 – 1.40 g/cm^3 and a mean value of 1.30 g/cm^3 for Obufa Esuk wetland soil. Lower values of bulk density were found in the surface horizons and increased gradually with depth of profiles in Atimbo soils. The bulk density of the study area did not vary so much, but the values obtain showed an ideal situation for good water retaining ability.

Particle density ranged from 2.30–2.54 g/cm^3 with a mean value of 2.44 for Atimbo and 2.20–2.70 g/cm^3 with a mean value of 1.30 for Obufa Esuk coastal plain soil whereas in wetland soils it ranged from 2.0 – 2.4 g/cm^3 with a mean value of 2.33 g/cm^3 for Atimbo and 2.0 g/cm^3 for Obufa Esuk. In coastal plain soil the total porosity ranged from 39.0–48.0 percent and 36.0–55.60 percent for Atimbo and Obufa Esuk respectively. These values were considered satisfactory as recorded by Kachinskii (1965). Conversely, in wetland soil, the total porosity ranged from 37.00 – 46.00 percent with a mean value of 42.67 percent for Atimbo and 30.00 – 40.00 percent with a mean value of 30.00 percent for Obufa Esuk. These values were considered unsatisfactory as recorded by Kachinski (1965). Moisture content in coastal plain soil ranged from 4.60–13.00 percent with a mean value of 8.35 and 5.10–12.10 percent with a mean value of 32.87 percent for Atimbo and Obufa Esuk respectively. Comparatively, the moisture content in wetland was quite high, ranging from 22.60 – 36.42 percent with a mean value of 31.11 percent for Atimbo soils and 23.40 – 38.80 percent with a mean value of 32.87 percent for Obufa Esuk soils.

Table 2: Physical Properties of coastal and wetland soils in Calabar

Horizon	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural class	Silt/Clay ratio	Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Moisture content (%)
					Atimbo coastal plain soil					
Ap	0 – 11	82.3	10.00	7.7	Loamy sand	1.29	1.30	2.50	48.00	13.00
A	11 – 46	78.3	7.00	14.7	Sandy loam	0.50	1.33	2.54	48.00	7.50
Bt1	46 – 88	69.3	11.00	19.7	Sandy loam	0.56	1.36	2.40	41.00	8.30
Bt2	88 -120	66.3	11.00	22.7	Sandy clay loam	0.48	1.40	2.30	39.00	4.60
	Mean	74.05	9.75	16.2		0.71	1.35	2.44	44.00	8.35
					Obufa Esuk coastal plain soil					
Ap	0 -11	87.0	10.00	3.00	Sand	3.33	1.20	2.70	55.60	5.80
Bt1	11 – 69	86.0	9.00	3.00	Loamy sand	3.00	1.40	2.20	36.00	10.5
Bt2	69 – 120	83.0	13.00	4.00	Loamy sand	3.25	1.20	2.70	55.60	5.10
C	120 – 196	72.0	18.00	10.00	Sandy loam	1.80	1.40	2.20	36.00	12.10
	Mean	82.0	12.5	5.00		2.85	1.30	2.45	45.8	8.38
					Atimbo wetland soil					
Ap	0 – 15	70.00	22.00	8.00	Sandy loam	2.75	1.30	2.40	46.00	22.60
Bt	15 – 45	66.00	22.00	12.00	Sandy loam	1.83	1.32	2.40	45.00	34.30
Bt2	45 – 65	62.00	15.00	23.00	Sandy clay loam	0.65	1.38	2.20	37.00	36.42
	Mean	66.00	19.67	14.33		1.74	1.33	2.33	42.67	31.11
					Obufa Esuk wetland soil					
Ap	0 -10	84.00	14.00	2.00	Loamy sand	7.00	1.30	2.00	35.00	23.40
AB	10 – 30	84.00	13.00	3.00	Loamy sand	4.33	1.40	2.00	30.00	38.80
B	30 – 71	45.00	23.00	32.00	Clay loam	0.72	1.20	2.00	40.00	36.40
	Mean	71.00	16.67	12.33		4.02	1.30	2.00	35.00	32.87

Chemical properties of the soils

Chemical characteristics of the coastal plain soil and wetland soils in Atimbo and Obufa Esuk are shown in Tables 3. The results are compared with the standard set by **Landon (1991)**. Except Ap horizon in Atimbo coastal plain soil, the pH observed were below 5.0. The soil pH in Atimbo coastal plain soil ranged from 4.6 – 5.0 with a mean value of 4.9. This indicates that the soils were generally acidic in nature. The acidic nature of the soils could be attributed to high rainfall nature of the environment and excessive leaching. Similarly, soil pH in Obufa Esuk ranged from 4.6 – 4.8 with a mean value of 4.7. Comparatively, the soil pH in wetland for Atimbo soil ranged from 4.6 – 4.9 with a mean value of 4.8 indicating also that the soil were acidic in nature. Similarly, soil pH in Obufa Esuk wetland soil ranged from 4.6 – 4.7 with a mean value of 4.6. Moreover, acidic nature of Calabar soils was reported by several authors (**Akpan-Idiok, 2012 and Amalu and Isong, 2015**). In all studied soils, low values of pH (<5) could be due to the dominance of Al^{+++} and H^{+} ions in the soil exchange complex (Soil Survey Staff, 2003). Also, acidic condition of the wetland soils under study could be attributable to greater oxidation of anions like sulphides and nitrites leading to soil acidification (Ahukaemere *et al., 2014)*. According to FAO (1998), moderately acidic soils may be deficient in phosphorus, calcium, magnesium and molybdenum. Although, these pH values were below the critical value of pH 5.0 recommended for the production of most crops in the soils of the Southeastern Nigeria (Enwezor *et al*., 1990), nevertheless the soils can be exploited for the cultivation of oil palm, coconut, plantain, pineapple and sugar cane, since these crops can perform well under acidic condition. The organic carbon content in Atimbo coastal plain soil ranged from 0.8 – 1.50 percent with a mean value of 1.12 percent and the values was low when compared with critical limit of 1.5% across the pedons and tend to decline with depth. Similarly, in Obufa Esuk coastal plain soils, organic carbon ranged from 0.7 – 2.01 percent with a mean value of 1.3 percent. Comparatively, the organic carbon content in Atimbo wetland ranged 1.2 – 2.30 percent with a mean value of 1.77 percent and the value was high across the pedons and tends to decline with depth. Similarly, in Obufa Esuk wetland soil, organic carbon ranged from 1.5 – 2.7 percent with a mean value of 2.10 percent. Judging from the critical limit set by Landon (1991) coastal plain soil were low in organic carbon both in Atimbo and Obufa Esuk, whereas wetland soil was moderate in the content of organic carbon in Atimbo and Obufa Esuk respectively. The high organic carbon content in the wetland soil could be attributed to high amount of plant litter and slow decomposition processes that usually accompany wetland environment (Patrick, 1990). Total nitrogen was low across the pedons especially at the surface horizons. In Atimbo coastal plain soil, it ranged from 0.04 – 0.80 percent with a mean value of 0.26 percent whereas in Obufa Esuk coastal plain soil it ranged from 0.05 – 0.12 percent with a mean value of 0.08 percent. Also in Atimbo wetland soils, total nitrogen was low across the pedons especially at the surface horizons and it ranged from 0.10 – 0.12 percent with a mean value of 0.11 percent whereas in Obufa Esuk wetland soils, it ranged from 0.11 – 0.13 percent with a mean value of 0.12 percent. The result indicated that total nitrogen content were generally low in both coastal and wetland soils. This low total nitrogen confirms the observation by Valiela and Teal (1974) that wetland tend to be N limited. 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 total nitrogen in coastal plain soil in calabar have been reported by Akpan-Idiok, 2012 and Amalu and Isong 2015.This low nitrogen values obtained for the coastal plain soil in this study are as a result of volatilization especially under high temperature that characterize the climate of the region including denitrification process and leaching of nitrates, as well as the rapid mineralization of organic matter. Onweremadu *et al*. (2007) and Ahukaemere *et al.* (2014) also reported low nitrogen in Wetland Soils in Nigeria. Available phosphorus in Atimbo coastal plain soil was high and ranged from 30.20 – 33.75 mg/kg with a mean value of 32.10 mg/kg. Also, those values obtained for Obufa Esuk coastal plain soil was also high and ranged from 31.75 – 33.2 mg/kg with a mean value of 32.42 mg/kg. Similarly, available phosphorus in Atimbo wetland soils was high and ranged from 30.85 – 33.75 mg/kg with a mean value of 32.73 mg/kg. Consequently, similar high available phosphorus was observed in Obufa Esuk wetland soil and it ranged from 33.64 – 34.20 mg/kg with a mean value of 33.88 mg/kg. Ukpong (2000) also reported high available P in Creek Town/ Calabar River swamps.

Exchangeable calcium in Atimbo coastal plain soil ranged from 3.2 – 3.8 cmol/kg with a mean value of 3.5 cmol/kg whereas in Obufa Esuk coastal plain soil it ranged from 2.6–3.8 cmol/kg with a mean value of 3.2 cmol/kg and were both moderate. Exchangeable Calcium in Atimbo wetland soils ranged from 3.4 – 3.8 cmol/kg with a mean value of 3.53 cmol/kg whereas in Obufa Esuk wetland soils, it ranged from 3.6 – 4.2 cmol/kg with a mean value of 3.93 cmol/kg. The exchangeable calcium content obtained for both coastal and wetland soil were all below the critical limit of 5.0 $cmolkg^{-1}$(Landon 1991).The low contents of exchangeable calcium may be due to low pH, intense leaching, weathering and ferrolysis. Exchangeable magnesium in Atimbo coastal plain soil was low and ranged from 1.0–1.40 cmol/kg with a mean value of 1.25 cmol/kg. The value obtained from Obufa Esuk coastal plain soil was also low and ranged from 0.8–2.0 cmol/kg with a mean value of 1.25 cmol/kg. Exchangeable magnesium in Atimbo wetland soils ranged from 1.2 – 1.4 cmol/kg with a mean value of 1.33 cmol/kg whereas in Obufa Esuk wetland soils it ranged from 1.0 – 2.2 cmol/kg with a mean value of 1.47 cmol/kg. Although wetland soils were only slightly below the critical value of 1.5cmol/kg when compared to its counterpart coastal plain soil, both soils were low in exchangeable magnesium content. Exchangeable potassium in Atimbo coastal plain soil was low and ranged from 0.09–0.11 cmol/kg with a mean value of 0.11 cmol/kg. The result obtained for Obufa Esuk coastal plain soil showed that the soil were also low in exchangeable potassium and ranged from 0.10–0.12 cmol/kg with a mean value of 0.11 cmol/kg. Exchangeable potassium in Atimbo wetland soils was low and ranged from 0.10 – 0.11 cmol/kg with a mean value of 0.10 cmol/kg. The exchangeable K ranging from 0.10 – 0.13 cmol/kg with a mean value of 0.12 cmol/kg was observed for Obufa Esuk, whereas mainly >0.2 Cmol(+)/kg is the critical level of K in soils of the zone. Exchangeable sodium in Atimbo coastal plain soil ranged from 0.09 – 0.11 cmol/kg with a mean value of 0.12 cmol/kg whereas in Obufa Esuk coastal plain soil it ranged from 0.06 – 0.07 cmol/kg with a mean value of 0.07 cmol/kg. These were below 0.3 cmol/kg judging from the standard set by **Landon (1991)** and are adequate for cultivation of arable crops. Exchangeable sodium in Atimbo Wetland soils ranged from 0.07–0.08 cmol/kg with a mean value of 0.07 cmol/kg whereas in Obufa Esuk Wetland soils it ranged from 0.07 – 0.08 cmol/kg with a mean value of 0.07 cmol/kg. Both soils were low and adequate for crop cultivation.

Exchangeable aluminium in Atimbo coastal plain soil ranged from 0.28–0.54 cmol/kg with a mean value of 0.38 cmol/kg whereas in Obufa Esuk coastal plain sand it ranged from 0.2–0.48 cmol/kg with a mean value of 0.37 cmol/kg. Exchangeable aluminum in Atimbo Wetland soils ranged from 0.28 – 0.54 cmol/kg with a mean value of 0.39 cmol/kg whereas in Obufa Esuk wetland soils ranged from 0.6 – 0.36 cmol/kg with a mean value of 0.43 cmol/kg. Amberger (2006) reported that a concentration of Al ion >1.0 cmolkg^{-1} in the soil solution could leads to Al toxicity. Exchangeable hydrogen ions in Atimbo coastal plain sand ranged from 0.36–0.60 cmol/kg with a mean value of 0.49 cmol/kg whereas in Obufa Esuk coastal plain sand it ranged from 0.28 – 0.48 cmol/kg with a mean value of 0.36 cmol/kg. Exchangeable hydrogen ions in Atimbo wetland soils ranged from 0.36 – 0.60 cmol/kg with a mean value of 0.48 cmol/kg whereas in Obufa Esuk Wetland soils it ranged from 0.25 – 0.48 cmol/kg with a mean value of 0.40 cmol/kg. Effective cation exchange capacity (ECEC) in Atimbo coastal plain sand ranged from 5.12–6.09 cmol/kg with a mean value of 5.49 cmol/kg whereas in Obufa Esuk coastal plain sand the value ranged from 4.77–8.71 cmol/kg with a mean value of 6.71 cmol/kg. Both soils had low ECEC when compared with standard value. Effective cation exchange capacity (ECEC) in Atimbo Wetland soils ranged from 5.13 – 6.9 cmol/kg with a mean value of 5.62 cmol/kg whereas in Obufa Esuk wetlands it ranged from 6.03 – 6.65 cmol/kg with a mean value of 6.36 cmol/kg. Percent Base saturation (PBS) in Atimbo coastal plain sand ranged from 81.0– 85.0 percent with a mean value of 83.5 percent whereas in Obufa Esuk coastal plain sand it ranged from 81.0 – 94.0 percent with a mean value of 85.8 percent. Both soils were were high in base saturation. Percent Base saturation (PBS) in Atimbo Wetland soils ranged from 84.0 – 85.0 percent with a mean value of 84.3 percent whereas in Obufa Esuk Wetland soils it ranged from 86.0 – 87.0 percent with a mean value of 86.7percent.

Fertility Ratios of Wetland and Coastal Plain Soils

Carbon- Nitrogen (C:N) Ratio: The C:N ratio in Atimbo coastal plain sand ranged 1.25 – 20.0 with a mean value of 11.45.This value was low across the pedons and tend to decline with depth. Similarly, in Obufa Esuk coastal plain soil C: N ratio ranged from 14.0 – 16.75 with a mean value of 15.48. The implications of the narrow C: N ratios in the soils reflect high levels of microbial activities and rapid decomposition of organic matter with a concomitant release of nutrient elements into soil solution for crop plant uptake. Comparatively, the C: N ratio in Atimbo wetland soils ranged 12.00 – 19.7 with a mean value of 16.39. Similarly, in Obufa Esuk wetland soil C: N ratio ranged from 13.23 – 24.55 with a mean value of 18.14. The implications of the high C: N ratios in the soils reflect low rate of decomposition because of anaerobic condition.

Magnesium-Potassium (Mg:K) Ratio: The Mg:k ratio in Atimbo coastal plain soil ranged from 11.11 – 14.0 with a mean value of 12.4, whereas in Obufa Esuk coastal plain soil Mg:K ratio ranged from 7.27–16.67 with a mean value of 11.16. The ratios of Mg:K were high when compared with a critical level of 1:2 for productive soils (Landon, 1991). This is an indication that Mg is available to crop plants in the soils relative to K content. Also, the Mg:K ratio in Atimbo wetland soils ranged 2.43 – 2.83 with a mean value of 2.65, whereas in Obufa Esuk wetland soil Mg:K ratio ranged from 1.64 – 4.00 with a mean value of 3.05. The ratios of Mg:K were high when compared with a critical level of 1:2 for productive soils (Landon, 1991). This is an indication that Mg is available to crop plants in the soils relative to K content.

Table 3: Chemical properties of coastal and wetland soils in Calabar

Horizon	Depth (cm)	pH	Org.C (%)	Total N (%)	Avail. P (mg/kg)	Ca	Mg	K	Na	Al^{+3}	H^{+}	ECEC	PBS(%)
						Cmol/kg^{-1}							
				Atimbo plain	**Coastal soil**								
Ap	0 – 11	5.0	1.50	0.11	33.75	3.8	1.4	0.11	0.11	0.54	0.36	6.09	85.0
A	11 – 46	5.0	1.20	0.11	33.60	3.4	1.4	0.10	0.10	0.28	0.60	5.45	84.0
Bt	46 – 88	4.8	1.00	0.80	30.85	3.4	1.2	0.10	0.10	0.36	0.48	5.31	84.0
Bt2	88 – 120	4.6	0.80	0.04	30.20	3.2	1.0	0.09	0.09	0.40	0.52	5.12	81.0
	Mean	4.9	1.12	0.26	32.10	3.5	1.25	0.10	0.12	0.38	0.49	5.49	83.5
				Obufa Esuk	**coastal plain**	**soil**							
Ap	0 -11	4.8	2.01	0.12	32.25	3.8	2.0	0.12	0.07	0.20	0.32	8.71	94.0
Bt1	11 – 69	4.8	1.57	0.10	32.50	3.0	1.4	0.11	0.08	0.36	0.48	5.43	85.0
Bt2	69 – 120	4.7	0.93	0.06	31.75	3.4	0.8	0.11	0.06	0.44	0.36	4.77	83.0
C	120 – 196	4.6	0.70	0.05	33.20	2.6	0.8	0.10	0.06	0.48	0.28	7.92	81.0
	Mean	4.7	1.30	0.08	32.42	3.2	1.25	0.11	0.07	0.37	0.36	6.71	85.8
				Atimbo wetland	**Soil**								
Ap	0 – 15	4.9	2.30	0.12	33.75	3.80	1.40	0.11	0.07	0.54	0.36	6.09	85.0
Bt	15 – 45	4.7	1.80	0.10	33.60	3.40	1.40	0.10	0.07	0.28	0.60	5.45	84.0
Bt2	45 – 65	4.7	1.20	0.10	30.85	3.40	1.20	0.10	0.08	0.36	0.48	5.31	84.0
	Mean	4.8	1.77	0.11	32.73	3.53	1.33	0.10	0.07	0.39	0.48	5.62	84.3
				Obufa Esuk	**wetland soil**								
Ap	0 -10	4.7	2.11	0.13	34.20	3.60	2.20	0.13	0.07	0.60	0.25	6.65	87.0
AB	10 – 30	4.6	1.50	0.11	33.80	4.00	1.00	0.11	0.08	0.36	0.48	6.03	86.0
B	30 – 71	4.6	2.70	0.11	33.64	4.20	1.20	0.12	0.06	0.34	0.48	6.40	87.0
	Mean	4.6	2.10	0.12	33.88	3.93	1.47	0.12	0.07	0.43	0.40	6.36	86.7

Calcium-Magnesium (Ca:Mg) Ratio: The Ca:Mg ratio in Atimbo coastal plain soil ranged 2.71 – 3.20 with a mean value of 2.79. This value was low across the pedons on the studied soils. Similarly, in Obufa Esuk coastal plain soil Ca:Mg ratio ranged from 1.90 – 4.25 with a mean value of 2.88. Some of the Ca:Mg ratio values were adequate when compared with a normal range of 3:1-5:1 for productive soils (Landon, 1991). This indicates that the soils have adequate amounts of Ca with considerable amount of Mg in the soil solution. Comparatively, The Ca:Mg ratio in Atimbo wetland soil ranged 12.0 – 14.0 with a mean value of 12.91. This value was high across the pedons on the studied soils. Similarly, in Obufa Esuk wetland soil Ca:Mg ratio ranged from 9.09 – 16.92 with a mean value of 12.0. The Ca:Mg ratio values were high when compared with a normal range of 3:1-5:1 for productive soils (Landon, 1991). This indicates that the soils have high amounts of Ca with considerable amount of Mg in the soil solution.

Relationship between selected physico-chemical properties in Coastal plain and Wetland Soils in the studied Soils

Percent silt content, moisture content, and exchangeable sodium of soil sample analyzed from wetland and coastal plain soil in Atimbo were significantly different ($p<0.05$) while the other physico-chemical properties were not significantly different as show in Table 7a. Coastal plain soils had high mean value of sand, clay, bulk density, particle density, porosity, pH, total nitrogen and sodium. On the contrary, wetland soils had low mean value of silt, silt- clay ratio, moisture content, organic carbon, available phosphorus, calcium, and ECEC. Similarly, in Obufa Esuk particle density, moisture content, available phosphorus, exchangeable calcium and exchangeable sodium were significantly different ($p<0.05$) while other physico-chemical properties were not significantly different as shown in Table 7b. Coastal plain soils had high mean value of sand, particle density, porosity, pH, exchangeable sodium and ECEC. On the contrary, wetland soils had low mean value of silt, clay, silt-clay ratio, moisture content, organic carbon, total nitrogen, Available phosphorus, exchangeable calcium, magnesium, and potassium, total acidity and percent base saturation.

Table 4: Fertility ratios of coastal and wetland soils in Calabar

Horizon	Depth(cm)	C:N	Mg : K	Ca:Mg
		Atimbo coastal plain soil		
Ap	0 – 11	13.64	12.73	2.71
A	11 – 46	10.91	14.00	2.43
Bt	46 – 88	1.25	12.00	2.83
Bt2	88 – 120	20.00	11.11	3.20
	Mean	**11.45**	**12.46**	**2.79**
		Obufa Esuk coastal plain soil		
Ap	0 -11	16.75	16.67	1.90
Bt1	11 – 69	15.70	12.73	2.14
Bt2	69 – 120	15.50	7.27	4.25
C	120 – 196	14.00	8.00	3.25
	Mean	**15.48**	**11.16**	**2.88**
		Atimbo wetland soil		
Ap	0 – 15	19.17	2.71	12.73
Bt1	15 – 45	18.00	2.43	14.00
Bt2	45 – 65	12.00	2.83	12.00
	Mean	**16.39**	**2.65**	**12.91**
		Obufa Esuk wetland soil		
Ap	0 -10	16.23	1.64	16.92
AB	10 – 30	13.64	4.00	9.09
B	30 – 71	24.55	3.50	10.00
	Mean	**18.14**	**3.05**	**12.00**

Table 5a: Relationship between selected physicochemical properties within coastal plain and wetland soils in Atimbo

Soil properties	Mean±std.				
	Coastal plain soil	Wetland soil	Mean difference	t- test	Sig.(2-tail)
Sand	74.05±7.50	66.00±4.00	8.05	1.8278	0.127
Silt	9.75±1.89	19.67±4.041	-9.92	-3.938	0.0291*
Clay	16.20±6.56	14.33±7.77	1.87	0.336	0.7537
Silt/Clay ratio	0.71±.39	1.74± 1.05	-1.03	-1.623	0.24608
Bulk Density	1.35±0.042	1.33±0.041	0.02	0.4406	0.6779
Particle Density	2.44±0.11	2.33±0.12	0.11	1.1869	0.3009
Porosity	44.00±4.69	42.67±4.93	1.33	0.361	0.7360
Moisture Content	8.35±3.48	31.11±7.44	-22.76	-4.908	0.016*
pH	4.85±0.19	4.77±0.12	0.08	0.7142	0.5070
Org. C	1.13±0.29	1.77±0.55	-0.64	-1.82661	0.16522
Total N	0.27±0.36	0.12±0.012	0.15	0.883	0.442
Avail. P	32.10±1.84	32.73± 1.63	-0.63	-0.48095	0.6508
Ca	3.45±.25	3.53±0.23	-0.08	-0.454	0.6684
Mg	1.25±0.19	1.33±0.12	-0.08	-0.7142	0.5070
K	0.10±0.0082	0.10±0.0058	0.00	-0.6324	0.5548
Na	0.10±0.0082	0.073±0.0057	0.027	5.059	0.0039**
Total acidity	.88±0.034	.87±0.030	0.01	0.4751	0.6548
ECEC	5.49±0.42	5.62±0.42	-0.13	-0.389	0.71709
PBS	83.50±01.73	84.33±0.58	-0.83	-0.89803	0.41994

*=significant at 5%, **=significant at 1%

Table 5b: Relationship between selected physicochemical properties within coastal plain and wetland soils in Obufa Esuk

Soil properties	Mean±std.				
	Coastal plain soil	Wetland soil	Mean difference	t- test	Sig.(2-tail)
Sand	82.00±6.88	71.00±22.52	11.00	0.818	0.49931
Silt	12.50±4.041	16.67±5.50	-4.17	-1.1059	0.330792
Clay	5.00±3.37	12.33±17.03	-7.33	-0.735	0.538957
Silt/Clay ratio	2.85±0.71	4.02±3.15	-1.17	-0.632	0.592016
Bulk density	1.30±0.12	1.30±0.10	0.00	-2.7E-15	1.0000
Particle density	2.45±0.29	2.00±0.00	0.45	3.118	0.052566*
Porosity	45.80±11.32	35.00±5.00	10.80	1.700	0.164301
Moisture content	8.38±3.45	32.87±8.28	-24.49	-4.816	0.017054**
pH	4.73±0.096	4.63±0.058	0.10	1.571	0.176886
Org. C	1.30±0.59	2.10±0.60	-0.80	-1.749	0.155081
Total N	.083±0.033	.12±0.011	-0.04	-1.9179	0.12758
Avail. P	32.43±0.60	33.88±0.29	-1.45	-4.22	0.013458**
Ca	3.20±0.52	3.93±.030	-0.73	-2.345	0.065952*
Mg	1.25±0.57	1.47±0.64	-0.22	-0.4616	0.668326
K	.11±0.0081	.12±0.010	-0.01	-1.414	0.2302
Na	0.12±0.0096	0.070±0.010	0.00	6.124	0.003602***
Total acidity	.73±0.14	.837±0.015	-0.11	-1.473	0.237186
ECEC	6.7075±1.90	6.36±.031	.035	0.3588	0.74350
PBS	85.75±5.73	86.67±.577	-0.92	-0.317	0.771741

*=significant at 10%, **=significant at 5%, ***=significant at 1%

CONCLUSION

The comparative assessment of wetland and coastal plain soil was carried out in Calabar, Cross River State. The result revealed that the total porosity in wetland soil was lower than coastal plain soil because the clay fraction increased with increasing depth down the profile and sand particles were dominant ranging from 74.05 - 82.00% for coastal plain soils and 66.00 -71.00% for wetland soils.

The moisture content in wetland soils was higher than coastal plain soils, and ranges from 8.35-8.38% and 31.11-32.87% respectively. This leads to higher microbial population in wetland soils than coastal plain soils which helps to fasten the rate of organic matter decomposition. Generally, the result of the studied soils showed that coastal plain soil are already degrading in fertility status, hence , there is need to harness wetland soil for crop productivity . Wet land soils could be used for the cultivation of rice, oil palm, coconut, plantain, pineapple and sugar cane with judicious application of lime, nitrogen and potassium fertilizer since the crops can perform well under acidic condition. Also, the use of organic manures and total return of crop residues are essential to maintain the productivity of the soils.

REFERENCES

Ahukaemere, C. M., Eshett, E. T and Ahiwe, C., 2014. Characterization and fertility Status of wetland Soils in Abia State agro-ecological zone of Southeastern Nigeria. Nigerian Journal of Soil Science, 24(1): 147 -157.

Akpan-Idiok, A. U., 2012. Physicochemical Properties, Degradation Rate and Vulnerability Potential of Soils Formed on Coastal Plain Sands in Southeast, Nigeria. International Journal of Agricultural Research, 7: 358-366.

Akpan–Idiok, A. U., Ofem, K. I and Chilekezi, C., 2012. Characterization and classification of soils formed on coastal plain sands in Southeast, Nigeria. Proceeding of the 30th Annual conference of the Soil Science Society of Nigeria (SSSN), 12 – 16th March (pp. 57 – 63). University of Nigeria, Nsukka.

Amalu, U. C and Isong, I. A., 2015. Land capability and soil suitability of some acid sand soil supporting oil palm(*Elaeis guinensis Jacq*) trees in Calabar, Nigeria. Nigerian Journal of soil science, 25: 92 – 109.

Amberger, A., 2006. Soil fertility and plant nutrition in the tropics and sub-tropics. IFA/IPI. Pp. 96.

Blake, G. R and Hartge, K. H., 1986. Bulk density. In Klute, A. (Ed.). Methods of Soil analysis, Part 1: Physical and Mineralogical methods (pp.595-624). Wiscosin: American Society of Agronomy.

Blake, G. R., 1965. Particle density. In Black, C. A. (Ed.), Methods of Soil Analysis, Part I: Agronomy (pp. 371-373). Madison, Wiscosin: American Society of Agronomy.

Bray, N. C and Kurtz, L. T., 1945. Determination of total, organic and available form of phosphorus in soils. Soil Science, 59:39-45.

Egbuchua, C. N and Ojobor, S., 2011. Characterization of some hydric soils in the Niger-Delta region of Nigeria for land evaluation purposes. International Journal Of Advance Biological Research, 1(1):77-82.

Enwezor, W. O., Ohiri, A. C., Opuwahribo, E. E and Udo, E. J., 1990. Literature Review on Soil fertility investigations in Nigeria. Federal Ministry of Agriculture and Natural Resources Lagos. P 281.

FAO (Food and Agricultural Organization)., 1990. Guideline on profile description. Food and Agricultural Organization Rome. Pp 66.

FAO., 1998. Guidelines on Land Evaluation for Rainfed Agriculture. Soils Bulletin No.52, FAO, Rome, Italy.

Gardner, W. H., 1986. Water content. In Klute, A. (Ed.), Methods of Soil Analysis, Part 1: Physical and Mineralogical Methods (2nd ed., pp. 635–662). Madison, Wiscosin: American Society of Agronomy and Soil Science Society of America.

International Institution for Tropical Agriculture (IITA). 1990. Inland valley farming systems. pp. 20-21. Annual Report. IITA, Ibadan, Nigeria.

International Institute of Tropical Agricultural (IITA) 1979. Selected Methods for soil and plant analysis. Manual series No. 1: Ibandan, Oyo state.

Jackson, M. L., 1969. Soil chemical Analysis. New York: Practice – Hall.

Juo, A. S. R and Hosner, L. R., 1992. Resource conservation and sustainable agriculture on wet soils. Pp. 161-167. In J. M. Kimble (ed) Characterization, Classification and Utilization of Wet Soils. Proc. VIII ISCOM, USDA Soil Conservation Service, National Soil Survey Centre, Lincoln, N.E.

Kachinskii, N. A., 1965. Soil Physics, part 1. Vissahyaskhola, Moscow.

Knudsen, D., Peterson, G. A and Pratt, P. F., 1982. Lithium, Sodium and Potassium. In Methods of Soil Analysis. Chemical and Microbiological Properties’. Agronomy no. 9, Part 2. 2nd edn (Ed. AL Page) pp. 225–246.(Soil Science Society of America: Madison, WI).

Landon, J. R., 1991. Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. John Wiley and Sons, New York, pp. 474, 849.

Lanyon, L. E and Heald, W. R., 1982. Magnesium; calcium; strontium and barium. In: A.L. Page et al. (eds). Methods of Soil Analysis; part 2. Chemical and Microbiological Properties. Agronomy Monograph No. 9 (2nd Edition). ASA-SSSA; Madison; WI.

McCartney, M., Rebelo, L. M., Senaratna, S. S and de Silva, S., 2010. Wetlands, Agriculture and poverty Reduction. Colombo, SriLanka: International Water Management Institute. IW MI Research Report. Pp. 39.

Nelson, D. W and Sommer, L. E., 1982. Total Organic matter. Inc. A. L. Page; R. H. Miller and C. Keenay (ed). Methods of soil Analysis. Part 2. Agronomy 9. Chemical and Microbiological properties, 2nd ed. Madison: American Society of Agronomy.

Ogban, P. I and Ibia, T. O., 1998. Characteristics and crop production potential of wetland soil from South Eastern Nigeria. Nigerian Journal of Agricultural Technology, 7:78-84.

Onweremadu, E. U., Ndukwu, B. N., Opara, C. C and Onyia, V. N., 2007. Characterization of Wetland Soils of Zarama, Bayelsa, State, Nigeria in relation to Fe and Mn distribution. Int J. of Agriculture and Food Systems 1(1):80-86.

Patrick, W. H., 1990. From wastelands to wetlands. York distinguished lecturer series, University of Florida, FL, pp: 3-14.

Sombroek, W. G and Zonneveld, I. S., 1971. Ancient dune fields and fluviatile deposits in the Rima – Sokoto River Basin (NW Nigeria). Soil survey paper no. 5, Netherlands soil survey Institute, Wageningen. Pp. 109.

Taiwo, O. J., 2013. Farmers' choice of wetland agriculture: checkingwetland loss and degradation in Lagos State, Nigeria. Geography Journal, 78:103–115.

Udo, E., Ibia, T. O., Ogunwaie, J. A., Ano, A. O and Esu, I. E., 2009. Manual of soil, plant and water analysis. Sibon book publishers, Ltd., Nigeria.

Ukpong, I. E., 2000. Ecological classification of Nigeruian mangrove usingsoil nutrient gradient analysis. Wetlands Ecol. Manag., 8: 263-272.

Valiela, I and Teal, J. M., 1974. Nutrient limitation in salt marsh vegetation. In Reimold, R. J. and Queen W. H. (eds). Ecology of Halophytes. Acedemic press, New York, pp. 547-563.

Van Wambeke, A., 1962. Criteria for classifying tropical soils by age. Journal of Soil Science. 13: 124 – 132.

Vomocil, J. A., 1965. Porosity. In C.A. Black (Ed.). Method of Soil Analysis, Part 1 (pp. 659 – 662). American Society of Agronomy.

Wong, M. T. F., Wild, A and Juo, A. S. R., 1991. Retarded leaching of nitrate measured in monolith lysimeters in south-east Nigeria. J. Soil Sci., 38:511-518.