DOI:https://dx.doi.org/10.4314/gjass.v17i1.1

GLOBAL JOURNAL OF AGRICULTURAL SCIENCES VOL. 17, 2018: 1-13
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CHARACTERIZATION OF PHYSICO-CHEMICAL PROPERTIES AND MICRONUTRIENTS STATUS OF SOIL DEVELOPED ON ANANTIGHA COASTAL MARINE SEDIMENT IN CALABAR

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(Received 11 July 2018; Revision Accepted 6 September 2018)

ABSTRACT

A study was carried out to characterize the physico-chemical properties and micronutrients status of soil developed on Anantigha coastal marine sediment in Calabar. Four profile pits were dug along the coastal area and soil samples taken from identified horizons were subjected to laboratory routine analysis. The data obtained were subjected to one-way Analysis of variance (ANOVA). The predominant colours observed for the study were mostly; dark greys (2.5YR 4/1) and black (10YR 2/1). The soil were massive in structure and has very sticky and very plastic in consistence and the boundary observed was mostly diffuse smooth and clear smooth. Percent sand fraction was the dominant particle size fraction except in profile 4. Soil in profile 1 was made up of sandy loam, silt loam loamy sand, loam and sandy clay loam, while soil in profiles 2, 3 and 4 were predominantly sandy loam, sandy clay loam and silt loam, respectively. Soil pH measured in water and calcium chloride were very strongly acidic and increases with horizon depth with pH mean values of 2.5 in H_2O and 2.2 in $CaCl_2$ for surface soil and 2.7 in H_2O and 2.4 in $CaCl_2$ for sub- surface soils. The organic carbon and organic matter content of the surface soils were high and those of the subsurface soils were moderate. The mean electrical conductivity was 2.0 and 2.3 $dsm^{-1}$for surface and subsurface soils respectively. The exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were moderate to high in both surface and subsurface soils. The exchangeable acidity (Al^{3+} and H^+) were high. CEC was low in surface soils and high in subsurface soils. Base saturation in both surface and subsurface soils was below 50 %. The results obtained for available micronutrients showed that the mean values for Zn, Cu, Fe and Mn were 1.43, 0.92, 134.65 and 5.05 mg/kg for surface soil and 1.89, 1.89, 121.29 and 1.48 mg/kg for subsurface soil. Zn and Cu were generally “low” to “medium” in all the horizons of the pedons while Fe and Mn values were “high”. Agronomic practice such as liming that will raise soil pH is recommended so that levels of nutrients that are below the critical levels will be made available in the soil.

KEYWORDS: Morphology, micronutrients, physicochemical, marine sediment

INTRODUCTION

In responding to the problems of food shortages, fluctuating prices of crude oil and food insecurity in Nigeria, government at all levels and other development partners have been embarking on sensitization campaigns and necessary reforms directed at encouraging people to embrace modern agricultural practices. Unfortunately, upland soils where all this campaign were directed at are faced with stiff competition for industrial uses and few available ones are losing its fertility status due to continuous cropping without addition of external inputs to restore its fertility status. Also, most of these soils required high level of irrigation depending on crop water requirement.

However, in order to ensure sustainable crop production, farmers are now seeking for alternative sources of growth medium which can mitigate the problem of soil/crop nutrient, water unavailability throughout the growing season and able to sustain long growing season crops with minimum or no addition of external inputs. Hence, wetland and/ or mangrove swamp soils seem promising.

Mangrove swamp soils occupy about 12.6 million hectares worldwide. In Nigeria, mangrove soils occupy 973, 000 hectares, while in the Cross River estuary; about 70,400 ha of coastal swamp are vegetated by mangroves (Akpan-Idiok and Esu, 2003). Coastal marshes are transitional habitats between terrestrial and aquatic systems where the ground water table is usually high, or the land is covered by shallow water tidally or seasonally. From soil science standpoint, it can be seen as soil developed from sediments deposited under natural conditions in tidal areas with high daily water-table

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fluctuations. Sediment is described as solid particles generated by the disintegration process of organic and inorganic materials (Bortone, 2006).

Coastal marine sediments are materials derived from fluvio-marine deposits and are in environment with peraquic moisture regime where gleization is a dominant pedogenic process (Akpan-Idiok, 2002). They occur on flat topography and possess fibric or sapric organic materials with massive structure. The parent materials of coastal area in Anatigha are both marine and marine-alluvial sediments. As with alluvial and/ or marine sediment soils, the development of coastal marsh soils is mostly affected by lithogenic processes which influences the distributions of nutrients. It has been reported by Umeri *et al.* (2017) that the mangrove swamp soils are rich in soil nutrients due to the leaf litter fall.

Despite the various uses to which soil developed on marine sediment can be put into, it has been observed that agricultural potential of this soil in Nigeria are unknown, hence they are grossly underutilized and mostly ignored by farmers owing to agronomic tasks associated with its workability (i.e its arduous and tedious nature), its acidic nature, their reclamation and management compared to its counterpart upland soil (Dublin-Green and Ojanuga, 1988; Effiong and Ibia, 2009). Therefore, the need to expand crop cultivation into wetland soils in Anatigha coastal area which is developed on coastal marine deposit necessitated the investigation of the fertility status and micro-nutrient status of this soil. This is because information on the profile distribution of soils' nutrient can provide the basis for making informed decision with respect to fertilization and other soil management practices. A good knowledge of the physical and chemical properties of soil and their interactions as it relates to micro-nutrient status is essential for good land evaluation which is a pre-requisite for sound land use planning (Iloeji, 2003; Umeri, *et al.,* 2017).

Hence, the objectives of this study were to characterize the physical and chemical properties of soil and its micronutrient status and assess the interrelationship and differences among the nutrients of soil developed on the coastal marine sediments of Anatigha coastal areas. The data gathered from this research will be considered a pioneer addition of information to literature.

MATERIALS AND METHODS

Description of the Study Area

The study was carried out in soil developed on coastal marine sediments in Anatigha coastal areas, Calabar (Fig. 1) The area is located between Latitudes 4^{o} 54´ North of the Equator and Longitudes 8^{o} 23´ East of the Greenwich Meridian and on altitude of 6 m above sea level. The area is characterized by two distinct tropical climates: the rainy and dry seasons. The rainy season usually starts from April and ends in mid-November with a double peak usually in July and September while dry season starts from November and end in March. The area has a total annual rainfall of above 3000 mm, and the minimum and maximum temperatures of 23 °C and 31 °C, respectively, while the relative humidity of the area averaged 84 % (NIMET, 2015). The soil along the coastal area is flavio-marine deposit. The area is used predominantly for horticultural and arable crop cultivations, where crops like maize, pepper, watermelon, fluted pumpkin, sugar cane, etc. are grown.

Soil Sampling and Preparation Methods

Guided by the geographical map of the study area (Fig. 1), soil samples were collected from four (4) locations within coastal marine sediment of Anatigha coastal area, namely- Anatigha Jamekon beach, Anatigha fish pond, Anatigha slughter and Ibesikpo timber. These were chosen to reflect the differences in soil and vegetational characteristics. The entire study area was divided into four morphological units or pedons namely; P1, P2, P3 and P4. Soil sampling was done at identified horizon within each soil profile. Representative soil samples were taken and bulked for each depth and location. At each pedon, soil samples collected from Ap horizon (surface layer) and sub-surface layers using a sterilized soil auger correspond to top-soil and sub-soil, respectively. The samples were air-dried at room temperature depending on moisture content for two (2) weeks and crushed to pass through 2 mm mesh sieve, bagged and labeled for soil routine analysis.

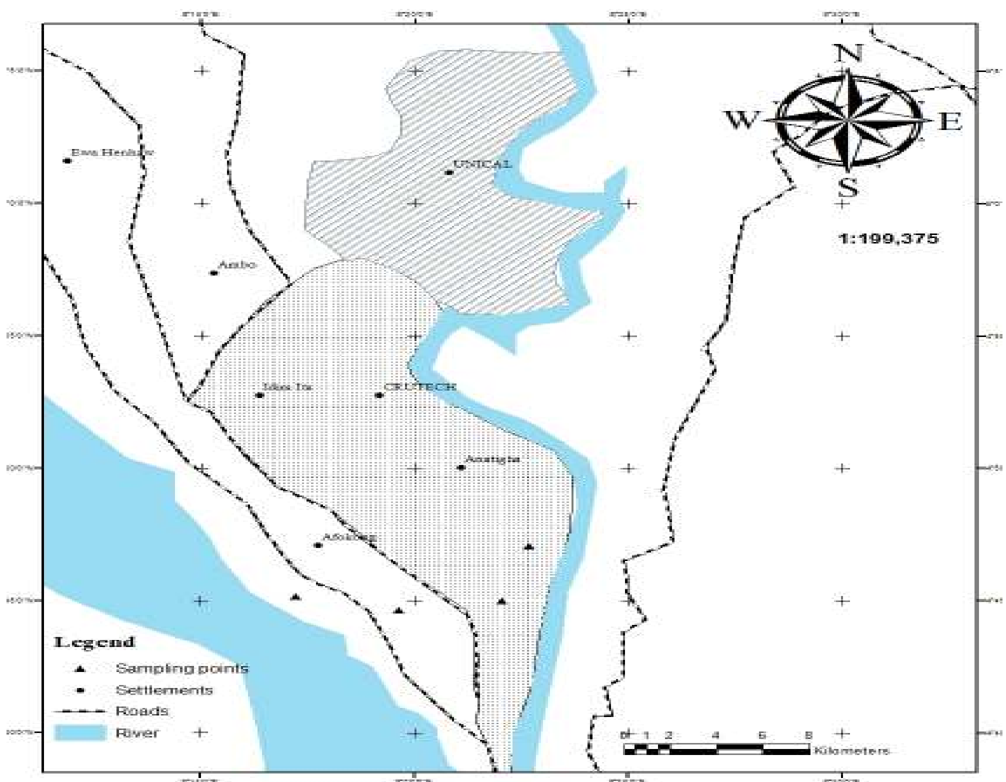

Fig. 1: Map showing the location of the study area

Laboratory Analysis

Soil samples were analyzed for physico-chemical properties following a standard procedure as outline below: The particle size distribution of the soil samples was done by the Hydrometer method as outlined by Gee and Or (2002). Soil colours were described using Munsell Colour Chart (KIC, 2000). The pH of the soil samples was determined in both distilled water and 1*M* KCl solution using a ratio 1:2.5 (soil: solution) by glass electrode pH meter following the procedure outlined by (Udo *et al.,* 2009). The organic carbon was determined by the dichromate wet oxidation method of Walkley and Black as outlined in Nelson and Sommers (1996) and converted to organic matter by multiplying by a factor of 1.742 (Van Bemmelen Correction Factor). The exchangeable bases (Ca^{2+} ,Mg^{2+}, Na^{+}, and K^{+}) were extracted by saturating soil with neutral 1*M* NH_4OAc (Thomas, 1982) and Ca and Mg were determined by the EDTA titration method while K and Na were determined by flame photometry. The exchangeable acidity (H^{+} and Al^{3+}) was determined by extracting the soil with 0.1*N* KCl solution and titrate the aliquot of the extract with 1*N* NaOH following the procedure outlined by Udo *et al*., (2009). Electrical conductivity (EC) was determined using conductivity bridge by dipping the electrode into the soil-water suspension. Cation exchange capacity (CEC) was determined by saturating the soil with 1*N* NH_4OAc at pH 7.0 (Black *et al.,* 1965). Base saturation was calculated as the sum of total exchangeable bases divided by NH_4OAc cation exchange capacity and expressed as a percentage.

The available Fe, Mn, Cu and Zn in soil samples were extracted with a DTPA solution (0.005M DTPA + 0.01 M $CaCl_2$ + 0.1M triethanolamine, pH 7.3 as outlined by Lindsay and Norvell (1978). The concentration of micronutrients in the extract was read using the atomic absorption spectrophotometer.

Data Analysis

Mean of the soil properties were computed and employed to compare the results with the critical limits for interpreting levels of soil fertility status. Correlation analysis was employed to indicate the relationship between micronutrients and soil pH. Data collected were further subjected to analysis of variance (ANOVA) procedures and the significant means compared using Least Significant Difference (LSD) at 5 % level of probability.

RESULTS AND DISCUSSION

Soil Morphological Features

Results on some morphological properties of the soils are shown in Table 1. P1 was characterized by black (10YR 2/1) colour at surface horizon overlained colour matrix ranging from black (10YR 2/1) colour to dark grey (5YR 4/1) at a depth of 60-80 cm and grey (5YR 5/1) at a depth of 80 -125 cm. The surface and subsurface horizons were mottled-free. The P2 had greyish brown (10YR 5/1) colour at the surface horizon overlained various grade of colours ranging from grayish brown

(10YR 5/2) to grey (5YR 6/1). The depth 0-25 cm and 25-51cm were mottled with each having yellowish brown mottles (10YR 5/8). The greyish brown colour of the bottom horizons of P2 with mottles of different shades of colors may be attributed to poor internal drainage condition (Esu, 2010). The P3 ranged from dark grey (2.5YR 4/1) at the surface horizon to strong brown (7.5YR 4/6) at depth 80-100 cm in subsurface soil. The surface horizons were mottle-free while the depth 80-100 cm in the subsurface horizon had grey mottles (2.5Y 6/1). The colour matrix observed all throughout the P4 were dark grey (2.5YR 4/1). Therefore, in the study area soil colour showed variations with soil depth within a profile and among the different locations which may be associated with the differences in the content of oeganicmatter content and perhaps iron oxides. With increasing soil depth, value keeps increasing with the same hue and sometime chroma implying that the organic matter distribution in the soil profile declines as the soil textural class mainly dominated by clay. Abayneh (2005) found that wet soil profiles have darker hues in the subsurface horizons compared to those with relatively dry horizons.

Characterization of Physical Properties

The soil samples from Anatigha Jamekon beach (P1), Anatigha fish pond (P2), Anatigha slaughter (P3) and Ibesikpo timber (P4) sampling sites were found to be sandy loam, silt loam, loamy sand, loam, clay, sandy clay loam. Soil samples from Anatigha Jamekon beach were found to be sandy loam at the surface and loamy sand to sandy clay loam at the sub-surface while at Anatigha slughter coastal area; it was found to be clay loam at the surface and sandy clay loam at the sub-surface. Also, soil at Ibesikpo timber, the soil were both silty loamy. As shown in Table 2, there was a considerable difference in soil particle size distribution under the four locations within Anatigha coastal marine sediment. Soil texture showed variability in percent sand, silt and clay content in both surface and subsurface soils.

Percent sand content was the most dominant particle fraction under the four locations within Anantigha coastal marine sediment studied. This result suggest that, the high precipitation in the region that promote illuviation or leaching of silt and clay particles below the epipedon could contribute to high sand fractions. Locations of the coastal areas did not have any significant ($p>0.05$) effect on the distribution of texture (sand and silt). However, clay showed significant ($p<0.05$) differences in its distribution. Although, soil textural composition rarely change, but in this case it was believed that the undulating positioning of the landscape could have let to the transportation and dislodged of lighter soil particles to the lower plains (lowland) where they accumulated on the topsoil influencing the texture and perhaps clay. The result obtained is in line with studies of Akpan *et al.* (2017), who also observed changes in soil properties in Calabar.

However, the texture observed irrespective of location can be favourable for agricultural cultivation. Most field crops could grow well in soils having sandy clay and sandy clay loam textural classes as these soils have a potentially well-balanced capacity to retain water, form a stable structure and provide adequate aeration (Aytenew, 2015).

Table 1: Morphological properties of the soil developed on Ananatigha coastal marine sediment in Calabar

Horizon Depth (cm)	Soil colour (wet)	Mottle	Structure	Consistence	Root	Boundary
P1						
0-20	10YR 2/1 (Black)	-	M	Sticky and very plastic	mn, fib	ds
20-40	10YR 2/1 (black)	-	M	Very sticky and very plastic	mn, fib	ds
40-60	10YR 2/1 (black)	-	M	Very sticky and very plastic	mn, fib	ds
60-80	5YR 4/1 (Dark grey)	-	M	Very sticky and very plastic	mn, fine fib	ds
80-125	5YR 5/1 (Grey)	-	M	Very sticky and very plastic	mn, fine fib	ds
P2						
0-25	10YR 5/2 (Greyish brown)	10YR 5/8 (yellowish brown)	M	Very sticky and very plastic	f,fine fib	cs
25-51	10YR 5/2 (Greyish brown)	10YR 5/8 (yellowish brown)	M	Very sticky and very plastic	f, fine	cs
51-95	10YR 3/1 (Very dark greyish)	-	M	Very sticky and very plastic	sap/fib	cs
95-150	2.5YR 3/1 (black)	-	M	Very sticky and very plastic	f,co, sap/fib	cs
150-176	5YR 6/1 (Grey)	-	M	Very sticky and very plastic	f,co	-
P3						
0-20	2.5YR 4/1 (Dark grey)	-	M	Very sticky and very plastic	f, fine,fib	cs
20-40	2.5YR 4/1 (Dark grey)	-	M	Very sticky and very plastic	fine, fib	cs
40-60	2.5YR 4/1 (Dark grey)	-	M	Very sticky and very plastic	fine, fib	cs
60-80	5YR 6/1 (Grey)	-	M	Very sticky and very plastic	co, f	cs
80-100	7.5YR 4/6 (Strong brown)	-	M	Very sticky and very plastic	co, f	-
P4						
0-20	2.5YR 4/1 (dark grey)	-	M	Very sticky and very plastic	co, f,fib	ds
20-40	2.5YR 4/1 (dark grey)	-	M	Very sticky and very plastic	co, f	ds
40-60	2.5YR 4/1 (dark grey)	-	M	Very sticky and very plastic	co, f	ds
60-80	2.5YR 4/1 (dark grey)	-	M	Very sticky and very plastic	co, f	ds
80-100	2.5YR 4/1 (dark grey)	2.5Y 6/1 (grey)	M	Very sticky and very plastic	co, f	ds

mn = many; f= few; fib =fibric; sap =sapric; co =common; m =massive; ds =diffuse smooth; cs = clear smooth; P1 = Anatigha Jamekon beach; P2 = Anatigha fish pond; P3 = Anatigha slughter ; P4 = Ibesikpo timber

Characterization of Chemical Properties

pH

pH determinations for wet and dry soil states presented in Table 2 have shown the tendency of all the samples to develop extreme acidity on air-drying. Soil samples from all the locations had pH values which were slightly below neutral in the wet state, but on air-drying, the pH decreased to less than 4.0 in all samples (Table 2). This decrease in pH indicates the presence of sulfidic materials in the soils which could release appreciable amount of acid on exposure. Dublin-Green and Ojanuga, (1988) have reported that potential acid sulfate soils are identified by simple pH measurement; where pH of these soils usually drops from near neutral in the moist state to less than 4 after oxidation by air drying for several weeks. The result of this study is in line with this report, and also, the yellow coloured mottles of jarosite observed was reported elsewhere (Dublin-Green and Ojanuga, 1988) to constitute one of the principal indicators of actual acid sulfate soil areas.

Soil pH both in (H_2O) and $CaCl_2$ (Table 2) at dry state in soils under the four locations within Anatigha coastal marine sediment was extremely acidic in reaction throughout the entire depth of the respective profiles following the critical limits (5.6 - 6.5) set by Landon (1991) for most arable crops. The extremely acidic conditions of this soil are due to oxidation of sulfidic materials to sulfates and sulfuric acid. Soil pH measured in KCl solution was lower than their respective pH value measured in water. The decrease in soil pH when measured in KCl solution indicates that appreciable quantity of exchangeable hydrogen (H) has been released into the soil solution through exchange reaction with potassium (K) in the KCl solution (Dublin-Green and Ojanuga, 1988). The decrease in pH increase soil acidity due to measurement of pH in KCl solution to high potential acidity of the soil system. The study found significant ($p<0.05$) difference in soil pH, both in wet and dry states for the four study locations (Table 3). These differences could probably be due to different stages of oxidation of the sulfidic materials (e.g. Iron Sulfides) in the soils.

The observed soil pH was low and lies between 1 and 4 pH units whereas Ronen (2007) and Landon (1991) had reported elsewhere that most soil nutrients available for plant uptake are in the pH range of 5.5- 6.5. This extremely low pH observed for this studied soil may tightly hold soil nutrients and make it unavailable for plant uptake. Consequent upon the observed pH value, if farmers in the area are to use the soil for crop cultivation, provision should be made for liming.

Electrical conductivity

Electrical conductivity of the saturation extract was low; < 4 d Sm^{-1} in soils under the four locations within Anatigha coastal marine sediment. This result indicates non saline nature of the studied soils which was defined by Shrivastava and Kumar (2015) as one in which the electrical conductivity (EC) of the saturation extract (EC) in the root zone is below 4 dSm^{-1}. Salt stressed soils are known to suppress the growth of plants (Paul, 2012). However, since the result obtained for this study is low, the soils will not pose any salinity problems to crops that would be grown on them. Salinity problems are usually encountered for sensitive crops when $EC_{25}°$ is above 4 d Sm^{-1}. There was a significant difference ($P < 0.05$) in EC between the four locations (Table 3).

Organic carbon and organic matter

The soils have a substantial amount of organic C contents (Table 2). These values translate into mean organic matter contents of 7.06 % and 3.42 % for surface and sub-surface soil respectively. The observed values might be due to high productivity and reduced decomposition and mineralization rates in swampy environment, resulting in the accumulation of high organic matter in soils (Ibia, 1995). It has been reported by Effiong and Ibia (2009) that organic matter is the main source of total nitrogen and base saturation and contributes slightly to exchangeable K and Na concentrations in the soils.

However, there was no significant ($p< 0.05$) difference in soil organic carbon content between the four locations within Anatigha coastal marine sediment. The organic carbon contents of the soils were moderate to high. The values of organic carbon content obtained in all parent materials were consistently higher in surface soil than subsurface soil. Organic matter is known to produce high percentage of net negative charges in exchange site (Harada and Lnoko, 1975).

Exchangeable cations

The exchangeable bases obtained for the studied soils exhibited regular trends with depth. In all soil under the four locations within Anatigha coastal marine sediment exchangeable bases consistently decreased with geomorphic surfaces (i.e from surface to subsurface soil). This result agree with the decreasing cation magnitude, that is $Ca^{2+} > Mg^{2+} > K^{+} > Na^{+}$. The result further showed that among the exchangeable bases, the exchange complex of the soils was dominantly occupied by Ca and followed by Mg, whereas K and Na were very fewer compared to the former two divalent cations.

The highest exchangeable calcium content of soil under Anatigha Jamekon beach, Anatigha fish pond, Anatigha slughter and Ibesikpo timber coastal sediment were 8.2, 6.4, 5.0 and 8.2 cmol/kg, respectively. The mean exchangeable calcium content of the surface and sub-surface soil under study were 6.2 and 4.6 cmol/kg. Similarly, highest exchangeable magnesium content of soil under Anatigha Jamekon beach, Anatigha fish pond, Anatigha slughter and Ibesikpo timber coastal sediment were 12.0, 20.6, 10.8 and 11.4 cmol/kg, respectively. There was a significant difference ($P < 0.05$) in Ca among the four locations (Table 3). The mean exchangeable magnesium content of the surface and sub-surface soil under study were 5.5 and 4.3 cmol/kg. Also, highest exchangeable potasium content of soil under Anatigha Jamekon beach, Anatigha fish pond, Anatigha slughter and Ibesikpo timber coastal sediment were 0.17, 0.19, 0.12 and 0.13 cmol/kg, respectively. The mean exchangeable magnesium content of the surface and sub-surface soil under study were 0.10 and 0.12 cmol/kg. The highest exchangeable sodium content of soil under Anatigha Jamekon beach, Anatigha fish pond, Anatigha slughter and Ibesikpo timber coastal sediment were 0.14, 0.11, 0.10 and 0.10 cmol/kg, respectively. The mean exchangeable magnesium content of the surface and sub-surface soil under study were 0.09 and 0.10 cmol/kg. There was no significant difference ($P < 0.05$) in Mg among the four locations (Table 3).

In the surface soils, the exchangeable K and Na were low, exchangeable Ca was moderate while exchangeable Mg was high. Similarly, in the subsurface soil, the exchangeable Ca, K and Na were low while exchangeable Mg was high (> 3.0 cmol/kg). The high levels of the divalent cations may be related to the high clay and relatively high organic matter content of the soils. Even though the pH of the soil are extremely acidic, the exchangeable Ca and Mg ions are adsorbed to the surface of high organic matter content of the soil and remains in the soil with few chance of leaching for this cations has made the exchangeable bases. However, since the soil is low in exchangeable K, it has greater propensity for increased fertility for K^+ if supplied with adequate amounts of K_20 fertilizer based on soil test.

Exchangeable acidity

The exchangeable acidity value was high in soils developed under the four locations within Anatigha coastal marine sediment. The exchangeable acidity values (Al^{3+}) for surfaces and sub-surface soil were 24.6 and 12.5 cmol/kg, respectively. Percent Al saturation value > 30 % may affect sensitive crops (Landon, 1984), while, over 60 % could bring about Al toxicity. Chapman (1966) reported absolute levels of 2-3 cmol kg^{-1} exchangeable Al as excessive for some crops while, Amberger (2006) indicated that a concentration of Al ion >1 cmol kg^{-1} in the soil solution could lead to Al toxicity. The value of exchangeable Al obtained for this study could resulted to Al toxicity to crop. Similarly, exchangeable H^+ concentration in the surface soil where plant root usually concentrate in the four locations could be detrimental to crop growth.

Cation Exchange Capacity

There was great variation in cation exchange capacity (CEC) of the soils under the different locations within the coastal marine sediment in both the surface and subsurface layers of the profiles. The cation exchange capacity (CEC) of the surface and subsurface soil were 62.0 and 45.1 cmol/kg. The surface horizons had the highest CEC than the subsurface soil. CEC decreased consistently from the surface to the subsurface horizons in accordance with the organic carbon content. The decrease in CEC with depth could be due to the strong association between organic matter and CEC. The value of 15-20 cmol kg^{-1} were stipulated as indicative moderate values in the top 20 cm of soils for satisfactory production under rainfed (Landon, 1991). The values obtained for this study were all above this critical limits. The high CEC may be attributed to high organic matter content that characterized the area.

Base Saturation (BS)

Following the percent BS rating developed by Landon (1991), BS values greater than 60 % are rated as high; between 20 and 60 % medium and less than 20 % as low. Therefore, the BS of the surface and sub–surface horizons of soil pedons was rated as low as they were all below 20 %, the separating index between fertile and less fertile soils (Landon, 1991).

Table 2: Physico-chemical properties of the soils in Ananatigha coastal marine sediment in Calabar

Horizon Depth (cm)	Sand	Silt	Clay	Texture	pH (wet)		pH(dry)		EC dsm^{-1}	OC	OM	Exch. cations				Exch. Acidity		CEC	BS %
												Ca	Mg	K	Na	Al	H		
	→ % ←				H_2O	$CaCl_2$	H_2O	$CaCl_2$		→ % ←		← cmol/kg →							
P1																			
0-20	57.3	3.7	4.0	[a]SL	6.2	5.7	2.3	1.9	2.73	3.75	6.53	8.2	12.0	0.19	0.14	32.8	13.6	71.0	20.53
20-40	44.3	51.7	4.0	SL	6.2	5.9	2.3	2.1	2.73	0.64	1.11	7.2	5.2	0.17	0.13	24.2	8.8	46.0	12.7
40-60	74.3	22.7	3.0	LS	6.0	5.9	2.3	2.0	2.63	2.15	3.75	5.8	11.2	0.12	0.10	23.2	4.8	70.0	17.22
60-80	82.3	11.7	6.0	L	6.1	6.0	2.4	2.1	0.74	1.16	2.02	4.6	2.8	0.11	0.08	10.4	2.4	26.0	7.59
80-125	62.3	6.7	31.0	SCL	6.0	5.9	3.3	2.8	0.97	1.06	1.85	4.4	5.0	0.12	0.09	2.4	1.6	24.0	9.61
P2																			
0-25	62.3	8.7	29.0	[a]SL	3.9	3.6	3.3	2.9	0.77	1.66	2.89	3.4	5.2	0.11	0.08	8.8	0.8	61.0	8.79
25-51	55.3	35.7	9.0	[a]SL	4.0	3.7	2.6	2.3	1.49	2.13	3.71	3.6	13.6	0.12	0.09	17.6	4.8	56.0	17.41
51-95	53.3	40.7	6.0	[a]SL	4.6	4.2	2.1	1.9	2.42	3.33	5.80	5.4	20.6	0.14	0.10	20.4	6.8	62.0	26.24
95-150	55.3	21.7	23.0	L	4.2	4.8	2.7	2.3	0.82	3.11	5.42	6.4	14.0	0.13	0.11	15.2	4.8	83.0	20.64
150-176	46.3	9.7	44.0	C	5.6	5.2	2.9	2.6	2.27	0.42	0.73	2.6	4.0	0.19	0.08	4.0	2.4	24.0	6.87
P3																			
0-20	5.3	83.7	11.0	CL	6.1	5.4	2.3	2.0	1.70	3.57	6.53	5.0	1.0	0.10	0.07	37.0	7.2	66.0	6.17
0-40	42.3	26.7	31.0	CL	6.3	5.4	2.9	2.6	1.77	2.81	4.89	3.4	10.8	0.11	0.09	13.6	3.2	55.0	14.4
40-60	39.3	19.7	41.0	SCL	6.4	5.4	2.9	2.6	0.52	2.19	3.81	3.6	8.6	0.12	0.10	24.0	2.4	50.0	12.42
60-80	59.3	4.7	36.0	SCL	6.6	5.4	3.4	3.0	0.37	0.12	0.21	1.6	1.0	0.08	0.06	1.6	0.8	14.0	2.74
80-100	60.0	6.0	34.0	SCL	6.4	5.4	4.1	3.5	2.54	3.11	5.42	1.6	3.0	0.08	0.05	1.6	0.4	17.0	4.73
P4																			
0-20	57.0	36.0	7.0	SL	5.9	5.5	2.2	2.0	2.81	7.06	12.29	8.2	4.0	0.13	0.10	20.0	8.0	50.0	12.43
0-40	46.0	47.0	7.0	SL	6.2	5.7	2.2	2.0	2.91	2.37	4.13	5.2	10.4	0.12	0.10	10.0	9.0	56.0	15.83
40-60	46.0	48.0	6.0	SL	6.3	5.8	2.2	2.0	2.77	2.39	4.16	4.6	11.4	0.11	0.09	10.6	5.0	52.0	16.2
60-80	55.0	28.0	17.0	SL	6.4	5.9	2.2	2.0	2.67	2.31	4.02	4.2	10.4	0.10	0.08	10.8	4.0	47.0	14.78
80-100	44.0	49.0	7.0	SL	6.5	5.9	2.3	2.1	2.82	2.10	3.66	4.8	10.4	0.12	0.10	1.6	11.8	50.0	15.42
Surface mean	45.5	41.8	12.0		5.5	5.1	2.5	2.2	2.2	4.0	7.06	6.2	5.5	0.1	0.4	24.6	7.4	62.0	11.98
Sub-surface mean	54.1	26.9	19.1		5.9	5.4	2.7	2.7	2.4	1.96	3.42	4.6	4.3	0.12	0.1	12.5	4.1	45.1	13.42

[a]SL = sandy loam; SL= silt loam; LS =loamy sand; L= loam; C =clay; SCL = sandy clay loam; P1 = Anatigha Jamekon beach; P2 = Anatigha fish pond; P3 = Anatigha slughter ; P4 = Ibesikpo timber

Table 3: Variation in physico-chemical properties of soil among the four locations in Anantigha coastal marine sediment in Calabar

Locations	Sand	Silt	Clay	pH (wet)		pH(dry)		EC dsm-1	OC	OM	Exch. Cations				Exch. Acidity		CEC	BS %
											Ca	Mg	K	Na	Al	H		
	→ % ←			H_2O	$CaCl_2$	H_2O	$CaCl_2$		→ % ←		← cmol/kg →							
P1	64.1	19.3	9.6b	6.10a	5.88a	2.52b	2.18b	1.96ab	1.75	3.05	6.4a	7.24	0.14	0.11	18.6	6.24	47.4	13.5
P2	54.5	23.3	22.2ab	4.46b	4.30c	2.72b	2.40ab	1.55b	2.13	3.71	4.28ab	11.48	0.14	0.092	13.2	3.92	57.2	16.0
P3	41.2	28.2	30.6a	6.36a	5.40b	3.12a	2.74a	1.38b	2.36	4.17	3.04b	4.88	0.098	0.074	15.6	2.80	40.4	8.1
P4	49.5	41.6	8.8b	6.26a	5.76ab	2.22b	2.02b	2.80a	3.35	5.65	5.40a	9.32	0.12	0.094	0.6	7.56	51.0	14.9
SEM	6.27	9.3	4.76	0.158	0.14	0.18	0.15	0.34	0.61	1.05	0.61	1.87	0.012	0.0079	3.28	1.52	7.32	2.23
LSD(0.05)	NS	NS	14.68**	0.48**	0.44**	0.55**	0.46**	1.04**	NS	NS	1.86**	NS	NS	NS	NS	NS	NS	NS

P1 = Anantigha Jamekon beach; P2 = Anantigha fish pond; P3 = Anantigha slughter ; P4 = Ibesikpo timber

S.E.M = Standard error of mean.

Note: *** and ** denote means significant at 1 and 5 % level of significant; NS = not significant; means within a column not sharing a letter in common differ from other means significantly following Fisher least significant difference (LSD).

Characterization of Available Micronutrients

The available micronutrients of the composite surface and sub-surface soil samples are presented in Table 4. Generally, the concentration of available micronutrients in the surface soil were found to be Fe>Mn>Zn>Cu order. The micro-nutrient content of soils is influenced by several factors among which soil organic matter content, soil reaction and clay content are the major ones. The results obtained for available micronutrients showed that the mean values for Fe, Zn, Cu and Mn were 134.65, 1.43, 0.92 and 5.05 mg/kg for surface soil and 121.29, 1.89, 1.89 and 1.48 mg/kg for subsurface soil. Zn and Cu were generally “low” to “medium” in all the horizons of the pedons while Fe and Mn values were “high”.

Table 4: Available micronutrients of the soil in Ananatigha coastal marine sediment in Calabar

Horizon depth (cm)	Available micro-nutrient mg/kg			
	Fe	Zn	Cu	Mn
P1				
0-20	140.14	0.88	1.46	6.20
20-40	14.89	1.00	1.65	6.15
40-60	126.63	1.05	2.46	6.49
60-80	130.01	1.12	1.96	3.19
80-125	130.01	1.36	1.64	2.92
P2				
0-25	128.32	0.65	0.44	3.96
25-51	138.45	0.61	0.55	3.96
51-95	136.76	0.71	0.52	2.92
95-150	140.14	0.71	0.91	3.19
150-176	102.99	0.69	1.12	2.52
P3				
0-20	126.63	2.14	1.06	3.63
0-40	87.80	1.36	1.97	3.67
40-60	121.56	2.58	1.35	3.34
60-80	104.68	2.58	1.35	3.34
80-100	37.144	1.92	1.35	2.88
P4				
0-20	143.51	2.034	0.73	6.34
0-40	134.07	4.45	1.05	6.19
40-60	133.38	3.37	1.73	9.04
60-80	133.38	3.37	1.64	6.61
80-100	136.76	3.30	1.36	7.20
Surface mean	134.65	1.43	0.92	5.03
Sub-surface mean	121.29	1.89	1.89	1.48

P1 = Anatigha Jamekon beach; P2 = Anatigha fish pond; P3 = Anatigha slughter ; P4 = Ibesikpo timber

Based on the critical value of iron (3-4.5 mg/kg) (Adeoye and Agboola, 1985) and zinc (5-9 mg/kg) (Sillanpan, 1972), respectively, the soil could be considered to be high in Fe and low in Zn contents. Also, the critical values of copper and manganese have been given as 3-4.5mg/kg (Adeoye and Agboola, 1985) and 5-9 mg/kg (Sillanpan, 1972). Based on these critical limits the soil could be considered to be high in Mn and low in Cu contents. Ibia (1995) in his study of inland swamp of Akwa Ibom State opined that exchangeable Zn level in soil between 4.5 mg/kg and 10 mg/kg would be detrimental to the growth of crop plants. Although most Zn and Cu values obtained in this study fell into medium classes, most of the values are found close to the lower and upper margins of the medium class. Therefore, care has to be made and monitoring their status at every five to seven years is vital to keep these soils productive. The available Mn contents of the soils were therefore high given the fact that all the values recorded were above 1.00 mg/kg. Black (1968) stated that exchangeable Mn levels in soil between 1 mg/kg and 15 mg/kg and above would be injurious to the growth of crop plants. Fe having higher value than Cu, Mn, Zn and B is in line with the findings of Esu (2010) who attributed this to the abundance of sesquioxides in the humid tropical soils. The high contents of the micronutrients in the soils could be associated with acidity of the soils and poor drainage. There was a significant difference ($P < 0.05$) in Zn, Cu and Mn content between the four locations (Table 5) while Fe content in the four locations showed no significant difference ($P < 0.05$). This again corroborates the findings of Esu (2010).

Table 5: Variation in available micronutrient of soil among the four locations in Anantigha coastal marine sediment in Calabar

Locations	Available micro-nutrient			
	→ mg/kg ←			
	Fe	Zn	Cu	Mn
P1	108.3	1.08a	1.83a	4.99a
P2	129.3	0.67a	0.71c	3.31b
P3	95.6	2.12b	1.41ab	3.37b
P4	136.2	3.30b	1.30b	7.08a
SEM	14.07	0.24	0.14	0.46
LSD(0.05)	NS	0.73***	0.44***	1.42***

P1 = Anatigha Jamekon beach; P2 = Anatigha fish pond; P3 = Anatigha slughter ; P4 = Ibesikpo timber
S.E.M = Standard error of mean.
Note: *** and ** denote means significant at 1 and 5 % level of significant; NS = not significant; means within a column not sharing a letter in common differ from other means significantly following Fisher least significant difference (LSD).

Relationship between micronutrients and pH of the soils studied

Results of the correlation analysis between micronutrients and pH of the soils studied are presented in Table 3. Inter-relationships among the micro-nutrients revealed that pH had a negative and significant correlation with manganese (r = -0.599) at 1 % level and a negative and non-significant correlation with Fe, Zn and Cu (r = -0.436, -0.187, -0.057). Also, Zn had a positive and significant correlation with manganese (r = 0.522). This implies that as the concentration of Zn increases, Mn also increases in similar proportion.

Table 5: Relationship between micronutrients and pH of the soils studied

	pH (H2O)	Fe	Zn	Cu	Mn
pH (H2O)	1				
Fe	-.436	1			
Zn	-.187	.136	1		
Cu	-.057	-.252	.145	1	
Mn	-.599**	.158	.522*	.290	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Potentials, constraints and management of coastal marine sediment for crop production

FAO (1976) uses some important soil characteristics, namely; texture, CEC, organic matter, exchangeable K and pH to rate the suitability of soils for crop production. Based on the data in Table 2, these soils are generally acidic and coarse in texture. All the soils are low in exchangeable K, BS and extremely acidic. Organic matter and exchangeable Ca were moderate in availability in all the soils while CEC was high. Based on this rating, the soils are low in fertility and may not sustain arable crop production efficiently without any external input because the exchangeable K and BS levels are low and the soil is extremely acidic and this constitutes constraints for crop production. These soils however, may be made moderately suitable for the cultivation of short season crops such as vegetables, pepper, garden egg, water leaf and others during the short dry period (November-March) carried out by women through liming and organic manuring. The soil should also be planted with acid tolerant crops.

CONCLUSION

The texture of the studied soils observed irrespective of location can be favourable for agricultural cultivation. The soils will not pose any salinity problems to crops as their electrical conductivity of the saturation extract was < 4 d Sm^{-1}, having substantial amount of organic carbon contents which translating into high mean organic matter content for surface and sub-surface soils. All the soils are low in exchangeable K, base saturation and extremely acidic, while exchangeable Ca was moderate and CEC was high. The coastal marine sediment in Anatigha can serve as a medium for crop cultivation, if properly managed. Hence, there is the need to continually monitor the fertility status of this soil for soil quality sustainability for agriculture.

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