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AGRICULTURAL POTENTIALS OF FLOODPLAIN SOILS WITH CONTRASTING PARENT MATERIAL IN CROSS RIVER STATE, NIGERIA

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ABSTRACT

This paper reports the soil properties and agricultural potential of floodplain soil in Obufa Esuk Orok, Calabar and Awi, Akamkpa, Cross River State and characterized the soils to develop a baseline for soil improvement and increased agricultural productivity. Floodplain soil developed on coastal plain sand and basement complex soils were examined with regards to their physical and chemical properties. The results showed that both soils were coarse-textured with a high content of sand exceeding 70 %, giving dominant textural classes of loamy sand and sandy loam. The soils were strongly to slightly acid in reaction with mean surface pH values of 5.54 and 5.43 for soil developed on coastal plain sand and basement complex. The surface soil developed in coastal plain sand within Obufa Esuk Orok, Calabar contains moderate amount of exchangeable Mg (0.8-2.2 cmol/kg), available P (10.0 -11.83 mg/kg), total N (0.20-0.25 %) and organic carbon (2.51-3.05 %) and was high in base saturation (93.11-95.50 %) and low in exchangeable acidity. Conversely, the floodplain soil developed on basement complex in Awi, Akamkpa was rated low in key fertility indicators. Hence, floodplain soil under this study notably, those developed on coastal plain soil can be exploited for the cultivation of rice, oil palm, coconut, plantain, pineapple, pepper, fluted pumpkin and sugar cane with judicious application of lime, and N and K fertilizer.

KEYWORDS: Floodplain Soil, Soil Fertility, Coastal Plain Soil, Basement Complex

INTRODUCTION

Food security is a first priority for the poor, especially people living in Sub-Sahara Africa. The projected world population estimated to be about 8.5 billion in 2030 (United Nations Population Division, 2015), has created concerned for many world economies including Nigeria. This increased population means increased resources will be required for meeting the demands of the growing population. However, agriculture can help tremendously in providing most of these resources, thus ensuring food security. In Nigeria, agriculture is the major source of livelihood for most of its populace, especially those living in the rural areas; it is the source of food and income for those who are engaged in the sector. With this rapidly increasing population, there is now need to intensify effort in meeting the increasing demand for food sustainably.

Currently, there is widespread decline in the yields of most upland crops in already existing agricultural land. This decline is primarily due to depletion of soil nutrients as a result of continuous cultivation (Yebo, 2015) and soil degradation (Yusuf and Yusuf, 2008). The few available fertile upland soils that would have helped to boost crop productivity and yields have been erroneously appropriated for non-agricultural purposes (i.e. urban, infrastructural or industrial uses), thus making upland soils for agriculture a scare resource (Aki, 2012; Aki and Isong, 2018).

It is now clear that an indispensable sector of Nigeria economy (i.e. agriculture) is facing serious constraints of scarcity of land and decline in soil fertility (Udo *et al.,* 2009). This could underscore why Nigeria was among countries that were affected with the last global food crisis (Oparaeke *et al.,* 2010) and has recently been enlisted as one of the poorest countries in the world. Therefore, it is necessary that pragmatic steps be taken to save Nigerians from an impending danger of more serious food crises in the near future.

Nevertheless, the problems related to land scarcity and/or declining productivity from upland agriculture could be alleviated through expansion of available cropping land into floodplain soils. Floodplain soil is an area of land adjacent to a stream or river which stretches from the banks of its channel to the base of the enclosing valley wall, and which experiences flooding during periods of high discharge (Goudie, 2004). The soils usually consist of levees, silts and sand deposited during floods. In recent times, agricultural use of floodplain soils has increased significantly in many developing countries particularly in Africa including Nigeria (Ogban and Ibia, 1998; Onyekwere *et al.,* 2001; Ogban et *al.,* 2011; McCartney *et al.,* 2010; Akpan-Idiok

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and Ogbaji, 2013; Akpan *et al.,* 2017). Soils of the floodplain have been characterized by moderate to high contents of basic cations, organic carbon, moderate to strong acidity and rated moderate to high in fertility status (Ogban and Babalola, 2009; Hossain *et al.*, 2011). Floodplain 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 upland soils.

Worldwide, floodplains soils are useful for agricultural production as they constitute a huge reserve of available nutrients for utilization by crops (Akpan-Idiok ans Ogbaji, 2013), and in Southeast Nigeria, extensive research has been done on floodplain soils and/ or wetland soils, and several studies have focused on the agro-potential of wetland (Aki, 2012; Akpan *et al.,* 2017; Ogban and Babalola, 2009; Egbuchua and Ojobor, 2011; Ayalew and Beyene, 2012), geomorphologic aspects, classification and characterization of wetland agro-ecosystems (Chukwu *et al.,* 2009; Nsor, 2017). Despite the over-whelming acceptance of floodplain soils for agriculture, those located within Obufa Esuk Orok, Calabar and Awi, Akamkpa have little been studied and are currently under-utilized and their soil qualities and agricultural potential to support crop growth and yield is unknown.

Although, wide variations in nutrient contents exist between upland soils developed on different parent materials within the same climatic condition and geographical location in Cross River State (Gbadegesin *et al.,* 2011, Afu *et al.,* 2017) and elsewhere, but it is not clear if there would be similar significant differences in nutrient contents of floodplain soils developed on different parent material within the same environmental condition, bearing in mind that in all floodplain soils, fresh materials are frequently added through depositions and are characterized with a mixture of clay, silts, sands, and organic materials, and therefore, would both be considered to have high and similar soil fertility status and hence, potential for crop production (Reddy and DeLaune, 2008; Daniel *et al.,* 2017).

Thus, there is a need for testing the floodplain soils located on soils of two parent materials in Cross River State to find out if there are differences in soil properties between the two soils and to avoid a situation whereby a wrong soil management practice is imposed upon the soil in the event of allocating it for crop cultivation. This paper therefore intends to generate data and information on the physical and chemical properties of floodplain soil in Obufa Esuk Orok and Awi in Cross River State that would serve as a convenient and quick guide to the suitability or otherwise of the soil for crop cultivation.

2. MATERIALS AND METHODS

Description of the study Area

The study was conducted in Obufa Esuk Orok, Calabar, (Latitudes 4°15′ and 5°05′ N and Longitudes 8°10′ and 8°30′E) and Awi, Akamkpa (Latitudes 5°00′ and 5°57′ N and Longitudes 8°06′ and 9°0′E) Cross River State, Southeastern Nigeria (GPS, 2017). The area lies within the humid tropical climatic environment characterized by two distinct seasons; wet and dry. The rainy season usually starts from April and ends in October with a double peak usually in July and September, while the dry season spans from November to March. This area receives average annual rainfall exceeding 2600 mm. The relative humidity is usually high averaging 85%. The mean annual temperature of the area is about 27^0 C with February and March being the warmest month (Amalu and Isong, 2017). The principal crops grown in the area include maize, sugar cane, cassava, oil palm and vegetable crops.

FIELD STUDY

A total of twenty (20) composite soil samples were collected each from soil developed on coastal plain sand and basement complex rock. The samples were collected with the aid of a soil auger at the depths of 0-15 and 15-30 corresponding to surface and subsurface soils respectively. Soil samples collected were properly labeled in an airtight and clean polythene bags and taken to the laboratory where they were air-dried, then gently grounded, sieved in a <2 mm sieve and the fine earth fractions were subjected to routine laboratory analysis.

LABORATORY ANALYSES

Particle size distribution was determined by Bouyoucos hydrometer method (Gee and Or, 2002). Soil pH (H_2O) was measured electrometrically using glass electrode pH meter in a solid-liquid ratio of 1:2.5 following the procedure outlined by Udo et al. (2009). Total organic carbon was analyzed by wet digestion method (Nelson and Sommers, 1996). Total nitrogen content of the soil was determined by wet-digestion, distillation and titration procedures of the Kjeldahl method as described by Bremner (1996). Phosphorous was determined by Bray I method according to the procedure of Kuo (1996). The exchangeable bases were determined through extraction method with 1M ammonium acetate at pH 7 (Thomas, 1982). Amounts of Ca and Mg ions in the leachate were analyzed by atomic absorption spectrophotometer, while K and Na ions were analyzed by flame photometer. Exchangeable acidity (hydrogen and aluminum) were determined by the titrimetric method using 1N KCl extract. The percent base saturation of the soil was calculated as the percentage of the sum of the basic exchangeable cations (Ca, Mg, K and Na) to the ECEC of the soil.

STATISTICAL ANALYSIS

The data obtained from laboratory analysis were subjected to both descriptive and inferential statistic. Descriptive statistics; mean and range of soil properties were computed and employed to compare the results with critical values. t-test was also computed to compare if there was any significant difference between soil properties in the two parent materials.

RESULTS AND DISCUSSION

The physico-chemical properties of floodplain soils are shown in Tables 1 and 2.

Physical Properties of the investigated soil samples

The results as presented in Tables 1, 2 and 3 showed that there were no considerable differences in soil particle size distribution in both surface and sub-surface soil in the two parent materials studied. In floodplain soil developed on coastal plain sand, the mean sand, silt and clay content for surface soil were 77.0, 21.3 and 17.4, respectively and 78.8, 15.4 and 5.8 % for subsurface soil. Whereas in soil developed on basement complex, the mean sand, silt and clay content for surface soil were 77.9, 16.4 and 5.7 %, and 78.1, 17.0 and 4.9 % for subsurface soil respectively. The trend in percent sand, silt and clay movement with soil depth in both parent materials were irregular. The soils are coarse-textured with a high content of sand exceeding 70%, giving dominant textural classes of loamy sand and sandy loam. Similar textural classes of loamy sand and sandy loam were also obtained in coastal plain soils in Imo state (Oguike and Mbagwu, 2009; Ukabiala et al., 2016) and in Akpabuyo, South East Nigeria, (Akpan-Idiok et al., 2012). The soil texture observed in this study also corroborate the findings of Ibanga et al. (2005), Aki (2012), Nsor (2017) and Akpan et al. (2017) who did similar studies on soils of Cross River State, Nigeria.

The difference in particle size distributions between coastal plain sand and basement complex rock were not statistically significant as depicted by the t-test values ($t = -0.061$, $df = 9$, $p > 0.05$), ($t = -0.235$, $df = 9$, $p > 0.05$), ($t = 0.394$; $df = 9$, $p > 0.05$) for sand, silt and clay, respectively (Table 3). This result contrast the report of Esu et al. (2014) and Yakubu and Ojanuga (2000) that topography, soil depth and parent materials are attributable to differences in pattern of soil distribution and properties of soil over landscape but corroborates the report of Reddy and DeLaune (2008) and Daniel et al. (2017) that in all floodplain soils, fresh materials are frequently added through depositions and are characterized with a mixture of clay, silts, sand, which may perhaps have similar properties. The texture observed irrespective of depth and parent materials can be favourable for agricultural cultivation. Most field crops could grow well in soils having sandy loam, loamy sand and sandy clay loam textural class as these soils have a potentially well-balanced capacity to retain water, form a stable structure and provide adequate aeration (Amalu and Isong, 2018).

Chemical Properties

The results of selected chemical properties of the soils are also presented in Tables 1 and 2. Interpretation of results was based on the fertility ratings of Landon (1991) and FPDD (1990) established for Nigerian soils.

pH

The result as shown in Tables 3 indicates that there was no significant difference in soil pH between coastal plain sand and basement complex ($t = -1.425$, $df = 9$, $p > 0.05$) (Table 3). In floodplain soil developed on coastal plain soil, the mean pH for surface and sub-surface soil were 5.54 and 5.28. Whereas in soil developed on basement complex, the mean pH for surface and sub-surface soil were 5.43 and 5.75. The values of pH obtained for this study indicated that the soils were strongly to moderately acid in soil reaction (Landon, 1991). This pH value is an indication that significant amount of exchangeable Al^{3+} and H^{+} are present to affect plant growth (Udo et al., 2009). Although, Brady and Weil (2002) had established pH range of 5.5-7.0 as optimal for overall satisfactory availability of plant nutrients but the values obtained from this study is however lower. Nevertheless, the soil could be utilized for crop cultivation with judicious application of lime.

TABLE 1: Physico-chemical properties of floodplain soil developed on coastal plain sand in Calabar

	Soil depth (cm)	Particle size			Texture	pH (H_2O)	OC	TN	AV. P (mg/kg)	Exch. Cations				Exch. Acidity		ECEC	BS (%)
		Sand	Silt	Clay						Ca	Mg	K	Na	Al^{+3}	H^+		
		%					%			Cmol/kg							
A	0-15	68	21	11.0	Sandy loam	5.6	3.05	0.25	10	5.2	1.2	0.09	0.08	0.0	0.36	6.93	94.8
	15-30	74	19	7.0	Sandy loam	4.5	2.23	0.18	9.75	2.4	1.0	0.07	0.05	1.64	1.32	6.48	54.3
B	0-15	74	20	6.0	Sandy loam	5.5	3.0	0.24	11.13	5.0	0.8	0.08	0.06	0.0	0.28	6.22	95.5
	15-30	83	12	5.0	Loamy sand	5.1	2.35	0.19	11.5	3.8	1.4	0.09	0.07	0.20	0.80	6.36	84.3
C	0-15	80	16	4.0	Loamy sand	5.7	2.63	0.21	10.75	4.2	2.0	0.09	0.07	0.0	0.32	6.68	95.2
	15-30	74	17	9.0	Sandy loam	5.5	1.82	0.14	10.0	3.0	2.0	0.08	0.07	0.24	0.52	5.91	87.1
D	0-15	82	15	3.0	Loamy sand	5.2	2.51	0.20	10.88	4.4	2.2	0.06	0.05	0.0	0.40	7.11	94.4
	15-30	81	15	4.0	Loamy sand	5.7	1.29	0.18	11.63	3.4	3.6	0.08	0.07	0.44	0.48	8.07	88.6
E	0-15	81	15	4.0	Loamy sand	5.7	2.73	0.22	11.83	2.8	1.4	0.07	0.06	0.0	0.32	4.65	93.11
	15-30	82	14	4.0	Loamy sand	5.6	2.27	0.18	12.0	3.0	4.0	0.08	0.05	0.16	0.72	8.01	89.0
Surface sample																	
Min		68.0	18.0	3.0		5..20	2.51	0.20	10.00	2.8	0.8	0.06	0.05	0.00	0.28	4.65	93.11
Max		82.0	21.0	11.0		5.70	3.05	0.25	11.83	5.2	2.2	0.09	0.08	0.00	0.40	7.11	95.50
Mean		77.0	17.4	5.6		5.54	2.78	0.22	10.92	4.3	1.5	0.08	0.06	0.00	0.34	6.32	94.60
SD		5.92	2.88	3.21		0.21	0.23	0.02	0.66	0.9	0.58	0.01	0.01	0.00	0.05	0.99	0.93
CV (%)		7.7	16.6	57.3		3.7	8.4	9.3	6.1	21.9	37.9	16.7	17.8		13.6	15.7	1.0
Sub-surface sample																	
Min		74.0	12.0	4.0		4.50	1.29	0.14	9.75	2.4	1.0	0.07	0.05	0.16	0.48	5.91	54.30
Max		83.0	19.0	9.0		5.70	2.35	0.19	12.00	3.8	4.0	0.09	0.07	1.64	1.32	8.07	89.00
Mean		78.8	15.4	5.8		5.28	1.99	0.17	10.98	3.12	2.4	0.08	0.06	0.54	0.77	6.97	80.66
SD		4.44	2.7	2.17		0.49	0.44	0.02	1.03	0.5	1.3	0.01	0.01	0.63	0.34	1.00	14.85
CV (%)		5.6	17.5	37.4		9.3	22.2	11.2	9.3	16.7	55.6	17.7	17.7	116.9	43.8	14.4	18.4
Overall mean		77.9	16.4	5.7		5.41	2.39	0.19	10.95	3.72	1.96	0.06	0.06	0.27	0.55	6.64	87.63

OC = organic carbon; OM = organic matter; TN = Total nitrogen; AV. P = available phosphorus; BS = base saturation; ECEC effective cation exchange capacity

Table 2: Physico-chemical properties of floodplain soil developed on basement complex in Akamkpa

	Soil depth (cm)	Particle size			Texture	pH5.5 (5.8H_2 O5.75)	OC	TN	AV. P ($mgkg^{-1}$)	Exch. cations				Exch. Acidity		ECEC	BS (%)
		Sand	Silt	Clay						Ca	Mg	K	Na	Al^{+3}	H^{+}		
		→	%	←			← %	→		→		$cmol^{+}kg^{-1}$	←				
A	0-15	78.3	17.0	4.7	Loamy sand	5.15	1.96	0.16	6.87	1.2	3.0	0.07	0.07	0.28	0.38	4.98	87.15
	15-20	73.3	19.0	7.7	Sandy loam	5.2	1.22	0.10	5.75	2.2	1.2	0.08	0.07	0.40	0.36	4.31	82.37
B	0-15	78.3	16.0	5.7	Loamy sand	5.15	2.15	0.18	4.60	4.0	2.0	0.09	0.05	0.24	0.40	6.78	90.56
	15-20	83.3	12.0	4.7	Loamy sand	5.6	0.86	0.07	6.12	3.2	1.2	0.08	0.06	0.16	0.52	5.22	86.97
C	0-15	81.3	10.0	8.7	Loamy sand	5.6	0.9	0.03	5.0	1.8	1.0	0.06	0.05	0.18	0.56	3.65	79.73
	15-20	78.3	18.0	3.7	Loamy sand	5.9	0.7	0.06	5.25	4.0	0.8	0.08	0.06	0.40	0.24	5.58	88.53
D	0-15	78.3	17.0	4.7	Loamy sand	5.5	1.3	0.10	5.87	2.4	1.2	0.07	0.05	0.22	0.40	4.34	85.71
	15-20	77.3	18.0	4.7	Loamy sand	5.8	1.3	0.09	5.75	3.0	1.4	0.07	0.06	0.20	0.44	5.17	87.62
E	0-15	73.3	22.0	4.7	Sandy loam	5.75	2.75	0.29	5.75	2.8	1.0	0.08	0.06	0.48	0.31	4.74	83.12
	15-20	78.3	18.0	3.7	Loamy sand	6.25	0.85	0.07	6.25	3.6	1.2	0.08	0.06	0.12	0.56	5.56	88.85
Surface sample																	
Min		73.3	10.0	4.7		5.15	0.90	0.03	4.60	1.2	1.0	0.06	0.05	0.18	0.31	3.65	31.09
Max		81.3	22.0	8.7		5.75	2.75	0.29	6.87	4.0	3.0	0.09	0.07	0.48	0.56	6.78	47.16
Mean		77.9	16.4	5.7		5.43	1.81	0.15	5.62	2.4	1.6	0.07	0.056	0.28	0.41	4.89	35.62
SD		2.88	4.28	1.73		0.27	0.73	0.09	0.88	1.1	0.86	0.01	0.01	0.12	0.09	1.17	6.54
CV (%)		3.07	26.1	30.4		5.0	40.1	0.64	15.6	43.5	52.7	15.4	16.0	42.0	22.4	23.8	18.3
Sub-surface sample																	
Min		73.3	12.0	3.70		5.20	0.70	0.06	5.25	2.20	0.80	0.07	0.06	0.12	0.24	4.31	33.65
Max		83.3	19.0	7.70		6.25	1.30	0.10	6.25	4.0	1.40	0.08	0.07	0.40	0.56	5.58	45.36
Mean		78.1	17.0	4.90		5.75	0.99	0.07	5.82	3.20	1.16	0.078	0.06	0.26	0.42	5.17	39.68
SD		3.56	2.83	1.64		0.387	0.26	1.6	0.39	0.68	0.22	0.004	0.004	0.13	0.13	0.52	4.211
CV (%)		4.6	16.6	33.5		6.7	26.3	21.1	6.7	21.2	18.9	5.7	7.0	5.3	30.0	10.0	10.6

OC = organic carbon; OM = organic matter; TN = Total nitrogen; AV. P = available phosphorus; BS = base saturation; ECEC effective cation exchange capacity.

Table 3: Differences in properties of floodplain soils developed on coastal plain sand and basement complex in Cross River State

Soil properties	Mean±SD					
	Coastal plain sand	Basement complex	Mean difference	t- test	df	Sig.(2-tail)
Sand	77.90±5.02	78±3.057	-0.10	-0.061	9	0.953^{NS}
Silt	16.4±2.84	16.7±3.43	-0.30	-0.235	9	0.819 ^{NS}
Clay	5.7±2.58	5.3±1.65	0.40	0.394	9	0.703 ^{NS}
pH	5.4±0.38	5.59±0.36	-0.18	-1.425	9	0.188 ^{NS}
Org. C	2.39±0.53	1.39±0.67	0.98	5.331	9	< 0.001***
Total N	0.19±0.032	0.12±0.076	0.084	4.209	9	< 0.001***
Avail. P	10.95±0.81	5.72±0.64	5.23	16.001	9	< 0.001***
Exch. Ca	3.72±0.96	2.82±0.93	0.90	1.882	9	0.092*
Exch. Mg	1.96±1.074	1.40±0.65	0.56	1.256	9	0.241 ^{NS}
Exch. K	0.079±0.0099	0.076±0.0084	0.0030	0.669	9	0.520 ^{NS}
Exch. Na	0.063±0.011	0.059±0.0074	0.0040	1.078	9	0.309 ^{NS}
Exch. H^+	0.55±0.32	0.42±0.11	0.135	1.283	9	0.231 ^{NS}
ECEC	6.64±1.0	5.03±0.86	1.61	3.862	9	0.004***
PBS	87.63±12.34	37.65±5.61	49.98	12.216	9	< 0.001***

***= significant at 1 %, ** = significant at 5 %; * = significant at 10; NS = not significant; SD = Standard Deviation

Organic carbon

Organic carbon (OC) in floodplain soil developed on coastal plain sand ranged from 2.51-3.05 % and 1.29-2.35 for surface and sub-surface soil with a mean value of 2.78 and 1.99 % for surface and sub-surface soil respectively and was rated high for surface soil and moderate for sub-surface. Similarly, organic carbon in floodplain soil developed on basement complex ranged from 0.90-2.75 % and 0.70-1.30 % for surface and sub-surface soil with a mean value of 1.81 and 0.99 % for surface and sub-surface soil respectively and was rated moderate for surface soil and low for sub-surface. In both parent materials, OC decreased with increasing soil depth, probably due to decreased faunal activities in the underlying horizons (Browaldh, 1995; Lawal et al., 2014). The result also showed that there was a significant difference in soil organic carbon between the two parent materials studied ($t = 5.33$, $df = 9$, $p < 0.01$) (Table 3). Soil developed on coastal plain sand parent material had the highest organic matter content than basement complex soil. The high and moderate levels of organic carbon detected on the floodplains soils of both parent materials could be attributable to the accumulation of residues of the fallow vegetation over a long time and the deposits brought by flood water. The upland soil of the study area from other previous studies is however noted to have low organic carbon levels (Amalu and Isong, 2015; Afu et al., 2017) when compared to those obtained in floodplain soil for this study, and this can significantly promote crop production. Hence, it can be infer that floodplain soil has higher potential for crop production in terms of organic carbon supply.

Total nitrogen

Total nitrogen in floodplain soil developed on coastal plain sand parent material ranged from 0.20-0.25 % and 0.14-0.19 % for surface and sub-surface soil with a mean value of 0.22 and 0.17 % for surface and sub-surface soil respectively and was rated moderate for surface soil and low for sub-surface soil. Similarly, total nitrogen in floodplain soil developed on basement complex ranged from 0.03-0.29 % and 0.06-0.10 % for surface and sub-surface soil with a mean value of 0.15 and 0.07 % for surface and sub-surface soil respectively and was rated low for both surface and sub-surface soil. Total nitrogen values were rated low in sub-surface soil of both parent materials. This low value of total nitrogen could be attributed to losses through leaching, percolation under flooded situation and volatilization once the flood water recedes especially under high temperature that characterized the study area (Brady and Weil, 2002). Thus, the results showed that soil developed on basement complex is deficient in nitrogen. This soil could be utilized for crop cultivation of crop with judicious application of N fertilizer. The low total N of the floodplain soil also conforms to the observations of Valiela and Teal (1974) that estuarine wetlands tend to have N limitations. The result further showed that there was a significant difference in total nitrogen between the two parent materials studied ($t = 4.21$, $df = 9$, $p <0.001$) (Table 3). Soil developed on coastal plain sand parent material had the highest total nitrogen content.

Available phosphorus

Available phosphorus in floodplain soil developed on coastal plain sand ranged from 10.0 -11.83 mg/kg and 9.75-12.0 mg/kg for surface and sub-surface soil with a mean value of 10.92 and 10.98 mg/kg for surface and sub-surface soil respectively and was rated moderate for both surface and sub-surface soil. Ukpong (2000) reported high available P levels in the Creek / Calabar River swamps. Similarly, available phosphorus in floodplain soil developed on basement complex ranged from 4.6-6.87 mg/kg and 5.25-6.25 mg/kg for surface and sub-surface soil with a mean value of 5.62 and 5.82 mg/kg for surface and sub-surface soil respectively and was rated low for both surface and sub-surface soil based on fertility rating of Landon (1991). The result further showed that there was a significant difference in available phosphorus between the two parent materials studied ($t = 16.0$, $df = 9$, $p < 0.001$) (Table 3). Soil developed on coastal plain sand parent material had the highest available phosphorus content than soil developed on basement complex. However, the present phosphorus content of the soil developed on coastal plain sand was within the critical limit of 8-20mgkg^{-1} stipulated for the "acid sands" of South-Eastern Nigeria (FPDD, 1990), whereas that obtained in soil developed on basement complex rock was below 8-20 mgkg^{-1} critical value. The low available phosphorus encountered in soil developed on basement complex in the study area indicates that P may be chemically bound as phosphates of Fe and Al owing to the observed low pH of the soil. This finding corroborates that of Nsor (2017) who also obtained the same result in similar soil. Uzoho et al., (2014) link low phosphorus content of soils to high soil acidity.

Exchangeable cations

The mean surface and subsurface soil values for exchangeable Ca were 4.30 and 3.12 cmol/kg for soil developed on coastal plain sand and 2.4 and 3.2 for soil developed on basement complex rock. Also, the mean surface and subsurface soil value for exchangeable Mg were 1.5 and 2.4 cmol/kg for soil developed on coastal plain sand and 1.60 and 1.16 cmol/kg for soil developed on basement complex rock. Similarly, the mean surface and subsurface soil value for exchangeable K were 0.08 and 0.08 cmol/kg for soil developed on coastal plain sand and 0.070 and 0.078 cmol/kg for soil developed on basement complex rock. The results obtained for exchangeable K in this study was somewhat comparable to 0.014, 0.28 and 0.09 cmol/kg for upper slope, middle slope and foot slope soils overlying basement complex in Southern Nigeria (Oku et al., 2010). The finding of this study is in agreement with the report of Attoe et al. (2016) who obtained higher value of exchangeable K in coastal plain sand soil (surface soil = 0.10 cmol/kg; subsurface soil = 0.14 cmol/kg) in Akamkpa than basement complex soil (surface soil = 0.08 cmol/kg; subsurface soil = 0.08 cmol/kg) in Ikot Omin, but contrast the report of Abam and Orji (2019) who obtained lower exchangeable K value of 1.3 cmol/kg in soil developed on coastal plain sand than 1.6 cmol/kg in soils developed on basement complex. Furthermore, the result also showed that the mean surface and subsurface soil values for exchangeable Na were 0.06 and 0.06 cmol/kg for soil developed on coastal plain sand and 0.056 and 0.06 cmol/kg for soil developed on basement complex. The result obtained for this study confirmed the findings of Ogban et al. (2011), that the soils of Southeastern Nigeria have low basic cations. However, among the basic cations determined only exchangeable Mg values in both soils were rated moderate when compared to fertility rating of Landon (1991). The rest of the exchangeable cations were rated low. The result further showed that the exchange complex of the soils was dominantly occupied by Ca and then followed by Mg, whereas K and Na were very fewer compared to the former two divalent cations, and follows a decreasing cation magnitude, that is $Ca^{2+} > Mg^{2+} > K^{+} > Na^{+}$. The difference in exchangeable cations of the soil between coastal plain sand and basement complex were not statistically significant as depicted by the t-test values ($t = 1.88$, $df = 9$, $p > 0.05$), ($t = 1.26$, $df = 9$, $p > 0.05$), ($t = 0.67$, $df = 9$, $p > 0.05$) and ($t = 1.07$; $df = 9$, $p > 0.05$) for Ca, Mg, K and Na respectively.

Effective Cation Exchange Capacity (ECEC)

Effective cation exchange capacity (ECEC) in floodplain soil developed on coastal plain sand ranged from 4.65-7.11 and 5.91 -8.07 cmol/kg for surface and sub-surface soil with a mean value of 6.32 and 6.97 cmol/kg for surface and sub-surface soil respectively and was rated low for both surface and sub-surface soil. Similarly, ECEC in floodplain soil developed on basement complex ranged from 3.65-6.78 and 4.31-5.58 cmol/kg for surface and sub-surface soil with a mean value of 4.89 and 5.17 cmol/kg for surface and sub-surface soil respectively and was rated low for both surface and sub-surface soil. It has been reported elsewhere that the soils of Southeastern Nigeria have low ECEC and basic cations (Ogban et al., 2011). The low ECEC have been attributed to the fact that soils in this region are strongly weathered, have little or no content of weathered materials in sand and silt fractions and have predominantly Kaolinite in their clay fractions. This finding is also in agreement with that of Akpan et al. (2017) who work on wetland soil in Calabar and observed low ECEC. The result also showed that there was a significant difference in soil ECEC between coastal plain sand and basement complex ($t = 3.86$, $df = 9$, $p < 0.001$) (Table 3). Although, ECEC was low in both soils but soil developed on coastal plain sand parent material had the highest ECEC than soil developed on basement complex rock.

Exchangeable Acidity

Exchangeable acidity (H^{+}) in floodplain soil developed on coastal plain sand ranged from 0.28-0.40 and 0.48-1.32 cmol/kg for surface and sub-surface soil with a mean value of 0.34 and 0.34 cmol/kg for surface and sub-surface soil, and was rated low for both surface and surface soil. Similarly, exchangeable acidity (H^{+}) in floodplain soil developed on basement complex rock ranged from 0.31-0.56 and 0.24-0.56 cmol/kg for surface and sub-surface soil with a mean value of 0.41 and 0.42 cmol/kg for surface and sub-surface soil and was rated low for both surface and sub-surface soil. The result indicated that there was no significant difference in soil exchangeable acidity (H^{+}) between coastal plain sand and basement complex rock ($t = 1.28$, $df = 9$, $p >0.05$) (Table 3). In this study, hydrogen ions rather than aluminum ions dominated the exchange acidity largely in agreement with reports of Amalu (1998) that H^{+} rather than Al^{3+} dominates in majority of soils with pH less than 5 units. Exchangeable acidity (Al^{+++}) in floodplain soil developed on coastal plain sand was not detected in surface soil, but ranged from 0.16-1.64 cmol/kg for sub-surface soil with a mean value of 0.54 and was rated low. Similarly, exchangeable acidity (Al^{+++}) in floodplain soil developed on coastal plain sand ranged from 0.18-0.48 and 0.12-0.40 for surface and sub-surface soil with a mean value of 0.28 and 0.26 for surface and sub-surface soil respectively and was rated low for surface and sub-surface soil. Ambergor (2006) indicated that a concentration of aluminum ion greater than one (>1 cmol/kg) in the soil solution could lead to aluminium toxicity. The value of exchangeable Al obtained for this study may not result to Al toxicity to crop. Similarly, the value of exchangeable H^+ obtained for this study in the both soils will not be detrimental to crop growth.

Base Saturation

Base saturation (BS) in floodplain soil developed on coastal plain sand ranged from 93.11-95.50 and 54.30-89.00 % for surface and sub-surface soil with a mean value of 94.6 and 80.66 % for surface and sub-surface soil respectively and was rated high for both surface and sub-surface soil. Similarly, BS in floodplain soil developed on basement complex ranged from 31.09-47.16 % and 33.65-45.36 for surface and sub-surface soil with a mean value of 35.62 and 39.68 for surface and sub-surface soil respectively and was rated moderate for surface and sub-surface soil. The result also showed that there was a significant difference in soil BS between coastal plain sand and basement complex rock ($t = 12.22$, $df = 9$, $p < 0.001$) (Table 3). Soil developed on coastal plain sand parent material had the highest BS than soil developed on basement complex rock. Akpan et al. (2017) also obtained high base saturation for wetland soil overlying coastal plain soil.

CONCLUSION

The result of this study has indicated that floodplain soils overlying coastal plain sand and basement complex parent materials showed no significant difference in physical properties studied but however, there were significant difference in key fertility indices (i.e. OC, N, P, Ca, ECEC, BS), thus both soils cannot be exploited for crop cultivation with similar management practices. Floodplain soil overlying coastal plain sand had high potential for crop production as it contains moderate amount of exchangeable Mg, available P, total N and organic carbon and is high in base saturation and low in exchangeable acidity. The soil is thus rated moderate in some key fertility indicators. This soil can be exploited for the cultivation of rice, oil palm, coconut, plantain, pineapple, pepper, fluted pumpkin and sugar cane with judicious application of lime, and N and K fertilizers. Conversely, the floodplain soil developed on basement complex in Awi was rated low in fertility. However, soil fertility management option in both areas should focus on liming and practices that will improve the soil organic matter, nitrogen and exchangeable cations (Ca and K) based on the soil test result.

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