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Characteristics and Constraints of Some River Flood Plains Soils to Crop Production in Southeastern Nigeria

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Abstract: Characteristics of some river flood plain soils in Southeastern Nigeria were assessed for their potentials and constraints to crop production. Soil texture varied remarkably from loamy sand in Imo (IMR) and Cross River (CRR) through sandy loam in Igwu (IGR) to sandy clay loam in Qua Iboe (QIR) river flood plains. Soil reaction ranged from strong to moderate with pH values averaged 4.9-5.2. Organic matter contents varied from moderate (16.9 g kg^{-1}), to high (28.1 g kg^{-1}). Total N (0.4 – 0.7 g kg^{-1}), exchangeable Ca (1.15-1.76 cmol kg^{-1}), K (0.07-0.8 cmol kg^{-1}) and CEC (1.72-2.83 cmol kg^{-1}) values were low and less than their critical levels in the soil. In contrast, exchangeable Mg level was high while, available P and percent base saturation levels varied from low to moderate: 7.28-39.79 mg kg^{-1} for P and 43.3-59.7% for base saturation. The main constraints of these flood plains to sustainable crop production are therefore, the low chemical fertility (moderate to high acidity, low Ca, K, CEC and total N concentrations). However, short season crops (vegetables) can be grown at the present level of subsistent farming. Ordinarily, fertilizer and lime would be recommended as measures to increase yield of crops, but these inputs are both unaffordable and unavailable at critical periods. Therefore, the farmers are encouraged to harness cheap resources found on the farms such as mulch and biofertilizers, to improve soil chemical fertility rather than rely on inputs that are normally not accessible.

Key words: Wetlands, soils, constraints, floodplains, crop production, Nigeria

INTRODUCTION

Floodplains are areas bordering or adjacent to the course of the major river streams. Generally, floodplains have low gradient and are liable to seasonal flooding during the rainy season. The soils have varied textures and drainage may range from well drained to poorly drained. Akwa Ibom State area, southeastern Nigeria, is washed by the lower parts and tributaries of Imo, Qua Iboe and Cross Rivers which, empty into the Atlantic Ocean. These river systems drain most of the state with an estimated drainage area of about 3900 km^2 (Uniuyo Consult Ltd, 2003). Since, about 26% of the landmass of the state is under swamp, it becomes imperative in these days of declining productivity from upland agriculture to expand arable cropping into these vast and hitherto little exploited wetland resources.

Despite the various uses, to which wetlands can be put, several workers (Obi, 1984; Opuwaribo and Isirimah, 1984; Ojanuga *et al*., 1996) have observed that in Nigeria wetland soils are unknown, undeveloped and grossly underutilized. The complexity of their habitat, coupled with the paucity of scientific knowledge of most of the wetland soils in Nigeria have contributed to their underutilization (Omoti, 2001). Again, wetland soils are largely ignored because the agronomic tasks on the soils are more arduous and tedious than on upland soils (Jalloh and Anderson, 1986; Eshett, 1990). Moreover, their characteristics and potentials are little understood (Ogban and Babalola, 2003). The need to expand food production into wetland soils necessitated the investigation of the characteristics, potentials and constraints of some river floodplains to enhance their maximum uses.

MATERIALS AND METHODS

Study area: The study was conducted in four river floodplains, namely: the Cross River (CRR) in the east; Qua Iboe River (QIR) in the centre; Imo River (IMR) in the west and Igwu River (IGR) in the north of Akwa Ibom area, located at latitude 4.5 and 5.5°N and longitudes 7.5 and 8.7°E of humid southeastern Nigeria. The climate is fairly typical for coastal regions of West Africa, being greatly influenced by the movement of the low pressure system known as the Intertropical Discontinuity (ITD)

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zone. The north-south movement of the ITD results in 2 seasons: the wet (April-October) and dry (November-March) seasons. The area is characterized by heavy annual precipitation (about 2500-3000 mm) with peaks in July and September and least rainfall occurs in December-February (Nig. Met. Service, 1996); high temperature of 24-30°C and a relative humidity range of 80-90%.

The soils are derived from various parent materials, including coastal plain sands (IMR), marine deposits (CRR and QIR) and sandstones/shale (IGR). The soils were classified (Soil Survey Staff, 1990 and FAO/UNESCO, 1988) as Typic Endoaquept (USDA) or Gleyic Cambisol (FAO) (CRR); Typic Fluvaquent (USDA) or Eutric Fluvisol (FAO) (QIR) and IMR) and Aeric Endoaquept (USDA) or Gleyic Cambisol (FAO) (IGR).

Field methods: Six representative soil profile pits, namely; KS_5(IMR), AB_8(QIR), BT_6 and BT_7 (IGR) and DU_9 and AU_{20} (CRR) were dug in the floodplains of these river systems. The profile pits were demarcated, described and sampled according to FAO (1977). Samples were collected at regular intervals of 20 cm to the water table. The bulk samples were identified and processed in the laboratory for particle size distribution and chemical analyses.

Laboratory methods: Conventional methods were used in the analysis of soil samples. Particle size, according to Bouyoucos hydrometer (Klute, 1986) and chemical properties, according to Sparks (1996), for pH, electrical conductivity, exchange acidity and exchangeable Al, organic C, total N, available P and exchangeable bases (Ca, Mg, K, Na). CEC was derived by summation (IITA, 1979), while, percent base saturation was obtained by division of exchangeable bases by CEC. Soil colours were described (Munsell Colour Chart) and texture, according to Glossary of Soil Science Terms (1987).

RESULTS AND DISCUSSION

Some physical and morphological properties: Mean and standard deviation of some physical and morphological properties of the soils are presented in Table 1. The soil texture varied widely from loamy sand in IMR and CRR to sandy loam in IGR through sandy clay loam in QIR floodplains. The floodplains soils of IMR, CRR and ICR have low water holding capacity and were partly saturated at the surface pedon. QIR was either partly or permanently saturated and as such belong to aquic soil moisture regime. These properties are attributed to either a periodically high water table and/or slow infiltration of surface water resulting from relatively moderately clay content, particularly in QIR swamp. The clay and silt contents were observed to increase with depth in QIR and IGR floodplains while, sand content decreased a phenomenon, which Essoka and Esu (2001) described as clay migration by lessivage to produce the process of illuviation. This observation also, suggests that the soil-forming sequence may have been from a variety of origins (Zonn, 1986). The soils colours varied from 10-5 years. The properties showed either as grey colours throughout, grey mottles or soft reddish concentrations and staining in the soil profiles. The surface soil colour varied from dark brown to yellowish brown.

Chemical properties: The pH values in soils varied from strongly acid in QIR and CRR swamps to moderately acid in IMR and IGR floodplains (Table 2). In all the swamps, the pH values in water suspension were higher than corresponding values in IMKCl solution, indicating that all soils at their natural pHs are negatively charged (Villapando and Graetz, 2001). Electrical conductivity of the saturation extract was low, being <1d Sm^{-1} in all the soils, indicating non saline nature of the soils. Therefore, the soils will not pose any salinity problems to crops that would be grown. Salinity problems are usually encountered for sensitive crops when $EC_{25}°$ is above 2 d Sm^{-1} (FAO-UNESCO, 1974).

Exchange acidity and exchangeable Al were variable and moderate in the soils with mean percent Al saturation being generally <30% (18.7-29.3%). Percent Al saturation value >30% may affect sensitive crops (Landon, 1984), while, over 60% could bring about Al toxicity (Kyuma, 1985). 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 >1cmol kg^{-1} (ppm) in the soil solution could lead to Al toxicity. Exchange acidity and exchangeable Al had the highest intercorrelations with other soil properties in the soils (Table 3), indicating the strong relation between the physical surface area characteristics and chemical composition in these acid soils.

Table 1: Some physical properties of river floodplains

Floodplain	Sand	Silt	Clay	Texture	Colour values (Munsell, moist)
	------------	g kg^{-1}	------------		
Imo River Floodplain (IMR) (6)*	821.60±54.04	56.40±24.49	122.00±41.47	LS	10-7.5 years
Igwu River Floodplain (IGR) (10)	745.15±29.63	75.29±26.67	179.56±16.67	SL	10 years
Qua Iboe River Floodplain (QIR) (6)	708.20±84.38	70.80±21.91	221.00±66.93	SCL	10-5 years
Cross River Floodplain (CRR) (12)	788.88±110.20	66.60±33.82	144.52±85.19	LS	nd

*-Parentheses indicate number of samples for each floodplain; LS = Loamy Sand, SL = Sandy Loam, SCL = Sandy Clay Loam, nd = not determined

Table 2: Mean and standard deviation for soil chemical properties of four river floodplains

Floodplain	pH H_2O	pH KCl	EC_{25}° (d sm^{-1})	Org. C	Tot. N	C/N	Av. P (mg kg^{-1})
				g kg^{-1}			
Imo River Floodplain (IMR)	5.2±0.5	4.5±0.5	0.092±0.021	13.20±2.7	0.06±0.1	24±1.7	11.30±6.73
Igwu River Floodplain (IGR)	5.2±0.3	4.6±0.3	0.110±0.03	16.30±2.7	0.7±0.1	24±1.2	12.03±3.23
Qua Iboe River Floodplain (QIR)	4.9±0.1	4.4±0.3	0.041±0.03	9.8±4.3	0.4±0.2	23±2.2	7.28±2.86
Cross River Floodplain (CRR)	4.9±0.1	4.7±0.4	0.078±0.03	12.5±6.7	0.5±0.3	23±1.2	39.78±13.93

Floodplain	Ca	Mg	K	Na	EA	EAl	CEC	BS (%)
	cmol kg^{-1}							
Imo River Floodplain (IMR)	1.15±0.2	0.50±0.06	0.08±0.02	0.05±0.01	1.25±0.044	0.58±0.37	1.78±0.27	59.7±6.6
Igwu River Floodplain (IGR)	1.72±0.3	0.97±0.22	0.09±0.07	0.06±0.01	2.22±0.94	1.27±0.47	2.83±0.52	56.5±9.9
Qua Iboe River Floodplain (QIR)	1.76±0.16	0.74±0.11	0.08±0.02	0.04±0.01	3.89±1.48	1.91±1.18	2.62±0.26	42.3±12.6
Cross River Floodplain (CRR)	1.23±0.21	0.51±0.11	0.07±0.01	0.05±0.01	1.80±1.33	0.98±0.87	1.72±0.38	55.6±19.88

EC = Electrical Conductivity, Org. C = Organic C, Tot. N = total N, C/N = Carbon to N ratio, Av.P = Available P, EA = Exchange Acidity; Eal = Exchangeable Al, CEC = Cation Exchange Capacity, BS = Percent Base Saturation

The soils have a substantial amount of organic C contents (Table 2). These values translate into organic matter contents of 22.8 g kg^{-1} for IMR, 28.1 g kg^{-1} for IGR, 16.9 and 21.6 g kg^{-1} for QIR and CRR floodplains, respectively. The observed values were due to high productivity and reduced decomposition and mineralization rates in wetland environment, resulting in the accumulation of high organic matter in soils (Kyuma, 1985; Patrick, 1990). Table 3 shows that organic matter is the main source of total N and BS and contributes slightly to K and Na concentrations in the soils. Total N levels were low with values in QIR and CRR being lower than in IMR and IGR swamps. The low total N confirms observations by Valiela and Teal (1974) that estuarine wetlands tend to be N limited. The ratio of C/N was relatively high and slightly below 25 being separating index for mineralization and immobilization of N (Paul and Clark, 1989), implying high N content due to mineralization. However, under poor drainage as in hydromorphic conditions, high C/N ratio may not necessarily hinder N mineralization and availability owing to partial decomposition of organic residues by soil organisms.

Available P levels were highest in CRR flood plain and are within the range earlier obtained by Ibia (1995) in some Inland Swamps. Ukpong (2000) reported high available P levels in CRR and Creek Town/Calabar River Swamps. Available P showed mostly significant negative correlations with basic cations (Ca, Mg, K) and CEC (Table 3). On this account, Ukpong (2000) suggested that the nutrient status of the soil may be defined in terms of saturation of the exchange complex by Ca, Mg and to a lesser extent by K. The low level of available P also, suggests that P may be chemically bound as Fe and Al phosphates due to high acidity in the sandy soils (Effiong *et al*., 2006; Ibia and Udo, 1993), or due to absolute low value of soil P (Ogban, 1999) or/and that P is removed by sedimentation (Patrick, 1990).

All the floodplains studied were in or closed to the middle estuarine and are therefore removed from direct tidal influence. This may explain the low level of CEC in the soils since according to Ukpong (2000), tidal imports, distance from the coast, fresh water input, runoff and seepage affect the level of cation concentrations in the soil. CEC values in the soils were low and varied from 1.72±0.38 in CRR to 2.83±0.52 cmol kg^{-1} in IGR swamps. These values are <8-10 cmol kg^{-1} stipulated as indicative minimum values in the top 30 cm of soils for satisfactory production under irrigation (FAO, 1979). High annual precipitation and runoff from adjacent upland areas (i.e., fresh water input), the small amount of basic cations in the parent materials, the low buffering capacity to retain them against leaching and their removal by erosion probably explain the low level of CEC in the floodplains.

Although, CEC was low, percent base saturation was high except in QIR swamp where BS was below 50%, the separating index between fertile and less fertile soils (Landon, 1984). Exchangeable Ca means in the floodplains were <4.0 cmol kg^{-1} regarded as the lower limit for fertile soils. In contract, exchangeable Mg levels varied from moderate to high in the soils with mean values >0.5 cmol kg^{-1}, the indicative minimum for Mg availability (Landon, 1984).

Exchangeable K was the least nutrient in the swamps and positively, though weakly, correlated with organic C. Fagbemi *et al*. (1985) attributed the weak correlation to small contents of K in both organic matter and flood supplies. High rate of K losses have been reported to occur in humid forests when cleared and removed (Likens *et al*., 1994) and in wetlands (IFPRI, 1999). Amberger (2006) reported large losses of K through erosion and leaching, highlighting the need to minimize erosion. Calcium, Mg, K and Na have significant positive intercorrelations among themselves while, only Ca correlated with sand and clay (Table 3). Exchangeable cation ratios, especially Ca Mg^{-1} ratio is

Table 3: Correlation matrix for some soil properties of river floodplains studied

Properties	pH	EC	EA	EAl	OC	TN	Av.P	Ca	Mg	K	Na	CEC	BS	Sand	Silt	Clay
pH	1.000															
EC	0.019	1.000														
EA	-0.398*	-0.292	1.000													
EAl	-0.289	-0.315	0.946**	1.000												
OM	0.312	0.538**	-0.515**	-0.527**	1.000											
TN	0.341	0.523**	-0.532**	-0.538**	0.988**	1.000										
Av.P	-0.039	-0.145	-0.176	-0.141	-0.268	-0.243	1.000									
Ca	-0.297	0.116	0.444*	0.422*	0.123	0.118	-0.498**	1.000								
Mg	-0.184	0.315	0.229	0.258	0.318	0.308	-0.433*	0.896**	1.000							
K	-0.017	0.393*	-0.040	-0.076	0.414*	0.399*	-0.406*	0.576**	0.637**	1.000						
Na	-0.103	0.432*	-0.119	-0.118	0.402*	0.398*	-0.083	0.523**	0.575**	0.812**	1.000					
CEC	-0.237	0.227	0.326	0.314	0.243	0.238	-0.494**	0.976**	0.959**	0.632**	0.579**	1.000				
BS	0.361	0.380*	-0.907**	-0.881**	0.643**	0.675**	0.008	-0.170	0.017	0.073	0.161	-0.049	1.000			
Sand	0.230	0.255	-0.704**	-0.725**	0.462*	0.470*	0.158	-0.420*	-0.308	0.002	0.022	-0.340	0.635**	1.000		
Silt	-0.387*	-0.195	0.564**	0.554**	-0.451*	-0.428*	0.118	0.207	0.128	0.016	0.108	0.163	0.584**	-0.590**	1.000	
Clay	-0.224	-0.370*	0.793**	0.813**	-0.651**	-0.675**	-0.161	0.381*	0.242	-0.009	-0.080	0.289	-0.785**	-0.841**	0.607**	1.000

known to affect the growth of plants. The appropriate maximum range of Ca Mg^{-1} ratio is 3:1-4:1 (Landon, 1984). The mean value calculated for these floodplains was the same (2:1). This low value may indicate low availability of Ca and this could lead to the weakening of the soil structure due to deflocculation of the clay particles by the abundant Mg ions.

Fertility evaluation of the floodplains for crop production: FAO (1976) uses some important soil characteristics, namely; texture, CEC, organic matter, total N, available P, 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 very low in total N, available P (except CRR) and exchangeable K. Only organic matter is moderately high in availability in all the soils. According to FAO (1976) ratings, the soils are low in fertility and cannot sustain arable crop production efficiently. IGR floodplain is grouped in S_1 while, IMR, CRR and QIR are in S_2 categories described as highly and moderately suitable for crop production, respectively with respect to organic matter, pH and available P while, QIR belongs to S_3 group (marginally suitable) with respect to available P. In terms of texture and total N all the floodplains are placed in S_3 category (marginally suitable) whereas QIR is grouped in S_1 category (highly suitable) with respect to texture of the soil. Exchangeable K and CEC levels were very low and therefore constitute constraints for crop production.

Potentials, constraints and management of floodplains for crop production: Some important fertility parameters like exchangeable K, CEC, total N, exchangeable Ca and pH (high acidity) constitute the main constraints of these floodplains to crop production. These soils are however, moderately suitable for the cultivation of short season crops such as vegetables-tomatoes, pepper, garden egg, water leaf and others during the short dry period (November-March) carried out by women. Apart from gathering sea foods from the swamps, these soils are however, (marginally) suitable for paddy rice production. Palm wine tapping, distilling and hunting are also, important providers of male incomes while, women provide most of the manual labour for cash as well as performing important marketing functions. These swamps are natural resources for wild life (including birds), numerous medicinal plant species, spices and various wild vegetables and fruits, which are generously utilized by rural dwellers.

The levels of organic C, exchangeable Mg and percent base saturation are high at the present level of subsistent farming. However, when the lands are cleared, burnt and cultivated, they are exposed to high rate of organic C decomposition and mineralization and losses from harvest, erosion and leaching occur under the high temperature and moisture conditions in the area. For high yield of crops, the use of mineral fertilizers will be recommended because fertilizer can promote and sustain the ability of soils to grow crops. However, fertilizer is both unaffordable and unavailable during critical periods because the importation of fertilizer is expensive due to shipping costs. Consequently, although mineral fertilizers can enhance and increase yield/unit area of land, they are playing a less than significant role in boosting food production by the predominantly peasant low resource farmers who traditionally substantially produce the food needs of the rapidly growing population (Ogban and Babalola, 2003) with little or no fertilizer use. The farmers thus, rely on soils nutrient mining (nutrient inflows<nutrient outflows) or local environmental resource in the traditional farming systems. Soil nutrient mining (depletion) is a major bottleneck to increased land productivity and has largely contributed to poverty and food insecurity (Gichuru, 2003). The farmers should

therefore be encouraged to use resources found on the farms to develop a sustainable or regenerative agricultural production system, instead of relying on inputs that are normally not accessible (Francis *et al*., 1986).

Mulching will ordinarily be recommended because of the abundant biomass (Agboola, 1978), but mulching is not an agronomic practice in the traditional farming systems practiced, although it can be accepted and adopted routinely when the benefits are demonstrated (Ogban and Babalola, 2003). On the alternative, the farmers can harness the benefits of biofertilizers. These fertilizers, according to FAO (1988), are those organisms and their ymbiotic systems, which continue to grow and improve the *in-situ* fertility of the ecosystem, in which they grow. However, the awareness of the beneficial role of the uses of biofertilizer as cheap alternative to inorganic fertilizer is limited. Their greatest potentials lies in N fixation by the various biological systems including free-living bacteria, Cyanobacteria, associative bacteria, Azolla/Anabaena, Frankia and legume/Rhizobium (Eikan, 1992). The use of such natural products as biofertilizer according to Yadav *et al.* (2001) will not only increase crop yields by 20-30%, replace chemical N and P by 25%, stimulate plant growth, activate the soil biologically, restore natural fertility, provide protection against some soil borne diseases, but also safeguard the soil health and quality of crop products.

Vesicular Arbuscular Mycorrhiza (VAM) improves crop production primarily trough enhanced P uptake, especially in P-deficient soils such as those in this study.

CONCLUSION

The need to expand food production from upland soils with declining productivity to seasonally and perennially wetland soils necessitated the study of the characteristics, potentials and constraints to crop production of some river floodplains soils in southeastern Nigeria. The soils are moderately to strong acid and suffer from multiple nutrient deficiencies. The most important constraints to crop production in these floodplains are the high acidity and low chemical fertility. These constraints can be alleviated by the use of mulching and other natural products (biofertilizers) to enhance N and P availability. These microbial inoculants (biofertilizers) have great potentials as supplementary renewable environmental friendly source of plant nutrients and production cost is minimal. This study has demonstrated the relatively moderately high potentials of river floodplains, which can be harnessed to relieve some of the pressures on upland soils, which are being rapidly degraded.

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