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Assessment of properties and agricultural potentials of some hydromorphic soils in Katcha Local Government Area of Niger State, Nigeria

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Abstract

Seasonal deposition of fluvial materials and high soil moisture makes floodplains a unique ecosystem for all season production. Soil properties of three hydromorphic sites, Gbakogi, Katcha and Kashe, along the banks of river Niger and its tributary, Gbako River, in Katcha Local Government Area of Niger State of Nigeria were assessed. In all sites, sand dominated the mineral fraction and its contents ranged from 578 - 658, 413 - 473 and 432 - 453 g kg^{-1} respectively for Gbakogi, Katcha and Kashe. In the same order, silt was 90 - 180, 173 - 353 and 133 - 173 g kg^{-1} and clay was 242 - 249, 334 - 354 and 294 - 414 g kg^{-1}. Soil reaction for the surface soils was moderate to slightly acid ($pH \leq 6.4$). Available phosphorus (P) was higher at the surface than subsurface horizons except in Kashe. The P values for surface horizons were 35, 26 and 12 mg kg^{-1} and were rated high in Gbakogi and Katcha and low in Kashe. Total nitrogen (N) was 0.07, 0.28 and 0.14 g kg^{-1} and was rated low in Gbakogi, high in Katcha and medium in Kashe. Organic carbon (C) was low irrespective of soil depth in all the sites and the values were ≤ 1.53 g kg^{-1}. Exchangeable bases and effective cation exchange capacity (ECEC) were rated high in all the soils. Percentage base saturation was rated medium to high. On the basis of soil attributes measured, all the sites have good potentials for sustainable arable agriculture.

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Introduction

Fadama is the Hausa name for hydromorphic lands in floodplains and low lying areas underlain by shallow aquifers (Jibrin, 2010). In Nigeria, fadama ecosystem was estimated to cover 65,785 km^2, equivalent to 7.2 % of the total land area of the country (Ojanuga *et al.*, 1996). Fadama have potential for all season agricultural production and are capable of supporting intensive cultivation of crops and grazing of livestock in Nigeria (Bello, 2006). Their high level of moisture in terms of ground/residual water even during the dry season or under drought conditions, allows water loving crops such as swamp rice to be grown in rainy seasons and vegetables during dry seasons (Singh, 1999; Idoga, 2006). Despite the potentials of fadama for all season farming, farmers prefer to cultivate the more easily exploitable uplands than fadama soils because of numerous challenges which include water-logging condition, low pH values, low phosphorus values and problem of salinity/sodicity among others (Onyekwere *et. al.*, 2001). Yet when fadama lands are put to use properly, their capacity to contribute to food security can be substantial in the long term (Ojanuga, 2006a).

Niger State of Nigeria has about 110,000 ha of fadama equivalent to about 3.5 % of its total land area (Gwarry, 1995). Katcha is one of the Local Government Areas (LGAs) in the southern part of the state inundated by river Niger and many of its tributaries. Thus, the fadama ecosystems in Katcha LGA over the years are being used commonly for the growing of paddy rice, vegetables and sugarcane under rain-fed condition. Available information for the study area concerns only the adoption of rice cultivars by farmers (Jirgi *et. al.*, 2009) and none concerning the inventory of soil resources of the area. Therefore, this work essentially was undertaken to assess some properties of soils of three fadama sites in Katcha LGA of Niger State, Nigeria, with a view to generating data that would aid in their optimum and sustainable exploitation for agriculture.

Materials and Methods

Katcha LGA is occupying an area of 1,681 km^2 in the southern part of Niger State, Nigeria. The study site is located by latitude 09° 09□ N and longitude 06° 14□ E in the southern Guinea savanna belt of Nigeria. The area was described as an extensive flat to very gently undulating lowlands with broad interfluves over very deep weathered Nupe sandstones. The soils are poorly drained gray soils classified as Dystric Fluvisols and are predominantly cropped to rice with annual rainfall ranging between 1182 and 1301 mm that usually covers the months of May and October (Ojanuga, 2006b).

Three hydromorphic (fadama) sites namely Gbakogi, Katcha and Kashe were identified from the baseline survey map of hydrogeology and soils of Niger State. Soil samples were collected along diagonal transects from each site at 0 - 15 cm and 15 - 30 cm depths, bulked together to form a composite sample for each site. The soil samples were analysed for physical and chemical properties and their chemical values rated according to Esu (1991) and Chude *et. al*. (2011).

The soil samples were air-dried and gently crushed to pass through a 2 mm sieve and some were further passed through 0.5 mm sieve for organic carbon (C) and total nitrogen (N) determination. Soil samples were subjected to analysis using standard methods as outlined in ISRIC/FAO (2002). Briefly, particle size distribution was determined by Bouyocous hydrometer method; pH in H_2O using 1:2.5 soil water ratio; organic C content by the Walkley-Black method; total N by Kjeldahl method; available phosphorus (P) by Bray P-1 method. Exchangeable cations, calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na), were extracted in ammonium acetate at pH 7. Ca and Mg were determined by atomic absorption spectrophotometry while K and Na were determined by flame photometry. Effective cation exchange capacity (ECEC) and base saturation were by calculation.

Results and Discussion

Soil physical properties

Data on particle size distribution of the soils is graphically shown in Fig. 1. Sand content ranged from 578 - 658, 473 - 413 and 453 - 432 g kg^{-1} for Gbakogi, Katcha and Kashe respectively. Except in Gbakogi, proportion of sand decreased with soil depth. This may be attributed to differences in sorting soil material by pedogenic and geological processes. However, in all sites sand was observed as most dominant mineral fraction in the soils. This may partly be attributed to the parent materials, cretaceous Nupe sandstone, the soils were derived from. According to Brady and Weil (2002), sandstone parent material usually gives rise to soils with high sand particle content. Also, the high sand content in the studied soils may be due to fresh seasonal cycle deposition of alluvial materials (Esu and Akpan-Idiok, 2010). In the same order as in sand, silt ranged from 90 – 180, 173 – 353 and 133 – 273 g kg^{-1}. With exception of Gbakogi, silt increased with soil depth due reason earlier explained. High contents of silt particles in the subsurface soil of Katcha and Kashi may encourage formation of micro-pores spaces with little room for water to flow into and within the soils making it difficult to drain (Miller and Donahue, 1992; Omar, 2011). Similarly, clay content ranged from 242 – 249, 334 – 354 and 294 – 414 g kg^{-1}. Except in Gbakogi, clay fraction was higher in the surface than subsurface with no evidence of clay migration within sampled depth. Silt/clay ratio was greater than 0.25 in all samples which implied that the hydromorphic soils assessed were relatively young. It also means that they may still have in them weatherable minerals needed for plant nutrition (Asomoa, 1973; Edem and Ndom, 2001). The textural class of the surface horizons was sandy clay loam for Gbakogi and Katcha and sandy clay for Kashe.

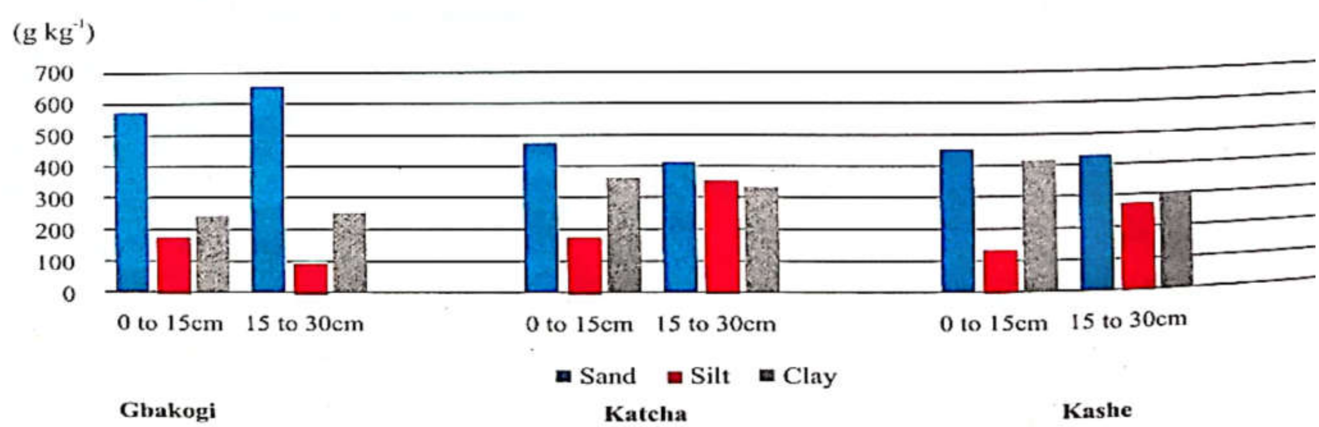

Figure 1: Particle size distribution of the soils of the selected hydromorphic sites in Katcha LGA, Niger State, Nigeria

Soil chemical properties

Results of some chemical properties are shown in Table 1 and their interpretation was based on Esu (1991) and Chude *et al*. (2011) (Table 2). The soil reaction was moderately acid in Katcha, pH 5.0, slightly acid in Gbakogi, pH 6.4, and Kashe, pH 5.8. The low pH may be attributed to their silica-rich parent material (Ojanuga, 2006a). A pH range of 5.5 - 7.0 was established to be optimum for the release of most plant nutrients (Brady and Weil, 2010). Consequently, low pH, especially in soils of Katcha may affect availability of some essential plant nutrients. In acid soils all nutrient elements except iron, manganese and zinc are deficient (Brady and Weil, 2010). Therefore, soil pH needs to be raised to fall within the established range to avoid acidity related problems.

Organic carbon (C) content in the surface soil was 0.47, 1.25 and 1.32 g kg^{-1} for Gbakogi, Katcha and Kashe respectively and it was rated low for all sites irrespective of soil depth. On the contrary, Ojanuga (2006a) had stated that fadama soils usually have relatively high levels of organic C due to seasonal flooding and deposition of alluvium. Thus, the low contents of organic C in all the assessed soils may either be attributed to decline in soil organic matter content as a result of intensive agricultural activities through clearing and clean cultivation of soils for annual cropping (Greenland *et. al*., 1992) or may be as a result of rapid decomposition and mineralization of organic matter under high temperature and moisture conditions (Ogban and Ekerette, 2001; Olowolafe and Kazeem, 2007) or both. In terms of organic C distribution within the soils, it was slightly more in the subsurface soil than the surface probably due to eluviation and illuviation processes. Content and distribution of available phosphorus (P) varied among the three hydromorphic sites. The P values for the surface soil were 35, 26 and 12 mg kg^{-1} for Gbakogi, Katcha and Kashe respectively and were rated moderate to high. Moderate to high P levels in the soils may be due to application of P-containing fertilizers by farmers because organic C content was low in all the soils assessed. However, a fairly uniform distribution of P observed in soils of Kashe may be due to mixing of the soil and fertilizer P during consistent deep tillage practices (Andraski *et. al*., 2003). Total nitrogen (N) content for soils of Gbakogi, Katcha and Kashe was all rated low at the surface and high in the subsurface. Similar to organic C, the total N increased with depth in all the soils and this may partly be linked to leaching of soluble N in nitrate form through seasonal flooding of these fadama sites. Since organic matter account for between 90 and 98 % of soil nitrogen (Konnovora *et. al*., 1966), higher amounts of N in the subsurface may also be attributed to eluviation and illuviation process involving organic matter. The carbon-nitrogen (C:N) ratios of the soils were < 20 for all the sites. The implication of this low C:N ratios may favour nitrogen mineralization in the soils (Brady and Weil, 2010).

Table 1: Chemical properties of the selected hydromorphic soils in Katcha LGA, Niger State, Nigeria

Location	Soil Depth (cm)	pH (H_2O)	Av. P (mg kg^{-1})	Total N	Org. C	C/N	Exch. bases (cmol kg^{-1})				Ex. Ac.	ECEC	% BS of ECEC
				(g kg^{-1})			Ca	Mg	K	Na	(cmol kg^{-1})		
Gbakogi	0 – 15	6.4	35	0.07	0.47	6.71	2.96	2.00	0.05	0.28	3.20	8.49	62.31
	15 – 30	6.0	5	0.39	0.54	1.38	9.72	4.94	0.10	0.63	5.60	20.99	73.32
Katcha	0 – 15	5.0	26	0.28	1.25	4.46	4.00	4.64	1.07	0.61	2.46	12.72	81.13
	15 – 30	5.4	7	0.42	1.50	3.57	5.28	4.00	0.78	0.65	3.60	14.31	74.84
Kashe	0 – 15	5.8	12	0.14	1.32	9.43	6.00	4.08	1.80	1.00	4.00	16.88	76.30
	15 – 30	4.8	14	0.21	1.53	7.29	4.00	3.52	0.51	1.37	3.20	12.60	74.60

*Av.P = available phosphorus; Total N = total nitrogen; Org. C. = organic carbon; Ex.Ac. =exchangeable acidity; ECEC = effective cation exchange capacity; BS = base saturation.

Table 2: Critical limits for interpreting levels of analytical parameters

Parameter	Low	Medium	High	Source
pH:				
Strongly Acid -	5.0 – 5.5			*
Moderately Acid -	5.6 – 6.0			"
Slightly Acid -	6.1 – 6.5			"
Neutral -	6.6 – 7.2			"
Slightly Alkaline -	7.3 – 7.8			"
Ca^{2+} ($cmol_{(+)}$ kg^{-1})	< 2	2 – 5	> 5	**
Mg^{2+} ($cmol_{(+)}$ kg^{-1})	< 0.3	0.3 – 1	> 1	"
K^{+} ($cmol_{(+)}$ kg^{-1})	< 0.15	0.15 – 0.3	> 0.3	"
Na^{+} ($cmol_{(+)}$ kg^{-1})	< 0.1	0.1 – 0.3	> 0.3	"
CEC ($cmol_{(+)}$ kg^{-1})	< 6	6 – 12	> 12	"
Org. C (g kg^{-1})	< 10	10 – 15	> 15	"
Total N (g kg^{-1})	< 0.1	0.1 - 0.2	> 0.2	"
Avail. P (mg kg^{-1})	< 10	10 – 20	> 20	"
B.S (%)	< 50	50 – 80	> 80	"

Source: *Chude *et. al*. (2011); **Source:Esu (1991).

Calcium (Ca) ranged from 2.96 - 9.72, 4.00 - 5.28 and 4.00 - 6.00 cmol kg^{-1} in Kashe for Gbakogi, Katcha and Kashe respectively and was rated high except for the surface horizon of Gbakogi which was medium. In all samples, Ca dominated the exchange sites probably because the alluvial materials from which the studied soils were derived, originated from sedimentary rocks, Nupe sandstones, rich in secondary minerals such as calcite or dolomite. In all the sites, magnesium (Mg) was rated high irrespective of soil depth, and Mg content was more in the surface than subsurface soil except in Gbakogi. Values for Mg were 2.00 - 2.94, 4.00 - 4.64 and 3.52 - 4.08 cmol kg^{-1} for Gbakogi, Katcha and Kashe respectively. Potassium (K) was low in Gbakogi, and high in Katcha and Kashe with values of 0.05 - 0.10, 1.07 - 0.78 and 1.80 - 0.51 cmol kg^{-1}. Similarly, sodium (Na) was rated high in all the sites except the surface horizon of Gbakogi where it content was rated medium. The values for Na were 0.28 - 0.63 cmol kg^{-1}, 0.61 - 0.65 cmol kg^{-1} and 1.00 - 1.37 cmol kg^{-1} for Gbakogi, Katcha and Kashe respectively. In all site, Na content increased with soil depth. The three studied soils are potentially sodic and hence the need for their proper management in order not to raise the Na to a level that may destroy the soil structure. Omar (2011) suggested incorporation of organic materials, crop residues and or farmyard manure into such soil to reduce Na ion concentration in them. The effective cation exchange capacity (ECEC) values ranged from 12.60 - 20.99, 12.72 - 14.31 and 12.60 - 16-88 cmol kg^{-1} respectively for Gbakogi, Katcha and Kashe. The ECEC in all the soils was rated high except in the surface horizon of soils of Gbakogi where it was rated as medium. The medium to high ECEC values was probably as a result of fairly high clay content in the soils. Base saturation was 62.31 - 73.32, 74.84 - 81.13 and 74.60 - 76.30 % for Gbakogi, Katcha and Kashe respectively. Percentage base saturation of the soils was rated medium except the surface soil of Katcha which marginally high. The result implied that leaching of plant nutrients was moderate in these soils (Lawal *et. al*. (2012). Also, Atofarati *et. al*. (2012) described medium to high percentage base saturation to reflect the dominance of basic cations in the exchange complex.

Conclusion

The soils of the three sites have clayey properties which accounted for their high exchangeable bases and high ECEC. However, their low organic C and high Na content may impact negatively on the soil structure. Therefore, these two properties, organic C and Na, may require special attention in the management of these hydromorphic soils in order not to destroy the soil structures. In addition, incorporation of organic matter may also improve nutrient supply especially organic C, P and N. Thus, this study advocate strongly a farming system which may encourage recycling of crop residues or incorporation of manures or organic fertilizers to the soils. Other soil properties such as available P and basic cations were rated medium to high. More importantly, high ECEC and percentage base saturation were good index indicating that the soils of the three hydromorphic sites assessed have high capability to effectively retain and release plant nutrients. These soils may therefore be rated as having potentials for optimum and sustainable exploitation for arable agriculture.

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