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FERTILITY STATUS OF FLOODPLAIN SOILS ALONG RIVER *TATSEWARKI*, KANO, NIGERIA

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ABSTRACT
A study was carried out on the floodplain soils along RiverTatsewarki, Kano, Nigeria to assess their fertility status to serve as a guide to farmers for increased and sustainable crop production in the area. An area of 1.5 km x 0.5 km, at the downstream portion of the river was purposely selected for the study. Composite soil samples were collected from 0 – 20 cm and analyzed for their physical and chemical properties using standard methods. Results indicated that the soils were generally sandy with sandy loam to loam texture dominating across the sections. The soils were slightly alkaline in reaction, but non-saline and non-sodic. The soils were also poor in fertility with generally low exchangeable Ca (0.047 to 0.089 cmol/kg), Mg (0.025 to 0.120 cmol/kg), K (0.008 to 0.040 cmol/kg), total N (0.5 to 0.8 g/kg) and OC (2.93 to 11.17 g/kg) across the sections. It is recommended that inorganic fertilizers, especially nitrogenous fertilizers, should be applied as well as incorporation of crop residues and/or manures especially at the upstream so as to improve the nutrient status of the soils for increased and sustainable crop production in the area studied.
Key words: Floodplain, Fertility, Properties, River Tatsewarki

INTRODUCTION

A floodplain is an area of land adjacent to a stream or river that stretches from the banks of its channel to the base of the enclosing valley walls and experiences flooding during periods of high discharge (Singh, 2001).Thus floodplain soils are soils that are found in floodplains. Technically floodplain soils are Fluvisols (FAO, 1974) or Fluvents (USDA, 1994). They are classified as hydromorphic (D'hoore, 1964) or fadama soils (Babaji, 2000) and are also referred to as soils of alluvial lowlands (FAO, 1991). Their properties vary from coarse to fine in texture, from acid to alkaline in reaction and from rich to poor in nutrient status indicating varying levels of fertility.However, they are mostly fertile (FAO, 1991) and their productivity is greatly increased through irrigation with good quality water. The soils are texturally finer and nutritionally richer than upland soils (Singh and Babaji, 1989, 1990). They provide a wide variety of medium to fine textured soils with reasonably good hydraulic properties, and therefore, provide farmers with a range of soil resource options suitable for different types of high value agronomic and horticultural crops. The significance of these soils in arable farming rests heavily on the fact that they contain high level of soil moisture (residual moisture) even during the dry season or drought. The ground water table is invariably close to the soil surface. Due to the characteristic moisture retention within or very close to the rhizosphere for greater part of the year, they are described as wetland soils (Scoones, 1992). However, these soils are poorly drained and flood-prone in several areas. The soils are developed from recent fluviatile, lacustrine or marine deposits, particularly in periodically flooded places; they are widely distributed, occur in all climates and essentially receive fresh sediments hence are regularly rejuvenated (FAO, 1991).Some flood-plain soils, those developed in marine or brackish water sediments, contain pyrite and may turn extremely acid when drained (thionic Fluvisols, commonly called acid sulphate soils) (Bhargava and Abrol, 1984; FAO, 1991).

In Nigeria, agricultural potentials of flood-plain have since been recognized by the Federal Government (FG) through the establishment of the National Fadama Development Programme (NFDP). This is timely and in line with the FG's agenda of diversifying the country's economic base to agricultural sector to address issues of food insecurity, poverty alleviation, unemployment and dwindling oil revenues. There is the need to assess the fertility status of these soils. Without maintaining soil fertility, one cannot talk about increment of agricultural production in feeding the alarmingly increasing population. Therefore, to get increased and sustainable crop production, soil fertility has to be maintained (Foth and Ellis, 1997) particularly in the study area where only little scanty data exist. The study is an attempt in this direction.

MATERIALS AND METHODS

Description of Study Area

The study was carried out on the floodplain soils along *River Tatsewarki* of Kano, Nigeria.

The study area is located on latitudes 11^{o} 53″ 20″ N to 11^{o} 56″ 40″ N and longitudes 8^{o} 30′ 0″ E to 8^{o} 33″ 20″ E (Figures 1 and 2). *River Tatsewarki* is one of the main drains in the southern part of Kano draining into River Challawa and conveys it to *River Challawa*(Bichi and Anyata, 1999). The area has an average elevation of 412 m above sea level, and the total length of this river has been estimated to be about 18.6 km; covering a longitudinal distance of about 12.3 km.

The study area is located within the savannah agro-ecological zone of West Africa. The climate is classified as tropical savannah. The area falls within the northern part of the Kano region with four distinct seasons namely; the dry and cool season, the dry and hot season, the wet and warm season (rainy season), and the dry and warm season as described by Olofin (1987). The mean annual rainfall is about 600 mm to 750 mm received between May and October in a normal year. The mean annual temperature ranges from 23 ^{o}C to about 26 ^{o}C in the coolest season and 27 ^{o}C to 33 ^{o}C in the hottest season (Olofin, 1987).

The dominant land use in the area includes residential, commercial, industrial, urban and peri-urban agriculture.The major crops grown under rain fed agriculture include maize, sorghum and millet. Some areas are also densely populated with tree crops such as mango and guava.

Field Work

A pre-sampling reconnaissance survey of the study area was conducted to identify prospective soil sampling sites and to put logistics in place prior to soil sampling.An area of 1.5 km × 0.5 km (75 ha) in the downstream portion of the river was selected for sampling. The Google Earth Satellite Imagery (Figure 1) and Global Positioning System (GPS) were used to demarcate the extent of the area.

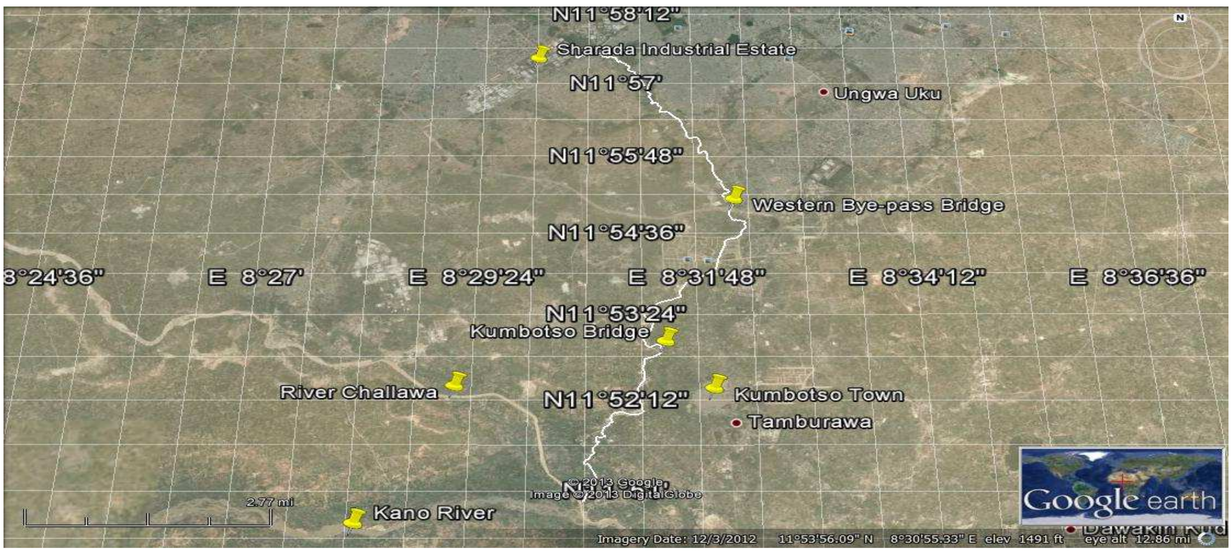

Fig. 1 Google satellite image of the study area outlining the effluent flow path.

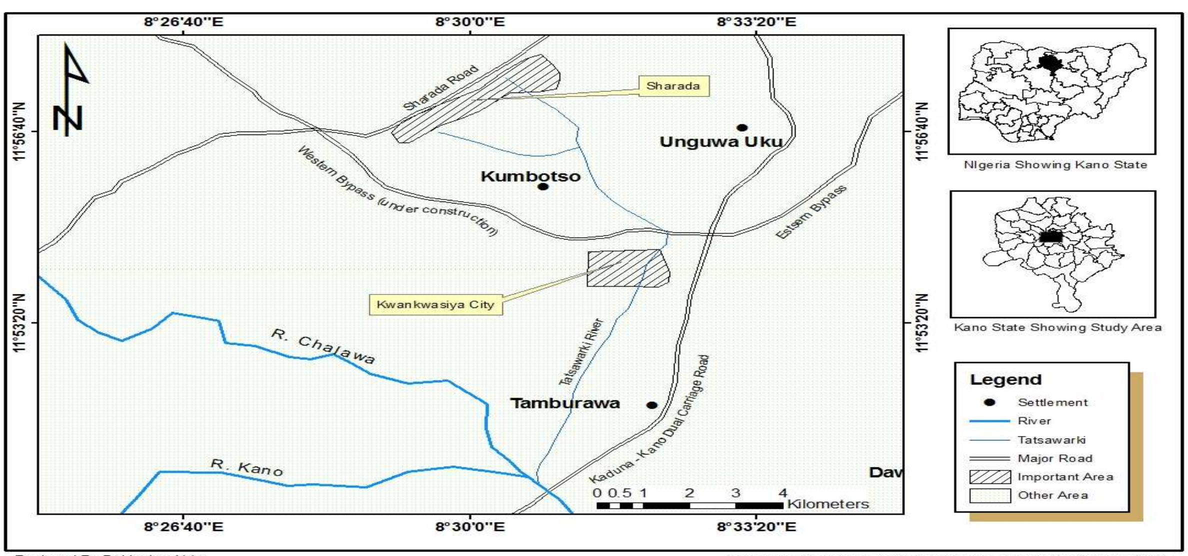

Fig. 2. A sketch map showing the location of Kano State and the study area.

The selection was based on the fact that settlements have overtaken most of the up- and mid-stream portions of the river from the source. The selected sampling site of the river floodplain was divided into three sections namely; up-stream, mid-stream and down-stream. Three farms were sampled along the floodplain at 20, 70 and 120 m intervals in each of the three sections selected and composite surface soil samples were collected from 0 - 20 cm using soil auger for analysis. Similarly undisturbed soil samples were collected using core samplers for determination of soil bulk density.

SOIL ANALYTICAL METHODS

Physical Properties

The particle size was determined using the Bouyoucous hydrometer method (Bouyoucos, 1962). Bulk density was determined using the following formular:

$$Bulk density = \frac{Mass of ovendry soil}{Bulk volume of soil}$$

Particle density of soil samples was determined by the pycnometer method as described by Blake and Hartage (1986).

$$Particle density = \frac{Mass of ovendry soil}{volume of soil particles}$$

Total porosity was calculated using the formular:

$$f = \left(1 - \frac{\rho_b}{\rho_s}\right) x\ 100$$

Chemical Properties

The soil pH was determined in soil water ratio of 1:2.5 by using glass electrode pH meter (Mc lean, 1965) while total nitrogen (N) and available P (phosphorus)were determined using the methods described byBremmer (1965) and Bray and Kurtz (1945), respectively.Organic carbon (OC) was determined by wet oxidation method as described by Nelson and Summers (1982). Exchangeable bases (Ca, Mg, K and Na) were extracted using the method described by Anderson and Ingram (1993). Potassium and sodium was determined using flame photometer while calcium and magnesium was determined using atomic absorption spectrophotometer. The electrical conductivity (EC) was determined using saturated paste extract of 1:2.5 soil water ratio using electrical conductivity meter at 25^{o}C (Bower and Wilcox, 1965).The cation exchange capacity (CEC) was determined with 1 m ammonium acetate saturationmethod (Chapman, 1965).

DATA ANALYSIS

The data obtained was subjected to analysis of variance (ANOVA) using the SAS statistical package (SAS, 1999).

RESULTS AND DISCUSSION

There was significant ($P < 0.05$) variation in the sand content in the mid and downstream sections. The sand fraction showed a decreasing pattern downslope.The soils are generally sandy at the upstream. Both silt and clay fractions increased downslope with the clay content showing significant ($P < 0.05$) variation in the sections.There was great variability ($P < 0.01$) in the distribution of bulk density across the sections (Table 1).

In the upstream, it decreased from 1.45 (70 m) to 1.41 (120 m) g/cm^3 and from 1.41 (20 m) to 1.29 (120 m) g/cm^3 at the midstream.Soil reaction varied significantly ($P < 0.01$) across the sections showing slight alkalinity and ranged from 7.3 to 8.0.The EC was low across the sections despite its significant variation.There was a significant ($P < 0.05$) variation in the CEC of the soils across the sections. An increasing trend with distance was also observed (Table 2). In the up, mid and downstream it ranged from 6.27 (20 m) to 11.30 (120 m) cmol/kg, 8.00 (20 m) to 13.03 (120 m) cmol/kg, and 8.47 (20 m) to 12.93 (120 m) cmol/kg, respectively.Exchangeable Ca, Mg, and K were low and did not vary across the sections (Table 1).Exchangeable Na is relatively high.The exchangeable sodium percentage, available P, Total N, and organic carbon showed no variation across the sections.However, available P increased down slope. The ESP was low ranging from 7.91 (downstream) to 14.11 (upstream). Available P was moderate but low at upstream (20 m) and midstream (20 m) and at downstream (70 m). Both total N and OC were observed to be low across the sections. However, OC was moderate at 120 m (10.71 g/kg; midstream) and 120 m (11.17 g/kg; downstream).

Physical Properties

Table 1 shows the effect of distance by sections on soil physical properties of floodplain soils of River Tatsewarki at Kano. It decreased from 61.7 (20 m) to 60.3 (120 m) % in the upstream; while in the mid and downstream the sand content decreased from 53.1 (20 m) to 49.0 (120 m) % and from 39.2 (20 m) to 25.1 (120 m) %, respectively.

This is in agreement with the findings of Paton (1978).The higher sand content at the upstream and increased silt and clay contents downstream can be attributed to transportation of finer soil materials by water. This clearly indicates that the soils at the upstream are less fertile due to high sand than those at the mid and downstream containing higher silt and clay fractions (Table 1). of low fertility due to the high sand content compared to silt and clay especially at the upstream.Havlin*et al.* (2005) reported that finer textures accumulate more organic matter which is related to high soil fertility.

The higher bulk density observed at the upstream is in agreement with the report of Mathan (1994) that soil bulk density is generally higher in top soils. The soil bulk density range (1.40 to 1.45 g/cm^3) observed at the upstream, where the soils were earlier observed to be sandy, falls within the range of 1.3 to 1.8 g/cm^3 reported by Mahilum(2004) for sandy soils. The bulk density values suggested that these soils are not compacted. This is in full agreement with the report of Brady (2002) that the bulk density of compacted soils ranges from 1.8 to slightly above 2.0 g/cm^3.

The implication of this is that the soils have good drainage and permeability which in turn enhance their fertility. This is further supported by the findings of Singh and Babaji, (1989, 1990) that floodplain soils have good hydraulic properties. There was highly significant ($P < 0.01$) variability in the particle density across the sections and distribution followed the same pattern as with bulk density (Table 1). There was no significant variation observed in the distribution of total porosity in the sections.

Chemical properties

The effect of distance by section on chemical properties of floodplain soils at Kano is presented in Table 2. Soil reaction varied significantly ($P < 0.01$) across the sections showing slight alkalinity and ranged from 7.3 to 8.0.This is contrary to the findings of Omar (2010) who reported that floodplain soils in South Western Bauchi State showed moderate acidity ranging from 5.46 to 6.36.The contradiction may be due to the frequent deposition of different materials during flooding which may cause variations in the soil reaction. The soil reaction fell outside the range of 5.5 to 6.5 reported to be optimum for the release of plant nutrients (Odunze*et al.* 2006).This means that the soils are poor in fertility implying also that the soils may respond to fertilizer application. The EC was low across the sections despite its significant variation. The soils are therefore not saline.

An increasing trend in CEC with distance was also observed (Table 2). In the up, mid and downstream the CEC ranged from 6.27 (20 m) to 11.30 (120 m) cmol/kg, 8.00 (20 m) to 13.03 (120 m) cmol/kg, and 8.47 (20 m) to 12.93 (120 m) cmol/kg, respectively. The general increase downslope is expected because finer particles associated with higher CEC values are moved downslope by either wind or flowing water. The CEC was observed to be moderate. The CEC measurements indicate overall assessment of the potential fertility of a soil andpossible response to fertilizer application. Soils with a CEC of <16 meq/100 g are considered infertile while fertile soils have a CEC of >24meq/100 g (Gachene and Kimaru, 2003).This implies that the soils are infertile as observed earlier. Exchangeable Ca, Mg, and K were low and did not vary across the sections (Table 1).The relatively high exchangeable Na may be due to the slight alkalinity of the soils. Thus the soils are once again considered low in fertility.The CEC was lower than CEC values reported for floodplain soils of Bauchi State (11.21 to17.68 cmol(+)kg^{-1}) reported by Omar (2010) but very much higher than 9.4 cmol (+)kg^{-1} for floodplain soils in Kebbi State(Singh, 1999) . The lower values observed for the soils under study may not be unconnected with the low values of exchangeable Ca, Mg, and K (Table 2). Similarly, higher values of exchangeable bases were reported for similar soils in Bauchi State (Omar, 2010).

Table 3 shows the distribution of ESP, available P, total N and OC in the study soil. The lack of variation in the exchangeable sodium percentage, available P, Total N, and organic carbon across the sections means that distance along the river had no effect on the distribution of these parameters. No particular pattern of distribution was observed. However, available P increased down slope. The ESP was low ranging from 7.91 (downstream) to 14.11 (upstream). The United State Salinity Laboratory Staff (1954) reported thatsoils with ESP lower than 15% are rated as non-sodic. This implies that the soils under study are non-sodic. Available P was moderate but low at upstream (20 m) and midstream (20 m) and at downstream (70 m). The general increase down the slope may be attributed to washing effect by flowing water down slope. Both total N and OC were observed to be low across the sections. However, OC was moderate at 120 m (10.71 g/kg; midstream) and 120 m (11.17 g/kg; downstream). Kparmwang (1996), Usman and Abdulmumini(1998), Odunze*et al.* (2006) and Omar (2010) reported moderate content of available P in similar soils. The moderate content of available P may be attributed to the slightly alkaline soil reaction (Table 1) which tends to promote P release.Akamigbo*et al.* (2005)attributed high phosphate potential of soils to low fixation rate of the phosphate ion in the soil.

The low total N observed is in conformity with the report of Kwari and Dada (2000) for floodplain soils of Bauchi State. The low nitrogen content of these soils could be probably due to the continuous leaching as a result of the seasonal flooding and the resultant anaerobic conditions during the flooding (Usman and Abdulmumini, 1998). The soils are likely to respond to nitrogen fertilization (Rending and Taylor, 1989). Even though the OC was observed to be low, it increased with distance within each section and down slope (Table 3) just like the case with silt and clay (Table 1). This is expected because finer soil particles are associated with OC as also observed by Singh (2001).The implication is that even though the soils are poor in fertility, they are more fertile at the bottom of the slope. The low OC may not be unconnected with the low total N (Table 3).Jones and Wild (1975) reported that the amount of nitrogen mineralized is approximately proportional to the total amount of organic matter present in the soil.

Table 1. Effect of Distance by Sections on Soil Physical Properties of floodplain Soils of River Tatsewarki, Kano, Nigeria.

DISTANCE/SECTION	Particle Size Analysis %Sand	%Silt	%Clay	Texture	BD (gcm^{-3})	PD (gcm^{-3})	Tot. Porosity (gcm^{-3})
Upstream							
20m	61.7a	24.88	13.4b	Sandy loam	1.40ab	2.60a	45.87
70m	61.7a	24.88	13.4b	Sandy loam	1.45a	2.55a	43.23
120m	60.3a	22.21	17.4ab	Sandy loam	1.41ab	2.50abc	43.52
Midstream							
20m	53.1ab	32.59	14.3b	Loam	1.41ab	2.55a	44.56
70m	49.7ab	32.88	17.4ab	Loam	1.40ab	2.42abc	42.15
120m	49.0ab	22.21	28.8ab	Sandy Clay/Loam	1.29abc	2.52abc	48.76
Downstream							
20m	39.2ab	38.00	22.8ab	Loam	1.42ab	2.44abc	41.82
70m	31.8ab	40.67	27.5ab	Loam	1.40ab	2.33bc	40.11
120m	25.1b	40.29	34.6ab	Loam Clay Loam	1.23bc	2.33bc	46.92
LSD	17.71 *	13.199	16.88 *		0.112 **	0.122 **	5.371

Means within a column followed by the same letter(s) are not significantly different at p≤0.05 by Least significant Difference.
*= Significant, **= highly significant

Table 2. Effect of Distance by Sections on Soil Chemical Properties of Floodplain soils of River Tatsewarki Kano, Nigeria.

DISTANCE/SECTION	$pH(H_20)$	$pH(CaCl_2)$	EC(dsm^{-1})	CEC ($cmolkg^{-1}$)	Na ($cmolkg^{-1}$)	Ca ($cmolkg^{-1}$)	Mg ($cmolkg^{-1}$)	K ($cmolkg^{-1}$)
Upstream								
20m	8.0a	7.2a	0.54c	6.27b	0.588	0.047	0.120	0.040
70m	7.6ab	6.9a	1.41bc	8.13ab	0.955	0.059	0.029	0.009
120m	7.7ab	6.9a	1.10c	11.30ab	0.835	0.056	0.044	0.015
Midstream								
20m	7.7ab	7.1a	0.87c	8.00ab	0.708	0.057	0.042	0.014
70m	7.6ab	7.1a	1.29bc	8.33ab	0.929	0.063	0.052	0.017
120m	7.6ab	7.0a	2.47ab	13.03ab	1.176	0.061	0.053	0.017
Downstream								
20m	7.6ab	6.8a	0.47c	8.47ab	0.622	0.073	0.031	0.010
70m	7.4ab	6.6a	0.54c	10.70ab	0.742	0.061	0.034	0.011
120m	7.3ab	6.4ab	1.16bc	12.93ab	1.091	0.064	0.044	0.014
Control	7.8a	7.1a	2.80a	5.80b	0.460	0.053	0.033	0.011
LSD	0.428 **	0.629 **	0.775 **	5.399 *	0.409	0.023	0.067	0.022

Means within a column followed by the same letter(s) are not significantly different at p≤0.05 by Least significant Difference.
*= Significant, **= highly significant

Table 3.Effect of Distance by Sections on Soil Chemical Properties of Floodplain Soils of River Tatsewarki Kano, Nigeria.

DISTANCE/ SECTION	ESP(%)	Available P (mgk^{-1})	Total N (gkg^{-1})	Org. Carbon (gkg^{-1})
Upstream				
20m	9.58	8.627	0.7	4.26
70m	14.11	10.035	0.5	2.93
120m	8.77	11.502	0.5	6.92
Midstream				
20m	9.28	9.507	0.6	7.38
70m	11.26	12.089	0.6	6.78
120m	10.36	15.200	0.6	10.71
Downstream	7.91	12.324	0.8	8.05
20m	8.40	9.977	0.7	9.91
70m	8.24	13.674	0.8	11.17
120m	7.91	11.796	1.1	3.19
LSD				

Means within a column followed by the same letter(s) are not significantly different at $p \leq 0.05$ by Least Significant Difference.

CONCLUSION

The soils weresandy at the upstream with sandy loam texture while at the mid and downstream sections they were generally loamy. The soils were non-saline and non-sodic. Even though the soils were of good drainage and permeability they were infertile particularly at the upstream as expressed by the slight alkalinity and low CEC, exchangeable bases, total N and OC.

RECOMMENDATION

There is thereforea clear need for inorganic fertilizer application, especially nitrogenous fertilizers, as well as incorporation of crop residues or manures particularly at the upstream so as to improve the nutrient status of the soils for increased and sustainable crop production in the area studied.

Contribution of Authors

The co-author contributed in no small measure both in the field work and in the laboratory analysis of soil samples collected from the field.

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