PROPERTIES, CLASSIFICATION AND AGRICULTURAL POTENTIALS OF THE SOILS OF LOWER OSHIN RIVER FLOODPLAINS IN KWARA STATE, NIGERIA.

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Abstract

A semi-detailed soil survey of the floodplains of lower Oshin River in Kwara State, Nigeria was carried out using rigid-grid survey method. Three soil units designated as OSH-1, OSH-2 and OSH-3 were identified on the basis of drainage, topography, soil texture and depth. The soil texture ranges from sandy clay loam in OSH-1 to sandy loam in OSH-2 and OSH-3 for the topsoil overlaying clay loam or sandy loam subsoil. The soil pH (H_2O) was moderately to slightly acid with values ranged from 5.1-5.7 in OSH-1 and 5.9-6.9 in OSH-2 and OSH-3. The available P in all soil units decreased with soil depth and the values for the topsoil were 22, 40 and 10 mg kg^{-1} respectively for OSH-1, OSH-2 and OSH-3 and was rated high in OSH-1 and OSH-2, and medium in OSH-3. Also, organic C content for topsoil was 27.5, 35.5 and 28.0 g kg^{-1} for OSH-1, OSH-2 and OSH-3 and its distribution within the profiles was irregular except in OSH-1 where it decreased regularly with soil depth. The CEC value for the topsoil was between 19.14 and 21.99 $cmol_{(+)}$ kg^{-1} and all rated high. The soil units were classified as Typic Endoaquepts/ Fluvic Cambisols (Clayic), Aquic Ustifluvents/ Gleyic Fluvisols (Arenic) and Oxyaquic Ustifluvents/ Gleyic Fluvisols (Eutric) using USDA Soil Taxonomy and WRB systems respectively. With exception of drainage problems which can be overcome by provision of adequate drainage infrastructure, the soils of the lower River Oshin floodplain have great potential for rain-fed agriculture.

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Introduction:

According to Food and Agricultural Organization and United Nations Environment Program (FAO/UNEP, 1999) a world increment of 90 million people per annum was projected for the years 2000 to 2025. The projection is worrisome, because ninety-five percent of the population increase was expected to take place in developing countries including Nigeria. Following the demographic trend of Nigeria, Ojanuga (2006a) remarked that, the present shortage of food and the increasing demand for food in the country require a substantial expansion of cultivated areas which includes the floodplains (wetlands) described as having high potential for agriculture.

Earlier investigations on some Nigeria's floodplain soils revealed that they are of alluvial origin and vary widely in their characteristics due to differences in parent materials and topography (Fagbemi and Akamigbo, 1986). For instance, Singh (1997) indicated that floodplain soils of Sokoto State, Nigeria were used intensively for both rain-fed and irrigated farming of rice, wheat, sugarcane, carrot etc. Elsewhere, Singh (1999) further clarified that aside from their nutrients status, floodplains had high level of moisture in terms of ground/residual water even during dry season as well as under drought conditions. Onyekwere *et al* (2001) described wetland soils as productive agricultural ecosystems which can be utilized for rice/fish integrated farming. Also, Idoga (2006) viewed floodplains as unique agricultural lands, because of seasonal water fluctuation which allows water loving crops such as swamp rice to be grown in rainy season while vegetables are grown in the dry season. In addition, floodplain conditions permit minimum input and maximum output when cultivated to rice because plant nutrients are supplied by annual floods while weeds are submerged by water. Furthermore, Ojanuga (2006a) indicated that when fadamas are put to use properly, their capacity to contribute to food security can be substantial in the long term. A study had shown that floodplains contributed a high percentage of the food supply of communities dwelling in the wetlands in some parts of Nigeria (Umoh, 2008).

The floodplain of the lower Oshin River in Kwara State, Nigeria beginning from early 1960's was cultivated to sugarcane by the defunct Nigerian Sugar Company Bacita. The demise of the company in 2005, led to abandonment of the land and the surrounding areas for sugarcane cultivation with subsequent conversion to cultivation of food crops such as lowland rice, maize, sorghum and vegetables. This change from sugarcane cultivation to food crops necessitates taking the inventory of the soil resources with a view to advising on the most desirable management programme for optimum and sustainable productivity of the floodplain. This study therefore was carried out to characterise, classify and assess the agricultural potential of the lower Oshin river floodplains in Kwara State, Nigeria.

Materials and Methods

The study site

The study site is the floodplain of Oshin river and estimated to be about 7,612 ha in size located between latitudes 9° 04′ and 9° 10′ N and longitudes 4° 52′ and 4° 56′ E in the southern Guinea Savanna of Nigeria. Oshin river, a large volume seasonal water body took it source from Ila-Oragun in Osun State and covers 152 kilometre distance before discharging into a loop of river Niger approximately eight kilometres east of Jebba, Kwara State, Nigeria.

The study area was categorized under sub-humid Central Niger-Benue Trough agro-ecological zone of Nigeria with an extensive flat to very gently undulating lowlands with broad interfluves over very deep weathered Nupe sandstones geomorphology (Ojanuga, 2006b). The lowland soils are broadly described as poorly drained grey soils (*Dystric Fluvisols*) and are predominantly cropped to rice. The mean annual rainfall of the study area is 1151 mm, lasting from mid-April to mid-October, while the mean annual temperature is 33.5 °C (Ojanuga, 2006b).

Field work

The semi-detailed soil survey was conducted using rigid-grid method (100 m × 100 m) on 778 ha of the floodplain. Soil inspection using soil auger was undertaken at intervals of 100 m along each traverse to identify the soil units. In each identified soil unit, two modal profile pits were dug and the most representative ones described according to FAO (2006) method. Bulk soil samples were collected from the genetic horizons identified in the profile pits and taken to the laboratory for analysis.

Soil Analysis

The bulk soil samples collected were air-dried, gently crushed using a mortar and pestle, and passed through a 2 mm-sieve to obtain fine earth separates. The processed soil samples were analysed for some physicochemical properties following the procedures outlined by the International Soil Reference and Information Centre and Food and Agricultural Organization (ISRIC/FAO, 2002). Briefly, particle size analysis was determined by the Bouyocous hydrometer method while soil pH H_2O suspension was determined with pH meter. Organic carbon was by Walkley-Black method. Exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were extracted with neutral 1N NH_4OAc solution and amounts in solution measured by atomic absorption spectrophotometry. Cation exchange capacity (CEC) was determined by the neutral 1 N NH_4OAc saturation method, while percent base saturation was by calculation. The exchangeable acidity (H^+ and Al^{3+}) was determined by titrimetric method.

Soil classification

Using the data generated from the field and laboratory, the soils were classified using Soil Taxonomy system (Soil Survey Staff, 2010) and correlated with World Reference Base for Resources (IUSS Working Group WRB, 2006).

Results and Discussions

Morphological and physical descriptions

Three soil units designated as OSH-1, 118 ha, OSH-2, 221 ha and OSH-3, 449 ha were identified. The morphological and physical properties of the three soil units are shown in Table 1. The soils are deposited on very low and moderately flat plain, therefore, making them prone to seasonal flooding. The OSH-1 was on a less than 3 % slope, while OSH-2 and OSH-3 occupies the lower portions, with fairly flat surfaces (< 1 % slope). All the soil units are deep, moderately to poorly drained as expressed by their different shades of greyish colouration and mottling.

Table 1: Some physical and morphological properties of soils of lower River Oshin Floodplain

Pedon	Horizon	Soil Depth (cm)	Colour (moist)	Structure*	Sand	Silt	Clay	Textural class**	Silt/Clay ratio
					← (g kg^{-1} soil) →				
	OSH-1 (Typic Endoaquepts/ Fluvic Cambisols (Clayic))								
OSH-1	Ap	0 – 29	10YR 5/2	2sbk	500	180	320	scl	0.56
	ACtg1	29 – 66	10YR 2/2	3abk	428	211	361	cl	0.58
	ACtg2	66 – 172	10YR 4/2	3sbk	500	220	280	scl	0.79
	R	172+		-	-	-	-	-	
	OSH-2 (Aquic Ustifluvents/ Gleyic Fluvisols (Arenic))								
OSH-2	Ap	0 – 30	5YR 4/1	2f.cr	720	90	190	sl	0.47
	ACg	30 – 49	10YR 5/3	2f.cr	768	51	181	sl	0.28
	ACg1	49 – 64	10YR 5/1	1f.cr	750	80	170	sl	0.47
	ACg2	64 – 89	7.5YR 7/2	1f.cr	808	41	151	sl	0.27
	ACg3	89 – 140	10YR 7/2	1f.cr	710	110	180	sl	0.61
	2C	140 – 152	7.5YR 6/2 (wet)	f. gr	908	11	81	S	0.14
	3C	152 – 180	10YR 5/1 (wet)	1ms	458	221	321	cl	0.69
	OSH-3 (Oxyaquic Ustifluvents/ Gleyic Fluvisols (Eutric))								
OSH-3	Ap	0 – 42	10YR 3/2	2f.cr	698	111	191	sl	0.58
	Cg1	42 – 65	7.5YR 6/2	1f.cr	680	140	180	sl	0.78
	Cg2	65 – 150	10YR 5/2	1f.cr	698	121	181	sl	0.67

*1 = weak; 2 = moderate, 3 = strong; gr = granular; ms = massive; cr = crumb; abk = angular blocky; sbk = sub-angular blocky; ** scl = sandy clay loam, cl = clay loam, s = sand. *** N.D. = Not determined. ‡IR = infiltration rate

The colour of the surface horizon vary from dark grey (5YR 4/1) in OSH-2, greyish brown (10YR 5/2) to very dark greyish brown (10YR 3/2) in OSH-1 and OSH-3 respectively overlaying brown (10YR 5/3), dark greyish brown (10YR 4/2) and pinkish grey (7.5YR 6/2). The colour of mottles also vary from dark yellowish brown (10YR 4/4) to yellowish brown (10YR 4/6) and mottling was restricted to 29-150 cm depth which probably coincided with upper and lower limits of seasonal ground water fluctuations. The structure was moderate to strong sub-angular blocky in OSH-1 and weak to moderate fine crumb in OSH-2 and OSH-3 respectively.

Soil surface texture was sandy clay loam for OSH-1 overlaying clay loam while OSH-2 and OSH-3 have predominantly sandy loam surfaces with occasional patches of sand overlaying sandy loam subsurface. The sand patches in OSH-2 and OSH-3 may be linked to the actions of burrowing animals especially in OSH-2 where biological activities was observed to be high. The sand fraction varied from 428 to 910 g kg^{-1} and it was irregularly distributed in all the soil units. The high sand values may be due to sedimentary parent materials (Nupe sandstones) from which these soils were developed. It was established that soil texture is often determined by the nature of the parent materials as are the rate and nature of some weathering processes (Brady and Weil, 2010). OSH-1 had sand value ranging from 420 to 500 g kg-^{1} followed by OSH-3 and OSH-2 with values between 680 and 698, and 458 and 908 g kg-^{1} respectively. The silt content for OSH-2 ranged widely from 11 to 221 g kg^{-1} and was irregularly distributed within the soil profile. In OSH-1, silt increased with soil depth with values from 180 to 220 g kg-^{1}, while OSH-3 had silt value increased from 111 g kg^{-1} at the surface horizon to 140 g kg^{-1} at ACg1. OSH-1 had the highest clay value of 320 g kg^{-1} at the Ap horizon and slightly increased to 361 g kg^{-1} at ACtg1 probably as a result of eluviation and illuviation processes (Akinbola *et. al.*, 2009). The clay values of OSH-2 ranged from 81 to 321 g kg^{-1} and it was irregularly distributed down the profile. The trend in clay distribution in OSH-2 differed from a trend reported by Idoga (2006) for the floodplain soils of Makurdi in Benue State, Nigeria. Furthermore, layers of discontinuity was observed in pedon OSH-2 from a depth of 140 cm which probably signified that the parent materials from which this soil unit was derived were deposited at different era. Meanwhile, the disparity observed in the profile distribution of clay in OSH-3 was not much.

Furthermore, the mean values of silt/clay ratios were 0.64, 0.42 and 0.68 for OSH-1, OSH-2 and OSH-3 respectively suggesting that all the soil units are relatively young. Young parent material usually have silt clay/clay ratio above 0.25 (Asomoa, 1973).

Chemical Properties

The soil chemical properties were rated using the critical limits established by Esu (1991) for soils of Nigeria (Table 2). The chemical properties of the soils are shown in Table 3. Generally, the soil reaction was moderately to slightly acidic which may be associated to their silica-rich parent material (Ojanuga, 2006a). The pH (H_2O) values ranged from 5.1 to 5.7 in OSH-1 and 5.9 to 6.9 in OSH-2 and OSH-3 and increased very slightly with soil depth probably due to leaching of basic cations from topsoil. A pH of 5.5 to 7 was established to be the optimal range for overall satisfactory availability of plant nutrients (Brady and Weil, 2010) implying that OSH-1 with pH of 5.1 to 5.7 may require special management such as liming for crops that are sensitive to soil acidity.

Table 2: Critical limits for interpreting fertility levels of analytical parameters.

Parameter	Low	Medium	High
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
Avail. P(mgkg^{-1})	< 10	10 – 20	> 20
B.S (%)	< 50	50 – 80	> 80

Source: Esu (1991).

The organic C content varied with values ranged from 22.3 to 27.5, 9.0 to 44.0 and 22.3 to 37.3 for OSH-1, OSH-2 and OSH-3 respectively. The trend of organic C distribution within the profiles was irregular except in OSH-1 where it decreased with soil depth. The irregular distribution pattern of organic C in the profiles of OSH-2 and OSH-3 reflects typical characteristic of fluvents (Soil Survey Staff, 2010). The organic content of the surface soils was 27.5, 35.5 and 28.0 for OSH-1, OSH-2 and OSH-3 respectively and all rated high. The high levels of organic C in these soils may be due to seasonal flooding and deposition of alluvium (Ojanuga, 2006a). Furthermore, poorly drained soils are typically known to accumulate higher levels of soil organic matter than well-drained soils (McCauley *et al.,* 2003). Accumulation of organic C (23.3 to 44.0 g kg^{-1}) at depth of 140 to 180 cm in OSH-2 might be due to deposited materials rich in organic matter during the era the materials were deposited, because there was no trend suggesting downward movement of organic C from the topsoil. The available P was higher in the surface than in the subsurface soils. The values of available P status was rated high for surface soils of OSH-1 (22 mg kg^{-1}) and OSH-2 (40 mg kg^{-1}) and medium for OSH-3 (10 mg kg^{-1}). The medium to high levels of available P may be as a result of earlier application of inorganic fertilizer when the land was under cultivation with sugarcane by the sugar company or due to high soil organic C in the surface soils. Organic matter is the main source of P in the soil (Brady and Weil, 2010).

Ca was the predominant exchangeable cations in the soils of lower Oshin River. The value of Ca in OSH-1, OSH-2 and OSH-3 ranged from 8.48 to 13.12 $cmol_{(+)}$ kg^{-1} (average, 10.13 $cmol_{(+)}$ kg^{-1}), 3.36 to 10.24 (average, 5.22 $cmol_{(+)}$ kg^{-1}) and 6.88 to 9.76 (average, 7.89 $cmol_{(+)}$ kg¯1) respectively and all rated high. High levels of Ca may be linked to their parent material (Nupe sandstone) from which they were derived. Usually soils derived from sedimentary rocks are rich in Ca (Brady and Weil, 2002). Mg was irregularly distributed within the profiles in all the soil units with mean values of 5.33, 3.41 and 5.44 $cmol_{(+)}$ kg^{-1} for OSH-1, OSH-2 and OSH-3 respectively and also rated high. Similarly, the K value ranged from 0.23 to 0.35, 0.12 to 0.40 and 0.12 to 0.44 $cmol_{(+)}$ kg^{-1} for OSH-1, OSH-2 and OSH-3 respectively and was irregularly distributed within the soil profiles. The K values for the topsoil was rated high in OSH-2 (0.40 $cmol_{(+)}$ kg^{-1}) and medium in OSH-1 (0.28 $cmol_{(+)}$ kg^{-1}) and OSH-3 (0.26 $cmol_{(+)}$ kg^{-1}) probably due to the reason adduced earlier for available P. Also, the pattern of distribution of Na vary among the soil units. In OSH-1, Na decreased with soil depth from 0.97 at Ap-horizon to 0.85 $cmol_{(+)}$ kg^{-1} at ACtg2, while in OSH-2 and OSH-3, it increased with soil depth from 0.76 to 1.22 $cmol_{(+)}$ kg^{-1} and 0.77 to 0.89 $cmol_{(+)}$ kg^{-1} respectively. Irrespective of soil depth, Na content was rated high in all the soil units. The built up of Na may be linked to decades of irrigation in the area by the defunct Nigerian Sugar Company. High Na ions may cause the dispersion of the mineral colloids leading to formation of tight soil structure and consequently slows the infiltration/percolation of water (Hach, 1993). Although Ca and Mg levels are high in all the soil units to counter the effects of the Na, it is still important to put Na into consideration in the management of these soils. Also, the CEC ranged between 14.65 and 28.71 $cmol_{(+)}$ kg^{-1}. The CEC values for the topsoil of OSH-1, OSH-2 and OSH-3 were 19.14, 21.96 and 21.99 $cmol_{(+)}$ kg^{-1} respectively and all rated high. The high soil organic C content might have conferred the high CEC values on the soil (Brady and Weil, 2010). The high CEC values indicated that the soils have high potentials for retaining plant nutrients. The mean values for base saturation (%) were 68.43, 54.54 and 63.23 % for OSH-1, OSH-2, and OSH-3 respectively and all rated medium. It means that leaching of plant nutrient is moderate in these soils.

Soil Classification

The three soil units designated as OSH-1, OSH-2 and OSH-3 were identified on the basis of drainage, relative positions, soil colour, texture and depth and classified according to USDA Soil Taxonomy system (Soil Survey Staff, 2010) and the World Reference Base for Soil Resources (IUSS Working Group WRB, 2006).

USDA Soil Taxonomy

The evidence of clay migration expressed in OSH-1 from 320 g kg^{-1} at Ap horizon to 360 g kg^{-1} at Ctg1 was not appreciable to be regarded as having an argillic, but rather a cambic horizon. On this basis OSH-1 was classified as Inceptisols. The aquic moisture characteristics and gleyization shown below the Ap-horizon starting from depth of 29 to 172 cm further qualified it as Aquepts at sub-order level. Also, the evidence of endo-saturation due to the impervious layer (from depth of 172 cm), further placed it at great-group level as Endoaquepts and at the subgroup level as Typic Endoaquepts.

OSH-2 was classified at order level as Entisols because of minimal diagnostic features differentiating the Ap-horizon and the subsoil (ACg1-3). Also, because of irregular distribution of organic-carbon with soil depth, it was further classified as Fluvents at sub-order level. The ustic soil moisture regime further placed it as Ustifluvents at great group level and at sub-group level as Aquic Ustifluvents due to aquic moisture characteristics.

Similarly, OSH-3 was classified at order level as Entisols because there was very little evidence of horizon differentiations. On the basis of an irregular distribution of organic-carbon with soil depth, it was further classified as Fluvents at sub-order level. Because of ustic soil moisture regime, this soil unit was further classified as Ustifluvents at great group level and Oxyaquic Ustifluvents for being saturated consecutively more than 20 days in each year.

WRB classification system

Development of a cambic horizon starting within 50 cm of the soil surface and having its base of more than 25 cm below the soil surface qualified OSH-1 at Reference Soil Group (RSG) level as Cambisols. The fluvic properties further qualified it as Fluvic Cambisols, and high clay content in all the horizons placed it as Fluvic Cambisols (Clayic).

The fluvic properties which started from 30 cm below the soil surface qualified OSH-2 at RSG level as Fluvisols. Also, because it has between 50 and 100 cm from the mineral soil surface in some parts reducing conditions and a gleyic colour pattern, OSH-2 was further classified as Gleyic Fluvisols. Been predominantly sandy loam, the soil unit was further qualified as Gleyic Fluvisols (Arenic).

Table 3: Some chemical properties of the soils of lower Oshin River floodplains

Pedon	Horizon	Soil Depth (cm)	pH (H_2O)	Org. C (g kg^{-1})	Avail. P (mg kg^{-1})	Exchangeable Cations Ca^{2+}	Mg^{2+}	K^+	Na^+	Exch. Acidity $H^+ + Al^{3+}$	CEC	(%) Base Saturation
						(cmol(+) kg^{-1} soil) →						
OSH-1 (Typic Endoaquepts/ Fluvic Cambisols (Clayic))												
OSH-1	Ap	0 – 29	5.5	27.5	22	8.48	5.12	0.28	0.97	1.00	19.14	77.60
	Ctg1	29 – 66	5.7	26.0	5	13.12	6.88	0.35	0.93	2.00	28.71	74.12
	Ctg2	66 – 172	5.1	22.3	12	8.80	4.00	0.23	0.85	2.00	25.06	53.57
	R	172+	-	-	-	-	-	-	-	-	-	-
OSH-2 (Aquic Ustifluvents/ Gleyic Fluvisols (Arenic))												
OSH-2	Ap	0 – 30	5.9	35.5	40	8.96	3.84	0.40	0.76	4.00	21.96	63.57
	ACg1	30 – 49	6.3	12.0	17	7.20	1.12	0.24	0.74	4.00	17.30	53.76
	ACg2	49 – 64	6.4	9.0	12	5.28	3.20	0.21	0.77	1.60	17.46	54.18
	ACg3	64 – 89	6.4	12.0	12	3.68	1.60	0.17	0.79	2.00	14.71	42.42
	ACg4	89 – 140	6.7	18.0	7	4.32	3.04	0.16	0.83	2.00	16.35	51.07
	2C	140–152	6.6	23.3	5	3.36	2.40	0.12	0.77	2.00	14.65	45.39
	3C	152–180	6.9	44.0	7	10.24	8.64	0.36	1.22	1.60	28.46	71.39
OSH-3 (Oxyaquic Ustifluvents/ Gleyic Fluvisols (Eutric))												
OSH-3	Ap	0 – 42	6.2	28.0	10	7.04	5.92	0.26	0.77	1.60	21.99	63.62
	Cg1	42 – 65	6.7	22.3	10	6.88	2.08	0.12	0.80	3.20	17.88	55.26
	Cg2	65 – 150	6.1	37.3	5	9.76	8.32	0.44	0.89	2.40	27.41	70.81

*CEC= cation exchange capacity; Avail. P= available phosphorus; Org. C= organic carbon.

The fluvic properties (redoximorphic properties) immediately below the Ap-horizon (29 cm) and beyond and absence of layers with andic or vitric properties with a combined thickness of 30 cm or more within 100 cm of the soil surface and starting within 25 cm of the soil surface qualified OSH-3 to be classified at RSG level as Fluvisols. Having between 50 and 100 cm from the mineral soil surface in some parts reducing conditions and in 25 percent or more of the soil volume a gleyic colour pattern, it was further classified as Gleyic Fluvisols. The base saturation above 50 percent place the soil unit as Gleyic Fluvisols (Euric).

Conclusion

This study rated the fertility status of the soils on the floodplain of the study area medium to high. Particularly, the high CEC values indicated that the soils have high potential for retaining plant nutrients. The acidic nature of soil of OSH-1 and poor drainage in all the soil units may be limiting factors which can be overcome by inclusion of management practices such as liming and provision of drainage infrastructures. Furthermore, the near flat surface of land (< 3 % slope) also makes it potentially suitable for mechanize agriculture. By general assessment of the soils and other environmental attributes such as annual rainfall of (average, 1150.9 mm), it may be concluded that the study area is endowed with land capable to sustain agriculture.

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