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Pedological Characteristics, Classification and Fertility Implications of Flood Plain Soil at Dakace, Zaria, Kaduna State

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ABSTRACT

This study was conducted in order to characterize, classify and determined the fertility conditions of Dakace flood plain soils located in Zaria, Kaduna state. Eight (8) profile pits were excavated in the study locations, examined, described and soil samples collected from each pedogenetic horizon for their physical and chemical properties analysis. The soils were classified based on the criteria of USDA soil taxonomy and correlated with FAO/UNESCO system. The results showed that the soils depth ranged from *moderately shallow* (85cm) to *very deep soil* (186 cm), *yellowish brown to grey in colour*, *Sandy loam and sandy clay loam in texture, slightly to moderately acidic*, *low in organic carbon content (mean 7.65 g/kg)*, *total nitrogen (high 0.46 g/kg)* and *available P (mean 8.70 mg/kg)*, *medium in base saturation (59.01%)*. The exchangeable bases were quite high with mean values of 6.62 cmol(+)kg⁻¹ for calcium, 1.59 cmol(+)kg⁻¹ for magnesium, 0.16 cmol(+)kg⁻¹ for potassium and 0.32 cmol(+)kg⁻¹ for sodium respectively and *cation exchange capacity (14.91 cmol(+)kg⁻¹)*. The soils were classified following the USDA (2010) soil taxonomy as *Typic Haplustalf*, *Fluventic Endoaquepts*, *Fluvaquentic Epiaquepts* and *Typic Endoaqualfs* and according to the FAO/UNESCO (2014) legend as *Rhodic Luvisols*, *Dystric Fluvisol*, *Dystric Gleysols* and *Gleyic Lixisols* for the identified soil mapping units G1, G2, G3 and G4 respectively. The Soils were low in fertility, hence there is need to adopt proper management strategy in terms of organic and inorganic fertilizer application to resuscitate and sustain the soil fertility.

Keywords: Zaria, soil characterization, pedon and organic carbon

INTRODUCTION

The soil of any country is its most valuable natural resource which requires careful management for sustainable development. Due to over exploitation and mismanagement of natural resources, coupled with socio-economic factors, the problem of land degradation is on the rise. However, management of land resources is inevitable for both continued agricultural productivity and protection for the environment. The common way of determination of land quality from land characteristics is mainly by assessing and grouping the land types in orders and classes according to their characteristics. A good knowledge of the soil resources of any given territory is indispensable for planning its agricultural development (Dijkerman, 1969). Soil surveys provide a scientific

inventory of the soils occurring within a specified land area and involve the systematic examination, description, classification and mapping of such soils. According to Esi (2004), during a soil survey, sufficient information is gathered in order to help the surveyor to correlate and to predict the adaptability of soils to various crops behavior and productivity under different management systems.

Pedological characterization provides valuable information and knowledge on soil characteristics and gives clear understanding on soil genesis, morphology, classification and spatial distribution of soils in an area. Characterization and classification of soils of any given location help in generating soil and soil-related data which are useful in sustained use of soil resource. Soil characterization and classification are the main

information sources for precision agriculture, land use planning and management (Ogunkunle, 1986). This is because characterization and classification provide information for the understanding of the micro-morphological, physical, chemical, mineralogical and microbiological properties of the soil (Ukut *et al.*, 2014).

Soil classification can also provide a basis for soil-related agro-technology transfer (Boul and Denton, 1984). Nahusenay *et al.* (2014) revealed that systematic soil classification links research results and their beneficial extension to field applications. Thus, soil classification is used to apply proper management practices, transfer technology and provide a ready-made legend for soil surveyors. This study is aimed at characterizing, classifying and determining the fertility implication of the floodplain soils of Dakace, Zaria, Kaduna state.

A thorough idea on soil pedology and agronomy are therefore important indices in most fertility surveys since soil data provides bases for guiding variety of land applications (Tekwa *et al.*, 2011). Soil fertility plays a key role in increasing crop production in the soil. It comprises not only in supply of nutrients but also their efficient management. The fertility of soil is affected by various physical, chemical and biological properties of soil (Tekwa and Usman, 2006). The fertility status of soil indicates their nutrient supplying capability. The Nigerian savanna zone soils therefore have low total nitrogen, organic carbon, available phosphorus and cation exchange capacity (Odunze, 2004). They also have very poor moisture holding capacity, and are therefore said to have poor fertility status and very low buffering capacity.

MATERIALS AND METHODS

Study Area Description

The study was conducted in Galma floodplain at Dakace within Zaria local government area of Kaduna state (Figure 1). It is located on Latitude N11° 04' 87" and Longitude 7° 44' 47". It has typical Northern Guinea Savanna vegetation type. The area lies within the tropical savanna (Aw) climate type with distinct wet and dry season (Kowal and Knabe, 1972). It is characterized by long dry season from November through March while the wet season last from April to October with a mean annual rainfall of 1100mm.

The temperature fluctuates within a range of 22°C during cold nights to over 38°C during the hot days. The relative humidity during the dry season is about 15% and reaches up to 60% during the rainy season (Kowal and Knabe, 1972). Geologically, the area lies within the high plains of northern Nigeria characterized by landforms which consist of inselbergs and pediment landscape overlying the basement complex, which are nearly level to gentle undulating plains (Yakubu, 2004).

Agriculture is the most prevalent land use in the study area. Farming systems is mixed livestock and crop production. In the floodplain, land use is dominated by the cultivation of crops such maize and rice in the rainy season while varieties of crops such as Cereal (maize), vegetables (onions, spinach, pepper, tomatoes, carrot, garden egg), roots and tuber such as Irish/Sweet Potato are grown during the dry season.

Field studies:

Preliminary study commenced with the acquisition and interpretation of Landsat-ETM imageries with 30 m resolution covering the entire Galma basin. Digital elevation model was used to delineate the landforms, from the landform map, the floodplain with a dimension of 500 m × 500 m which occupied an area of 25 hectares was selected for this study. A base map was prepared with grids at 50 m intervals. This was geo-referenced uploaded into the GPS for detailed soil survey. Detailed soil survey of the area was carried out using a rigid grid method at the scale of 1:2000. The soils were examined by augering at 50 m intervals to determine changes in soil depth, colour, texture and drainage. Soils with similar properties were grouped and placed in a soil mapping unit. Two (2) soil profile pits were dug in each soil mapping unit identified and described according to the procedure described in the Soil Survey Manual (Dent and Young, 1981 and Soil Survey Staff (1990).

Following their descriptions, disturbed bulk samples were collected from the genetic horizons identified in the soil pedons and Core samples were collected at an interval of 25cm. Bulk samples were used to determine the physical-chemical parameters of the soil while the core samples were used to determine the bulk density.

Pedological Characterization

The particle size distribution was determined by the Bouyoucos hydrometer method described by Gee and Or (2002). Bulk density was determined by using core-sampling method (Blake and Hartge 1986). Particle density (PD) was determined by the pycnometer method as outlined by Blake and Hartge (1986). Total porosity was calculated mathematically from the results of bulk density and particle density (Agbenin, 1995).

The pH of the soils was determined in H₂O (pH-H₂O) and 1M KCl (pH-KCl) using 1:2 soil to solution ratio using pH meter as outlined by Van Recuwijk (1993). Organic carbon content of the soil was determined using the wet combustion method of Walkley and Black as outlined by Van Ranst *et al.* (1999). Soil total nitrogen was analyzed by wet-oxidation procedure of the Kjeldahal method (Bremner and Mulvaney, 1982). Available phosphorus was determined following the procedure described by IITA (1979) using the Bray- 1 extraction method (Bray and Kurtz, 1945) and the amount of available P was determined by the spectrophotometer at



Fig. 1: Location of the Study Area in Kaduna State, Nigeria.

882 nm wave length. Exchangeable basic cations were extracted using NH_4OAc saturation method at pH 7.0 as described by Thomas (1982), the exchangeable cations (Ca and Mg) in the leachate were determined by the Atomic Absorption Spectrophotometer (AAS), whereas K and Na were measured by flame photometer. Cation exchange capacity (CEC) of the soils was determined by using the 1M ammonium acetate (pH 7) method according to the percolation tube procedure (Van Rieuwijk, 1993).

Determination of soil fertility levels in Dakace. Topsoil samples (0-15 cm depth) were collected from forty (40) selected areas across the floodplain and mixed thoroughly to obtain representative composite samples. The samples were air-dried, ground and passed through a 2-mm sieve for laboratory analysis as in the case of disturbed samples for pedological characterization. The analyses were done to assess the general soil fertility trends in the study area.

Statistical data analysis

Data generated was analysed using ranges and means while soil fertility trends analytical data were subjected to Spearman's rank correlation to show the relationship among the soil parameters.

Classification of soils

Using field and laboratory analytical data for pedological characterization, the soils were classified to family level of the USDA Soil Taxonomy (2010) and correlate it with FAO/UNESCO World Reference Base (2014).

RESULTS AND DISCUSSION

Soil morphological properties

Four soil mapping units were identified and denoted as soil mapping units G1, G2, G3 and G4 as shown in Figure 2 below. A summary of morphological properties of the soil mapping units are presented in Table 1. Soil depth varied from moderately shallow (85cm) to very deep soils (174cm). Soil mapping unit G4 has the shallowest pedon (85cm deep) due to the occurrence of water table.

The soils were poorly to well drained. The soils colour varied from 5YR 4/6 to 10YR 4/2 in Soil mapping unit G1, 2.5Y 6/1 to 10YR 4/3 in Soil mapping unit G2, 2.5YR 4/1 to 5Y 3/1 in soil mapping units G3 and 2.5Y 6/2 to 10YR 6/2 in soil mapping unit G4 (Table 1). These variations in soil colour appear to be the function of chemical, mineralogical composition, soil organic matter

Table: 1 Physical Properties of the Study Area

Soil Mapping Units			Horizons	Depth cm	Clay	Silt	Sand	Silt Clay ratio	Textural Class	Bulk Density mg/cm ³	Particle Density	Total Porosity %
G1	Pedon G1P1		Latitude N11 04.921	Longitude E7 44.442	Elevation 612.00 m							
		Ap	0-17	80.00	400.00	520.00	5.00	SL	1.33	2.52	47.22	
		Btj1	17-51	160.00	260.00	640.00	1.63	SL	1.59	2.59	38.61	
		Btj2	51-143	200.00	240.00	560.00	1.20	SL	1.67	2.63	36.5	
		BC	143-176	100.00	280.00	620.00	2.80	SL	1.75	2.64	33.71	
	Pedon G1P2		Latitude N11 04.896	Longitude E7 44.413	Elevation 611.70 m							
		Ap	0-29	80.00	260.00	660.00	3.25	SL	1.39	2.55	45.49	
		Bt1	29-52	140.00	280.00	580.00	2.00	SL	1.50	2.58	41.86	
		Bt2	52-97	220.00	200.00	580.00	0.91	SL	1.66	2.65	37.36	
		Bt3	97-186	220.00	200.00	580.00	0.91	SL	1.66	2.67	37.83	
G2	Pedon G2P1		Latitude N11 04.952	Longitude E7 44.361	Elevation 607.00 m							
		Ap	0-32	200.00	200.00	600.00	1.00	SL	1.40	2.59	45.95	
		BC	32-61	120.00	120.00	620.00	1.00	SL	1.50	2.61	42.53	
		AB	61-92	130.00	220.00	650.00	1.69	SL	1.61	2.64	39.02	
		2A	92-120	120.00	280.00	600.00	2.33	SL	1.55	2.64	41.29	
		2B	120-150	80.00	220.00	700.00	2.75	SL	1.60	2.66	39.85	
		3Ag	150-160	180.00	200.00	620.00	1.11	SL	1.80	2.67	32.58	
	Pedon G2P2		Latitude N11 04.927	Longitude E7 44.332	Elevation 607.20 m							
		Ap	0-37	140.00	220.00	640.00	1.57	SL	1.44	2.57	43.97	
		AB	37-64	140.00	280.00	580.00	2.00	L	1.48	2.59	42.86	
		BC	64-110	120.00	120.00	620.00	1.00	SL	1.50	2.62	42.75	
		2Ag	110-123	200.00	260.00	540.00	1.30	SL	1.57	2.62	40.08	
		2C	123-148	100.00	420.00	480.00	4.20	L	1.73	2.65	34.72	

Table 1 Cont.: Physical Properties of the Study Area

Soil Mapping Units	Horizons	Depth Cm	Clay	Silt	Sand	Silt Clay ratio	Textural Class	Bulk Density mg/cm ³	Particle Density	Total Porosity %
G3	Pedon G3P1		Latitude N11 05.059		Longitude E7 44.394			Elevation 607.80 m		
	Ap	0-45	260.00	220.00	520.00	0.85	SCL	1.34	2.6	48.46
	Bt1	45-82	340.00	200.00	460.00	0.59	SCL	1.55	2.63	41.06
	Bt2	82-119	320.00	220.00	460.00	0.69	SCL	1.53	2.64	42.05
	2Ag	119-137	300.00	220.00	480.00	0.73	SCL	1.59	2.66	40.23
	Pedon G3P2		Latitude N11 05.012		Longitude E7 44.254			Elevation 607.20 m		
	Ap	0-25	320.00	120.00	560.00	0.38	SCL	1.39	2.59	46.33
	Btg 1	25-64	400.00	180.00	420.00	0.45	C	1.46	2.62	44.27
	Btg 2	64-94	420.00	140.00	440.00	0.33	C	1.53	2.65	42.26
	Pedon G4P1		Latitude N11 05.067		Longitude E7 44.229			Elevation 435.00 m		
G4	Ap	0-42	280.00	210.00	510.00	0.75	SCL	1.45	2.56	43.36
	Bt	42-85	460.00	130.00	430.00	0.28	C	1.50	2.64	43.18
	Pedon G4P2		Latitude N11 05.093		Longitude E7 44.258			Elevation 432.60 m		
	Ap	0-36	230.00	190.00	580.00	0.41	SCL	1.44	2.59	44.4
	Bt	36-78	280.00	210.00	510.00	0.75	SCL	1.55	2.6	40.38
	Bt2	78-120	410.00	170.00	420.00	0.41	C	1.54	2.63	41.44

content, textural make up of soils, topographic position and moisture regime (Abate *et al.*, 2014).

One of the most distinct and diagnostic morphological characteristic of the hydromorphic soil was the presence of mottled and or gleyed horizons which occurred in soil mapping units G2, G3 and G4. These features are indications of soil wetness brought about by oxidation-reduction cycles due to ground water fluctuation (Oso *et al.*, 2012).

Sub angular blocky and massive structures were the dominant soil structures found within the study area. Soil mapping units G1 and G2 had consistence ranged from non sticky non plastic to slightly sticky slightly plastic (wet) while soil mapping units G3 and G4 had consistence which ranged from sticky and plastic to very sticky very plastic (wet). Consistency of soil changed with variation in clay content, as reported by Thangasamy *et al.* (2005). The overall friable to firm consistency of the soils indicates that the soils are workable at appropriate moisture content (Abate *et al.*, 2014).

Soil Physical and Chemical Properties

The result of physical characteristics of soils of the study area is as shown in Table 1. The particle size distribution is dominated by the sand fraction. The high sand fraction in the surface soil over the subsurface soil might be attributed to deposition from the upland (Mortimore, 1989) and vertical and lateral clay translocation (Malgwi, 2001). A notable feature in all the soil mapping units is their high silt content. Higher content of silt in their profiles could be attributed to the fact that the study area is located in a low-lying area hence, received fine colluvial and alluvial sediments from the upper slope positions through erosion and deposition from Galma River. The distribution of clay in soil mapping units G1, G3 and G4 increases with depth thus, the soils showed higher clay contents in the subsoil than the surface horizons to be due to clay translocation and surface erosion or a combination of these processes (Sharu *et al.*, 2013). The dominant textural class for surface and sub surface soil for soil mapping units G1 and G2 were sandy loam while soil mapping units G3 and G4 was sandy clay loam and clay for surface and sub surface soil respectively.

The silt clay ratio ranged from 0.33 to 5.00 within the study area. The silt to clay ratio shows a general decrease with increase in soil depth. The low silt to clay ratio in the surface indicate that the soils are at an advance stage of development (Abayneh, 2005, Abate *et al.*, 2014), confirm the existence of both clay migration and translocation in the pedons.

Bulk density of the surface layers has a mean of 1.40 mgcm^{-3} and ranged from 1.33 to 1.45 mgcm^{-3} was generally low, but increased to high values with increased depth. Increase in bulk density with increase in soil depth could be attributed to decrease in organic matter and the

possibility of migrating clay filling up the pore spaces in the horizons of illuviation (Ahukaemere, and Akpan, 2012).

Particle density ranged between $2.52 - 2.67 \text{ mgcm}^{-3}$ (Table 1) indicating that quartz, feldspar, micas and colloidal silicates with densities between $2.60 - 2.75 \text{ mgcm}^{-3}$ forms the major portion of minerals in the study area (Brady and Weil, 2008).

Total porosity with mean of 41.06% and range from 32.46 to 48.46% decreased with depth in all the pedons (Table: 1). High pore spaces recorded in the surface horizons may be attributed to loosening of soil materials by plant roots and during cultivation of soil (Ahukaemere and Akpan 2012). Brady and Weil (2008) stated that optimum total pore space value for crop production is $>50\%$.

Soil Chemical Properties

Organic carbon in the study area was generally low with a mean of 7.65 g/kg (Table 2). The low rate of organic carbon could be attributed to rapid decomposition and mineralization of organic materials due to high temperature and sparse vegetation in the hot semi arid climate (Sharu *et al.*, 2013). Organic carbon content in soil mapping units G3 and G4 were higher than G1 and G2. Higher content of organic carbon in the poorly drained environment of soil mapping units G3 and G4 may be attributed to water logging condition which causes a relative accumulation of organic matter due to reduced microbial activities, less frequent and less severe translocation of mineralized products at the start of the rains (Esu, 1982).

The total nitrogen content of the soil was rated low with an average of 0.46 g/kg (Table 2) and followed a similar trend as the organic carbon content. The values were generally low with higher values in the topsoil than in the subsoil. The total nitrogen values of the soils in the area changed irregularly with depth which could be attributed to influence of continuous cultivation, a common practice in the area that is accompanied by nearly crop residue removal (Noma *et al.*, 2011).

The values for available phosphorus (Table 2) was rated low to medium with a range of 3.68 to 44.97 mg/kg and mean of 8.70 mg/kg in all the soil mapping units. Available P values were higher in the AP horizons and decreased drastically in the B horizons of the profile. High available P in the top soil may be attributed to some anthropogenic influences such as addition of phosphorous containing fertilizer and high organic matter content (Sai Kumar *et al.*, 2013).

The soil reaction (pH) ranged from moderately acidic (5.15) to slightly acidic (6.55) in the study area (Table 2). Higher pH in the top soil may be attributed to the influence of organic matter through biogenetic cycling of bases, capillary rise in water within the basin this process reduces the acidification of soils (Mohammad, 2011), the

Table 2: Chemical properties of soils of the mapping units at Dakace flood plains (Fadama)

Soil Mapping Units	Horizons	Depth cm	OC g/kg	TN g/kg	AP mg/kg	Ca	Mg	K	Na cmol(+)kg ⁻¹	AL+H	CEC	BS %	pH
G1													
Pedon G1P1		Latitude N11 04.921		Longitude E7 44.442		Elevation 612.00m							
Ap		0-17	11.00	0.80	44.97	8.36	0.80	0.08	0.11	0.80	11.90	78.52	6.55
Btj1		17-51	3.60	0.30	6.30	6.94	0.59	0.07	0.10	0.40	12.50	61.54	6.53
Btj2		51-82	4.10	0.20	5.60	5.11	0.90	0.10	0.14	0.40	14.80	42.21	6.04
BC		82-173	2.20	0.10	5.60	1.85	0.49	0.08	0.11	0.40	7.70	32.75	6.10
Pedon G1P2		Latitude N11 04.896		Longitude E7 44.413		Elevation 611.70m							
Ap		0-29	11.10	0.60	16.63	8.66	1.35	0.09	0.33	1.10	12.90	80.85	6.34
Bt1		29-52	4.40	0.10	5.43	5.13	0.80	0.06	0.23	0.60	12.50	49.72	6.28
Bt2		52-79	4.00	0.03	4.55	4.87	1.13	0.08	0.33	0.60	11.40	56.20	6.13
Btj3		79-168	2.60	0.01	3.85	4.93	2.31	0.14	0.33	0.20	13.30	57.92	6.11
G2													
Pedon G2P1		Latitude N11 04.952		Longitude E7 44.361		Elevation 607.00m							
Ap		0-32	10.30	0.70	12.43	8.70	1.44	0.13	0.17	1.00	15.30	68.23	6.41
BC		32-61	8.00	0.10	5.78	4.98	0.78	0.02	0.28	0.40	9.80	61.74	6.25
AB		61-92	5.20	0.10	6.48	5.26	1.45	0.04	0.24	0.40	10.20	68.52	6.02
2A		92-120	5.00	0.10	8.23	2.87	1.10	0.03	0.19	0.40	10.80	38.78	6.18
2B		120-150	5.00	0.30	7.70	2.60	1.67	0.02	0.27	0.40	12.20	37.33	6.23
3Ag		150-160	5.00	0.40	7.53	5.18	1.26	0.06	0.60	0.20	13.30	53.38	6.18
3C		160-174	4.40	0.40	7.53	2.62	0.67	0.02	0.39	0.20	8.60	42.98	5.88
Pedon G2P2		Latitude N11 04.927		Longitude E7 44.332		Elevation 607.20m							
Ap		0-37	11.10	0.70	15.05	6.81	1.10	0.07	0.26	1.00	11.90	69.22	6.10
AB		37-64	8.60	0.10	5.78	5.26	1.45	0.04	0.76	0.60	12.93	58.07	5.83
BC		64-110	7.00	0.10	4.55	4.88	2.38	0.02	0.70	0.40	10.30	77.48	5.69
2Ag		110-123	5.00	0.10	4.90	4.44	1.36	0.05	0.52	0.40	10.27	61.98	6.32
2C		123-148	4.40	0.30	4.73	2.60	0.86	0.02	0.47	0.40	11.59	34.05	6.13

Table 2 count.: Chemical properties of soils of the mapping units at Dakace flood plains (Fadama)

Soil Mapping Units	Horizons	Depth cm	OC	TN g/kg	AP mg/kg	Ca	Mg	K	Na cmol(+)kg ⁻¹	AL+H	CEC	BS %	pH
G3													
Pedon G3P1		Latitude N11 05.059		Longitude E7 44.394		Elevation 607.80m							
Ap		0-30	13.20	1.30	7.35	9.81	2.47	0.51	0.31	1.20	19.40	67.54	5.84
Btg 1		30-69	10.10	0.30	7.18	8.29	2.48	0.36	0.23	1.00	20.10	56.50	5.36
Btg 2		69-94	7.20	0.20	3.68	7.90	2.31	0.30	0.21	0.50	22.20	48.31	5.28
Pedon G3P2		Latitude N11 05.012		Longitude E7 44.254		Elevation 607.20m							
Ap		0-45	14.40	1.10	13.65	11.29	2.27	0.21	0.48	1.25	20.90	68.16	6.29
Bt1		45-82	9.00	0.70	5.96	10.34	2.31	0.27	0.38	1.20	18.50	71.90	6.07
Bt2		82-116	7.60	0.40	5.95	6.51	2.00	0.24	0.28	1.00	20.80	43.42	5.15
2Ag		116-137	7.20	0.40	5.95	5.66	1.53	0.38	0.18	0.60	24.10	32.15	5.22
G4													
Pedon G4P1		Latitude N11 05.067		Longitude E7 44.229		Elevation 435.00m							
Ap		0-42	14.34	1.30	12.03	11.32	2.35	0.42	0.43	1.34	20.27	71.63	5.89
Bt		42-85	11.21	0.64	7.03	10.50	2.43	0.27	0.25	1.10	18.40	73.10	5.21
Pedon G4P2		Latitude N11 05.093		Longitude E7 44.258		Elevation 432.60m							
Ap		0-36	14.10	1.50	11.37	12.53	2.27	0.39	0.38	1.23	20.20	77.08	6.01
Bt		36-78	9.37	0.83	9.60	10.37	2.34	0.21	0.22	0.90	17.60	74.66	5.41
Bt2		78-120	5.01	0.43	4.90	5.12	2.13	0.26	0.21	0.40	20.45	72.32	5.38

addition of bases cation to the surface soil layer as loess during the harmattan (Esu, 1982) or partly due to the aluminosilicate clay minerals releasing Al^{3+} and H^+ into the soil solution through isomorphous substitution (Lawal *et al.*, 2012a).

Exchangeable calcium (Ca) is the most predominant cation on the exchange sites. The Ca content of the surface soil rated high (Table 2). The predominance of Ca over other cations in these soils may be due to specific affinity for Ca on exchange sites in soils (Esu, 1982) or may be due to the existence of calcium bearing parent material (Nahusenay *et al.*, 2014). The relatively higher content of Ca in soil mapping units G3 and G4 may be due to the saturation of these soils with base enrichment from groundwater (Esu, 1982).

The mean distribution of available Mg content in soil mapping units G1 and G2 generally show an increase with increase in pedal depth while soil units G3 and G4 show a decrease in available Mg content with increase in depth (Table 2). Increase in available Mg content with depth in profiles found in soil units G1 and G2 may be attributed to the leaching of available Mg from the surface to the subsoil. This result is in agreement with the findings of Ashenafi *et al.*, (2010).

The surface and sub surface soil value for available Na was rated medium to high, higher content of available Na in the poorly drained soil might be associated to capillary movement of water from the water table to the surface (Malgwi, 2001) or by prolong irrigation with water high in available Na coupled with deteriorated structure of subsoil and poor drainage characteristics (Lawal *et al.*, 2012b).

The higher concentration of available potassium was observed in the surface horizons and showed decreasing trend with increasing soil depth (Table 2). This may be attributed to more intense weathering, release of labile K from organic residue, and through the application of K fertilizers (Sai Kumar *et al.*, 2013). The relatively high amount of available K in soil mapping units G3 and G4 may be due to saturation of these soil mapping units with base enriched ground water (Esu, 1982).

The CEC values were rated low to high in the study area with a mean of $14.91 \text{ cmol}(+) \text{ kg}^{-1}$ and a ranged of 7.70 to 24.10 (Table 2). This could be attributed to high contents of basic cations in the exchange sites. The higher CEC in the poorly drained soil typified by soil mapping units G3 and G4, compared to the red soils (soil mapping unit G1) may be due to the presence of more amorphous materials and zeolites (Basanta *et al.*, 2013).

The values of base saturation (BS) ranged from 32.15 to 80.85% and averaged 59.01% was rated low to medium. FAO (1999) reported that soils with base saturation of $>50\%$ are regarded as fertile soils while soils with less than 50% were regarded as not fertile soils. Based on this, the soils are considered to be generally fertile. This implies that the soils are generally fertile.

Fertility Implication

The fertility of a soil is determined by both its nutrient reserves and its physical properties. Blocky structure dominated soils of soil mapping units G1 and G2. Soil of mapping units G3 and G4 were structureless (massive) thus probably constituting a severe limitation to root penetration and to water permeability with consequent increase in surface runoff. Sand dominated the particle size fractions of the fine earth portion of the soils. Soil texture were, therefore, medium (mostly sandy clay loam) which area ideal for most crop.

The pH value of all the soil mapping units falls within the normal range of 5.5-7.0 reported to be optimum for the release of plant nutrients (Sharu *et al.*, 2013). Cation exchange capacity was low to high. The values of BS are rated low to medium, this means that the soil have low nutrient retention capacities. The incorporation of organic residues will increase nutrient retention capacities, improve soil aeration, drainage structural development, reduce erosion, increase soil pH of the acidic soil and reduce leaching losses (Maniyunda, 1999).

Organic carbon was observed to correlate with total nitrogen, available phosphorus, exchangeable calcium, exchangeable potassium, macro nutrient and cation exchange capacity (Table 3) thus indicating that organic matter was the main source of these nutrients. (Kebeney *et al.*, 2015) therefore, any measure to maintain the organic matter or increase it will improve the fertility status of the soils. This may include incorporation of cattle dung, poultry droppings and other organic wastes as well as discouraging bush burning and the removal of crop residues for fuel and building purposes.

Soil Classification

Soil Mapping units were classified based on their diagnostic horizons and other diagnostic features. The Soil mapping unit G1 has an argillic horizon which increases in clay content with depth and high base saturation ($>50\%$ by NH_4OAc) hence, the soil is grouped into the order Alfisol and sub order Ustalfs respectively by virtue of its ustic moisture regime. At the Great Group and Subgroup they are classified as Haplustalf and Typic Haplustalf respectively because they do not fit into other Ustalfs and Haplustalf.

Soil mapping units G2 and G3 are classified into order Inceptisol because of its Orchric epipedon as well as cambic horizon. They are classified as Aquepts at the suborder level because it has an aquic conditions for some time in normal years (or artificial drainage). They do not meet the criteria of other Aquepts hence classified as great group Endoaquepts. They were classified at the sub group level as Fluventic Endoaquepts because it has hue of 10 YR with a colour value and chroma of 3 or more.

Soil mapping unit G4 has an argillic horizon with a base saturation more than 50% (CEC) hence it is classified as Alfisol. It is classified as Aqualfs at the sub order level

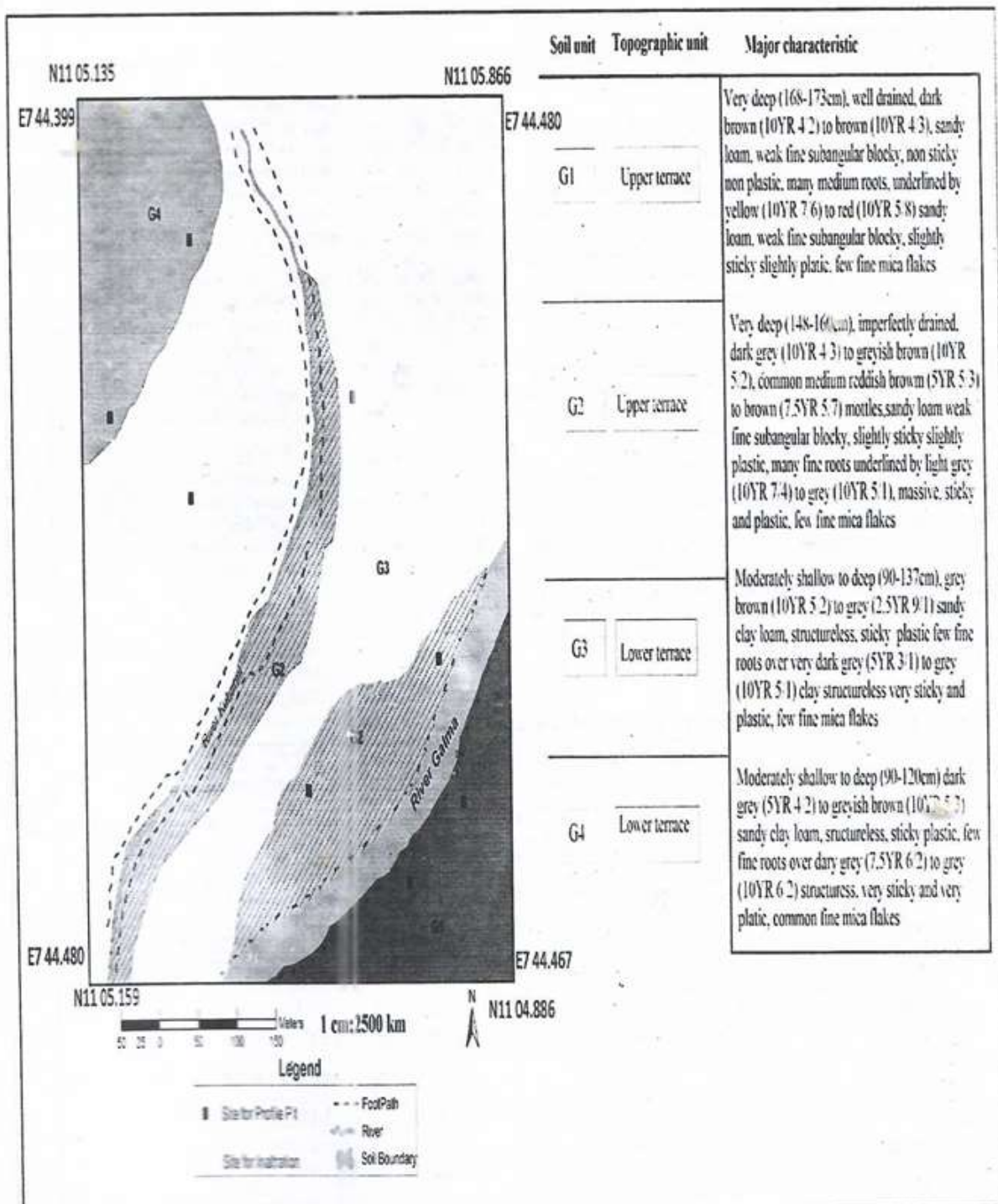


Figure 2 Soil map of the study area

of classification because it has an aquic conditions. It does not meet the criteria of other Aqualfs hence classified as great group Endoaqualfs. It classified at the sub group level as Typic Endoaqualfs because it do not meet the criteria for other Endoaqualfs.

The first level of classification in soil mapping unit G1 are classified as Lixisols because soils have a higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes (especially clay migration) leading to an *argic* subsoil horizon. At the lower level of classification, as Nudiargic Lixisols by its virtue of having an *argic* horizon starting at the mineral soil surface.

The soils of soil mapping units G2 and G3 are classified as Fluvisol because of *fluvic* material starting within 25 cm of the soil surface or starting immediately below a plough layer of any depth and continuing to a depth of 50 cm or more. At the lower level of classification as Dystric Fluvisol by virtue of its having a base saturation (1N H₂OAc) of 50 percent or more in depth between 20 and 100 cm from the soil surface.

The soil mapping unit G4 is classified as Lixisols because of higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes (especially clay migration) leading to an *argic* subsoil horizon. Lixisols have a high base saturation at certain depths as demonstrated in the soil mapping unit. At the second level of classification it is classified as Gleyic Lixisols because it has *gleyic* properties throughout and *reducing conditions* in some parts of every sub layer.

SUMMARY AND CONCLUSION

Soil depth varied from moderately shallow to very deep soils. The drainage condition of the study area differ from well to poorly drained condition. All the soil mapping units ranged from moderately acidic to slightly acidic with a pH range of 5.15-6.55. The soils are mostly sandy loam and sandy clay loam in textures. The soils are low in total Nitrogen and organic carbon low to medium in available P and base saturation. However, all the soils contain medium to high levels of Available K, available K and cation exchange capacity.

The soils of the study area were classified in line with USDA soil taxonomy and World Reference Base for Soil Resources system (FAO-WRB). Soil mapping unit G1 have been Typic Haplustalf and Nudiargic Lixisols respectively while soil mapping units G2 and G3 have been classified as Fluventic Endoaquepts according to Dystric Fluvisol correspondingly. Similarly, Soil mapping units G4 classified as Typic Endoaqualfs and Gleyic Lixisols, respectively.

For sustainable use of the floodplain soil, a guided and judicious use of organic and mineral fertilizers should be in corporate in the farming program of the area to enhance soil nutrients availability. Again, the return of harvested crop residues (crop residues management) is essential to enhance the soils productivity.

Table 3: Soil fertility trend of the study area

	OC	TN	AP	Ca	Mg	K	Na	CEC	Clay	Silt	Sand	pH
OC	1.00	0.77**	0.65**	0.83**	0.54**	0.45**	0.18	0.85**	0.33*	-0.28	-0.30	-0.17
TN		1.00	0.72**	0.77**	0.34*	0.57**	0.01	0.73**	0.32*	-0.17	-0.28	-0.10
AP			1.00	0.55**	0.02	0.23	-0.08	0.44**	-0.15	0.12	0.21	0.27
Ca				1.00	0.54**	0.72**	-0.02	0.95**	0.54**	-0.30*	-0.36*	-0.16
Mg					1.00	0.43**	0.27	0.72**	0.67**	-0.57**	-0.50**	-0.60**
K						1.00	-0.28	0.70**	0.70**	-0.29	-0.43**	-0.31*
Na							1.00	0.11	-0.06	-0.14	0.08	-0.04
CEC								1.00	0.60**	-0.42**	-0.44**	-0.28
Clay									1.00	-0.60**	-0.78**	-0.59**
Silt										1.00	0.25	0.45**
Sand											1.00	0.52**
pH												1.00

** . Correlation is significant at the 0.01 level.

* . Correlation is significant at the 0.05 level.

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