

CHARACTERIZATION AND CLASSIFICATION OF SOME FLOOD PLAIN SOILS AT WEPPA, EDO STATE, NIGERIA FOR SUSTAINABLE AGRICULTURAL PRODUCTIVITY

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ABSTRACT

The need to increase agricultural production as a result of increasing population pressure on land resources, competitive land use and declining agricultural productivity of upland soils has brought about increased utilization of the flood plains to meet man's needs for food and fibre. Judicious use of land resources requires basic knowledge of the soil characteristics. The objectives of this study were to characterize and classify some flood plains soils in Southern Nigeria and to identify soil management options for sustainable agricultural productivity. A detailed soil survey was carried out at Weppa, Edo State using the rigid grid method and six mapping units were identified. A soil profile pit was dug on each mapping unit and described in detail. Samples were taken from each genetic horizon of these profiles and subjected to laboratory analyses using standard procedures. The soils were characterized for their morphological, physical, chemical, properties and weathering indices. Soil classification was carried out using local and international classification systems.

*All profiles were mottled showing impeded drainage. The distribution of texture, colour and organic carbon were irregular in most profiles. The soil weathering indices such as amorphous to crystalline iron ratio, clay co-migration, Silt/Clay ratio and CEC/Clay revealed that the soils were young. There was significant ($p < 0.01$) negative correlation between calcium and exchangeable sodium percentage ($r = -0.674^{**}$); calcium and hydrogen ($r = -0.503^{**}$) and between aluminum and base saturation ($r = -0.449^*$) while there were significant positive correlation ($p < 0.01$) between crystalline iron and amorphous iron ($r = 0.506^{**}$); amorphous iron and iron ratio ($r = 0.580^{**}$). The soils were classified at series level as Edozhigi, Indaloke, Illah, Agaie, Badeggi and Mawogi series belonging to the Inceptisols and Entisols in the soil Taxonomy. Low weathering, nutrient status and moisture availability in these soils could sustain reasonable agricultural productivity. However, they require careful management to ameliorate acidity, nutrient deficiencies and poor drainage conditions.*

Keywords: Alluvial soils, floodplains, soil characteristics, weathering indices

INTRODUCTION

Flood plain soils are soils adjacent to major rivers or streams (Effiong and Ibia, 2009). These soils are highly heterogeneous as a result of the hydromorphic environment in which they are formed. Flood plain soils as a

natural resource can only be properly managed with proper understanding of its characteristics (Idoga *et al.*, 2005).

The agricultural productive potentials of river banks and floodplains such as the Nile valley has been identified as the origin of great

human civilizations (Carating *et al.*, 2014). Floodplain soils tend to be more fertile than adjoining upland areas and availability of moisture makes them suitable for year-round cropping (Ogban and Babalola, 2009; Ukabiala, 2012). Despite their potentials, the flood plain soils in Nigeria are largely underdeveloped and underutilized. The complex nature of these soils, arduous agronomic task on management coupled with inadequate information on these soils in Nigeria has contributed to their underutilization (Ukabiala, 2012).

Soil characterization provides information on the morphological, physical and chemical properties of soils. This could involve the measurement of weathering indices of soils using iron oxides which provide information about soil age, weathering rate and drainage conditions. These oxides also play an important role in the morphological properties of soils such as the conferment of soil colour (Uzoho, 2014). Soil characterization is key to the systematic grouping of soils into classes on the basis of similarity or differences in their profile characteristics otherwise known as soil classification. Soil characterization and classification are powerful tools required for judicious soil management for the benefit of mankind especially in the area of food security and environmental sustainability (Sharu *et al.*, 2013).

Weppa lies in the lowland area along the western floodplains of the River Niger in Edo State, Southern Nigeria and experiences yearly seasonal flooding during the rainy season. Sediments and organic material transported by flood water are deposited on soils as they make their way through the river

to the adjoining lowlands, the delta regions and into the Atlantic Ocean. These soils are thus seasonally rejuvenated as a result of these alluvial deposits. However, despite the agricultural productive potentials of these soils, little information exists about their characteristics and classification. The objectives of this study were to characterize and classify the soils encountered along the middle course of the Niger River after the confluence with River Benue and before the splitting into the delta area. It is believed that this will help to identify soil management options for sustained agricultural productivity in this and similar floodplain areas.

MATERIALS AND METHODS

Description of the study Area

The location of the study area is at Weppa, in Estako East Local Government Area of Edo State with a spatial coverage of about 108 hectares. The study site lies between latitudes N 7.02526° and N 7.035905° and longitudes E 6.56068° and E 6.56952°. The site is located in the Rainforest belt with a mean annual rainfall of 1540 mm; and a mean annual temperature of 31°C (Weppa, Farms weather station). The rainy season is from April to October, while the dry season is from early November to March. The parent rock is sedimentary and the parent material of the soils is river alluvium. The physiographic position of the site is a plain. It is a fairly flat land (plain) with the elevation ranging from 36 m to 59 m (as the highest point) above sea level. The area is seasonally flooded during the rainy season, when River Niger overflows its bank. The study site is located on the lower course of the River Niger, in this region; the

river basin formation is of cretaceous sedimentary origin (Ojha *et al.*, 2008). The area surrounding the study site is planted to Teak (*Tectonia grandis*) and other tall trees. The study area is currently used for cassava (*Manihot esculenta*), cashew (*Anacardium occidentale*) and oil palm (*Elaies guineensis*) farming. The previous land use includes maize (*Zea mays*) and rice (*Oryza sativa*) cultivation.

Field Survey

The soil survey was done using the rigid grid method, which involved the cutting of transects. A total of five transects at 200 m interval were made. Auger observations at 100 m interval were made on each transects. Auger observations were taken at depths of 0-30 cm, 30-60 cm, 60-90 cm and 90-120 cm at each grid node. At each node point the morphological and physical characteristics were recorded according to the FAO (2006) guidelines. Soils with similar morphological properties were grouped together to form mapping units. The mapping units were examined in detail using a total of six modal soil profiles. Samples were collected from each layer of the soil genetic horizons identified. The samples were prepared and taken to the laboratory for routine physical and chemical analyses using standard procedures (Udo and Ogunwale, 1986).

Laboratory Analyses

The soil samples collected from each genetic horizon were air dried and passed through a 2mm sieve. Particle size distribution was determined using the Bouyoucos hydrometer method (Bouyoucos 1962). Soil pH and

Electrical Conductivity were determined using 1:1 soil/water suspension with a glass electrode pH and conductivity meter. Soil organic carbon was determined using the Walkley and Black wet oxidation Method (Nelson and Sommer, 1982). Available phosphorus was extracted using Bray-1 and determined colourmetrically using a Spectrophotometer. Exchangeable bases were extracted with normal neutral Ammonium Acetate (NH_4OAc) buffered at pH 7.0. The extracts for sodium and potassium were read using the Flame Photometer, while the extracts for calcium and magnesium were read using the Atomic Absorption Spectrophotometer. Total nitrogen was determined using Micro-Kjedahl method. Exchangeable Acidity was determined using titration method (Anderson and Ingram, 1993). Effective Cation Exchange Capacity was determined by summing the exchangeable bases and exchange acidity. The Base Saturation was calculated by dividing the sum of the exchangeable bases by the ECEC and multiplying the quotient by 100. The Micronutrients were extracted using 0.1N HCl and then read with the Atomic Absorption Spectrophotometer. The ECEC/Clay was calculated by dividing the ECEC by the percentage clay and multiplying the quotient by 100. The Exchangeable Sodium Percentage was calculated by as a percentage of sodium in the total exchangeable bases. The Sodium Absorption Ratio was calculated as ratio of sodium to the square root of half the summation of calcium and magnesium expressed in percentage as measure of sodium hazard in the soils.

Determination of Weathering Rate

The amorphous iron oxides were extracted using the acid ammonium oxalate extraction method (Schwertmann, 1964). The free iron oxides were extracted using Dithionite-Citrate-Bicarbonate (DCB) extraction (Mehra and Jackson, 1960). Less active Fe was calculated by subtracting Oxalate extractable Fe from DCB extractable Fe (Arduino *et al.*, 1984) while the Fe ratio was calculated by dividing Oxalate extractable Fe by DCB extractable Fe. Fe /Clay co-migration was calculated by dividing the clay value by the Fe dithionite value. Silt /clay ratio was calculated by dividing percentage silt by clay. Clay activity was calculated by dividing CEC by percentage clay and multiplying the quotient by 100.

Soil Classification

The soils were classified at sub-group level using Soil Taxonomy 12th Edition (Soil Survey Staff, 2014) and World Reference Base for Soil Resources (FAO/IUSS, 2014). The Local Series classification was done using the method of Moss (1957).

Statistical Analysis

Correlation analysis was done on all soil properties to identify soil factors that correlated or differed significantly. It was also used to determine the intricate connections between and among soil properties.

RESULTS AND DISCUSSION

The morphological, physical and chemical properties of the study area are shown in Tables 1 and 2. The profiles were deep (100cm - 200cm). The difference (abrupt

textural changes) observed in between the genetic horizons of the soil profile were as a result of different deposition from the river around the flood plain when it overflows the flood plain. The grayish colouration of some of the profiles indicates that the soils were imperfectly or poorly drained (Esu, 2010). The yellowish colour in some of the profiles may be attributed to the presence of sesquioxides in hydrated forms especially goethite (Lawal *et al.*, 2013). They could also be due to the mobilization and immobilization of iron during redox cycles in the soils (Fasina *et al.*, 2007).

Mottling indicates that the soils are subject to alternate wetting (reducing) and drying (oxidizing) conditions (FAO, 2006) occasioned by fluctuating water table. It indicates the poor drainage conditions of the soil. Most of the profiles were hydromorphic, evident by the presence of mottles in line with the findings of Eze *et al.* (2016) who studied the alluvial soils Sabie sand river basin in South Africa.

The soils of the study area were generally sandy; this was in agreement with the findings of Oko-Oboh *et al.* (2016) who characterized some alluvial soils in Edo State. Flood plains serve as nutrient sinks for the retention of nutrients (Verhoeven *et al.*, 2006). The source of nutrients in these soils could be attributed to the deposition of nutrient-enriched sediments by flooding and organic matter decomposition during dry periods (Powell, 2009). The pH of the soils of the study site ranged from extremely acidic (3.7) to strongly acidic (4.9). This is probably because during flooding, the soil becomes highly reduced, leading to leaching of soil nutrients such as N, P, K, Ca, Mg and Na

which may result in decreased soil pH (Ogg, *et al.*, 2017). The electrical conductivity of the soils is generally low, indicating that the soils are non-saline.

The organic carbon content of these soils decreased irregularly down the soil profile. Alves and Ross (2010) stated that uneven distribution of organic carbon down the soil profile is a diagnostic test for fluvial material or flood plain soils. The organic carbon content of the soil is rated between low to moderate. The low organic matter content of these soils may be due to high rainfall intensity, high temperature and high relative humidity which favour rapid mineralization of organic matter (Fasina *et al.*, 2006). Nitrogen and phosphorus enter flood plain soils in different ways. Nitrogen occurs in these soils as dissolved nitrate while phosphorus is bound to soil sediments (Klaus, *et al.*, 2011). The nitrogen content of the soil ranged from medium (1.2 g/kg) to high (3.9 g/kg), possibly due to fertilizer application on these soils. Nitrogen is lost in flood plain soils by denitrification (Deutsch *et al.*, 2006). Phosphorus content also ranged from moderate to high. The high phosphorus content could be as a result of reactions of various phosphate compounds into soluble forms and phosphorus diffusion during flooding. Phosphorus has a strong affinity for soil sediments and during flooding, sediments are deposited and this results in high phosphorus content (Ogg *et al.*, 2017).

Potassium is more mobile than Nitrogen and Phosphorus in flood plain soils. Conditions during flooding may favour leaching of K from the soil, hence preventing strong enrichment (Antheunisse *et al.*, 2006).

During the dry season, organic matter mineralizes into soil nutrients such as Ca, thus increasing the content of this cation. The Low K, high P, Ca and Mg content observed in the study site were in agreement with the findings of Ogbodo, (2011) who studied Abakaliki urban flood plains. The Sodium content of these soils were relatively high because flood water transports salts, which are deposited on the soils as the flood water recedes and evaporation occurs leaving salt crusts and crystals behind (Ogbodo, 2011). The soils were sodic as indicated by the Exchangeable Sodium Percentage of >15% (Brady and Weil, 2008).

The soils had high exchange acidity because of high aluminium saturation. Aluminium is the dominant exchangeable cation in these soils; the aluminium toxicity increased the acid content of these soils. High Aluminium saturation is a common occurrence in the flood plains of Edo State (Isitekhale *et al.*, 2014). Most of the soils of the State are acidic and are therefore characterized by low cation retention and buffering capacities, this is because of their high leaching potentials (Imasuen and Onyeobi, 2013). Generally, the ECEC of the soils were low and this could be attributed to the nature of the clay minerals and the less than 16 cmol/kg ECEC observed also indicates low clay activity (Hassan *et al.*, 2011; Yakubu *et al.*, 2011). The high Aluminium saturation, high exchange acidity and low CEC observed were in agreement with the findings of Effiong and Ibia (2009) who studied the flood plains of some soils in South Eastern Nigeria. The micronutrient composition of this soil was in the order of Fe > Mn > Zn > Cu. This was in agreement with the findings of (Jimoh, 2015) that

characterized and evaluated the Kubanni flood plains in Zaria.

Soil weathering indices

Soil weathering indicators used in the study are shown in Table 4. Soil properties that change with duration and intensity of weathering provide vital clues to the pedogenesis of a soil (Bera *et al.*, 2015). Profile distribution of different forms of iron (Fe) oxides, especially dithionite and oxalate extractable Fe, serve as useful indicators in identifying the horizon of accumulation of secondary oxides. Alluvial derived soils usually have an erratic increase in weathering intensity with no specific trend of profile development because the source of the parent material is transported sediments which are deposited in different cycles (Bera *et al.*, 2015). The content of the different forms of iron oxides in tropical soils increases as the soil ages, largely due to the influence of weathering (Osodeke *et al.*, 2005). Amorphous and crystalline Fe oxides occurring in soils could be used in understanding the genesis, properties and classification of soils (Ibia, 2005) and the difference between the values obtained by the two methods ($Fe_d - Fe_{ox}$) represents the amount of Fe present in definite crystalline forms (Arduino *et al.*, 1984). The amount of oxalate Fe is higher in younger soils. This is because the rate of release of iron from primary minerals during the initial stages of weathering exceeds the rate of crystallization of secondary Fe oxide minerals (Bera *et al.*, 2015). As the soil ages, the release rate of Fe decreases and the amorphous, oxalate Fe crystallizes into Fe oxide minerals (Ciolkosz *et al.*, 1993).

Generally Fe_{ox}/Fe_d which is the active iron ratio decreased irregularly with depth and. Soils with high iron ratios have been reported to be more active. A high Fe reactivity indicates young soil age; this is because the rate of Fe release from primary mineral lattices exceeds the rate of Fe crystallization (Ogg *et al.*, 2017). The low Fe ratio values of the subsurface layers indicate the predominance of crystalline iron oxides, while the high values in the surface horizons were as a result of the inhibition of organic matter in the development of iron oxide crystallinity. Soils with poor drainage conditions have been reported to have high active Fe ratios; this is because poor drainage conditions prevent strong weathering and formation of sesquioxides (Mielki *et al.*, 2016). Fe ratios have also been used in classifying soils into well drained and poorly drained conditions. It has been reported that values of active iron greater than 0.35 represents poorly drained conditions, while values lower than 0.35 indicate that the soil is well drained (Eze *et al.*, 2016). The iron ratio in this study ranged from 0.22-1.00, which is similar to the findings of Ibia (2005). The high active Fe ratios observed in this study indicate that a large fraction of the total free iron oxides exists mainly in the amorphous forms. This is because impeded drainage reduces the crystallization of iron oxide minerals (Ibia, 2005, Enya, *et al.*, 2011).

The ratio of clay to dithionite ($Clay/Fe_d$) has been used to indicate the co-migration of clay and iron oxides from the A horizon to the B horizon (Enya, *et al.*, 2011). The $clay/Fe_d$ ratio increases with depth in cases where horizon formation is well expressed, but in most cases the $clay/Fe_d$ ratio is irregular with

depth. This can be attributed to a decrease in the extractability of Fe by dithionite. Increase in clay with soil depth has been attributed to clay translocation and erosion in surface horizon (Ojha *et al.*, 2008). The irregular Clay/Fe_d ratio with soil depth is in agreement with the findings of Uzoho (2014), who studied the sesquioxide distribution of Egbema. He attributed this lack of consistency in the pattern of distribution of clay/Fe_d ratio with soil depth to lack of co-migration of clay and iron oxides. Maniyunda *et al.* (2015) also had the same findings, and they attributed this trend to partial co-migration between clay and Fe in soils because more clay was illuviated into the sub soil than Fe oxide.

High silt/clay ratio in flood plains indicates that the soils were formed from recent deposits (Ajiboye *et al.*, 2015). High Silt/clay ratio (> 0.15) observed in the soil profiles indicates intermediate to low degree of weathering. The irregular decrease in silt/clay ratio was in line with the findings of Neto *et al.* (2015) who studied some flood plain soils in Brazil. They attributed this trend to inhibition of weathering intensity by relatively recent sediments from which the soils were formed and the low landscape positions of these soils. The CEC/Clay ranged from 15-599 indicating that the soils had high clay activity and were moderately to weakly weathered.

Table 1: Morphological and physical properties of flood plain soils at Weppa

Mapping Units	Depth (cm)	Horizon	Colour (moist)	Mottles (moist)	Structure	Consistence (moist)	Roots	Boundary Form	Sand Silt Clay			Texture	ECEC/ Clay
									Sand	Silt	Clay		
1	0-24	Ap	10YR 3/2	-	1, vf, cr	fr	c, m	w c	810	100	90	LS	120.7
	24-82	IIBt	10 YR 4/3	10YR 5/6	2, c, sbk	v fi	vf, fw	s d	550	70	380	SCL	36.3
	82-124	Bt1	10YR 5/6	10YR 4/2	2, m, sbk	fi	-	s c	600	70	330	CL	40.0
	124-180	Btg	10YR 5/2	2.5YR 3/6	2, m, sbk	fi	-	-	660	50	290	CL	30.4
2	0-43	Ap	7.5YR 3/2	-	1, vf, cr	fr	c, m	s c	940	50	10	S	938
	43-83	C1	7.5YR 5/4	-	1, vf, sg1, t	lo	vf, fw	s d	940	10	50	S	180
	83-159	C2	7.5YR 6/4	-	1, f, sg	lo	m, fw	s d	940	30	30	S	388
	159-190	C3	7.5YR 7/3	2.5YR 3/6	1, f, sg	lo	m, vfw	-	980	10	10	S	908
3	0-23	Ap	7.5YR 3/2	-	1, vf, cr	fr	c, m	s c	860	60	80	LS	136.4
	23-68	AB 1	5YR 4/6	-	1, vf, sbk	fr	f, fw	s c	880	20	100	LS	124.9
	68-131	AB 2	5YR 5/3	-	1, vf, sg	lo	f, fw	s c	970	20	10	S	1032
	131-140	Bw 1	5YR 4/6	10 YR 5/6	1, f, sbk	fr	f, fw	s c	820	30	150	LS	76.30
	140-180	Bw 2	10YR 5/3	2.5YR 3/6	1, m, sbk	fr	vf, vfw	-	720	110	170	SCL	49.0
4	0-27	Ap	7.5YR 3/	-	1, vf, cr	fr	m, m	s c	920	10	70	LS	122.4
	27-59	B 1	5YR 4/6	-	1, f, sbk	fr	m, c	s c	920	10	70	LS	124.4
	59-103	B 2	10YR 5/3	2.5YR 3/6	1, m, sbk	fr	m, fw	s d	730	140	130	SL	79.50
	103-140	B / C1	5YR 4/4	-	1, m, sbk	lo	f, vfw	s d	940	30	30	S	280.7
	140-180	B/C2	5YR 4/6	5YR 7/2	1, f, sg	lo	f, vfw	-	940	50	10	S	735.0
5	0-20	Ap	7.5YR 3/2	-	1, vf, sbk	fr	f, fw	s c	860	70	70	LS	152
	20-55	B 1	5YR 4/6	-	1, f, sbk	fr	f, fw	s c	880	110	10	LS	80.7
	55-77	B 2	5YR 4/6	-	2, m, sbk	fr	m,	s d	800	50	150	SiL	59.7
	77-118	Bt	10YR 5/3	-	2, m, sbk	fi	fw	s d	540	210	250	SCL	50.4
	118- 160	Bts	10YR 5/3	2.5YR 3/6	1, f, sbk	vfi	-	-	500	70	430	SC	27.3
6	0-25	Ap	10 YR 5/3	5YR 4/6	1, f, sbk	fr	m, m	s d	500	360	140	SL	80.7
	25-89	AB 2	10YR 5/2	5YR 4/6	2, m, sbk	fi	m, c	s d	660	90	250	SCL	37.7
	89-137	AB 2	10YR 5/2	-	1, f, sbk	fr	m, fw	s d	720	110	170	SiL	55.8
	137-160	Bg	10YR 5/2	5YR 4/6	1, vf, sbk	fi	f, fw	-	620	110	270	CL	44.0

Structure: sbk = Sub-angular blocky; cr = Crumb; sg = Single grain; vf = Very fine; f = Fine; m = Medium; 1 = Weak; 2 = Moderate. Texture: S = Sand; LS = Loamy Sand; SL = Sandy Loam; SiL = Silty Loam; CL = Clay Loam; SCL = Sandy Clay Loam. Consistence: SC = Sandy Clay; fr = Friable; lo = Loose; fi = Firm, Vfi = Very Firm; Roots: m, fw = Medium, Few, m, vf = Medium, Very Few; m, c = Medium, Common; f, fw = Fine, Few; v, vfw = Very fine, Very few; m, m = Medium, Many; m, fw = Medium, Few. Boundary Form: s c = Smooth, Clear; s d = Smooth Diffuse

Table 2: Chemical Properties of the floodplain soils at Weppa

Mapping Unit	Depth (cm)	pH (H ₂ O)	Org.		P (mg/kg)	Ca	Mg	Na	K (cmol/kg)	H	Al	ECEC	BS (%)	ESP (%)	EC (µS/cm)	Fe	Zn	Mn	Cu	SAR
			C (g/kg)	N (g/kg)																
1	0-24	4.5	13.6	1.7	48	1.1	0.74	0.84	0.18	0.8	7.2	10.86	26.38	29.4	62	79.1	3.81	45.3	2.32	0.88
	24-82	4.4	9.2	2.5	14	4.00	1.43	0.87	0.20	0.3	7.0	13.81	47.14	13.4	81	30.2	2.78	18.4	2.4	0.53
	82-124	4.8	5.6	1.7	16	3.17	1.36	0.76	0.21	0.3	6.4	12.2	45.09	13.8	34	34.2	4.36	10.6	2.01	0.51
	124-180	4.5	8.8	2.0	15	2.93	1.34	0.87	0.17	0.5	3.0	8.81	60.25	16.4	28	26.4	2.64	9.6	1.36	0.6
2	0-43	4.9	15.2	1.7	40	1.98	0.74	0.44	0.12	0.2	5.9	9.37	34.93	13.4	26	27.3	4.27	21.6	1.07	0.38
	43-83	5.1	0.4	2.2	31	0.94	0.64	0.43	0.09	0.6	6.3	9.00	23.33	20.5	39	28.6	2.13	3.2	0.97	0.48
	83-159	5.0	0.8	3.4	20	3.23	0.55	0.78	0.09	0.2	6.8	11.66	39.91	16.8	28	23.3	2.4	4.2	1.06	0.57
	159-190	4.4	14.4	2.2	23	0.74	0.60	0.44	0.10	1.2	6.0	9.07	20.64	23.4	22	20.4	1.16	2.4	0.93	0.54
3	0-23	4.0	13.6	1.7	21	1.57	0.89	0.71	0.14	0.4	7.2	10.91	30.33	21.5	37	31.3	5.46	54.2	1.84	0.64
	23-68	4.4	8.4	2.0	13	2.12	1.31	1.22	1.36	1.2	6.5	13.7	43.78	25.5	20	25.2	1.69	14.6	1.28	0.93
	68-131	4.6	16.4	2.5	15	0.72	0.63	0.44	0.13	0.5	7.9	10.31	18.52	22.9	11	19.9	1.96	3.5	0.56	0.54
	131-140	4.1	6.0	3.9	15	1.24	0.81	0.87	0.12	1.4	7.0	11.45	26.61	28.6	40	35.2	2.29	17.7	1.56	0.86
	140-180	4.0	3.6	2.5	14	0.98	0.77	0.44	0.14	0.7	5.3	8.33	27.95	18.9	16	45.1	1.98	15.1	1.34	0.47
4	0-27	4.3	8.4	3.1	14	0.83	0.67	0.44	0.13	0.9	5.6	8.57	24.15	21.3	30	55.6	2.86	32.5	1.01	0.51
	27-59	3.9	0.4	2.5	15	0.61	0.57	0.43	0.1	0.6	6.4	8.71	19.63	25.1	46	23.8	1.78	6.0	0.89	0.56
	59-103	4.1	2.4	3.4	13	1.97	0.99	0.96	0.12	1.1	5.2	10.34	39.04	23.8	17	34.9	2.17	25.4	1.55	0.79
	103-140	4.1	2.4	4.2	17	0.79	0.68	0.44	0.11	0.6	5.8	8.42	23.95	21.8	25	24.8	1.62	7.3	0.81	0.52
	140-180	4.8	10.4	3.6	16	0.62	0.61	0.43	0.09	0.6	5.5	7.35	23.81	24.6	15	18.0	1.68	3.6	0.86	0.55
5	0-20	4.4	15.2	2.5	18	1.66	0.83	0.8	0.15	0.6	6.6	10.64	32.35	23.3	79	31.0	4.56	54.7	1.21	0.71
	20-55	4.7	8.4	1.2	16	1.25	0.44	0.43	0.15	0.3	5.5	8.07	28.1	18.9	33	32.7	3.23	12.7	1.66	0.36
	55-77	4.7	13.2	2.2	17	0.87	0.42	0.86	0.12	0.5	6.2	8.96	25.2	38.1	39	37.2	2.72	8.6	1.53	1.08
	77-118	4.7	9.6	4.2	40	3.53	1.18	0.70	0.18	0.3	6.9	12.6	42.87	12.9	63	22.2	1.82	8.3	1.52	0.47
	118-160	4.3	16.4	2.8	13	3.30	1.97	0.63	0.16	0.3	5.4	11.76	51.53	10.4	33	23.2	2.28	13.9	1.95	0.39
6	0-25	3.7	14.8	2.0	14	1.56	0.92	0.78	0.14	1.4	7.9	11.31	30.12	26	7.0	24.5	5.36	86.8	2.1	0.7
	25-89	3.8	6.8	5.6	13	1.67	1.03	0.7	0.13	0.3	5.6	9.42	37.39	19.8	36	89	3.82	18.6	2.39	0.6
	89-137	4.0	5.2	2.0	14	1.18	1.08	1.20	0.13	0.4	5.5	9.48	37.77	33.4	26	33.4	4.61	11	2.74	1.13
	137-160	4.0	4.4	2.5	38	1.55	1.04	0.87	0.12	1.0	7.3	11.89	30.19	24.3	24	35.6	3.78	17.4	2.43	0.76

Relationships between soil properties and weathering indices

Correlation analysis shown in Table 3 revealed the relationship between some soil properties and soil weathering indices which varied from weak positive and weak negative correlation, to significantly positive and negative correlation. Organic Carbon had mostly insignificant correlations with the soil textural and weathering indices considered. This indicates that organic carbon matter mineralization had not exerted significant influences on the soil properties and nutrient availability. Organic carbon also exhibited a weak positive correlation with silt and clay but had a negative correlation with potassium. This was in agreement with the findings of (Effiong and Ibia 2009) who studied some flood plains in South Eastern Nigeria. They attributed this negative correlation to the fact that little amounts of N and K are supplied in both organic matter and flood supplies. There was also a negative correlation between organic Carbon and sand. This indicates that the higher the sand content, the lower the organic matter content of the soil. There was a significant negative correlation between Ca and ESP, this indicates that the higher the calcium content the less sodic the soil will be.

There was a weak positive correlation between Fe_d and Fe ratio. This indicates that the higher the dithionite, the more crystalline the soil will be. There was a significant positive correlation between Fe_o (amorphous Fe) and Fe_d (crystalline Fe), this was in agreement with the findings of Bera *et al.* (2015) and they attributed this possibly to the fact that the extractants removed the same forms of Fe oxides. There was a negative

correlation between Fe ratio and Clay/ Fe_d . This implies that the higher the Fe ratio, the lower the clay co-migration; and the higher the Fe ratio, the lower the expression of horizon formation of the soil profile. There was a significant negative correlation between Fe_{ox} and Fe ratio. This means that the Fe-ratio was composed mainly of amorphous Fe and that the soils were young and weakly weathered.

There was a weak positive correlation between Clay and Fe_{ox} , ECEC and Fe_{ox} and ECEC and Fe_d . This was in agreement with the findings of Bera *et al.* (2005), who attributed this relationship to the availability of Fe from the exchange sites. The negative correlation observed between Organic carbon and Fe_{ox} ; clay and Fe_d were in agreement with the findings of Bera *et al.* (2015) and they attributed this to the presence of Fe fractions within the crystal lattices or the presence of sorbed Fe on the surface of soil colloids. The positive correlation between Fe_d and P, Fe_{ox} and Base saturation and the negative correlation between Fe_d and Clay, and Fe_d and N, Fe_{ox} and K, Fe_d and Silt/Clay ratio were in agreement with the findings of Uzoho, (2014) who studied the sesquioxide distribution of soils on sedimentary lithology at Ebgema. There was also positive correlation between Fe_d and Fe-ratio this indicates that the higher the dithionite the older the soil. There was also positive correlation between Fe_d and Clay/ Fe_d . This indicates that the higher the Fe_d the higher the clay co-migration and the more the expression of horizon formation of the soil profile. There was a significant negative correlation between Clay and Clay/ Fe_d ; ECEC and Silt/Clay; ECEC and Clay/ Fe_d and

Base Saturation and Clay/ Fe_d . This indicates that the older or more weathered the soil is, the lower these nutrient parameters in that soil.

Taxonomic Classification

The taxonomic classification of the study area according to the USDA Soil Taxonomy (Soil Survey Staff, 2014), correlated with the WRB system (FAO/ IUSS 2014) and Local classification of soils on sedimentary deposits of Moss (1957) is shown in Table 5. Classification of soils is imperative for the understanding of soil properties and the extrapolation of research result to needed areas. The soils of the study area have a udic moisture regime characterized by prevailing rainfall and insipient underground moisture; Isohyperthermic temperature regime characterized by high temperatures all year round and they have low base status (Dystric) The soils of mapping units 1 and 5 of the study site fit into orders Alfisol as a result of sufficient evidence of clay enriched subsoil with evidence of clay illuviation. Morphological observations showed that both pedons are moist almost throughout the year therefore were of Udalf suborders with typical expressions of the suborder hence were both Hapludalf. However, the argillic layer of mapping unit 1 is slightly less than 35cm while that of mapping unit 5 have base saturation less than 60 % therefore they were classified as Inceptic Hapludalf and Ultic

Hapludalf respectively. Mapping units 2 and 4 are sandy with little profile development and are moisture saturated by seasonal fluctuating water table. Pedon 2 was classified Aquic Udipssament while pedon 4 was Aquic Udifluent being an entisol with fluvial properties of irregular decrease in organic carbon between 25 and 125 cm or \geq 0.2% organic carbon at 125 cm, which implies seasonal cycles of pedogenic organic matter depositions (Soil Survey Staff, 2014). Pedons 3 and 6 were classified as Inceptisol because of their weakly expressed profile development and textural expressions. In the WRB classification, fluvic (irregular decrease in organic carbon down the soil profile) properties were more expressed than the illuvial accumulation of clays. The soils were mottled because of the alternate wetting and drying conditions of their environment (Aquic or Gleyic) thus were placed in the Fluvisol, Cambisol and Arenosol reference soil groups. With some being sandy all through, Arenic oxyaquic and gleyic qualifiers further describe their properties for pragmatic management. The series classification as Edozhigi, Indaloke, Illah, Agaie, Badeggi and Marworgi series respectively (Moss, 1957) are mainly based on drainage classes since all the soils were formed on the same sedimentary parent material and occupying lowlands. The other distinguishing characteristics are textural classes and underground water.

Table 3: Weathering indices of the studied soils

Mapping Unit	Depth (cm)	Fe _{ox}	Fe _d g/kg	Fe _{ox} /Fe _d	Fe _d - Fe _{ox}	Clay/Fe _d	Silt/Clay	CEC/Clay cmol/g
1	0-24	0.6	0.8	0.75	0.2	112.5	1.11	40.67
	24-82	0.7	1.0	0.70	0.3	380.0	0.02	17.89
	82-124	0.5	0.8	0.63	0.3	412.5	0.21	17.58
	124-180	0.6	0.7	0.85	0.1	414.3	0.17	20.03
2	0-43	0.6	0.8	0.75	0.2	12.50	5.00	348.0
	43-83	0.2	0.6	0.33	0.4	83.33	0.20	54.00
	83-159	0.2	0.3	0.33	0.1	100.0	1.00	161.8
	159-190	0.3	0.3	1.00	0.0	33.33	1.00	308.0
3	0-23	0.4	0.6	0.67	0.2	133.33	0.74	46.38
	23-68	0.7	0.9	0.77	0.2	111.11	0.20	599.0
	68-131	0.3	0.3	1.00	0.0	33.33	2.00	242.0
	131-140	0.2	0.9	0.22	0.7	166.7	0.20	29.60
	140-180	0.7	1.0	0.70	0.3	170.0	0.65	17.82
4	0-27	0.7	0.9	0.77	0.2	77.78	0.14	42.43
	27-59	0.6	0.7	0.86	0.1	100.0	0.14	33.00
	59-103	0.2	0.4	0.50	0.2	325.0	1.08	39.54
	103-140	0.4	0.6	0.67	0.2	50.00	1.00	87.33
	140-180	0.2	0.3	0.67	0.1	33.33	5.00	235.0
5	0-20	1.2	1.3	0.92	0.1	53.85	1.00	57.71
	20-55	0.6	1.1	0.55	0.5	9.090	11.0	257.0
	55-77	0.1	0.3	0.33	0.2	500.0	0.33	16.40
	77-118	0.4	0.6	0.67	0.2	416.7	0.84	22.84
	118-160	0.2	0.7	0.29	0.5	614.3	0.16	14.79
6	0-25	0.5	1.0	0.5	0.5	140.0	2.57	34.29
	25-89	0.3	0.8	0.38	0.5	312.5	0.40	15.32
	89-137	0.9	1.6	0.56	0.7	106.3	0.65	23.47
	137-160	0.8	1.2	0.67	0.4	225.0	0.41	16.96

Table 4: Correlation coefficients of selected soil properties and soil weathering indices

	Org. C	N	P	Ca	Mg	Na	EA	K	ECEC	Sand	Silt	clay
Org.C	1	-.112	.141	.098	.078	.128	.184	-.021	.141	-.110	.196	.023
BS	.036	-.069	-.132	.819**	.348	.626**	-.395*	.210	.509**	-.637**	.169	.723**
ESP	-.024	-.131	-.087	-.674**	-.448*	.090	.341	.132	-.258	.289	.005	-.377
Sand	-.110	.071	.047	-.650**	-.286	-.646**	.061	.121	-.477*	1	-.665**	-.891**
Silt	.196	.095	.100	.276	-.022	.370	.126	-.152	.188	-.665**	1	.254
Clay	.023	-.149	-.121	.674**	.384*	.611**	-.155	-.064	.504**	-.891**	.254	1
Fe _o	-.053	-.020	.135	-.061	-.125	-.086	-.182	.219	.014	.028	-.094	.021
Fe _d	-.125	.031	.084	.089	.192	.186	-.091	.077	.133	-.362	.205	.344
Fe _d -Fe _o	-.169	.005	-.162	-.244	.032	.217	.066	-.055	-.034	-.028	-.023	.050
Fe _o /Fe _d	.134	-.052	.206	-.041	-.073	-.330	-.066	.127	-.054	.206	-.194	-.149
Clay/Fed	.081	-.126	-.128	.618**	.199	.601**	-.209	-.093	.389*	-.763**	.196	.869**
Silt/Clay	.196	.718**	.052	-.225	-.465*	-.418*	-.167	-.112	-.391*	.243	.213	-.444*
ECEC/Clay	.344	-.117	.167	-.271	.041	-.575**	.058	.701**	-.303	.608**	-.327	-.588**

*= p<0.05; **= p<0.01

Table 5: Taxonomic Classification of the soils of the study area

Mapping Unit	USDA Soil Taxonomy (Soil Survey Staff, 2014)	World Reference Base (FAO/IUSS, 2014)	Local Series (Moss, 1957)	Percentage Area Covered
1	Inceptic Hapludalf	Gleyic Fluvisol (Stagnic, Clayic)	Edozhigi Series	22
2	Aquic Udipsamment	Dystric, Fluvic Arenosol (Oxyaquic)	Indaloke Series (Coarse Variation)	12
3	Psammentic Dystudept	Fluvic Cambisol (Arenic)	Illah Series	10
4	Aquic Udifluent	Arenic Fluvisol (Oxyaquic)	Agaie Series	20
5	Aquultic Hapludalf	Dystric Fluvisol (Clayic, Oxyaquic.)	Badeggi Series	18
6	Aquic Dystudept	Endogleyic Cambisol (Densic, Dystric)	Mawogi Series	18

CONCLUSION AND RECOMMENDATION

The nutrient status coupled with the low weathering of these soils would make them able to sustain agricultural productivity. However, they require careful management to reduce acidity, ameliorate sodicity and reduce nutrient toxicities by liming and addition of organic residues. The use of acid-forming fertilizers should be avoided to prevent leaching and compounded acidity problems. Suitable drainage measures such as the use of buried drains made of baked clay or perforated PVC and ditches could be used to bring areas of poor drainage under cultivation. Strip cropping such as the alternate growing of crops on the contour at right angles to the flood direction could be used to reduce flow velocity of flood water. The sandy nature of these soils makes them vulnerable to erosion during flooding periods. The land should be carefully tilled

especially during the rainy season because mechanical tillage could expose the subsoil to erosion and compaction; and also concentrate water flow in the tire tracks of tillage equipment used.

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